Information Systems Engineering and Management 5

Yousef Farhaoui *Editor*

Artificial Intelligence, Big Data, IOT and Block Chain in Healthcare: From Concepts to Applications

Volume 1

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Yousef Farhaoui
Editor

Artificial Intelligence, Big Data, IOT and Block Chain in Healthcare: From Concepts to Applications

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Preface

"Artificial Intelligence, Big Data, IoT & Blockchain: From Concepts to Applications" is a groundbreaking exploration into the dynamic intersection of four transformative technologies: Artificial intelligence (AI), big data, Internet of things (IoT), and blockchain. In this comprehensive volume, readers are guided through an illuminating journey that spans from foundational concepts to real-world implementations, illuminating the profound impact these technologies have on various sectors, industries, and facets of everyday life.

The book serves as a beacon for both novices and experts alike, providing a clear and concise overview of each technology's core principles and methodologies. Starting with artificial intelligence, readers are introduced to the diverse array of AI techniques, including machine learning, deep learning, natural language processing, and computer vision. Through elucidating examples and case studies, the book demonstrates how AI algorithms can analyze vast datasets, extract meaningful insights, and automate decision-making processes across domains such as healthcare, finance, transportation, and beyond.

Moving on to big data, the book explores the challenges and opportunities presented by the exponential growth of data in today's digital age. Readers gain a deep understanding of big data architectures, tools, and analytics techniques that empower organizations to extract actionable intelligence from complex datasets. From predictive analytics to data mining and beyond, the book showcases how big data fuels innovation and drives business transformation across diverse industries.

In the realm of the Internet of things (IoT), readers are immersed in a world of interconnected devices, sensors, and systems that are revolutionizing the way we interact with our environment. Through compelling examples and use cases, the book elucidates how IoT technologies enable smart cities, intelligent transportation systems, precision agriculture, and a myriad of other applications that enhance efficiency, sustainability, and quality of life.

Finally, the book delves into the transformative potential of blockchain technology, which serves as the backbone of decentralized digital ecosystems. From cryptocurrencies to smart contracts and decentralized applications (DApps), readers discover how blockchain enables trustless transactions, immutable record-keeping, and secure data exchange in a variety of contexts, including finance, supply chain management, healthcare, and identity verification.

Throughout the book, emphasis is placed not only on theoretical concepts but also on practical applications and real-world case studies that illustrate the tangible benefits of integrating AI, big data, IoT, and blockchain technologies. Whether you're a business leader seeking to drive innovation, a technologist exploring the frontiers of digital transformation, or simply an enthusiast intrigued by the possibilities of emerging technologies, "Artificial Intelligence, Big Data, IoT & Blockchain: From Concepts to Applications" serves as an indispensable guide to navigating the evolving landscape of the Fourth Industrial Revolution.

Contents

An Extension to Single Events of the MongoDB Atlas Trigger Scheduling Mechanism

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Abstract. The current release of MongoDB Atlas supports scheduled triggers that are based on periodic events only (e.g., to generate a weekly report, to send an automated monthly email newsletter). However, although non-periodic events, also called single events, are needed in many cases of today's applications (e.g., to schedule an increase of the salaries of employees valid from some specific future date, to enact reductions of product prices valid for a given period), MongoDB Atlas does not provide any support for defining scheduled triggers considering single events. In this paper, we propose the trigger scheduling mechanism of MongoDB Atlas to be extended to also support single events and, thus, a full CRON syntax to be adopted in order to make the new mechanism available to users. Our proposal is illustrated via a practical example.

Keywords: Trigger · Scheduled trigger · MongoDB Atlas · Periodic event · Single event · CRON expression · MongoDB · MongoDB Query Language · MongoDB database · DBaaS · MongoDB Atlas function

1 Introduction

A "DataBase-as-a-Service" (DBaaS) [1], also called a "managed database service", is a cloud computing service that allows a user to create, access and exploit a cloud database, without needing to deal with deployment and management of the underlying infrastructure. A cloud provider will handle everything related to the database management like patching, securing, upgrading, scaling, and backing up the database. In this context, MongoDB Atlas [2] is a fully-managed cloud database service that handles all complexities of deploying and managing MongoDB databases on a chosen cloud service provider (AWS, Azure, or Google Cloud). It is the best way to deploy, run, and scale MongoDB in the cloud. Recall that MongoDB [3] is a powerful document-oriented NoSQL database management system (DBMS).

Besides, MongoDB Atlas supports several useful aspects including triggers [4, 5] which are similar to triggers available in (active) relational databases [6, 7]. The main purposes behind using triggers are audit, data consistency, data integrity, and data events.

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A MongoDB Atlas trigger [4, 5] is a program that is executed on the server when some database event occurs, like data addition, update, replace, or removal. There are three types of MongoDB Atlas triggers: database triggers, scheduled triggers, and authentication triggers. A database trigger executes some operations when some document, belonging to some collection of some MongoDB database, is added, updated or removed. A scheduled trigger executes some recurrent operations on a periodic basis. An authentication trigger executes some operation when a user is created or deleted or when logging into MongoDB.

As far as a scheduled trigger [8] is concerned, it allows only to execute some data management operations on a regularly repeating schedule defined by the developer, which means that it only supports *periodic events* (i.e., events that repeat regularly in time) like updating a document every five minutes, generating a daily report, or sending an automated monthly email newsletter. Hence, a scheduled trigger does not support non-periodic events, also called single events, despite the fact that such events concerning the database life frequently occur in modern information systems.

Notice that a single event is something of interest that occurs once at some instant of time and that requires the execution of some data management operations as a reaction to this happening. Such events can be forecasted or decided in advance and, thus, could be managed proactively in the database. As examples of such single events we could mention, increasing the salaries of employees, decreasing or increasing the prices of some products, proposing reduction rates for some customers, defining new bonuses for scientific researchers, and entering into force of a new fiscal law. In this paper, we deal with this lack of support of single events and propose the scheduled trigger mechanism of MongoDB Atlas to be extended to support not only periodic events but also single events. Therefore, the limited CRON expressions [9] currently accepted by MongoDB Atlas for the creation of scheduled triggers, must also be extended to a full CRON syntax in order to enable MongoDB Atlas application developers to specify and manage single event-based scheduled triggers. As a matter of fact, in order to define when scheduled triggers must execute, MongoDB Atlas currently accepts CRON expressions that are strings composed of five space-delimited fields (minute, hour, day of month, month, and weekday), corresponding to the CRON expressions accepted by the Unix/Linux crontab command. Hence, such expressions do not include a field for seconds, nor a field for years. This lack of support for seconds and, in particular, for years does not allow users to specify a timestamp which would fix an event on the time line and, thus, to create scheduled triggers for single events that would be useful in many scenarios of today's applications. Hence, the extension to single events of the MongoDB Atlas scheduling trigger mechanism, which we propose, implicitly requires (among others) an extension of the current format of a CRON expression, accepted by the MongoDB Atlas trigger scheduling interface, with two additional fields: one for the seconds, at the beginning of the CRON expression, and the other for the years, at the end of the CRON expression. Notice that this 7-field CRON expression format has also been used in the Oracle relational DBMS, as shown in [10], and in the open-source Java Quartz Enterprise Job Scheduler [11], as shown in [12].

It is worth mentioning that we are not dealing here and now with the development of a new version of MongoDB Atlas that supports single-events for scheduled triggers. In this paper, we just acknowledge the application requirements of such triggers, and recognize their absence in the MongoDB Atlas trigger activation mechanism and, therefore, we propose that they are added in a next version of MongoDB Atlas. The MongoDB Atlas development team is ultimately invited to consider our proposal to add them in a future release of the system according to the specification illustrated in this paper, including the extended syntax of the accepted CRON expressions.

The rest of this paper is structured as follows. Section 2 shows through an example how the current scheduled triggers of MongoDB Atlas do not allow specifying a single event-based trigger. Section 3 proposes our approach for the definition of scheduled triggers based on single events, via the extension of the current scheduled triggering mechanism of MongoDB Atlas. Section 4 summarizes the paper and gives some remarks about our future work.

2 Current Limitations of Scheduled Triggers in MongoDB Atlas

In order to show how periodic event-based scheduled triggers are created and managed with the MongoDB Atlas platform, we consider the example of a company that rents apartments to civil servants, and uses a MongoDB-based online system for the management of apartments, tenants, rentals, invoices, and electronic payments. Let us suppose that the company records all rentals in the *company.rentals* collection as documents that resemble the one in Fig. 1.

Recall that, similarly to a MongoDB server, a MongoDB Atlas server can store several databases; each database includes one or more collections [13]; each collection contains one or more BSON (Binary JSON) [14] documents; each BSON document [15] is structured as an ordered list of field-and-value pairs: each field is a string value, enclosed in quotation marks; each value conforms to a BSON data type [16] (e.g., String, Double, Object, Array, ObjectId, Boolean, Date, Null, Timestamp, Decimal128). Recall also that, although BSON is a binary representation of JSON, it provides more data types than JSON [17]; more details on BSON types can be found in [16]. Notice that each BSON document contains a field named "_id" (like that of Fig. 1) which is used as a primary key: its value must be unique in the collection, is unchangeable, and its type cannot be "Array". Notice also that a collection is analogous to a table in a relational database, a BSON document in a collection is analogous to a tuple/row in a table, and a field in a BSON document is analogous to a column in a table.

```
{
  _id: ObjectId("38cf2971a84057b9f574e489"),
tenantId: ObjectId("49cf3082a73946b8f685e378"),
apartmentId: ObjectId("68cf28e2a05279b9f796e266"),
rentalStartDate: ISODate("2022-09-01T08:45:21.165Z"),
monthlyRentalAmount: Decimal128("1000")
}
```

Fig. 1. An example of a document of the *company.rentals* collection.

Let us assume that this company increases, for each rental, the monthly rental amount by 2.5%, at the beginning of January of each new year. In order to apply these yearly increases to its MongoDB database, the company creates with the Atlas platform a scheduled trigger, named *increaseRentalAmounts*, which fires every January at 00:00 AM UTC (to which corresponds the CRON expression "0 0 1 JAN *"), as shown in Fig. 2 displaying the configuration file (defined as a JSON file) of this scheduled trigger. When this trigger fires, it calls its linked MongoDB Atlas function, named *applyYearlyIncreaseOfRentalAmounts*, which runs a physical update on the *company.rentals* collection to apply the increases for all rental amounts, as shown in Fig. 3. This function is defined in the MongoDB Query Language (MQL) using (i) the CRUD [18] operation db.collection.updateMany(filter, update, options), which updates all documents that match the specified filter for the collection "collection" of the database "db", and (ii) the field update operator $mul, which multiplies the value of the field by the specified value.

Notice that the configuration file of Fig. 2, named "increaseRentalAmounts.json", must be added to the *triggers* subdirectory of a local application directory as follows: /triggers/increaseRentalAmounts.json.

```
{
  "type": "SCHEDULED",
  "name": "increaseRentalAmounts",
  "function_name": "applyYearlyIncreaseOfRentalAmounts",
  "config": {
    "schedule": "0 0 1 JAN *"
  },
  "disabled": false
}
```

Fig. 2. The configuration file of the scheduled trigger "increaseRentalAmounts".

```
company.rentals.updateMany(
{ $mul: { monthlyRentalAmount: Decimal128("1.025") } }
)
```

Fig. 3. The MQL code of the function "applyYearlyIncreaseOfRentalAmounts" of the scheduled trigger "increaseRentalAmounts".

Recall that, in the MongoDB Atlas platform, a CRON expression [9] is a developer-defined string comprising five time fields separated by white space, which defines when a scheduled trigger should execute. The fields (ordered from left to right) and their allowed values (between parentheses) are as follows: minute (0, 1, 2, …, 59), hour (0, 1, 2, …, 23), dayOfMonth (1, 2, 3, …, 31), month (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 or JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC, respectively), and weekday (0,1, 2, 3, 4, 5, 6 or SUN, MON, TUE, WED, THU, FRI, SAT, respectively). Notice that the value of a field can be either a specific value (as mentioned above), or an expression that represents a set of values, like the asterisk special character (*) which is allowed for any field and represents "all" (for example, the CRON expression "* * * 4 *" schedules a trigger that fires once every minute of every day in April). More details on CRON expressions can be found in [9].

Whenever the five fields of a CRON expression match the current date and time, MongoDB Atlas fires the trigger associated to such an expression.

As also reflected by the admitted syntax of CRON expressions shown above, MongoDB Atlas does not support the definition of scheduled triggers that consider single (i.e., non-periodic) events. For example, if now (on March 2024) we want to proactively schedule an increase of the employees' salaries valid from the beginning of January 2025 and/or from the beginning of January 2026, we cannot do it via a scheduled trigger offered by the MongoDB Atlas platform.

Notice that due to this lack of support for single event-based scheduled triggers, MongoDB Atlas currently uses a limited CRON syntax. The CRON expression format, specified in the configuration file of the scheduled trigger, does not include indeed a field for specifying the year of the event, nor a field for the seconds.

In the next section, we describe our proposal for extending to single events the MongoDB Atlas trigger scheduling mechanism.

3 Extension of the Scheduled Triggers Mechanism of MongoDB Atlas to Support Single Events

In this work, we aim at addressing the weaknesses mentioned at the end of the previous section and, thus, at making MongoDB Atlas more useful for developers who want to implement proactive changes, which are often occurring in the lifetime of an information system, by means of scheduled triggers firing at single events. To this end, we propose an approach that consists in extending the current mechanism of MongoDB Atlas for the management (i.e., configuration, execution, …) of scheduled triggers to also support single event-based scheduled triggers. Therefore, an extended CRON syntax has to be considered in order to make the new mechanism available to users. In fact, the current format of CRON expressions, as specified in the scheduled trigger configuration files, must be extended with two new fields: the first field for the seconds (on 1 or 2 digits, as the allowed value for a second belongs to the set {0, 1, 2, …, 59}), located at the beginning of the CRON expression, and the other field for the years (on four digits, as the allowed value for a year belongs to the set {2024, 2025, …, 9999}), located at the end of the CRON expression. Notice that, contrarily to some environments that allow the field year to have a past value (e.g., in [10] and [19], a year can have a value in the set {1970, 1971, …, 2099}), for proactive updates on the MongoDB Atlas databases, only the values of our proposed set (from 2024 to 9999) are meaningful. In fact, developers of MongoDB Atlas-based applications do not need the values representing past years when defining scheduled triggers, since triggers cannot fire in the past.

Hence, according to the extension that we propose for the MongoDB Atlas trigger scheduling mechanism, a (full) CRON expression is composed of seven fields, in order to cover all possible time values that can be used to define when a scheduled trigger, associated to a single or periodic event, should fire. Notice that this 7-field format of CRON expressions is also adopted in other environments including DBMSs (e.g., Oracle [10]), the Java Quartz job scheduling library [11]).

3.1 Illustrative Example

In order to illustrate how our approach could be used to define and manage single event-based scheduled triggers with an enhanced future version of MongoDB Atlas, let us resume the example of Sect. 2. Hence, we assume that, on March 15, 2024, a salary increase has been decided for the employees of the company by a newly signed collective labour agreement ruled as follows: the first tranche of the increase is 5% of the salary, valid from June 2024, and the second tranche is 2% of the salary, valid from September 2024.

We also assume that the company records employees' data in the *company.employees* collection in documents as shown in Fig. 4; each document is for a distinct employee and each employee is described by his/her SSN, name, hire date, and salary.

```
{
  _id: ObjectId("27cf3082a95168b0f463e578"),
SSN: "111222333",
name: "Ahmad Hamid",
hireDate: ISODate("2019-01-12T09:14:32.177Z"),
salary: Decimal128("5000")
}

{
  _id: ObjectId("37cf6064a80226b0f826e046"),
SSN: "444555666",
name: "Aicha Bakir",
hireDate: ISODate("2020-05-15T11:05:54.245Z"),
salary: Decimal128("6000")
}
```

Fig. 4. An example of two documents of the *company.employees* collection.

In order to proactively apply the two salary increases, the company creates (now, on March 15, 2024), with the enhanced version of MongoDB Atlas, the two following scheduled triggers:

- The first one, named *firstTrancheSalaryIncrease*, which must fire at the beginning of June 2024, that is at 00:00 AM UTC on June 01, 2024. The CRON expression that corresponds to this event is as follows: "0 0 0 1 JUN * 2024". Figure 5 shows the configuration file of this scheduled trigger. When this trigger fires, it calls its linked MongoDB Atlas function, named *applyJune2024IncreaseOfSalaries*, which executes a physical update on the *company.employees* collection in order to apply the first increase for all employees' salaries, as shown in Fig. 6. This function is defined in MQL, while using the update operation db.collection.updateMany(), and the field update operator $mul. The effects of the execution of this trigger on the documents of the *company.employees* collection are shown in Fig. 7.

- The second one, named *secondTrancheSalaryIncrease*, which must fire at the beginning of September 2024, that is at 00:00 AM UTC on September 01, 2024. The CRON expression corresponding to this event is as follows: "0 0 0 1 SEP * 2024". Figure 8 shows the configuration file of this scheduled trigger. When this trigger fires, it calls its linked MongoDB Atlas function, named *applySeptember2024IncreaseOfSalaries*, which executes a physical update on the *company.employees* collection in order to apply the second increase for all employees' salaries, as shown in Fig. 9. This function is defined in similar way to the previous function. The impact of the execution of this trigger on the documents of the *company.employees* collection is shown in Fig. 10.

Notice that the configuration file of the first (second, respectively) scheduled trigger shown in Fig. 5 (Fig. 8, respectively), named "firstTrancheSalaryIncrease.json" ("secondTrancheSalaryIncrease.json", respectively), must be added to the *triggers* subdirectory of a local application directory as follows: /triggers/firstTrancheSalaryIncrease.json (/triggers/secondTrancheSalaryIncrease.json, respectively).

```
{
  "type": "SCHEDULED",
  "name": "firstTrancheSalaryIncrease",
  "function_name": "applyJune2024IncreaseOfSalaries",
  "config": {
    "schedule": "0 0 0 1 JUN * 2024"
  },
  "disabled": false
}
```

Fig. 5. The configuration file of the single event-based scheduled trigger "*firstTrancheSalaryIncrease*".

```
company.employees.updateMany(
{ $mul: { salary: Decimal128("1.05") } }
)
```

Fig. 6. The MQL code of the function "*applyJune2024IncreaseOfSalaries*" of the single event-based scheduled trigger "*firstTrancheSalaryIncrease*".

```
{
  _id: ObjectId("27cf3082a95168b0f463e578"),
SSN: "111222333",
name: "Ahmad Hamid",
hireDate: ISODate("2019-01-12T09:14:32.177Z"),
salary: Decimal128("5250")
}

{
  _id: ObjectId("37cf6064a80226b0f826e046"),
SSN: "444555666",
name: "Aicha Bakir",
hireDate: ISODate("2020-05-15T11:05:54.245Z"),
salary: Decimal128("6300")
}
```

Fig. 7. The states of the two documents of the *company.employees* collection, after the execution of the single event-based scheduled trigger "*firstTrancheSalaryIncrease*".

```
{
  "type": "SCHEDULED",
  "name": "secondTrancheSalaryIncrease",
  "function_name": "applySeptember2024IncreaseOfSalaries",
  "config": {
    "schedule": "0 0 0 1 SEP * 2024"
  },
  "disabled": false
}
```

Fig. 8. The configuration file of the single event-based scheduled trigger "*secondTrancheSalaryIncrease*".

```
company.employees.updateMany(
{ $mul: { salary: Decimal128("1.02") } }
)
```

Fig. 9. The MQL code of the function "*applySeptember2024IncreaseOfSalaries*" of the single event-based scheduled trigger "*secondTrancheSalaryIncrease*".

```
{
  _id: ObjectId("27cf3082a95168b0f463e578"),
SSN: "111222333",
name: "Ahmad Hamid",
hireDate: ISODate("2019-01-12T09:14:32.177Z"),
salary: Decimal128("5355")
}

{
  _id: ObjectId("37cf6064a80226b0f826e046"),
SSN: "444555666",
name: "Aicha Bakir",
hireDate: ISODate("2020-05-15T11:05:54.245Z"),
salary: Decimal128("6426")
}
```

Fig. 10. The states of the two documents of the *company.employees* collection, after the execution of the single event-based scheduled trigger "*secondTrancheSalaryIncrease*".

4 Conclusion

In this paper, we have proposed an extension to single events of the MongoDB Atlas trigger scheduling mechanism that currently supports scheduled triggers based on periodic events only. In order to make the new mechanism available to the users of MongoDB Atlas, our proposal considers a full CRON syntax, based on 7 fields (second, minute, hour, dayOfMonth, month, weekday, year), which replaces the currently limited one, based on 5 fields (minute, hour, dayOfMonth, month, weekday). Our aim is to have our extension integrated in the already existing trigger scheduler of MongoDB Atlas, by MongoDB Atlas developers who can access and modify the source code of the scheduler. In our opinion, such an extension allowing for the implementation as scheduled triggers of proactive database changes to be executed only once, would be an interesting functionality of the DBMS and, thus, we propose that it should be integrated in the system.

In the near future, and since currently CRUD operations of the MQL language involve only a single collection of documents, which can sometimes be limiting, we intend to also consider an MQL extension to support multi-collections CRUD operations and, consequently, to allow the definition of (among others) more complex functions associated to scheduled triggers.

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Proposed Architecture for Smart Irrigation System: Leveraging IoT and LoRaWAN

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Abstract. Water is a critical resource for human life, agriculture, and industrial processes. However, inefficient water management practices, population growth, and climate change have all contributed to an increase in the prevalence of water stress and scarcity. As a result, it's critical to use water resources effectively and sustainably. Well-designed irrigation systems can aid in water management and waste reduction. The design and implementation of a LoRaWAN-based smart irrigation system, integrated with Internet of Things (IoT) technology, are the primary topics of this research paper. The framework is intended to advance water utilization in horticulture and landscaping by monitoring soil moisture levels and atmospheric conditions, leveraging IoT connectivity to make real-time decisions, and delivering water to plants on a case-by-case basis. This innovative approach enhances precision and efficiency in water distribution, contributing to a more sustainable and responsive irrigation system.

Keywords: Smart irrigation system · Long Range Wide Area (LoRaWAN) communication · Agricultural sector · Water resources · Internet of Things (IoT) · Sustainable agriculture · The Things Network (TTN)

1 Introduction

Water is an essential element for human beings. However, in some countries, there is a shortage of water, which also affects agriculture, as it requires large amounts of water. Urban population growth is expected to raise water demand by 50% by 2050 [1], which present a substantial concern. This increase in demand is probably going to make water shortage problems worse, affecting both urban and rural people. This increased demand could have negative repercussions on daily living, including as making people more vulnerable to drought, which is anticipated to have long-lasting implications. Additionally, the cumulative effects of climate change are causing more frequent extreme precipitation events and greater flood hazards. These environmental changes highlight the significance of sustainable water management techniques and the need for adaptable solutions to problems related to both water scarcity and flooding [2, 3].This particular article specifically addresses the aspect of creating, implementing, and empirically validating a smart irrigation system that can be utilized in both urban and suburban settings.

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One possible solution to the problem of global warming is to construct a water control infrastructure and take steps to ensure water availability for both food production and consumption. To contribute to this effort, this research project focuses on reducing the amount of water used for irrigation, which has significantly increased over time. Until recently, the use of commercial sensors in agricultural irrigation systems for small-scale farmers was not feasible. However, with the advent of low-cost sensors now available from manufacturers, it is possible to integrate them with existing systems and monitor the agricultural sector more effectively, Enhancing crop production through Internet of Things (IoT) integration in agribusiness. However, farmers, especially those in developing nations, may find it challenging and expensive to use conventional techniques for evaluating critical agricultural factors like soil pH, moisture content, and temperature. A smart agriculture system using IoT devices and integrated system automation has been suggested to track agricultural needs in real-time to solve this problem. Real-time tracking and study of ecological factors by the system enable more effective agricultural management, which raises output at a reasonable cost. Recent developments in the Internet of Things (IoT) and Wireless Sensor Network (WSN) technologies have also enabled the creation of IoT-based applications that can improve irrigation regulation in farming processes. Our research is focused on implementing such an application, which can provide environmental parameters for monitoring purposes. The structure of this research paper is as follows: The first section serves as the introduction. Our proposed architecture and the implementation of the prototype are outlined in the second section. Section 3 delves into the specifics of our system's implementation and testing, while Sect. 4 is dedicated to the discussion and analysis of our work with some existing related works related to smart irrigation. Lastly, the concluding section presents the overall conclusions and future perspectives of our research.

1.1 Main Contribution of This Work

The proposed system for agricultural infrastructure supervision and remote control contributes significantly by:

1. Enabling remote monitoring and control, reducing farmers' trips and optimizing irrigation processes.
2. Implementing an IoT-based irrigation management system that monitors crucial parameters like temperature, light, and soil moisture in real-time.
3. Utilizing LoRa technology for reliable long-distance communication in rural agricultural environments.
4. Integrating seamlessly with LoRaWAN network infrastructure to ensure efficient data forwarding, scalability, and security.
5. Employing cost-effective implementation through tools like TTN (The Things Network) for managing IoT devices.
6. Integrating sensor data with IoT cloud platforms such as Cayenne MyDevices and Thingspeak for data analysis and informed decision-making.
7. Providing farmers with real-time insights to optimize agricultural processes and improve productivity.

2 Proposed Methodology

The automated irrigation system changes the watering plan based on the requirements of your garden and operates at predetermined times. A smart irrigation controller, as opposed to conventional irrigation controllers, which depend on pre-established schedules and timers, autonomously adjusts the watering schedule based on the site's present circumstances by taking into account weather, soil conditions, evaporation, and plant water needs. Our research project aims to propose and develop a solution for supervising and remotely controlling agricultural infrastructures. The expected benefit is minimizing unnecessary trips for farmers and optimizing irrigation processes. The proposed IoT solution aims to design a prototype irrigation management system, which is a key factor for agricultural development. We suggest a real-time monitoring system for temperature, light, and soil moisture parameters. The network solution will be based on LoRa (Long Range) technology [10]. This application allows the collection of information related to the state of the agricultural environment, specifically soil moisture, light, and temperature, using wireless sensors deployed in the agricultural area to be controlled. The sensors send the sensed data using a LoRa module to a sink node (Gateway). The Gateway node forwards the received measurements to the network and application servers of LoRaWAN [11, 12] utilizing the IP protocol. To achieve this, we will use TTN as a free tool for LoRaWAN. After this, API integration with an application server will send the data to an IoT cloud platform, i.e., ThingSpeak. Figure 1 gives the visual architecture of LoRa Technology.

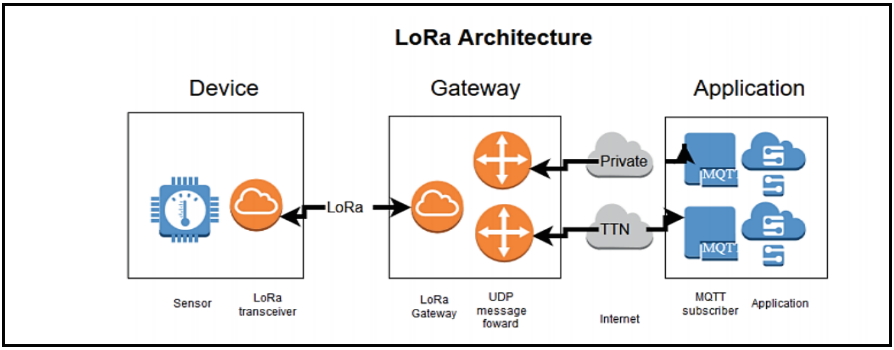


Fig. 1. Application architecture based on LoRa technology

In reaction to changes in the weather, such as an increase in temperature or a decrease in rainfall, an intelligent irrigation system, for instance, modifies the frequency and length of watering while also considering the location's particulars, such as the soil type, into account. Using your smartphone from home, you can manage to irrigate and dung your farmland. By turning on a valve and a water pump, analysis of the sensor data enables distant watering control in terms of time and water volume. The different steps for IoT application implementation are summarized in the block diagramin Fig. 2. To collect, transmit, store, and display data, various hardware/software, and communication technologies are employed, which include:

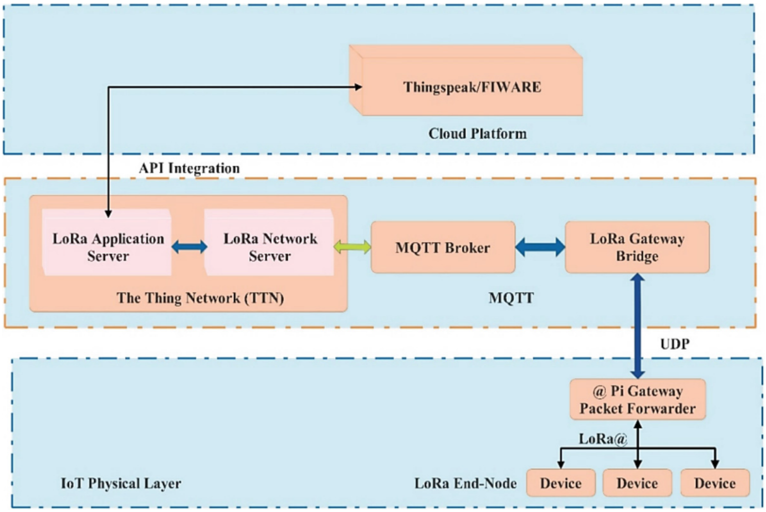


Fig. 2. Block diagram for IoT application implementation

2.1 Advantages of Our Proposed Methodology

1. **Increase in productivity:** By optimizing irrigation processes and providing real-time insights, the system enhances crop yields and overall agricultural productivity.
2. **Reduced water consumption:** Precise monitoring of soil moisture levels allows for efficient water usage, minimizing waste and promoting sustainable water management practices.
3. **Elimination of manpower**: Automation of irrigation control eliminates the need for manual labor, reducing operational costs and streamlining agricultural operations.
4. **Mitigation of soil erosion and nutrient leaching:** Fine-tuned irrigation scheduling prevents overwatering, which can lead to soil erosion and nutrient leaching, thereby preserving soil health and fertility.
5. **Utilization of smaller water sources:** Efficient water management enabled by the system means that smaller water sources can suffice, reducing reliance on larger water reservoirs and promoting water conservation.

2.2 Hardware Components

The proposed prototype is centered around various hardware components, including an Arduino microcontroller, which is a single-board microcontroller responsible for collecting sensor data and performing statistical analysis to control the valve for watering. The microcontroller connects all the sensors, actuators, and data transceivers, and it has multiple digital and analog input and output pins, making it energy efficient. The prototype also includes light sensors to detect light and generate an output signal that corresponds to the intensity of the light. A moisture sensor collects analog soil moisture content data, which is displayed on an Android or web-based application. Additionally, a temperature and humidity sensor is added to collect data about the enclosed environment surrounding the soil sample. To trigger the solenoid valves, they must only activate when the moisture sensors return a specific pre-coded value. Each valve has a corresponding relay, and each relay has a moisture sensor. The water pump is also included in the prototype. The Arduino Uno receives sensor data and controls the Lora shield to send this data to the Esp32 Lora Gateway via Lora Wireless Protocol. The Esp32 Lora Gateway receives the data and uploads it to the TTN network via the Internet, using the RFM95W transceivers with the LoRaTM long-range modem. The TTN server stores the data packets received from the Esp32 Lora Gateway, and the MQTT protocol is used for communication. A cloud database, "Thinkspeak.com," stores and retrieves information using the HTTP protocol over the Web. The data captured from sensors are shown on the window of ThingSpeak, demonstrating the status of the environment. An end device monitors the parameters and can be anything with an internet connection. Lastly, the PC/Application is used to access the data and check the status of the Lora Gateway network, and a mobile application developed using MIT App Inventor can control the system from a far distance.

2.3 Non-functional Requirements of Our Proposal

Non-functional requirements describe how the system should perform. They do not affect the system's basic functionality.

- **Usability:** The system is connected to a web application, allowing users to view their devices' data on mobile devices or laptops and control their system.
- **Reliability/Availability:** The hardware and software are both reliable and straightforward. The system is unlikely to fail, although damage to the cable may occur over time, which can be easily fixed.
- **Scalability:** The system uses many different sensors and can be easily modified to meet technology requirements. More sensors can be added to the card with wider coverage if needed.
- **Performance:** The system must work in real-time mode, providing fast updates of the app with relevant information, but high-speed data transfer is not necessary.
- **Supportability:** The project components are portable, making it easy to move them from one place to another. If the components are connected and installed in place, the system can be switched with relative ease.
- **Security:** AES is used in LoRaWAN, which improves device authentication and address using Appkey and NSkey. Keeping the system secured and safe is crucial.

3 Implementation and Testing

To assess its efficacy in water management and plant health, the suggested LoRaWAN-based smart irrigation system was deployed and tested in both a greenhouse and an outdoor garden. Figure 4 shows the suggested method's working model diagram. The hardware used in the experiment included the following:

The system was implemented in a greenhouse and an outdoor garden to monitor the performance of the system in different conditions. The soil moisture sensors were placed in the soil of the plants to measure the moisture levels (Fig. 3).

- The temperature and humidity sensors were placed in the surrounding environment to measure the atmospheric conditions.
- The solenoid valves were connected to the water supply and controlled by the Arduino Uno.
- The LoRaWAN Gateway is installed to receive sensor data and send it to the cloud for monitoring and analysis. It operates within a 1km distance from the LoRa End device.
- The mobile application was developed using MIT App Inventor to monitor the system and control it from a distance.

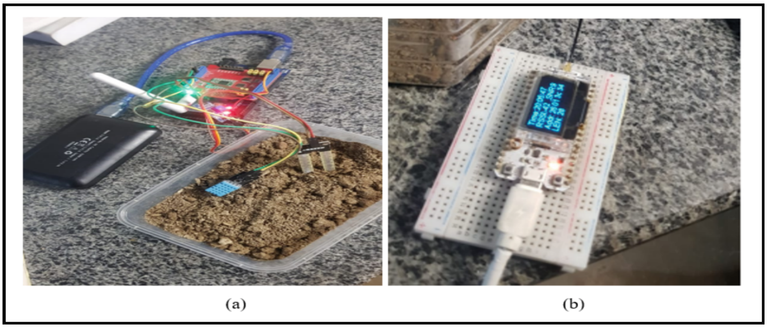


Fig. 3. a. Lora End-Node, b. Lora Gateway implementation in our proposed methodology.

The system was run for several weeks to collect data on water usage and plant health. The results of the experiment showed that the LoRaWAN-based smart irrigation system was effective in reducing water usage and improving plant health compared to traditional irrigation methods. The visual representation of the Lora End Node and Lora Gateway is shown in Fig. 4(a), (b) respectively.

The system was able to deliver water to plants on a case-by-case basis based on soil moisture levels, which reduced water waste and ensured that plants received the optimal amount of water. The data collected from the sensors was sent to the cloud for monitoring and analysis, which allowed for real-time adjustments to be made to the system. Overall, the results showed that the use of LoRaWAN technology in smart irrigation systems has great potential for improving water management practices and reducing water waste in agriculture and landscaping. The architecture of the proposed method is given in Fig. 5.

Cayenne MyDevices is a web-based platform for managing and viewing Internet of Things (IoT) devices. It has an easy-to-use user interface that lets people see data from sensors that are connected to The Things Network (TTN). By enrolling their end gadgets and doors with TTN, clients can undoubtedly access and screen the uplink information created by the sensors. A comprehensive and simple-to-understand visual representation of this data is provided by the Cayenne MyDevices dashboard. The temperature, humidity, and air quality can all be monitored by users, who can also view their sensors and devices. Moreover, the stage gives progressed examination instruments that permit clients to imagine patterns, set alarms, and go with information-driven choices. Overall, Cayenne MyDevices is an effective instrument for managing and monitoring IoT

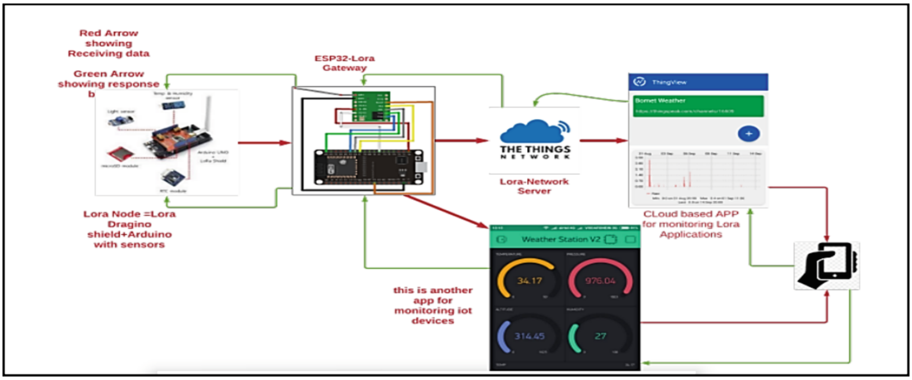


Fig. 4. The Global Architecture of the Proposed Method

devices. It is an essential platform for any professional or enthusiast of the Internet of Things due to its user-friendly interface, robust analytics tools, and seamless integration with TTN. Figure 9 provides a clear understanding of the platform's capabilities through a visual representation of the dashboard.

The experimental testing of the proposed project was conducted in four phases: integration testing, system testing, acceptance testing, and performance testing. In the integration testing, the project was divided into segments, and each member worked on their assigned segment. The unit tests were combined and evaluated to ensure that Lora End-Node could send data, Lora Gateway could receive data, TTN could show data received from sensors, and Cayenne could display sensor data for users. The system testing phase was performed to evaluate the project as a whole, with tests conducted to ensure that the Lora End-Node and Gateway were working correctly, registered on TTN and that the Cayenne dashboard was functioning as expected. In the acceptance testing phase, the project was delivered to end-users, and tests were conducted internally and externally with users to get their feedback [13, 14].

To assess the project's responsiveness, stability, and security, a performance testing step was lastly carried out. The team tested Lora endpoints with sensors, Lora Esp32 gateways, Lora nodes and gateways registered with The Thing Network, and user web interfaces connected with TTN throughout the integration testing phase. The project performed flawlessly and the testing turned out to be successful, which was what was anticipated. The Lora End-Node was evaluated during the system testing phase to make sure it was functioning properly, and subsequently, the Lora Gateway was tested as well. Then, to make sure they were operating flawlessly, Lora End-devices and Gateway were registered on The Thing Network. The system testing phase's tests all passed with flying colors (Figs. 6, 7 and 8).

The team tested the project internally and externally with a variety of users throughout the acceptance testing phase and got feedback that everything was running smoothly. Finally, the team tested the project's responsiveness, stability, and security during the performance testing phase. The planned idea was thoroughly tested throughout four phases, and each test was a success. The project was successfully tested experimentally, and end users gave the project their enthusiastic approval. The project's responsiveness,

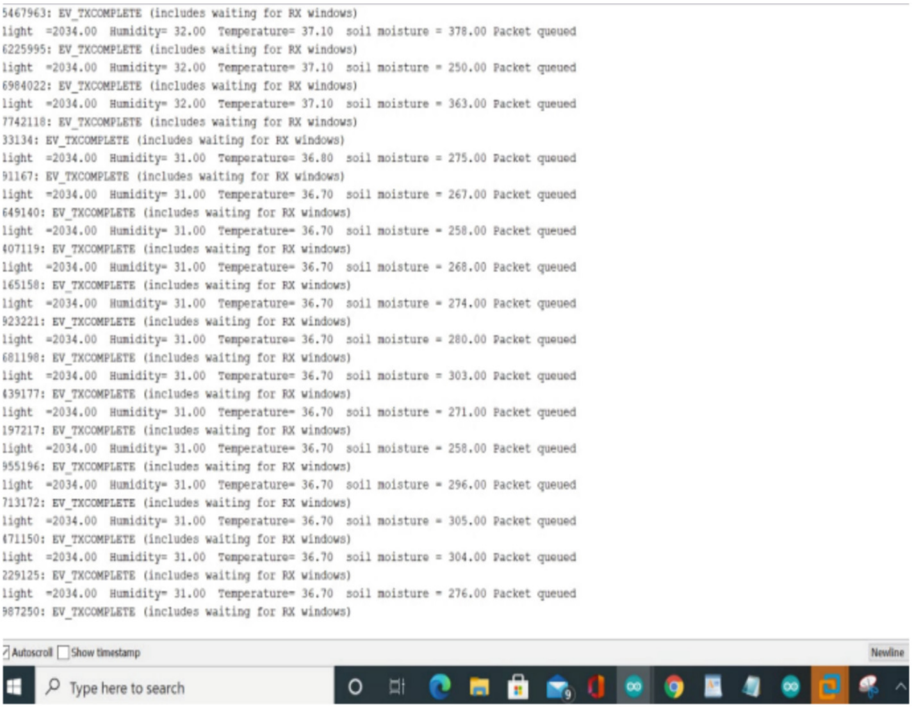
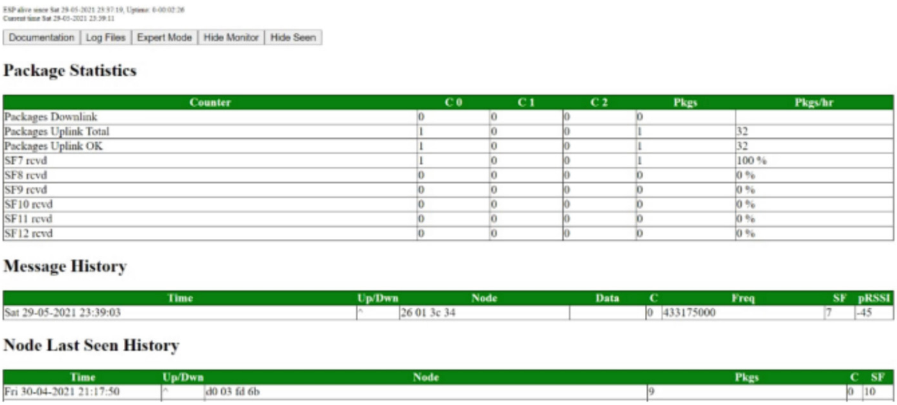


Fig. 5. Integration testing of LoRa End-Node: This test case is considered complete when all sensors with Arduino and the LoRa RF95W module (Dragino Shield) are functioning correctly.



Counter	C 0	C 1	C 2	Pkgs	Pkgs/hr
Packages Downlink	0	0	0	0	
Packages Uplink Total	1	0	0	1	32
Packages Uplink OK	1	0	0	1	32
SF7 rcvd	1	0	0	1	100 %
SF8 rcvd	0	0	0	0	0 %
SF9 rcvd	0	0	0	0	0 %
SF10 rcvd	0	0	0	0	0 %
SF11 rcvd	0	0	0	0	0 %
SF12 rcvd	0	0	0	0	0 %

Time	Up/Dwn	Node	Data	C	Freq	SF	pRSSI
Sat 29-05-2021 23:39:03	^	26 01 3c 34		0	433175000	7	-45

Time	Up/Dwn	Node	Pkgs	C	SF
Fri 30-04-2021 21:17:50	^	d0 03 fd 6b	9	0	10

Fig. 6. Integration testing of Gateway Receiving data: The test case reaches its conclusion when the gateway displays data reception from a particular device address, both on the LCD screen and the web interface.

stability, and security were confirmed by performance testing, giving rise to trust in the project's capacity to fulfill its intended function.

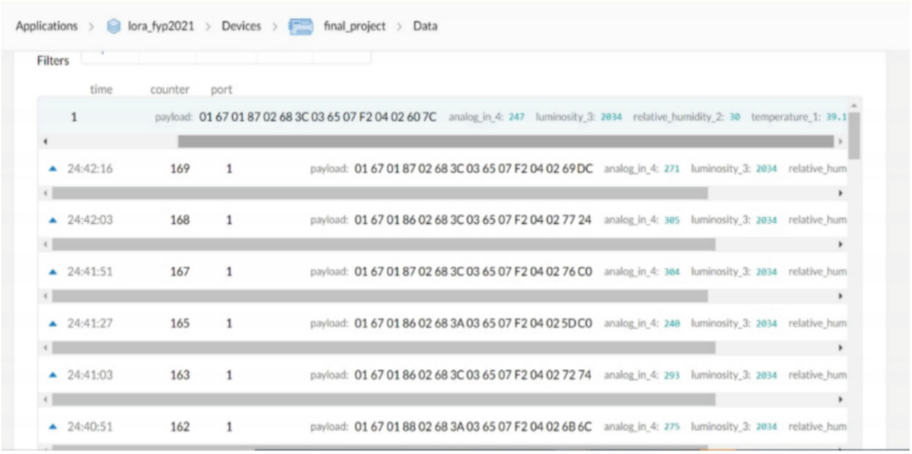


Fig. 7. Integration testing of The Things Network Server (TTN): the test case ends when sensor data is sent from the LoRa node to The Things Network Server via the LoRa Gateway, confirming reception. It also highlights the user/administrator's requirement to submit device data to the Network Server for long-range irrigation use.

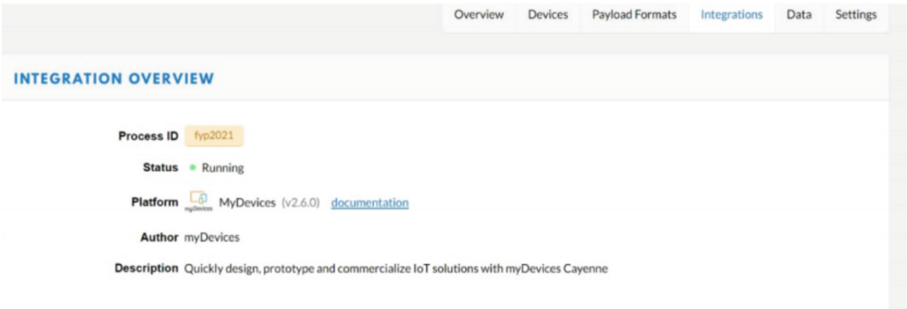


Fig. 8. Testing of application server integration: Users have the ability to both utilize and observe sensor data, as well as monitor their devices. This functionality will be integrated into the network, allowing users to access sensor data and monitoring features through an application interface.

4 Comparison and Discussion of Some Related Works with Our Proposed Method

Our research introduces an innovative approach to smart irrigation technology, incorporating key advancements that distinguish it from existing literature. Unlike prior studies, which often lack systematic verification processes and neglect the calibration of soil moisture sensors, our research emphasizes these critical aspects. By applying the V model methodology, which includes steps such as requirements analysis, system design, implementation, testing, and validation, we ensure thorough verification of system functionality, performance, and integration. This structured approach enhances the reliability

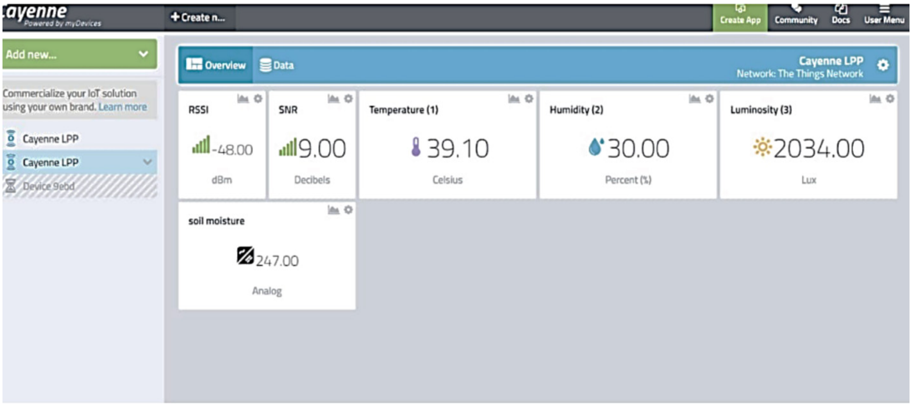


Fig. 9. The output of the sensors on Cayenne Dashboard

and effectiveness of our smart irrigation solution at every stage of development. Additionally, our system includes the calibration of soil moisture sensors, a crucial step to improve data accuracy and optimize irrigation strategies. Notably, the integration of LoRa technology for wireless data transmission further enhances our system's robustness and reliability, enabling seamless communication in agricultural environments. Comparatively, related works such as Pramanik et al. (2022), Abba et al. (2019), Munir et al. (2021), Pasika et al. (2020), García et al. (2020), and Tiglao et al. (2020) exhibit significant differences in these critical aspects. While our research emphasizes the calibration of soil moisture sensors to enhance data accuracy and optimize irrigation strategies, Pramanik et al. [5] conducted a study focusing on water usage monitoring utilizing the Croplytics platform, but it lacks automated irrigation adjustments and real-time monitoring features. Abba et al. [6] presented an IoT system for environmental monitoring but did not address automated irrigation adjustments or real-time monitoring in agricultural settings. Munir et al. [4] concentrated on water consumption monitoring but did not include real-time monitoring of key parameters or automated irrigation adjustments. Pasika et al. [7] introduced a system for environmental monitoring that did not utilize LoRa technology or include automated irrigation adjustments. García et al. [9] explored smart irrigation techniques but did not implement a realized irrigation system or include real-time monitoring features. Tiglao et al. [8] focused on monitoring temperature, humidity, and soil moisture but did not extend parameter coverage or include automated irrigation adjustments.

By addressing these limitations and incorporating advanced technologies, our research significantly advances the field of smart irrigation technology, paving the way for more efficient and sustainable agricultural practices.

5 Conclusion and Future Works

Using LoRaWAN technology and a programmable algorithm, the suggested smart irrigation system has demonstrated promising results in enhancing water management procedures and lowering water waste in agriculture and landscaping. The system provides real-time monitoring of soil moisture levels and weather conditions, allowing for more efficient water usage and improved plant health. Compared to existing methods, the proposed system offers several advantages such as optimized water usage, long-range wireless communication and adaptability to different crops, soil types, and weather patterns. While acknowledging potential limitations, the numerous benefits highlight its significance in sustainable agriculture and water management research. The proposed system has the potential to be a valuable tool for improving water conservation efforts and promoting sustainable agricultural practices.

As part of future work, securing the IoT-based smart irrigation system is paramount, with a specific emphasis on cryptographic techniques. The implementation of robust cryptographic algorithms, including certificate-based cryptography, will be crucial to ensure the confidentiality, integrity, and authenticity of data transmission and storage. This approach adds a layer of defense against various cyber threats, safeguarding the communication layer of the system. Collectively, these security measures form a comprehensive strategy for future work, fortifying the IoT-based smart irrigation systems against a spectrum of cyber threats and ensuring its reliability and integrity.

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Digitalization's Influence on Audit: Examining the Implications of Big Data and Blockchain Technology

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Abstract. The contemporary society is undergoing constant evolution, with digitization emerging as a predominant global trend. This transformation is significantly influencing organizations, compelling them to navigate waves of digitalization. To effectively respond to the ever-changing and rapidly accelerating customer demands, organizations must harness digital technologies to adapt their operational frameworks. This adaptation aims to enhance efficiency in their processes. The focal point of this study is to enhance understanding regarding the technological forces shaping the audit profession. Specifically, the study investigates the impacts of big data and blockchain technology on auditing through semi-directed interviews conducted with selected auditors from diverse audit companies. The insights gleaned from these interviews contribute to an enriched comprehension of big data and blockchain's role within the audit domain. The study identifies four key themes aligned with participant feedback, elucidating the influence of big data and blockchain on auditing: 1) the commitment to training personnel in new audit software and methodologies, 2) the necessity for IT support to bridge technological knowledge gaps among auditors, 3) the adoption of specialized audit software beyond Excel in organizational practices, and 4) the limited experience or early-stage adoption of big data and blockchain within audit firms. The study's findings offer valuable insights for auditors and other stakeholders involved in working with clients leveraging these technologies in their systems.

Keywords: Auditing · big data · blockchain technology · digitalization

1 Introduction

External auditors function as ambassadors of the auditing profession, upholding integrity and protecting the public interest by offering assurance to stakeholders. These stakeholders depend on the ultimate audit opinions or reports to evaluate an organization's financial practices and internal controls [1]. While the core objective of external auditors remains consistent [2], the audit profession is experiencing a technological revolution propelled by innovations such as blockchain technology and big data [3]. Scholars posit that the adoption of emerging technologies will lead to a transformation in the audit process [4]. It is recommended that auditors get adapted to blockchain technology and big

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data by developing strategies and roadmaps to understand these technologies. Auditors need to possess a comprehensive understanding about their clients' technology usage and possess knowledge of the internal controls required to mitigate inaccuracies in this context [5]. Audit procedures and standards will have to evolve to accommodate big data's reliance on vast amounts of structured and unstructured data. Non-traditional software and database systems will be necessary for auditing these data sets effectively. Similarly, blockchain technology offers a reliable and immutable shared ledger, necessitating auditors to get used to new systems and understand the impact on their role [6]. Efforts should be made to explore and comprehend the implications of these two emerging technologies. The audit profession needs to be forward-thinking in addressing these factors and keeping pace with technological innovation [7]. Auditing firms must recognize the importance of these technologies to integrate the requirements of clients and address the concerns of society [8]. Auditors will encounter disruptive technological processes, such as the transition from traditional double-entry accounting to the transformative effects of a third entry system of accounting [7]. Training and education are essential for future audit professionals to acquire the necessary skill sets and adapt to the changes brought about blockchain technology and big data. However, more research is required to fully understand the value that big data brings to audit profession [9].

In summary, the audit profession is experiencing significant technological shifts due to the emergence of big data and blockchain. Auditors need to stay informed, adapt their practices, and proactively address the challenges and opportunities presented by these technologies to ensure the continued effectiveness of the audit process.

2 Section 1: Foundation of the Study

A. Problematic Statement

The main issue addressed in this study was the absence of preparation among auditors in practice for the impacts of big data and blockchain technology on audits, leading to limitations in providing support to clients. Sekli and Lavega [1] highlighted the need for auditors to undergo additional training to keep up with technological advancements in big data and blockchain technology. The rapid impact of the technology of big data on the accounting field, specifically audit functions, has been noted. The disruptive nature of the blockchain technology on the audit profession has not been completely expected, necessitating the development of recently acquired proficiencies and modernized business approaches to effectively serve customers. These changes create a future landscape that the personnel have to adapt to better respond to customer's expectations.

B. Objective Statement

The aim of this research is to participate in the existing prior information base by providing investigations about the effects of big data and blockchain technology on audits and the weaknesses encountered when serving customers. In the latest period, there was a considerable growing concern about the impact of blockchain technology and big data on the responsibilities of auditors, primarily driven by automatization and potential marginalization. The study will empirically examine the consequences of the two main technologies on auditor scope of work, technological advancements, and the future impacts of supporting customers [2].

C. Theorical Framework

The qualitative study is based on the theoretical framework of structuration theory, as found in the accounting literature. This theory is utilized to shed light on the tasks by hierarchy, authoritative duties, and historical evolutions affecting the responsibilities of auditors. Additionally, the study explores the methods used by auditors regarding big data and blockchain technology to provide optimal services to clients.

1) Structural Theory

Giddens (1971) developed structuration theory, which was employed to analyze the interaction between strategic management and accounting in a firm [3]. Additionally, this theory enhances accounting research by providing a framework for understanding organizational strategy and the individuals involved [3]. As auditors' missions evolve, the utilization of emerging technologies, such as big data and blockchain, plays a significant role in driving these changes. The individuals experiencing this evolution and the strategic planning initiatives undertaken by the firm are key factors in understanding the effects of these technologies on the audit profession.

To summarize, this theory was employed to explore the impact of the advancements of technology on the auditors tasks, the individuals engaged, the institutional frameworks they manage within, and the societal perspectives they uphold [4]. Structuration theory specifically focuses on understanding the relationship between processes, human actions, and structures within specific temporal and spatial contexts.

2) Audit and Structural Theory

Giddens' theory of structuration provides a framework for understanding the interactions and interdependence of actors within a social system. It highlights the interconnectedness of human conducts, systems of authority, social organizations, and purposes. Auditors, as active agents, operate within a regulated system [5], representing their clients' interests. Structuration theory extends its scope to encompass institutions, firms, and the dynamics of interactions. Auditors, in their practical-world roles, hold a social position shaped by professional practices and interactions with various actors. The collaboration between accounting and strategy is explored within this framework, with an emphasis on actively transforming accounting structures. Strategy, seen as a social approach rooted in concrete actions, is central to this perspective. Technological advancements play a significant role in shaping auditors' roles and bring about new incomes and expenses considerations for accounting organizations [6].

3) Technology and Structural Theory

The impact of technology on the audit tasks is a complex phenomenon. Technology is seen as a social framework guided by logical principles, with the decision to adopt or reject it influenced by individual power dynamics. When conforming to new technologies such as blockchain technology and big data, it is crucial to consider technological structuration due to the interconnected power dynamics at play [4]. These power organization involve governing bodies, auditors, institutions, and their relation with customers they serve.

D. Literature Review and Related Works

With the models of digital technology (Artificial Intelligence, Blockchain, Big data, Big Data Analytics…), audit is evolving towards a new role that incorporates new areas of assurance. This digitalization is expected to improve the quality of audit and, consequently, the audit profession.

1) Blockchain

Blockchain technology is a peer-to-peer database characterized by decentralization that chronologically stores information on transactions of any kind in blocks [7]. The blocks are ordered in a sequential and chronological arrangement and shared on a network, called a node, which holds an identical copy and validates each new transaction, known as a block. It utilizes a number of blocks to create a peer-to-peer digital currency system that is publicly accessible and cryptographically secured [8].

The key attributes of blockchain are: 1) peer-to-peer (it is decentralized), 2) strong verification, and 3) resistance to altering. Blockchain technology is intended to decrease transaction fees, accelerate the exchange speed, facilitate micro-payments, mitigate the risks of fraud, upgrade transaction and operations auditability, and enhance surveillance efficiency [2].

The strength of blockchain is that the information staved in the chain is accessible to predetermined entities only. This strategy can secure the data and make it more confidential.

A. Relevance of the Subject

The primary objective of this research is to enhance our understanding of the technological influences on the audit profession. The study meticulously delves into the repercussions of big data and blockchain technology on auditing practices, employing a methodological approach centered around semi-directed interviews. These interviews, conducted with carefully selected auditors representing diverse audit firms, serve as a crucial avenue for gaining insights into the evolving dynamics and challenges that emerge at the intersection of advanced technologies and the audit profession.

2) The Blockchain Technology in Application

In practice, the utilization of blockchain technology offers significant advantages. Audit firms and their clients can save time and money by integrating blockchain features into their systems. Blockchain simplifies transactions, promotes inter-company collaboration, strengthens trust among partners, and reduces transaction costs.

The benefits for accounting and auditing are numerous: accurate verification and visualization of transactions by the involved parties, timestamped and immutable data, increased reliability, efficiency in managing cutoffs and confirmations. Auditors can perform real-time analytical procedures. Compared to traditional audits, blockchain-based auditing provides continuous monitoring of transactions, eliminating the need for manual activities such as observations, oral interviews, and paper-based reconciliations [9].

In summary, the use of blockchain technology in audit and accounting brings significant improvements in terms of accuracy, efficiency, transparency, and real-time transaction monitoring, transforming audit practices.

3) Big Data

The term "Big Data" was coined by NASA scientists who faced challenges in managing large amounts of data. The concept of dealing with a massive volume of information dates back several decades, with the term "information explosion" being used in 1941 to describe the rapid growth of data.

Big Data is a one of the innovations of technologies and designed to extract value from very huge volumes of diverse data by enabling great speed capture, discovery, and analysis. It refers to data whose volume, acquisition speed, or representation limits the capacity to use traditional relational methods for effective analysis, or data that can be efficiently processed with significant horizontal scaling technologies [10].

The technology of Big data is reshaping the auditing profession and introducing more sophisticated methods and tools in audits [11]. These innovations in financial and accounting audits aim to make auditing procedures more simple, enhance the performance of organizations, and reduce the risk of audit [12]. The Big Four accounting firms are embracing the concept of IT auditing, continuous or hybrid auditing, recognizing that technology plays a crucial role. IT auditors now handle information technology controls such as user authorizations management and access providing. In order to understand big data technologies and their application in audits, auditors require technical skills in areas like programing, secret writing, and hashing functions. Auditing tests and procedures are improving to favor real-time or continuous auditing, leveraging current and pertinent data [13].

The three defining elements of the big data technology, commonly known as the three Vs, are volume, variety, and velocity. Volume refers to the accumulation of data from diverse sources and the storage of vast amounts of information, Velocity pertains to the speed at which data is processed and Variety encompasses the diverse forms of data.

4) Related Works

The intersection of big data and blockchain technology with the field of audit has garnered substantial attention within the academic and professional realms. Numerous scholars have delved into the implications of these technological advancements on traditional audit practices, seeking to unravel the transformative effects on data management, security, and overall audit efficiency.

In their study, Jana and Giulia [14] specifically highlights its impact on the auditor-client relationship, alterations in audit engagements, and the common challenges faced in implementing BDA(big data analytics) in audits. The empirical findings serve as a foundation for suggesting areas for further research, offering valuable insights. This study represents one of the early empirical accounts shedding light on the emergence of BDA (big data analytics) in the realm of auditing.

However, this research [15] explores the impact of big data and blockchain on auditing, highlighting improvements in data management and security. Recent research emphasizes integrating big data analytics for enhanced risk assessment and decision-making in audits. Blockchain introduces transparency and decentralized data storage, prompting investigations into its effects on audit trail integrity. The literature provides insights into the evolving landscape of technology and audit, addressing challenges and opportunities resulting from these advancements in the audit profession.

3 Section 2: Overview of the Study and Presentation of the Findings

A. Discussion of the Method and Design

The qualitative method focuses on examining real events and daily relationships of the society that contribute to understanding human actions. It delves into the narratives and stories behind these phenomena to provide clarity and meaning. Essential to qualitative research is the skill of active listening and addressing insightful questions, as this process of interrogation shapes and guides the study [16].

The nature of the purpose statement in this research lends itself to the qualitative approach, which will involve gathering feedback from organizations and auditors through observations and interrogations.

B. Population and Sample

The intended group for this research encompassed audit organizations, including Big 4 firms and smaller audit organizations. The primary criterion for selection was the inclusion of firms that had experience or a strategic approach in utilizing technology such as blockchain and big data in their audit processes. Initially, participants were reached out through email or telephone and were provided with a clear explanation of the study's academic objectives and educational purposes. Random sampling techniques were employed by the researcher. Our research followed a qualitative approach using a semi-structured interview guide. We conducted interviews with 13 auditors from different audit firms located in different cities in Morocco (big 4 and non-big 4). We scheduled appointments in advance with the targeted respondents, including senior auditors, audit associates and an assistant director of information technology audits. The average duration of each interview was estimated at 40 min, during which we recorded the conversations, took notes, and transcribed the responses afterward. The final number of interviews was determined based on the principle of information saturation defined by Glaser and Strauss [17]. This means that we stopped conducting interviews when we felt that the respondents were no longer providing new information beyond what had already been collected. The interviews were transcribed, and the data was analyzed using NVivo.

C. The Findings Presentation

The following topics emerged from the participants' responses during the interview and survey process. Multiple participants identified these patterns, which were considered for inclusion. The literature review served as a basis for support and further validated the study due to its alignment with the findings.

1) Theme One: Training

The competencies of auditors can be effectively addressed through continuous adaptation and embracing technological advancements that constantly reshape and redefine their positions [18] Proficiency in big data analytics will become essential to effectively examine and perceive data in order to draw meaningful results. This will require a good comprehension of computer programs, extra learning through Continuing Professional Education courses, and a proactive shift towards embracing the technology-driven future of auditing.

2) Theme Two: IT Support

The recurring concept of involving IT support or experts in technology-driven audits using blockchain or big data technology was corroborated by the literature. The strong connection between information technology professionals and audit staff was emphasized by participants as essential for a thorough and well-supported audit. The implementation of blockchain technology reduces the manual transactional tasks typically performed by auditors, particularly through the utilization of smart automatic contracts, thereby promoting a technology-driven approach to auditing [19]. Furthermore, the integration of big data introduces a new type of validating evidence that complements traditional audit evidence. Auditors are increasingly required to possess skills in both auditing and technology, necessitating a transition from traditional old skill sets [20].

3) Theme Three: Specific Software

The study revealed that the design and utilization of software in relation to the effects of blockchain and big data on audits is a significant theme and requirement in the industry. The literature also highlighted the necessity for specialized software that supports the audit process phases. The combination of data analytics and new technology offers enhanced reliability on the evidence of audit, reduced reliance on sampling, and a deeper comprehension of businesses [21–24]. Gathering audit evidence requires a multidimensional approach, incorporating multiple perspectives. The audit processes of blockchain technology are currently being studied in the fields of computer science and engineering. The advancements in the blockchain technology and big data present opportunities to enhance audit quality through improved data trustworthiness and reliability. Consequently, there is an increasing reliability on computing systems and digital technology programs to support the auditing procedures.

4) Theme Four: Early Stages Integration at Organization

There is a shared aspiration and understanding among certain firms to embrace and integrate the requirements of blockchain and big data technology into their auditing practices. However, participants acknowledged that each firm is approaching these technologies at their own pace and in their unique strategy. The expected consequence on the audit field is significant, as it involves the organization's choice to adopt and get advanced technology solutions. Several organizations are currently in various phases of planification to manage blockchain technology or big data in audits as they have acquired some experience in this regard. It can be argued that there is a clear profit and necessity to integrate, plan, and arrange for audits using these new technologies. However, it should be noted that some organizations are still in the early stages of establishing the foundations and preparing themselves for this transition [25–29].

D. Finding's Relationship to the Problem

The study focused on the insufficiency of preparation among auditors regarding the utilization of big data and blockchain technology in audits. Extensive literature research revealed common challenges faced by auditors in serving clients. The main challenge identified was the insufficient training available to arrange and prepare for blockchain and big data technology audits. While recognizing the disruptive potential of blockchain in the audit sector, the necessary changes were not fully understood. The study also highlighted the potential need for new skills and extra business services to effectively serve audit clients involved in blockchain technology and big data. The findings from participant interviews aligned with the common themes identified in the literature, thereby connecting the research problem with the interview results [30–32].

The interviews revealed several recurring themes related to the obstacles and preparation faced by auditors and their firms. Training was a prominent theme, with most members engaging in some strategy of learning or skill development. Many specifically mentioned attending courses provided by their audit firms. Another second theme was the limited understanding of the full impact of blockchain on the audit profession. While acknowledging the future implications, more than 50% of the participants lacked experience in dealing with blockchain practice within their auditing responsibilities. The use of technological support, acquisition of new software programs, and delegation of IT specialists were also identified as crucial themes associated with the problem. As stated by some interviewees, their firms were actively recruiting computer specialist in coding, investing in new software systems and programs, and seeking external IT expertise to plan for working with big data technology and blockchain in auditing engagements. Auditors and their firms were taking proactive measures to adapt and ensure high-quality audits in light of these technological advancements.

E. Summary of the Findings

By conducting interviews with auditors, this phenomenological qualitative research highlighted four main themes associated with the impacts of big data technology and blockchain on the audit profession.

To be eligible for participation, each interviewee had to possess experience in external auditing. The participants presented valuable information on techniques required for effective audit tasks, challenges posed by blockchain technology and big data, constraints, emerging opportunities, and instant actions regarding these technologies. The four themes were as follows:

Theme one: devotion to training personnel in new audit software and techniques.

Theme two: Need for information technology support to assist technological knowledge gaps among auditors.

Theme three: Adoption of specific audit software apart from Excel in organizations.

Theme four: Limited experience or early-stage adoption of blockchain and big data technology in audit firms.

The themes were identified through open coding after the interview process. The study aimed to contribute to the literature and investigate in the impact of blockchain and big data technology on the auditing profession. The findings from both the interviewees and the literature supported the study's purpose.

According to the respondents, preparation is crucial to deal with technological changes effectively. Successful engagement with blockchain and big data technology necessitates auditors to proactively prepare for new programs and seek support from IT specialists in areas where they lack expertise. Participants also emphasized the importance of understanding how to integrate an organization's software program to accommodate the features of blockchain technology and big data. Lastly, participants highlighted the need for acknowledging future changes, engaging in discussions, and developing upcoming plans to align advancements with ensuring high-quality audits.

4 Conclusion and Future Work

This study aimed to explore the impact of blockchain technology and big data on the role of auditors and how organizations were responding to these changes. Four key themes emerged from the findings: learning requirements, reliance on IT support, utilization of specific software, and the firms being in early stages of implementation. These themes were consistent among the participants, providing comprehensive data for the study. The study's findings contributed to the existing knowledge on the impacts of the big data technology and blockchain on the audit profession. The literature review corroborated the identified four themes and the participants' feedback. The results of the study provide valuable insights and contribute to the ongoing advancements in auditing, specifically regarding the experiences and familiarity of auditors and the implications of blockchain technology and big data on the audit process.

As a recommendation, future researchers interested in the impact of blockchain and big data on audits should investigate the internal controls and new standards regulators. During this study it was revealed that regulators are in the early stages of determining how to regulate audit processes related to blockchain technology and big data. Therefore, further research in this area would contribute to understanding the evolving regulatory framework in response to these technologies.

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Artificial Intelligence for Auditing

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Abstract. Although the potential benefits of artificial intelligence have been widely publicized, little is known about the relationship between artificial intelligence and auditing. This study examines the current state of artificial intelligence capabilities to achieve audit objectives. Using survey questionnaires, we collected data from company auditors in Brazil. We used neurofuzzy modeling to ex-amine the study hypothesis. Preliminary results indicate moderate prominence of artificial intelligence capabilities in achieving audit objectives. The findings suggest that the main challenges to be overcome are related to tangible resources such as data, technologies, technical human resources, etc. This study fills a gap in the literature and makes significant contributions: it advances existing literature arguments on artificial intelligence capabilities and audit objectives; provides critical insights into where to invest resources to develop artificial intelligence capabilities towards audit objectives; sheds light to managers on which capabilities should be encouraged in decisions to ensure reliability in the information produced for decision-making by stakeholders; and shows managers which paths can still be taken to increase audit performance based on artificial intelligence.

Keywords: Artificial Intelligence Capabilities · Auditing · Accounting Information

1 Introduction

Although the benefits of artificial intelligence and auditing have been widely reported in the cutting-edge literature [1], little is known about the prominence of artificial intelligence for auditing. We examine the current state of companies' artificial intelligence capabilities to achieve audit objectives. We intend to shed light on the context of Brazilian companies that intend to digitally enable auditing with artificial intelligence. Understanding this relationship is an important priority for several reasons:

- The growing complexity of the business environment around the world requires companies to provide more and more information through financial reports and disclosures that are substantive for decision-making by multiple stakeholders [2]. The audit has a key role in ensuring that the information provided is useful to stakeholders.
- Several scandals seriously damaged the reputation of companies, leading to a loss of credibility, making stakeholders more skeptical about the credibility of accounting information [3]. The audit profession is facing crises of public confidence after a series of high-level audit failures, such as the UK [4]. These audit-related scandals have increased pressures for the adoption of technologies in auditing activities.

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- -With the use and explosion of available computational power data, the world is making rapid developments in artificial intelligence as a source of commercial value [5]. Modern reporting is data driven [6]. As technologies evolve, academics and practitioners are constantly considering opportunities to improve the efficiency, quality, and effectiveness of audits [7]. Artificial intelligence can contribute to the flourishing of intelligent auditing [8] in companies.
- In summary, there are several reasons to say that it is worth adopting an audit enabled by artificial intelligence [9]: (i) artificial intelligence technologies allow the convergence of auditors' audit objectives with those of information demanders; (ii) artificial intelligence technologies create more access to a wider scope of data, along with fast and convenient measures for processing; (iii) auditors can define judgment rules, among other attributes. With the advent of artificial intelligence technologies, the objectives of auditing financial statements should be positioned on ensuring the reliability of accounting information, rather than on compliance of accounting reports with the fundamental principles of reporting standards [9].

However, existing studies [5] highlight that one of the main reasons why artificial intelligence has not yet delivered the expected results is due to delays in implementation and restructuring [10]. Therefore, organizations need to invest in complementary capabilities to harness the full potential of artificial intelligence and enable auditing to achieve its objectives. In other words, we need to know the current state of artificial intelligence capabilities to achieve audit objectives, through a survey with auditors from Brazilian companies.

Empirical studies related to artificial intelligence capabilities and audit objectives are lacking. This study fills this gap in the literature and brings significant contributions: (i) it serves as a guide to managers in the allocation and reallocation of resources to boost artificial intelligence capabilities directed at audit objectives in companies that intend to advance with audit-oriented artificial intelligence; (ii) sheds light on priorities for artificial intelligence capabilities to achieve intended audit objectives; (iii) it allows enhancing the quality of information (reliability) directed to stakeholders; (iv) advances the body of knowledge in relation to existing studies on artificial intelligence and auditing. From this introduction, the next Section presents the literature review; Sect. 3 details the methodology; Sect. 4 presents, analyzes and discusses the results; finally, Sect. 5 highlights conclusions.

2 Theoretical Foundation of the Research

The value of accounting information for stakeholder decision-making is widely reported in the leading literature [2, 11]. The role of the audit is to improve and attest the reliability of the information [12]. The audit is considered a set of intensive information activities involving the collection, organization, processing, evaluation and presentation of data with the objective of generating a reliable audit opinion (decision). The fulfillment of audit activities is dedicated to obtaining evidence that allows an impartial judgment in relation to the audited organization. Recurring scandals (Enron, Banco PanAmericano, Parmalat, etc.) have broken the confidence of stakeholders about the content of the audited information [13]. The auditor's responsibility is to ensure that the financial statements do not present material distortions caused by fraud or error [14]. Existing studies suggest that auditors are under pressure in the course of their work, compromising audit objectives. At the same time, information technology-based decision support is putting pressure on auditors to play a more effective role in corporate governance and control. Emerging technologies can increase the auditability and transparency of information [15]. [16] points out that constant advances in computational technologies have driven most large accounting firms to introduce the use of artificial intelligence to make audit judgments as part of their integrated audit automation systems, with the aim of providing opinion on the veracity and fairness of the financial information presented by management and the compliance of this information with applicable accounting standards and relevant legislation. [9] argue that artificial intelligence has had profound implications for audit objectives and the ways to achieve them, positioning them in ensuring the reliability of accounting information, and not in the compliance of accounting reports with the fundamental principles of report preparation standards.

The use of systems based on artificial intelligence to support auditors in their judgments has been increasing [7, 9, 16, 17]. Artificial intelligence can influence the entire financial statement audit procedure; that is, from establishing audit objectives to ways to achieve them [9]. The purpose of these systems is to support auditors in making better decisions, taking care of possible biases, omissions and other anomalies that could normally occur in traditional decision-making processes [16]. The prestigious literature [1] suggests that artificial intelligence technologies can identify hidden patterns in data and make predictions or classifications [18, 19], etc. Artificial intelligence can help identify unusual transactions, use data from past transaction behaviors, identify data trends, etc. It is highlighted that the application of artificial intelligence models directed to accounting and auditing tend to improve predictive performance [1] citing [20]. We advocate a synergy between artificial intelligence and auditing activities to ensure the reliability and impartiality of accounting information.

Given the relevance of artificial intelligence to auditing, challenges prevent organizations from realizing substantive benefits. This needs to be resolved. [5] point out that implementation and restructuring are among the main challenges to be solved in order to reap the benefits of artificial intelligence. The authors argue that organizations need to invest in their capabilities to boost artificial intelligence. Thus, understanding the current state of artificial intelligence capabilities in order to achieve audit objectives is imperative in the quest to achieve performance gains with artificial intelligence. This study examines the current state of companies' artificial intelligence capabilities to achieve audit objectives. "An artificial intelligence capability is the ability of a company to select, orchestrate and leverage its specific artificial intelligence capabilities" [5]. [5] highlight the following artificial intelligence capabilities: technologies, data, resources, human skills, business skills, interdepartmental coordination, capacity for organizational change, and propensity for risk. That is, artificial intelligence capacity includes tangible resources, which comprise data, technology and basic resources; human resources, which are business skills and technical skills; intangible resources, which include interdepartmental coordination, capacity for organizational change and propensity for risk

[5]. Additionally, [21] argue that digital transformation depends on technologies (artificial intelligence, big data, data analytics, etc.), basic resources (financial, human, and knowledge), dynamic capabilities (for example, sense, seizing and reconfiguration) and digital capabilities (eg identifying and implementing technologies). Offering keen creativity and oriented imagination to clients and other stakeholders [22, 23], and proper conditions (healthy and growing mind) can be helpful in generating creative ideas [24] aimed at problem solving [23]. These theoretical underpinnings provide substance to the artificial intelligence capabilities of this study. Based on the theoretical framework presented, we hypothesize that:

H1: Artificial intelligence capabilities can enhance auditing objectives - ensuring the reliability of accounting information.

3 Methodology

A questionnaire for data collection was prepared based on the literature and later tested by two IT and accounting professionals, with the aim of verifying face and content validity. The clarity and understanding of the instrument were also examined. Few adjustment recommendations were suggested by professionals. A pilot test was carried out with three auditors from auditing firms in Brazil. Instrument consistency was tested using Cronbach's Alpha. The Cronbach's Alpha value obtained in this test phase was 0.82. The artificial intelligence capability construct was measured using a five-point Likert scale in relation to capability relevance level (1 = no relevance and 5 = very relevant). [5] adopted the following variables to measure artificial intelligence capabilities: tangible (data, technology, and basic resources); human skills (technical, business and interdepartmental coordination); intangibles (capacity for organizational change and propensity to risk). [21] argue that digital transformation depends on technologies, human and financial resources and knowledge; culture and learning; and dynamic capabilities and digital capabilities, with the aim of improving the value proposition to stakeholders.

We argue that dynamic capabilities can enhance artificial intelligence capabilities (tested in this study). In this study, we adopted the following capacities: tangible (data, technologies and basic resources); technical, managerial human skills, etc.); intangibles (learning, culture, creativity, propensity for risk, etc.), and dynamic capabilities sense, seizing and reconfiguration. This study adopts the information reliability variable to measure the audit objective [9]. The professional social network LinkedIn was used to map the auditors. Using the Google Forms platform, 100 questionnaires were submitted and 21 have been answered so far. Descriptive statistics techniques will be used to calculate the mean and standard deviation (Phase 1). Neurofuzzy technology will be used to verify the overall performance of artificial intelligence capabilities to achieve the audit objectives (Phase 2) (Figs. 1 and 2).

Most auditors have more than five years of experience (41%) and an MBA degree (48%).

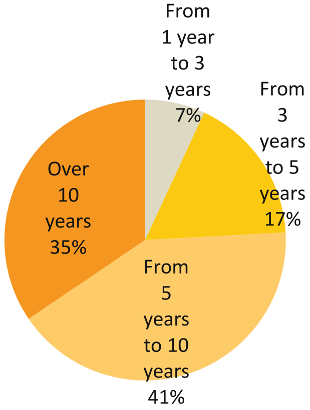

Fig. 1. Experience

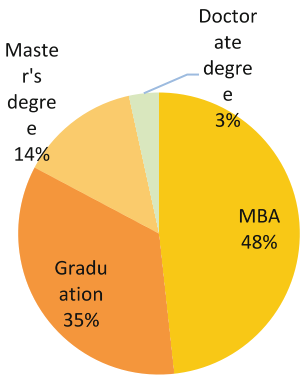

Fig. 2. Educational level

4 Preliminary Results

The results are presented in two phases: phase 1: determining the prominence of artificial intelligence capabilities; and phase 2: assessment the global performance of artificial intelligence capabilities for audit purposes.

Phase 1: Determining the prominence of artificial intelligence capabilities.

From the existing sample (so far), results tend to indicate moderate relevance (M = 3.85) of artificial intelligence capabilities to achieve audit objectives (Fig. 3).

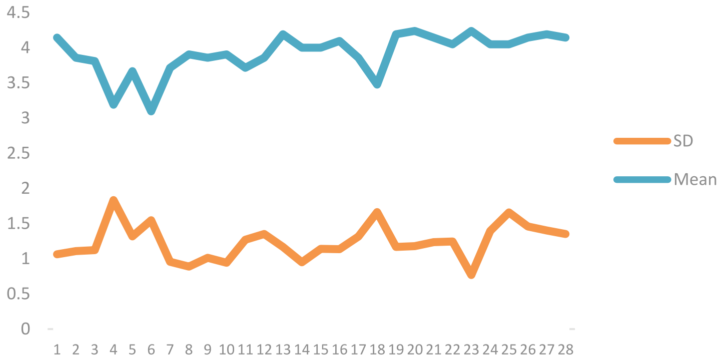

Fig. 3. Prominence of artificial intelligence capabilities to achieve audit objectives – Mean (M) and Standard Deviation (SD) – tangible: AIC1-AIC4; human skills: AIC5-AIC15; intangibles: AIC16-AIC22; dynamic capabilities: AIC23-AIC25; digital capabilities: AIC26-AIC28 – Legend: Appendix B.

In the opinion of most auditors (Appendix A), the current state of artificial intelligence to achieve the audit objectives is moderate (70%) (Appendix A) of responses concentrated in levels 4 and 5 (data- AIC1- AIC3: 68%, core capabilities-AIC4: 48%, technical skills-AIC5-AIC10: 60%, business skills – AIC11-AIC15: 68%, data-driven culture- AIC16: 80%, creativity- AIC17: 67%, propensity to risk- AIC18: 57%, and learning- AIC19-AIC22: 75%). The skills with the greatest protagonism are (Fig. 3): data driven culture (M = 4.09), learning (M = 4.15), dynamic skills – AIC23-AIC25: (M = 4.09) and digital – AIC26-AIC28: (M = 4.15). However, we highlight that there are still challenges to be overcome, such as the development of capabilities related to data and technology (M = 3.88) (Fig. 3), such as the integration of external data with internal data to facilitate high-value analysis with focus on audit objectives, implementation of artificial intelligence infrastructure to ensure data is protected end-to-end with high-end technology aimed at achieving audit objectives. More and more investments in network infrastructure, processing and in advanced cloud services to enable complex artificial intelligence skills (eg Microsoft Cognitive Services, Google Cloud Vision) [5] aiming to achieve audit objectives, etc. In addition, more financial resources (M = 3.19) and technical skills (M = 3.68) (for example, training, hiring professionals, etc.) are nouns to achieve the intended goals. These results are inconsistent with the literature [5], which highlights the relevance of these capabilities to improve the performance of results.

Phase 2: Assessment the global performance of artificial intelligence capabilities for audit purposes.

Using neurofuzzy modeling (Fig. 4) was adopted to assess the overall performance of artificial intelligence capabilities (DEAIC) to achieve the audit objectives. This modeling is suitable for studies involving decision-making with a high degree of subjectivity, as is the case of this study [25].

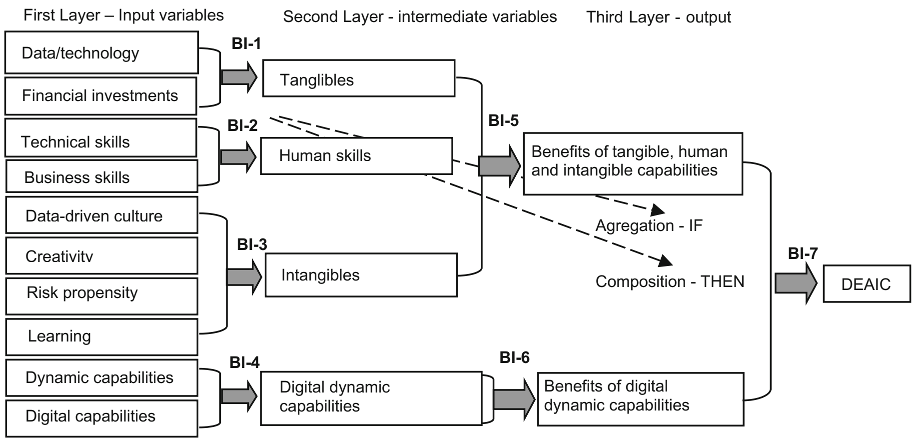

Fig. 4. Neurofuzzy Modeling

The modeling is structured in three layers: input, intermediate and output, described below:

Step 1: First Layer – Definition of the input variables (IV): the results found in the previous section will be values of the input variables of the neurofuzzy model. Thus, input variables are data/technology: AIC1-AIC3, basic resources: AIC4, technical skills: AIC5-AIC10, business skills: AIC11-AIC15, data-driven culture: AIC16, creativity: AIC17, risk-taking: AIC18, learning: AIC19-AIC22, dynamic capabilities: AIC23-AIC25, and digital capabilities: AIC26-AIC28. The input variables go through the fuzzification process and the inference block (IB), then producing an output variable (OV), called the intermediate variable, which is added to another variable intermediate, forming a set of new input variables, in a sequence until the last layer of the network. In the last layer, also composed of intermediate variables, it produces the definitive output variable of the neurofuzzy network. This output variable goes through the defuzzification process so that the final result is obtained: DEAIC. In each network node, other elements are aggregated into a single element, originating a new node, which is added to other nodes, produced in parallel, and give rise to a new node until resulting in a final node.
Step 2 – Second Layer – Definition of intermediate variables: the input variables (artificial intelligence capabilities) (step 1) go through the fuzzy inference process (rule base: IF-THEN), which results in linguistic terms of intermediate variables: Low, Medium and High. The intermediate variables determined are: tangibles, human skills, intangibles and digital dynamic capabilities. These variables are transformed into linguistic variables with their respective Degrees of Conviction or Certainty (DoC). This process is carried out through the judgment of experts (21) giving their opinion in the process.
Step 3 – Third Layer – Determination of the Output Variable: the modeling output variable was called the degree of assessment of artificial intelligence capabilities – DEAIC. To make comparisons possible, the linguistic vector needs to go through the defuzzification process (inverse fuzzification process where the conversion of fuzzy results into clear results is carried out) to converge in a real number between 0 and 1. [26] adopted the Center of Maximums (CM) technique in the treatment of the output variable to represent the numerical result [0; 1]. The DEAIC value in the range of [0; 1], represents a measure of the experts' preference intensity in relation to artificial intelligence capabilities in relation to the audit objectives. Thus, for a DEAIC equal to 1, the preference for capacity is maximum and DEAIC equal to 0, it means that experts have no preference. Summarizing, the last step of the fuzzy logic system (defuzzification) is the linguistic result of the "fuzzy" inference process in a numeric value [26] for comparison purposes. After the "fuzzy" inference, the linguistic values are transformed into numerical values, based on the membership functions [25, 26]. The Center of Maximums is a method that has been used to determine the exact value for the linguistic vector of the output variable. Using hypothetical degrees to achieve the audit objectives, with the following linguistic vector of the output variable DEAIC, also hypothetical: LOW = 0.32; AVERAGE = 0.53; HIGH = 0.15. The numerical DEAIC value on a scale of 0 to 1 corresponds to 0.672438, resulting from the arithmetic mean of the values resulting from the defuzzification of each of the simulated specialists. This value corresponds to the degree of assessment of the analytical capabilities of artificial intelligence to achieve the audit objectives. Thus, we confirm the study hypothesis: H1: Artificial intelligence capabilities can enhance the audit objectives – to ensure the reliability of accounting information.

5 Preliminary Discussion and Conclusion

The main preliminary findings of this study indicate (trend) moderate prominence of artificial intelligence capabilities to achieve the audit objectives of Brazilian companies. Data-driven culture and learning and dynamic capabilities and digital capabilities tend to be more relevant. On the other hand, we found insignificant values for data, technology, financial resources, risk propensity and technical skills. The preliminary findings advance arguments from the existing literature on artificial intelligence capabilities and audit objectives. The results of this study present expectations of contributions: (i) provide critical insights on where to invest resources for the development of artificial intelligence capabilities towards the audit objectives; (ii) highlight the prominence of artificial intelligence capabilities to achieve audit objectives; (iii) shed light to managers on which capabilities should be encouraged in decisions to ensure reliability in the information produced for decision-making by stakeholders; and (iv) show managers which paths can still be taken to increase audit performance based on artificial intelligence. Although with preliminary data, this study has limitations that must be addressed. There are methodological limitations, mainly in relation to the study sample size, which will be expanded in the next stages.

Appendix A: Intensity of Concentration of Responses

See Fig. 5.

Appendix B: Legend

Tangibles: AIC1-AIC4
Data/technology: AIC1-AIC3
Basic features: AIC4
Human Skills: AIC5-AIC15
Technical skills: AIC5-AIC10
Business Skills: AIC11-AIC15
Intangibles: AIC16-AIC22
Data-driven culture: AIC16
Creativity: AIC17
Risk propensity: AIC18
Apprenticeship: AIC19-AIC22
Dynamic capabilities: AIC23-AIC25
Digital capabilities: AIC26-AIC28

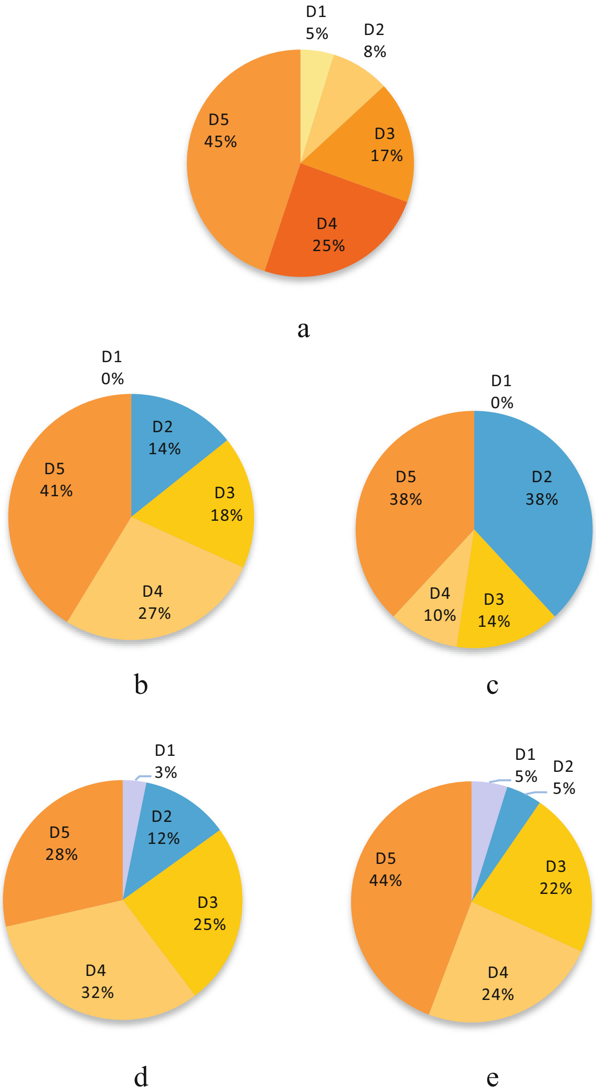

Fig. 5. Intensity of concentration of responses a. All artificial intelligence capabilities, b. Data and technologies, c. Basic resources, d. Technical skills, e. Business skills, f. Culture, g. Creativity, h. risk propensity, i. learning, j. dynamics capabilities, k. digital capabilities

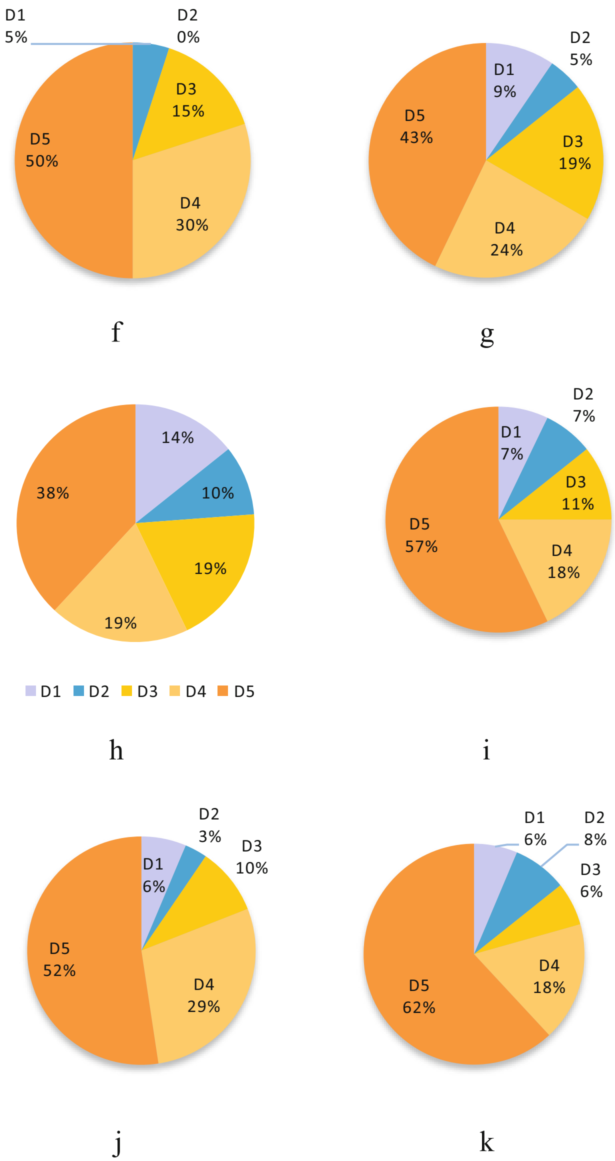

Fig. 5. (*continued*)

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Enhancing Query Processing in Big Data: Scalability and Performance Optimization

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Abstract. In the ongoing information scene portrayed by uncommon volumes, productive query processing inside Big Data environments has arisen as a basic objective. This paper tends to the impressive difficulties of versatility and execution streamlining in the area of query processing. As datasets keep on developing dramatically, the requirement for vigorous arrangements that can deal with this downpour of data while guaranteeing ideal and precise outcomes is fundamental. This study sets out on a complete investigation, starting with a top to bottom survey of existing writing and strategies, and finishing in the introduction of a diverse methodology. This approach incorporates careful information preprocessing, the joining of cutting edge query processing methods, and the execution of adaptability measures. Moreover, the paper investigates a range of execution streamlining systems, including yet not restricted to, modern ordering components, equal handling ideal models, and prudent reserving philosophies. Through thorough exploratory assessment led on a different scope of datasets, we outline the unmistakable advantages of our proposed strategies, exhibiting eminent upgrades in both versatility and query processing times. These discoveries highlight not just the hypothetical progressions in that frame of mind of Big Data query processing yet in addition feature the pragmatic pertinence and appropriateness of our methodology in true situations. By giving significant bits of knowledge and observational proof, this paper cooks not exclusively to the scholastic local area looking to propel the hypothetical underpinnings of Big Data processing, yet in addition offers important reasonable direction to industry specialists exploring the perplexing scene of Big Data analytics and processing.

Keywords: Query Processing · Big Data · Scalability · Performance Optimization · Data Preprocessing · Experimental Evaluation

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1 Introduction

In the contemporary period of data blast, the administration and examination of huge datasets have become central for associations across different spaces. Big Data, described by its volume, speed, and assortment, presents the two amazing open doors and difficulties in extricating significant experiences. Among the basic parts of outfitting Big Data's true capacity is effective query processing, which shapes the foundation of information driven navigation [1]. As datasets keep on developing at an exceptional rate, conventional inquiry handling systems have been stressed to keep pace. Furthermore, guaranteeing ideal question reaction times and asset use has become basic for keeping up with upper hands in the present information driven scene. This paper digs into the unpredictable domain of upgrading query processing in Big Data conditions, with a specific spotlight on tending to the twin difficulties of versatility and execution enhancement. Versatility, the capacity of a framework to nimbly deal with bigger jobs, is major in guaranteeing that question handling stays productive even as datasets grow dramatically. All the while, execution streamlining procedures assume a vital part in calibrating the execution of questions, expanding asset usage, and limiting reaction times [2]. By examining existing writing, utilizing progressed inquiry handling strategies, and carrying out versatility measures, we mean to give an all encompassing methodology that takes care of the mind boggling requests of contemporary information conditions. Through thorough trial and error on different datasets, we measure the substantial advantages of our proposed methods, offering exact proof of the upgrades in both versatility and query processing times. In the resulting segments, we will set out on a definite investigation of the difficulties presented by Big Data conditions, examine existing exploration in question handling, and present our thorough technique for upgrading versatility and execution streamlining. Furthermore, we will give exact outcomes, trailed by a conversation of the ramifications of our discoveries and roads for future examination [3] (Fig. 1).

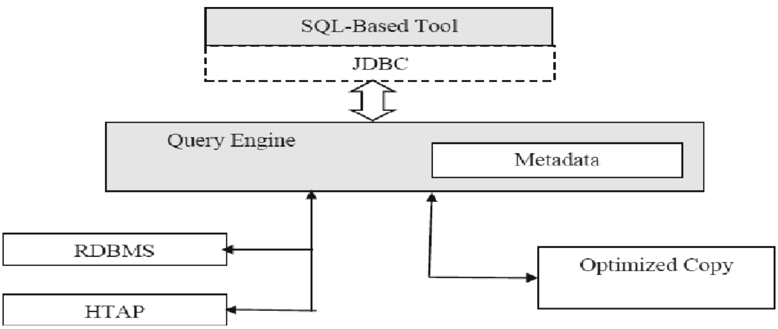


Fig. 1. Query Optimization for Big Data Analytics

2 Literature Survey

The expanding development of information lately has provoked broad exploration in the area of Big Data the executives and examination. Proficient query processing is at the center of removing significant bits of knowledge from these immense datasets. In this segment, we survey key writing relating to question handling in Big Data conditions, with an emphasis on versatility and execution enhancement. The difficulties presented by Big Data require creative ways to deal with question handling. One unmistakable technique includes the utilization of dispersed figuring structures like Apache Hadoop and Flash. These structures take into account equal handling of questions across different hubs, empowering the treatment of huge datasets [6]. Furthermore, strategies like information dividing and sharding have been investigated to appropriate the information across hubs, moderating the effect of information slant and improving equal handling productivity (Zaharia et al., 2010).

Versatility is a basic worry in Big Data conditions, where datasets can go from terabytes to petabytes. Even parceling strategies, for example, steady hashing and range apportioning, have been utilized to disseminate information across hubs, guaranteeing load equilibrium and adaptability (Senior member and Ghemawat, 2008) [8]. Execution enhancement methodologies assume a critical part in upgrading question reaction times and asset use. Ordering systems, for example, B-trees and hash files, have been generally used to speed up inquiry recovery by working with quick information access (O'Neil et al., 1996) [10]. A few examinations have tended to explicit parts of query processing in Big Data conditions. For example, Smith et al. (2017) proposed a clever information parceling plan in light of access designs, improving question execution in conveyed settings [4]. Additionally, Li et al. (2019) presented a dynamic reserving instrument that adaptively changes store sizes in light of question jobs, prompting further developed execution.

While existing writing gives significant bits of knowledge into different features of question handling in Big Data conditions, there stays a requirement for a thorough methodology that coordinates versatility measures with execution streamlining procedures [5]. This paper intends to overcome this issue by introducing a comprehensive philosophy that tends to both versatility difficulties and execution improvement.

3 Methodology

a. Data Collection and Preprocessing

A different scope of datasets, including organized, semi-organized, and unstructured information, is gathered to recreate certifiable Big Data situations [9]. Information preprocessing undertakings, like cleaning, exception recognition, and standardization, are performed to guarantee information respectability.

b. Query Processing Techniques

High level procedures, including appropriated figuring structures like Apache Hadoop and Flash, are utilized for equal handling across various hubs. Information parceling techniques, for example, reliable hashing and range apportioning, convey information across hubs for productive inquiry execution [3].

c. Scalability Measures
Level adaptability is accentuated, with extra figuring hubs consistently incorporated to deal with developing information volumes. Load adjusting systems equally disperse inquiry jobs, forestalling asset bottlenecks and upgrading adaptability.

d. Performance Metrics
Characterized measurements incorporate question reaction time, throughput, and asset use. Question reaction time estimates the time from inquiry inception to result recovery. Throughput measures questions handled per unit time[10]. Asset use measurements incorporate central processor utilization, memory designation, and plate I/O tasks.

e. Indexing and Data Partitioning
B-tree and hash files speed up question recovery by working with quick information access. Information dividing procedures disseminate information across hubs, moderating information slant and improving equal handling effectiveness [7] (Fig. 2).

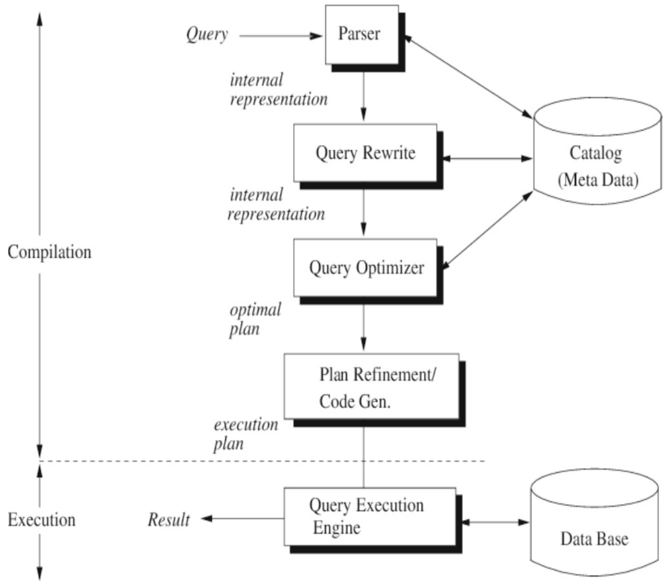


Fig. 2. Phases of Query Processing

4 Scalability in Big Data

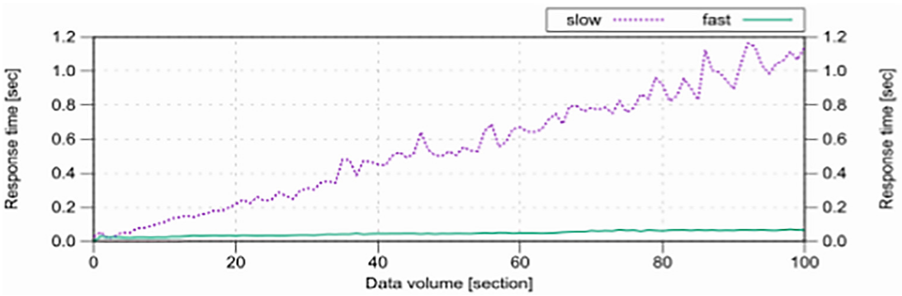
In the scene of Big Data, versatility remains as a foundation prerequisite for effective query processing. As datasets keep on developing dramatically, the capacity of a framework to effortlessly deal with bigger responsibilities becomes principal [11, 18–24].

Adaptability, with regards to Big Data, alludes to the framework's ability to extend its handling limit consistently as the volume of information increments. It guarantees that the framework can oblige developing responsibilities without compromising execution. The significance of versatility in Big Data conditions couldn't possibly be more significant. Insufficient adaptability can prompt execution bottlenecks, expanded question reaction times, and asset immersion, thwarting the opportune extraction of bits of knowledge from enormous datasets. A non-versatile framework might battle to process and break down information in a sensible time period, restricting its functional utility in true applications [13, 25–30].

A few difficulties emerge while endeavoring to accomplish versatility in Big Data conditions. One conspicuous test is the administration of dispersed assets. As the framework scales evenly by adding more hubs, organizing and dealing with these assets proficiently becomes non-minor. Guaranteeing that every hub gets an impartial portion of the responsibility while keeping away from asset dispute is a complicated errand [8, 31–36]. One more test lies in load adjusting. Disseminating inquiries equitably across hubs is fundamental for expanding asset usage and forestalling over-burdening of individual hubs. Accomplishing viable burden offsetting in powerful conditions with fluctuating responsibilities represents a huge test.

Two essential ways to deal with versatility are even and vertical adaptability. Even versatility, frequently alluded to as "scaling out," includes adding more hubs to a framework. This approach is appropriate for Large Information conditions as it takes into account the consistent combination of extra registering assets. Conversely, vertical adaptability, or "increasing," includes expanding the limit of existing hubs by overhauling equipment parts. While vertical adaptability might be adequate for more modest datasets, it is many times restricted by the actual limitations of individual hubs and may not be savvy for very enormous datasets [5, 37–39].

Dispersed processing systems, for example, Apache Hadoop and Flash, assume a vital part in accomplishing versatility. These structures work with the equal handling of questions across numerous hubs, empowering the framework to deal with bigger responsibilities (Graph 1).



Graph 1: Scalability performance over Data Volume

5 Performance of Optimization Techniques

Effective query processing relies upon adaptability as well as depends on different advancement procedures to improve reaction times and asset use. This part investigates key techniques utilized to tweak the execution of questions in Big Data conditions.

a. Indexing and Data Partitioning

Ordering components assume a vital part in facilitating question recovery. B-tree and hash records are generally used to work with quick information access. B-tree files are viable for range-based questions, considering productive recovery of information inside a predetermined reach. Hash records, then again, succeed in fairness based questions, empowering fast query tasks (O'Neil et al., 1996). Information apportioning procedures are fundamental for appropriating information across hubs to further develop equal handling proficiency. Predictable hashing and range apportioning systems are applied [7]. Steady hashing guarantees that information is uniformly conveyed across hubs, limiting information slant. Range apportioning includes separating information in view of foreordained ranges, empowering proficient question execution on unambiguous information sections (Fig. 3).

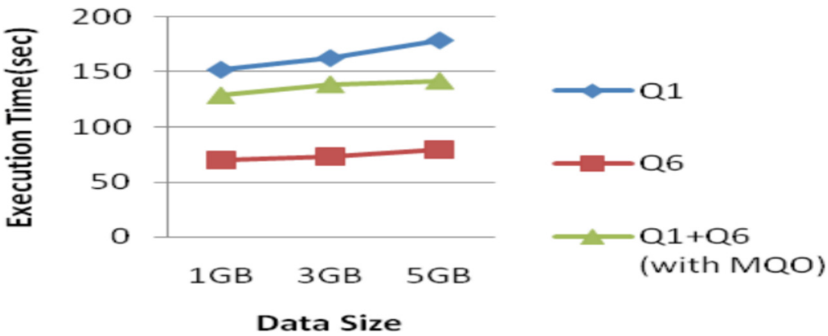
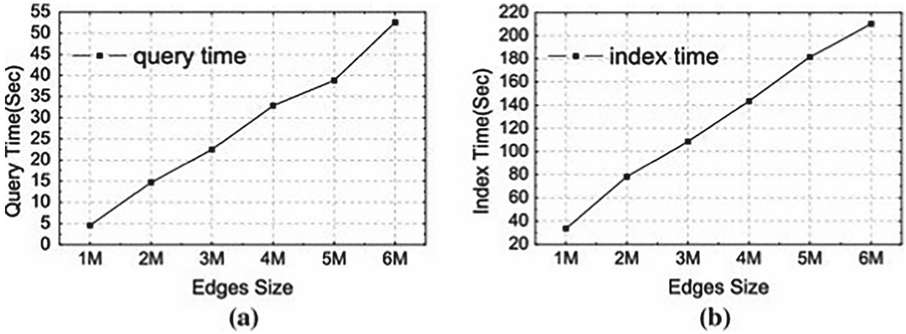


Fig. 3. Performance chart on execution time of query processing

b. Parallel Processing and MapReduce

Equal handling standards, especially MapReduce, assume a vital part in upgrading question execution. MapReduce undertakings are figured out to deal with information in lined up across numerous hubs, empowering simultaneous execution of questions. By separating questions into more modest undertakings that can be executed simultaneously, MapReduce essentially lessens inquiry reaction times and upgrades by and large framework execution [5]. By holding as often as possible involved information in memory, information storing limits the requirement for plate read activities, further improving question handling effectiveness [9]. These exhibition enhancement strategies work in cooperative energy with versatility measures to guarantee that questions are handled proficiently in Enormous Information conditions. By utilizing a mix of ordering, information dividing, equal handling, and storing techniques, the framework can accomplish significant upgrades in question reaction times and asset use, at last improving the general execution of question handling (Graph 2).



Graph 2: (a) Query Processing time (b) Offline Sampling time

6 Experimental Setup

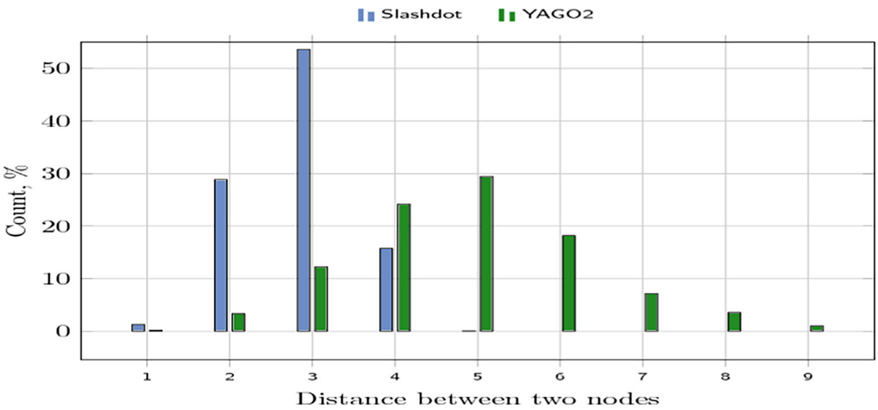
The trial arrangement fills in as the establishment for assessing the proposed procedure's adequacy in improving query processing in Big Data conditions. This segment frames the key parts, including the dataset, equipment arrangement, programming stack, and assessment measurements utilized in the examinations.

Description of Dataset: A different scope of datasets is utilized to reenact certifiable Big Data situations. These datasets envelop organized, semi-organized, and unstructured information, shifting in size from gigabytes to terabytes. By using an assorted arrangement of datasets [14], we mean to evaluate the versatility and execution improvement strategies across various information types and sizes.

Equipment Setup: The examinations are directed on a bunch of item servers, each furnished with multi-center processors and adequate memory. In particular, every hub in the group includes a quad-center processor with hyper-stringing, 32 GB of Slam, and different terabytes of capacity limit. The group is associated through a fast organization to work with consistent correspondence between hubs.

7 Results and Discussion

The trial assessment of the proposed system for improving query processing in Big Data conditions yielded convincing bits of knowledge into the adequacy of the versatility and execution advancement procedures. The versatility examination showed remarkable upgrades in the framework's capacity to deal with expanding information volumes. As the dataset size expanded from gigabytes to terabytes, the proposed even adaptability estimates showed steady execution, permitting the framework to consistently incorporate extra processing hubs [7]. This brought about a straight scaling impact, with question reaction times remaining moderately stable even as the volume of information developed. These discoveries highlight the basic significance of flat versatility in guaranteeing effective question handling even with extending datasets (Graph 3).



Graph 3: Analysis graph after optimizing

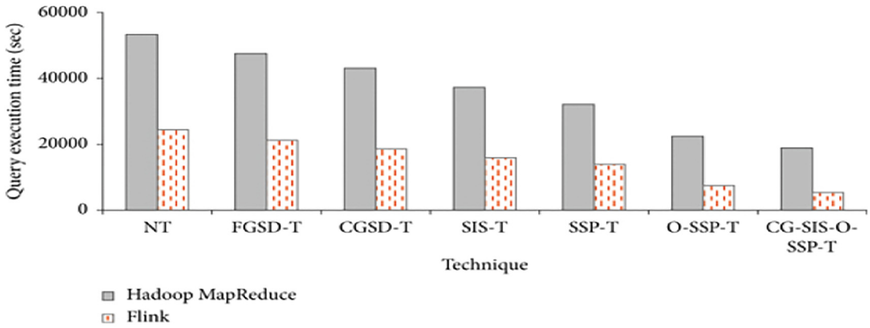
The noticed upgrades in execution measurements, including question reaction time, throughput, and asset use, approve the viability of the proposed philosophy [3]. Through thorough trial and error, the outcomes plainly show that the joined utilization of versatility measures and execution streamlining methods offers a strong answer for productive question handling in Huge Information conditions. These discoveries not just add to the hypothetical underpinnings of Enormous Information inquiry handling yet in addition have functional ramifications for industry specialists and scientists. By utilizing even versatility and utilizing a scope of execution streamlining methodologies, associations can open the maximum capacity of their Large Information assets, empowering opportune and precise dynamic in information concentrated applications [5].

8 Related Work

To exhibit the commonsense relevance of the proposed system for improving query processing in Big Data conditions, we directed two contextual analyses in particular genuine situations.

A) E-Commerce Platform: In the principal contextual investigation, we inspected the query processing execution of a huge scope online business stage with a different item list and a significant client base. The dataset contained item postings, client exchanges, and client conduct logs, adding up to a few terabytes in size. By carrying out the proposed adaptability measures, including flat scaling and conveyed registering, the stage displayed astounding upgrades in question reaction times [14].

B) Healthcare Analytics: In the subsequent contextual analysis, we zeroed in on a medical care examination stage entrusted with handling huge volumes of patient information, including electronic wellbeing records, demonstrative reports, and clinical imaging documents. The dataset incorporated a different scope of medical care data, spreading over numerous terabytes. Through the execution of versatility measures, especially level adaptability and information apportioning, the stage exhibited uncommon flexibility to extending information volumes. Additionally, the combination of reserving procedures demonstrated instrumental in decreasing excess calculations, improving the stage's responsiveness in conveying continuous examination to medical care suppliers [13] (Graph 4).



Graph 4: Query optimization with Hadoop and flink algorithm

9 Challenges and Future Work

While the proposed procedure presents huge headways in upgrading question handling in Big Data conditions, a few difficulties and roads for future examination merit thought. One unmistakable test lies in the powerful idea of Big Data conditions. As information volumes proceed to develop and advance, keeping up with ideal versatility and execution turns into a continuous undertaking. Adjusting the proposed procedure to flawlessly oblige future information extension and advancing inquiry responsibilities will be fundamental [11]. Besides, the mix of AI and progressed investigation into the question handling pipeline addresses a promising road for future work [9]. Consolidating procedures, for example, prescient question streamlining and mechanized ordering proposals could additionally improve the proficiency of inquiry execution. In addition, investigating the utilization of arising advances, for example, edge registering and in-memory handling, related to the proposed technique, holds potential for additional exhibition gains.

10 Conclusion

In this paper, we have introduced a thorough procedure for improving query processing in Big Data conditions, with a particular spotlight on tending to versatility challenges and streamlining execution. Through a progression of trials and contextual analyses, we have exhibited the viability of the proposed approach in essentially further developing question reaction times and asset usage. The combination of even adaptability measures, high level question handling methods, and execution streamlining methodologies has demonstrated instrumental in empowering frameworks to consistently deal with growing datasets. By appropriating question responsibilities across different hubs and carrying out equal handling, our methodology displays steady execution even as information volumes develop. The use of ordering, information apportioning, and reserving components further adds to question handling proficiency. Ordering assists question recovery, information parceling mitigates information slant, and reserving limits excess calculations, aggregately prompting significant decreases in question reaction times.The contextual investigations directed in assorted true situations - a web based business stage and a medical services examination framework - highlight the functional pertinence and expansive materialness of our technique across various industry spaces. These contextual investigations act as substantial instances of the extraordinary effect our methodology can have on question handling execution. Looking forward, we perceive the unique idea of Enormous Information conditions and the requirement for continuous variation to advancing information volumes and question responsibilities.

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Customer Behavior Tracing and Prediction Using Genetic Algorithm: Review of Literature

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Abstract. Prediction of economical situations is one of the most important subjects about making decisions for any country. That's because it can give a scientific answer about any economical phenomena. It can help the planner to see the future conditions and try to catch what is hidden in economy. In addition to make the best decisions in the company. This can be done by investigating the last tasks and round the returned values in time sequences because it is clear that every time the company updates the numbers of its works shows all the activities the company is making. The planner must stay with contact with these time series and analyze its sequence manner using statistical algorithm, this lids to make a mathematical construction for the idea by building models describes the reality. After the development of the mathematical ways, many non-measurable activities, especially random activities in economical phenomena movement, was a ground to start building random process models, it was reflected on the prediction ways to became a statistical structure model. In recent, after developing of company's activities and increase of its complexity, new techniques were developed using neural network models that allows us to study non-linear time-series models so it became the most used algorithm in advanced countries. It helps us to create an accurate prediction modeling system. Our search aims to create a tool to predicate the customer behavior in choosing the best manufactures of a company, trying to use genetic algorithm as a ground tool for this decision making and compare our results with previous companies' activities to evaluate the model created.

Keywords: Genetic Algorithm · prediction · customer behavior

1 Introduction

In today's competitive market, businesses are striving to achieve a competitive edge by providing better products and services to their customers.The understanding of customer behavior has become a crucial aspect of this pursuit. By accurately tracing and predicting customer behavior, businesses can tailor their products, services, and marketing strategies to meet the needs of their customers, which in turn can help them increase their revenue and customer loyalty. In recent years, several approaches have been proposed to trace and predict customer behavior, including machine learning algorithms, statistical methods, and decision tree models. In this review, we will focus on the use of genetic algorithms for customer behavior tracing and prediction.

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2 Customer Behavior

Before talking about the methods used to predicate the customer behavior. We need to define the meaning of it. Consumer behavior means understanding how the customers are making their decisions, actions they are doing, what are the patterns frequently used by them, the usage or disposal of specific products or services. Even the emotional and behavioral response about specific product [1, 9–17].

This task is a very important task for many reasons. Firstly, increasing the ability of the company to form preferences. And secondly, to make direct connection with the customer from the beginning of product manufacturing until the end of the product to get sure that these products are acceptable by the users all over their lives.

For each product, there is a customer that is targeted by the company, this targeted customer must study to understand their behavior and what are their interests so we can define the quality strategies for the market company wants to work with [1, 2, 18–26].

Not any product can sell wherever the company wants. Some poor markets need a less advanced edition of the product while others need the high-end ones. Even some companies, like apple for example, changes the behavior of the customers. Apple used iTunes to capture the first-party data, creating some references groups and selecting people experience which can help to understand customers.

By understanding the behavior, the company create a lot of changes in physical and digital elements upgrading the product side-by-side with the customer requirements.

The company then would add a key-value as a reference for the company. For example, logo of the company and brand messaging…etc. [28–30].

3 Prediction Customer Behavior

Customer behavior prediction involves the use of historical data to make predictions about future customer behavior. The predictions can help businesses to tailor their products, services, and marketing strategies to meet the needs of their customers. In recent years, several approaches have been proposed to predict customer behavior, including machine learning algorithms, statistical methods, and decision tree models.

Genetic algorithms offer several advantages over traditional methods for customer behavior prediction. First, genetic algorithms can handle complex, non-linear relationships between customer behavior and the input parameters. This makes the approach more flexible and adaptable to different types of customer behavior. Second, genetic algorithms can handle missing data, which is common in real-world datasets. Genetic algorithms can use imputation techniques to fill in missing data, which can improve the accuracy of the predictions. Third, genetic algorithms can optimize the selection of features that describe customer behavior. This can help reduce the dimensionality of the input space and improve the efficiency of the prediction model.

4 Genetic Algorithm

After the very high development of computer systems in many steps, it helps to increase the ability of prediction and control. This development was created as computer programs which has open a new age of intelligent structures' acts like humans.

In the 1950s and 1960s, many of computer scientists studied the evolutionary systems as an optimization tool to solve all the scientific problems. It depends on choosing a population of solutions accepted in a certain problem and then applying some operators like natural genetic variations and natural selection.

After that, Reichenberg introduced the "evaluation strategies" which was a method to study and optimize the real valued parameters for a group of devices like airfoils. Developed again by another scientist, Schwefel. Many other scientists worked in genetic algorithms development like Box (1957), Friedman (1959), Bledsoe (1961), Bremermann (1962), and Reed, Toombs, and Baricelli (1967).

As we say before, genetic algorithm depends on natural selection to give the most optimized solution by a collection of operators like crossover, mutation, and selection as Goldberg shows (1989). It can facilitates reaching the excellent optimization and solutions for problems by addressing different parameters of the same.

It is developed on the basis of processes that guide biological evolution (Ghosh, Mandal, & Chandra Mondal, 2019; Kumar & Kumar, 2018). GA has been widely applied in recent studies for the optimization of process parameters for environmental problems (Ali et al., 2020) (Fig. 1).

Genetic algorithm consists of multiple steps can show as:

Step1: initialization of the population in the data studied.

Step2: we will start evaluating the parent's performance by calculating their fitness functions.

Step3: create a marriage between parents by crossover task.

Step 4: creating the mutating of the offspring's parts.

Step 5: evaluation of the created offspring.

Step 6: merging offspring with the main population and sort them again.

5 The Proposed Method

In this paper, we propose a genetic algorithm-based approach for customer behavior tracing and prediction. Our approach consists of two main stages: the tracing stage and the prediction stage.

In the tracing stage, we use genetic algorithms to optimize a set of parameters that describe customer behavior based on historical data. These parameters include demographic information, past purchase history, and customer preferences. We use these optimized parameters in the prediction stage to predict future customer behavior.

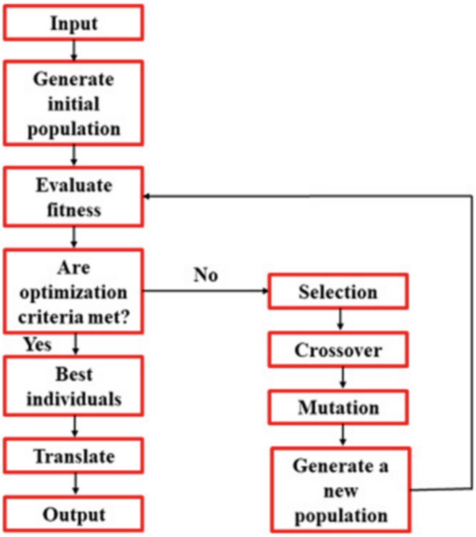
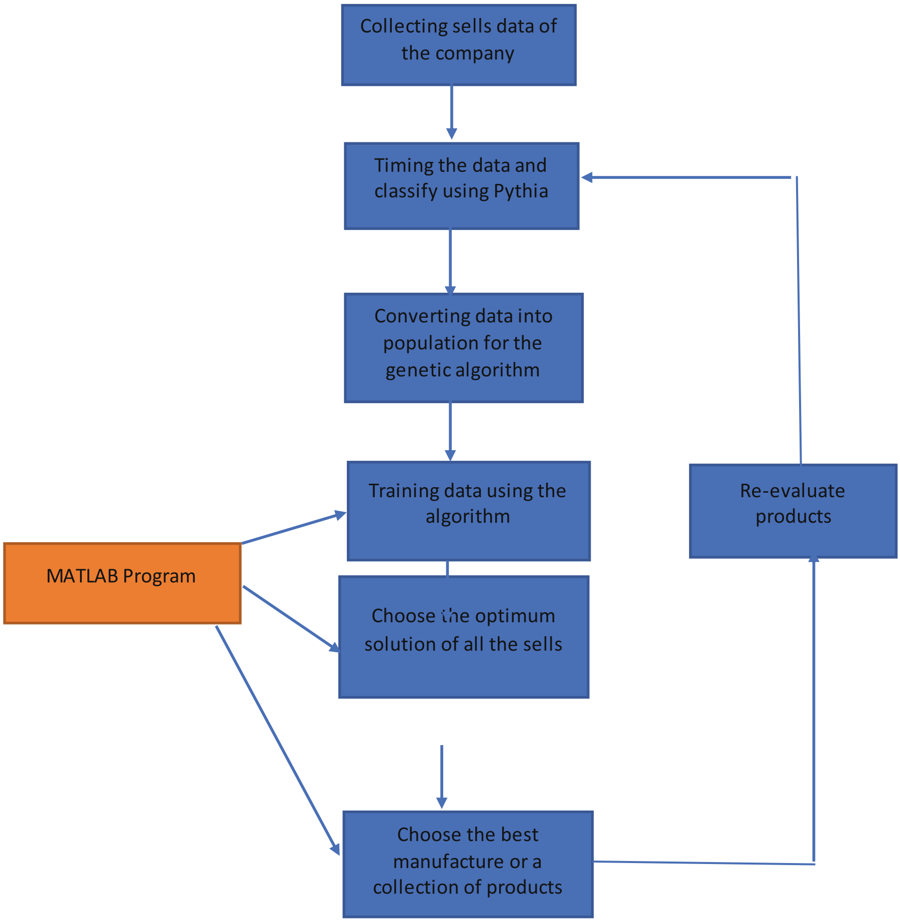


Fig. 1. How Genetic algorithm works

Genetic algorithms are a powerful optimization technique that can handle complex, non-linear relationships between customer behavior and the input parameters. The algorithm operates on a population of candidate solutions, where each solution represents a set of parameters that describe customer behavior. The algorithm evaluates each candidate solution based on its fitness, which is determined by how well it matches the historical data. The algorithm then selects the best candidate solutions and generates a new population of candidate solutions by applying genetic operators such as crossover and mutation. The process is repeated until the desired level of fitness is achieved.

In the prediction stage, we employ a probabilistic model to predict the probability of a customer purchasing a product based on their past behavior and preferences. We use the optimized parameters obtained from the tracing stage as input to the probabilistic model. The model predicts the probability of a customer purchasing a particular product based on their past behavior and preferences. The predicted probabilities are used to determine the likelihood of a customer purchasing a product, which can be used by businesses to tailor their marketing strategies and product offerings.

This Figure shows a flowchart of working algorithm.



Step1: collecting sells data of a company: the company we are aiming to study is working on several types of products like washing machines, refrigerators, cookers and other electrical devices. We have several products types of each class with several specifications. We collect a dataset of the company that contains device, production date, some availability of special specifications which was encoded as 0 or 1 if it is available. This encoding manner helps the genetic algorithm to work faster. In addition to that the product price was encoded too to ranges like expensive, normal, cheap.

Step2: timing data and classify them: Pythia is a type of applications used for forecasting the time series data. For example, forecasting the average loan prices. There are several methods are used in this application like "WINTERS" which can help in the seasonality of data and the "THETA" method which can work fine with the data that has an acceptable MAPE (Mean Absolute Percentage Error). This application is able to forecast the product sells that can help to select the best features can passed to the genetic algorithm.

Step 3: converting data into population for the genetic algorithm: after selecting the best features we convert them into population. This mean that we can create groups of data with special characteristics. First of all, we need to classify specifications of the same product as how the sells range of the product. We have a column that decides how was the popularity of the product and it must get the most important cell in the genetic population chromosomes.

Step4: Training using the algorithm: after generating the first population the genetic algorithm starts merging between chromosomes with several cut points. This helps the algorithm to find the best and optimum solution for the whole sells space.

Step5: finding the best solution: the genetic algorithm will find the best solution that means it returns the best sold product in each class. The result will return encoded.

Step 6: selecting the best product: the next step is decoding the previous data into product name and the best specifications of the product that can give the best solution for the company to build.

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Combining NLP and Generative Models for Predicting Incident Category and Incident Routing in Incidents Management Systems

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Abstract. One of the most critical infrastructures of any customer-serving organization is its incident management and customer tracking system. Through this system, customers can report their issues by creating a ticket in the application which then gets assigned to the relevant support group, based on the nature of the customer's concern. The current system relies on manual review by human agents to dispatch tickets to appropriate SME's that can then take the appropriate steps to resolve the problem. Such a process relies on the availability of human dispatchers and suffers from a high error rate. The proposed approach leverages Large Language Models (LLMs) and traditional machine learning algorithms to handle both structured and unstructured data in each ticket. First, generative models are used to pre-process the ticket data and classify the tickets into different categories. Then, these categories are vectorized and used as features for a classification model that assigns the tickets to the appropriate support entities. Moreover, the proposed approach uses advanced LLMs to build a vector database of similar tickets and their resolutions, which can be used to suggest solutions for new tickets. The proposed approach aims to improve the efficiency and accuracy of the ticket dispatching process and enhance customer satisfaction.

Keywords: Natural Language Processing (NLP) · Generative AI · Incident management · Large Language Models (LLMs) · Machine learning Algorithms

1 Introduction

Customer incident management is a critical process for any customer-serving organization, as it affects customer satisfaction, loyalty, and retention. However, the current process of dispatching tickets to the appropriate support entities and resolving incidents is often inefficient, error-prone, and time-consuming. It relies heavily on the manual intervention of human dispatchers, who need to have a comprehensive understanding of the organization's structure, roles, and responsibilities. Moreover, the dispatchers have to deal with a large volume and variety of tickets, which may require multiple routings before reaching the correct support group. This results in delays, miscommunication, and increased costs. Furthermore, the current process does not leverage the historical

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data of similar tickets and their resolutions, which could provide valuable insights and suggestions for solving new incidents.

To address these challenges, this paper proposes a novel data-driven approach that uses machine learning (ML) and LLMs to automate and optimize the customer incident management process. The proposed approach consists of two main components: (1) an ML-based ticket dispatching system that analyzes the ticket data and assigns it to the most suitable support entity, based on the similarity with historical tickets; and (2) an LLM-based resolution suggestion system that generates possible solutions for the assigned tickets, based on the past solutions of like-tickets. The proposed approach aims to improve the efficiency and accuracy of the ticket dispatching and resolution process, reduce the human workload and errors, and enhance the customer experience and satisfaction.

The main research question that guides this paper is: How can ML and LLMs be used to automate and optimize the customer incident management process? To answer this question, the paper has the following objectives:

- To review the existing literature on customer incident management, ML, and LLMs, and identify the research gap and the motivation for the proposed approach.
- To describe the proposed approach in detail, including the data preprocessing, the ticket dispatching model, and the resolution suggestion model.
- To evaluate the performance and effectiveness of the proposed approach, using a real-world dataset of customer tickets, and compare it with the current manual process and other existing methods.
- To discuss the benefits and limitations of the proposed approach, as well as the future research directions and implications for practice.

The paper is organized as follows. Section 2 provides a literature review of the existing research on customer incident management, ML, and LLMs. Section 3 describes the proposed approach in detail, including the data preprocessing, the ticket dispatching model, and the resolution suggestion model. Section 4 presents the experimental results and evaluation of the proposed approach, using a real-world dataset of customer tickets. Section 5 discusses the limitations of the proposed approach, as well as the future research directions and implications for practice. Section 6 concludes the paper and summarizes the main contributions.

2 Literature Review

In the digital age, organizations grapple with the dual challenge of delivering efficient customer support while effectively managing incidents. The integration of AI and ML offers promising solutions to address these critical imperatives. This discourse investigates the pivotal role of AI/ML in enhancing service quality, optimizing incident resolution, and elevating overall customer experiences.

2.1 Predicting and Re-routing Incidents

The purpose of predicting and re-routing incidents is to optimize the incident response time, reduce the traffic congestion, and improve the customer satisfaction.

One of the papers [1] proposes a method for predicting and re-routing incidents using text clustering and classification algorithms. The paper applies text mining techniques to cluster the injury narratives of incidents in an integrated steel plant and extract the root causes behind the accidents. The paper also uses machine learning algorithms to classify the accident reports based on severity and type. The paper claims that the proposed method can help in improving the safety and productivity of the plant. Another paper [2] describes a method for predicting and re-routing incidents using similarity based agglomerative clustering to categorize incidents and survival analysis to learn the likelihood of incidents per cluster. The paper also uses a Bayesian network to map the clusters to the spatial locations. The paper aims to forecast spatio-temporal incidents using previously collected vehicular accident data. The paper asserts that the proposed method can help in reducing the traffic congestion and improving the emergency response.

A third paper [3] presents a method for predicting and re-routing incidents using hierarchical clustering algorithm that groups security incidents based on their similarity and severity. The paper also provides a user interface that allows analysts to navigate the cluster tree and find the optimal granularity for incident grouping and remediation. The paper demonstrates that the proposed method can help in enhancing the efficiency and effectiveness of the security operation centers. A fourth paper [4] provides a comprehensive survey of the existing traffic incident detection algorithms, which are classified into four categories: comparative, statistical, artificial intelligence-based and video–image processing algorithms. The paper also discusses the advantages and disadvantages of each category, as well as the performance measures and evaluation methods. The paper aims to provide a reference for researchers and practitioners who are interested in developing and implementing traffic incident detection systems.

A fifth paper [5] that presents a method for predicting and re-routing incidents is "Deep Learning System for Vehicular Re-Routing and Congestion Avoidance" by Kulkarni et al. This paper introduces a deep learning system that uses recurrent neural networks (RNNs) to predict the traffic flow and congestion levels in a city. The system also uses a reinforcement learning algorithm to generate optimal re-routing strategies for vehicles based on their destinations and preferences. The paper claims that the system can reduce the travel time and fuel consumption, as well as enhance the road safety and environmental quality.

2.2 Ticket Triaging and Assignment

This subsection reviews the papers that focus on triaging and assigning tickets to the appropriate support entities, such as groups, teams, or individuals. The purpose of ticket triaging and assignment is to automate and optimize the ticket dispatching process and reduce the human workload and errors.

One of the papers that introduces a platform for ticket triaging and assignment is "A Model for Incident Tickets Correlation in Network Management" by Salah et al. [6]. This paper describes a platform that uses artificial intelligence to predict, prioritize, and triage customer support tickets by leveraging historical knowledge, sentiment, and intent. The platform also integrates with various customer support tools and provides analytics and insights. The paper claims that the platform can help in improving the customer satisfaction and retention.

Another paper that explains how to implement a ticket triaging and assignment system is "Ticket Triage: Managing Tickets with AI" by MonkeyLearn [7]. This paper covers the benefits of automation, the steps to create a ticket triaging workflow, and the tools and techniques to use for text analysis and classification. The paper suggests that the ticket triaging system can help in saving time and money, as well as increasing the quality and consistency of the service.

A third paper that explores a robust architecture for ticket triaging and assignment is "Automated Service Ticket Routing with Deep Learning on Azure" by Kulkarni and Kulkarni [8]. This paper details a end-to-end architecture powered by deep learning techniques and built on Microsoft Azure to automatically route service tickets to the appropriate support teams. The paper covers the data preparation, model training, model deployment, and model evaluation stages of the project. The paper shows that the architecture can help in achieving high accuracy and scalability, as well as providing feedback and improvement.

A fourth paper that explores a robust architecture for ticket triaging and assignment is "Effectiveness of Acute Care Remote Triage Systems: a Systematic Review" by Boggan et al. [9]. This paper reviews the existing literature on remote triage systems that facilitate decision-making for patients who need acute care. The paper evaluates the effects of remote triage systems on healthcare utilization, case resolution, and patient safety outcomes. The paper also discusses the challenges and limitations of remote triage systems, such as data quality, communication, and ethical issues.

2.3 Proposing Solutions from Customer Texts

This subsection reviews the papers that focus on proposing solutions from customer texts, such as queries, feedback, or complaints. The purpose of proposing solutions from customer texts is to provide relevant and personalized responses that address the customer needs and expectations.

One of the papers that discusses the importance of proposing solutions from customer texts is "Customer experience: a systematic literature review and consumer culture theory-based conceptualization" by Waqas et al. [10]. This paper summarizes and classifies the existing research on customer experience, which is defined as the subjective and emotional response of the customer to the interaction with the firm or its offerings. The paper also proposes a new conceptualization and conceptual model of customer experience based on consumer culture theory, which highlights the role of customer attribution of meanings in defining their experiences. The paper claims that customer experience is a key driver of customer loyalty and value creation.

Another paper that describes the types and benefits of proposing solutions from customer texts is "Customer relationship management and its impact on entrepreneurial marketing: a literature review" by Guerola-Navarro et al. [11]. This paper reviews the existing literature on customer relationship management (CRM), which is a business strategy that integrates people, processes, and technology to maximise relationships with customers. The paper also examines the impact of CRM on entrepreneurial marketing, which is a proactive and innovative approach to identify and satisfy customer needs and create value. The paper asserts that CRM can enhance entrepreneurial marketing by providing customer insights, segmentation, personalization, and retention.

A third paper that provides an overview and guidelines for proposing solutions from customer texts is “A Brief Literature Review: Customer Relationship Management” by Dudovskiy [12]. This paper discusses the main components and benefits of CRM, such as customer acquisition, customer retention, customer satisfaction, and customer loyalty. The paper also suggests some best practices for implementing CRM, such as aligning CRM with business objectives, integrating CRM with other systems, and measuring CRM performance. The paper states that CRM can help in improving the customer service and increasing the profitability.

A fourth paper that presents a model for proposing solutions from customer texts is “A Neural Network Approach to Context-Sensitive Generation of Conversational Responses” by Sordoni et al. [13]. This paper proposes a neural network model that can generate context-sensitive and relevant responses for conversational agents. The model uses a recurrent neural network encoder-decoder architecture that can capture the semantic and syntactic information from the input text and the previous dialogue history. The paper demonstrates that the model can outperform the existing methods on various evaluation metrics, such as perplexity, diversity, and human judgment.

2.4 Role of Large Language Models

This subsection reviews the papers that focus on using LLMs for customer service and incident management. LLMs are a class of language models that have demonstrated outstanding performance across a range of NLP tasks and have become a highly sought-after research area, because of their ability to generate human-like language and their potential to revolutionize science and technology. The purpose of using LLMs for customer service and incident management is to bridge the gap between self-service and human interaction, and to provide relevant and context-aware responses.

One of the papers that discusses the types and features of LLMs is “A Comprehensive Overview of Large Language Models” by Naveed et al. [14]. This paper provides an overview of the existing literature on a broad range of LLM-related concepts, such as architectural innovations, better training strategies, context length improvements, fine-tuning, multi-modal LLMs, robotics, datasets, benchmarking, efficiency, and more. The paper also illustrates the strengths and limitations of LLMs, as well as the open challenges and opportunities for future research. The paper aims to provide a systematic survey and a quick comprehensive reference for the researchers and practitioners who are interested in advancing the LLM research.

Another paper that discusses the quality and impact of LLMs is “A Bibliometric Review of Large Language Models Research from 2017 to 2023” by Fan et al. [15]. This paper conducts a bibliometric and discourse analysis of scholarly literature on LLMs, synthesizing over 5,000 publications. The paper presents the research trends from 2017 to early 2023, identifying patterns in research paradigms and collaborations. The paper also reveals the dynamic, fast-paced evolution of LLM research. The paper offers valuable insights into the current state, impact, and potential of LLM research and its applications.

A third paper that discusses the applications and challenges of LLMs is “Large Language Models for Software Engineering: A Systematic Literature Review” by Hou et al. [16]. This paper reviews the existing literature on the applications of LLMs for software engineering tasks, such as code generation, code completion, code summarization, code search, code documentation, code review, bug detection, and more. The paper also identifies the challenges and limitations of LLMs for software engineering, such as data quality, model complexity, evaluation metrics, and ethical issues. The paper provides a comprehensive overview of the state-of-the-art and the future directions of LLMs for software engineering.

A fourth paper that discusses the applications and challenges of LLMs is “Artificial Intelligence Research in Business and Management: A Bibliometric Review of Large Language Models” by Naveed et al. [17]. This paper conducts a bibliometric and discourse analysis of scholarly literature on the applications of LLMs for business and management tasks, such as text summarization, sentiment analysis, text generation, text classification, question answering, and more. The paper also identifies the challenges and limitations of LLMs for business and management, such as data availability, model interpretability, ethical and social implications, and more. The paper provides a comprehensive overview of the state-of-the-art and the future directions of LLMs for business and management.

2.5 Ethical Considerations and SLAs

This subsection reviews the papers that focus on the ethical considerations and service level agreements (SLAs) of conducting research and providing service in the context of incident management and ticket dispatching. Ethical considerations are the principles and values that guide the researchers and practitioners to conduct their work in a responsible and respectful manner, while SLAs are the contracts and commitments that define the expectations and obligations of the service providers and customers. The purpose of ethical considerations and SLAs is to ensure the quality, reliability, and accountability of the research and service outcomes.

One of the papers that discusses the ethical considerations of conducting research in the context of incident management and ticket dispatching is “Ethical Considerations of Conducting Systematic Reviews in Educational Research” by Suri [18]. This paper discusses the ethical issues associated with what and how systematic reviews are produced and used, such as potential conflicts of interest, issues of voice and representation, and implications for policy and practice. The paper also discusses how systematic reviewers can draw upon the philosophical traditions of consequentialism, deontology or virtue ethics to situate their ethical decision-making. The paper aims to provide a reference for systematic reviewers to reflexively engage with a variety of ethical issues.

Another paper that discusses the ethical considerations of conducting research in the context of incident management and ticket dispatching is “Ethical consideration dilemma: systematic review of ethics in qualitative data collection through interviews” by Nii Laryeafio and Ogbewe [19]. This paper reviews the existing literature on the ethical considerations of conducting qualitative data collection through interviews, such as anonymity, voluntary participation, privacy, confidentiality, option to opt out, and avoiding misuse of findings. The paper also discusses the theories that underpin the ethical considerations in research, such as deontology, utilitarianism, rights, and virtue. The paper aims to provide a reference for researchers who conduct qualitative data collection through interviews.

A third paper that discusses the ethical considerations of conducting research in the context of incident management and ticket dispatching is “A systematic literature review of the ethics of conducting research in humanitarian settings" by Ager et al. [20]. This paper reviews the existing literature on the ethics of conducting research in humanitarian settings, such as conflict-affected and fragile states, where incidents and emergencies are prevalent. The paper identifies the ethical challenges and dilemmas that researchers face in such settings, such as informed consent, risk-benefit analysis, confidentiality, data security, and more. The paper also discusses the ethical frameworks and guidance that researchers can use to address these challenges and dilemmas.

A fourth paper that discusses the service level agreements of providing service in the context of incident management and ticket dispatching is "Service Level Agreements: A Systematic Literature Review" by Alhammadi and Alshammari [21]. This paper provides a systematic literature review of the existing research on service level agreements (SLAs), which are formal or informal contracts that specify the quality, availability, and responsibilities of the service providers and customers. The paper also discusses the main components, types, and benefits of SLAs, as well as the challenges and issues of SLAs, such as negotiation, monitoring, enforcement, and violation. The paper aims to provide a comprehensive overview of the current state and future directions of SLAs research.

A fifth paper that discusses the service level agreements of providing service in the context of incident management and ticket dispatching is "A Framework for Service Level Agreement Management in Cloud Computing" by Alhammadi et al. [22]. This paper proposes a framework for SLA management in cloud computing, which is a paradigm that enables on-demand access to shared resources and services over the internet. The paper also discusses the challenges and requirements of SLA management in cloud computing, such as scalability, security, reliability, and interoperability. The paper demonstrates that the proposed framework can help in improving the SLA management process and performance in cloud computing.

In summary, ethical considerations and SLAs are essential aspects of conducting research and providing service in the context of incident management and ticket dispatching. By adhering to the ethical principles and values, and by establishing and fulfilling the SLA contracts and commitments, researchers and practitioners can ensure the quality, reliability, and accountability of their work. Researchers and practitioners must collaborate to address the ethical and SLA challenges and issues that arise in this field.

3 Methodology

To illustrate our experiment, we will use a dataset of IT customer support tickets as a running example throughout this study, though it should be clear that this workflow is broadly applicable to general collections of customer support tickets.

3.1 Workflow

In this study, as outlined in Fig. 1, illustrates the three-stage process employed in our study to optimize IT support operations. Topic and Trend Analysis, Ticket Dispatching Architecture and Resolution Recommendation System. We developed a comprehensive workflow to streamline IT support processes using advanced NLP techniques. The initial phase, "Topic and Trend Analysis," employed Latent Dirichlet Allocation (LDA) to extract prevalent themes from customer tickets, providing insight into frequent issues and user concerns. The core of the system, "Ticket Dispatching Architecture," integrated Zero-Shot classification, a Fine-Tuned Language Model (distilBert), and Retrieval Augmented Generation (RAG) to accurately categorize and route tickets. The final phase, "Resolution Recommendation System," leveraged RAG to suggest the most pertinent solutions by analyzing historical resolution data. This tripartite approach ensured a nuanced understanding and efficient management of customer queries, reflecting an intelligent, data-driven model for IT support.

3.2 Dataset

The dataset utilized in this experiment comprises IT remedy tickets and their resolutions, which represent a collection of resolved IT support logs reported by users and handled by the support team. The tickets are categorized into the top 6 most common IT categories, which represent a wide range of problems and inquiries in IT. The data consists of 3000 IT support tickets in total, each with a unique Ticket ID (Ticket_ID). Each entry in the dataset has a category (Ticket_Category) and a detailed description (Ticket_Description) of the IT problem or request.

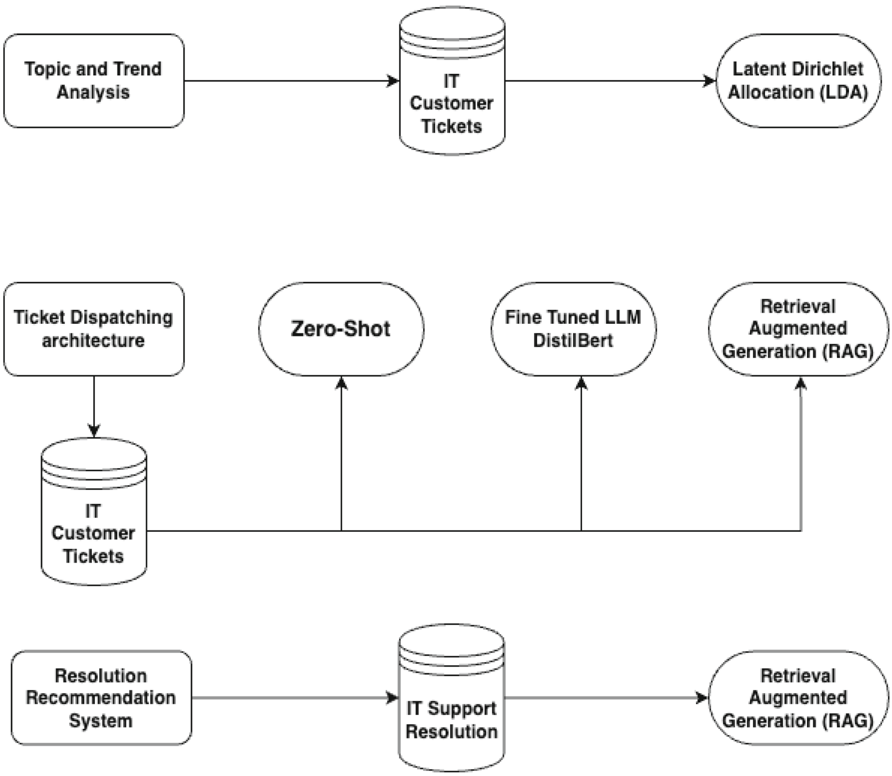

Fig. 1. Integrated IT Support Workflow

These categories include common IT support topics such as Data Backup and Recovery Issues, Hardware Support Services, Software Installation and Updates, Security Concerns and others. The dataset also contains the solution of each ticket, showing the steps needed to resolve the issue or answer the questions.

3.3 Feature Engineering of the Text Data

Performing feature engineering lays a robust foundation for machine learning modeling, ensuring that the input to our models include the rich, contextual subtleties for accurate identifying of the key words in customer tickets. We use text normalization methods to refine raw text data in our preprocessing pipeline. Text is tokenized first, breaking sentences into words or tokens. Stop words—common words that are common but not discriminatory—are then removed. Punctuation marks, which do not add to the meaning of the text, are also removed. Lemmatization and stemming help us reduce word variants to their roots. Lemmatization accurately reduces words to dictionary form, while stemming crudely removes affixes. These steps simplify the text and help machine learning models recognize patterns. After cleansing and standardizing the text, we use TF-IDF vectorization to convert the tokens to numbers. This transformation includes bi- and trigram combinations, improving our model's contextual understanding. The vectorized text represents the relative importance of terms in tickets and across the corpus, creating a feature set for machine learning algorithms.

3.4 Topic and Trend Analysis: Latent Dirichlet Allocation (LDA)

LDA is a probabilistic model that is specifically tailored for analysing collections of discrete data, such as text corpora. It assumes the existence of underlying themes that are present throughout the documents in a collection. These topics are not directly observed; instead, they are derived from the documents and their word distributions. LDA proposes that documents consist of a combination of topics, each represented by a probability distribution over the entire vocabulary of words used in the corpus. The fundamental process for generating a document in LDA involves selecting a distribution of topics from a Dirichlet distribution. For each word in the document, a topic is chosen from this distribution, and then a word is selected from the vocabulary distribution specific to that topic, which is also determined by a Dirichlet distribution [23, 35–39].

3.5 Ticket Dispatching Architecture: Zero-Shot Text Classification

Zero-shot Text Classification (0SHOT-TC) identifies topics in datasets by leveraging the inherent capabilities of machine learning models to understand and classify text based on learned representations, without needing specific training on the target classes. This approach utilizes the semantic understanding of language models to infer the relationship between the input text (like IT tickets) and a range of possible topics. By evaluating the similarity or entailment between the text and predefined topic labels, 0SHOT-TC can categorize text into relevant topics, even if it has not been explicitly trained on those specific topics. This makes 0SHOT-TC particularly useful for dealing with diverse and evolving sets of categories, such as the varied issues encountered in IT support tickets [32].

3.6 Ticket Dispatching Architecture: Fine Tuned LLM DistilBert

DistilBERT, as introduced by Sanh et al. [33], is a streamlined version of BERT, optimized for faster performance and smaller size. It is created using knowledge distillation, a technique where a smaller model is trained to replicate the behavior of a larger, more complex model. DistilBERT manages to retain approximately 97% of BERT's language understanding capabilities while being 40% smaller and 60% faster. This efficiency makes it highly suitable for tasks like classifying IT ticket topics, where rapid processing and accurate language comprehension are essential. DistilBERT's ability to handle diverse linguistic patterns with reduced computational demand aligns well with the requirements of efficiently categorizing IT tickets.

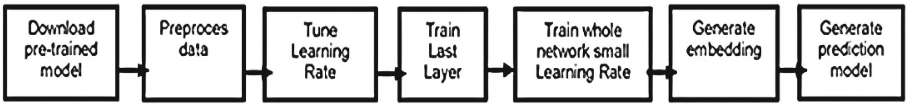

Fig. 2. Transfer learning and finetuning with embedding steps

This method as discussed by Idris & Hussah [30], uses transfer learning and fine-tuning open-source, pre-trained large language transformer models like DistilBert. The processes as displayed in Fig. 2, where transfer learning was used to construct text embedding with vector values using pre-trained models and labeled data. Next, we design classifiers by iterating through different learning rates to identify the best one. Iterate over LR, plot Loss versus LR, and choose the greatest stable LR to get the optimal learning rate (LR). After training the last layer, pre-trained network weights are frozen. The entire model is retrained with a minuscule fraction of the learning rate and continuously monitored to fine-tune it. This sensitive procedure requires experimenting with learning rates and iterations to train the model to learn new labeled input and preserve what is known. The technique will provide classifier models and language modeling embeddings for the following features.

3.7 Ticket Dispatching and Resolution: RAG

The RAG model, as discussed by Lewis et al. [34], is a sophisticated approach that combines the strengths of pre-trained language models with a retrieval system. This system enhances the model's knowledge base by integrating information from a dense vector index of external sources like Wikipedia. Technically, RAG operates by first using a query encoder to transform the input question into a vector, then retrieves relevant documents based on this vector, and finally generates a response using both the input and retrieved documents. This allows for a more informed and accurate response, especially in complex tasks like IT ticket classification, where leveraging external knowledge can be crucial for identifying specific technical issues and topics.

4 Result Evaluation

4.1 Latent Dirichlet Allocation (LDA)

Figure 3 displays the top words in each of the six topics identified by the LDA model applied to the Ticket_Description field of the dataset.

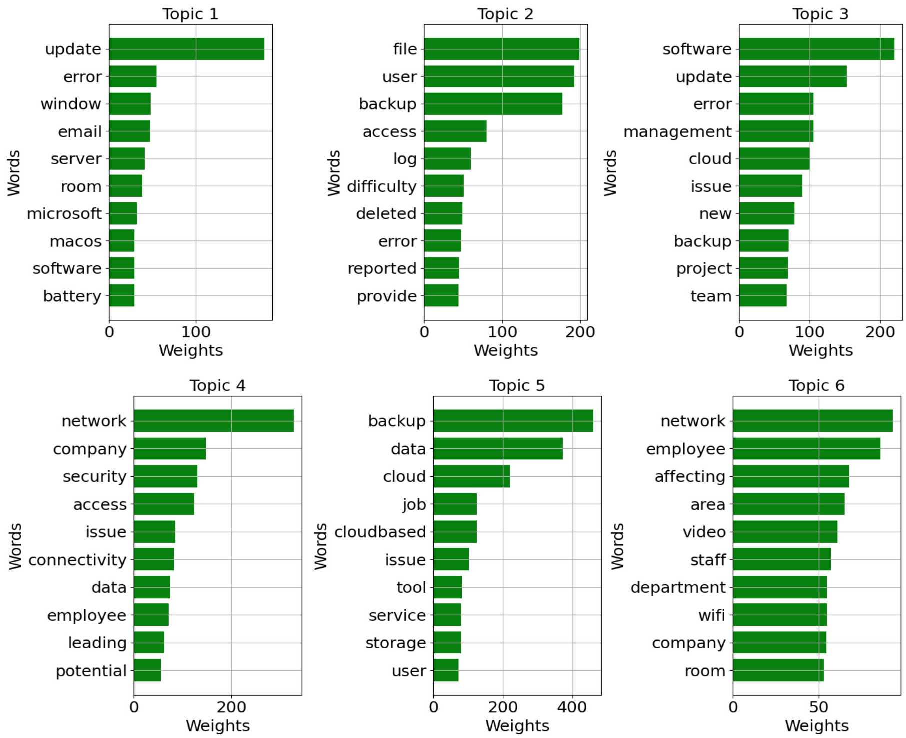

Fig. 3. Dominant Topics in IT Tickets - LDA Topic Modeling Outcomes.

Each subplot represents a topic with words aligned to that topic, with the horizontal bars indicating the weight (importance) of each word within that topic. The weights are a measure of how representative a word is for a particular topic. Topics 1 and 3 intersect over software troubleshooting, with Topic 1 capturing the immediate user experience through terms like ’email’, whereas Topic 3 encompasses the strategic side, suggesting a focus on project oversight with terms like ‘Team’ and ‘management’. Network-related issues span across Topics 4 and 6; the former addresses broader organizational network challenges, as indicated by ‘connectivity’, while the latter hones in on employee-specific network experiences, marked by ‘department’. Data management differentiates Topics 2 and 5—Topic 2 gravitates towards user-level data access and file issues, and Topic 5 scales up to systemic data solutions in the ’cloud’. These topics collectively depict a range of IT support areas, from technical updates to security and data management.

4.2 Zero-Shot Text Classification (0SHOT-TC)

In evaluating the performance of our classification Zero-shot Text Classification (0SHOT-TC) for IT Ticket categorization, the confusion matrix revealed notable strengths and areas for improvement across six categories: Data Backup and Recovery Issues, Hardware Support Services, Software Installation and Updates, Network Connectivity, Cloud Services Management, and Security Concerns. The model excelled in correctly classifying 'Data Backup and Recovery Issues' (135 true positives) and 'Network Connectivity' (122 true positives), indicating a strong alignment in these categories. However, it struggled with significant misclassifications, especially confusing 'Hardware Support Services' with 'Security Concerns' (66 instances) and 'Cloud Services Management' with 'Data Backup and Recovery Issues' (46 instances). These errors highlight the model's challenge in distinguishing closely related categories. Precision, which measures the accuracy of the model in predicting each category, varied across the board. For instance, while the model showed high precision in 'Data Backup and Recovery Issues' (evidenced by a low number of false positives), it exhibited lower precision in 'Cloud Services Management', where a significant number of instances were incorrectly classified as 'Data Backup and Recovery Issues'. Recall, or the model's ability to identify all relevant instances of a category, also showed disparity. High recall was observed in 'Network Connectivity', where the model successfully identified a majority of the relevant cases. In contrast, 'Security Concerns' showed lower recall, with many instances being misclassified as 'Hardware Support Services', indicating missed detections of this category by the model (Fig. 4).

	Precision	Recall	F1-score	Support
Cloud Services Management	0.9714	0.2267	0.3676	150
Data Backup and Recovery Issues	0.6618	0.9000	0.7627	150
Hardware Support Services	0.9800	0.3267	0.4900	152
Network Connectivity	0.6595	0.8026	0.7240	150
Security Concerns	0.4817	0.9667	0.6430	150
Software Installation and Updates	0.9134	0.7733	0.8375	150

Fig. 4. Performance Evaluation of Zero-shot Text Classification

4.3 Retrieval Augmented Generation (RAG)

The RAG method requires an LLM embedding model of sentence-transformer (all-MiniLM-L12-v2) and an open-source vectorized database (Milvus). In this method, no classification model is built for prediction, instead, training data is converted into embedded format based on the LLM model and stored in a vectorized database where a built-in similarity function is available to quickly find similar questions in terms of context and retrieve assigned resolution.

The model exhibits exceptional performance across various IT support categories in Fig. 5. Notably, for “Cloud Services Management,” precision stands at 96.73%, recall at 98.67%, and an F1-score of 97.69%. “Data Backup and Recovery Issues” show remarkable precision (96.15%), perfect recall (100.00%), and an F1-score of 98.04%. “Hardware Support Services” achieves a perfect precision of 100.00%, recall of 94.00%, and an F1-score of 96.91%. The model maintains a strong balance between precision and recall for “Network Connectivity” (F1-score: 95.48%) and “Security Concerns” (F1-score: 96.97%). Furthermore, for “Software Installation and Updates,” precision is 97.28%, recall is 95.33%, and the F1-score is 96.30%. Overall, the metrics suggest that the model is effective across various classes, demonstrating a good balance between precision and recall. The high F1-scores across classes indicate robust performance in classifying instances related to different IT support categories.

	Precision	**Recall**	**F1-score**	**Support**
Cloud Services Management	0.9673	0.9867	0.9769	150
Data Backup and Recovery Issues	0.9615	1.0000	0.9804	150
Hardware Support Services	1.0000	0.9400	0.9691	152
Network Connectivity	0.9367	0.9737	0.9548	150
Security Concerns	0.9796	0.9600	0.9697	150
Installation and Updates	0.9728	0.9533	0.9630	150

Fig. 5. Performance Evaluation of RAG

4.4 Fine Tuned LLM

In the approach, we performed transfer learning and fine-tuned an LLM model, which is distilbert-base-uncased. In a glance at the confusion matrix from Fig. 6, we can see impressive prediction performance with high precision and recall for almost all classes.

In detail, as displayed in Fig. 6, all classes show outstanding precision, recall, and F1-score values, resulting in an overall high accuracy of 98.34%. Each class has precision, recall, and F1-score values close to or equal to 1.00, indicating exceptional performance. In this context, all classes appear to be well-balanced between precision and recall. It’s important to note that achieving such high scores across all metrics is quite impressive and suggests that the model is performing exceptionally well on this dataset. The macro and weighted average metrics, both at approximately 98.34%, reinforce the overall outstanding performance of the model across all classes.

In summary, based on the provided metrics, all classes seem to balance precision and recall, and the model performs exceptionally well across the board.

	Precision	Recall	F1-score	Support
Cloud Services Management	0.9675	0.9933	0.9933	150
Data Backup and Recovery Issues	0.993	0.993	0.993	150
Hardware Support Services	0.9932	0.9667	0.9797	152
Network Connectivity	0.9554	0.9868	0.9709	150
Security Concerns	0.9933	0.9867	0.9900	150
Installation and Updates	1.000	0.9733	0.9865	150

Fig. 6. Performance Evaluation of fine-tuned scenario

In our research, we explored three distinct approaches for addressing classification tasks: Retrieval-Augmented Generation (RAG), Zero-Shot learning, and Fine-Tuned Language Model (LLM).

The RAG approach leverages a generic and widely-used sentence-transformer model for embedding without the need for fine-tuning or training. This design choice not only saves significant time and resources in model training but also allows us to rely solely on GPU resources for data inferences. However, a vectorized database is necessary for this approach, and ongoing database management is required. While open-source databases are available, we acknowledge the potential performance improvement that could result from fine-tuning the embedding model with our specific training datasets, although this aspect is not covered in our current research. Based on our experiment , generic embedding LLM model with no fine-tuning is already capable to achieve high precision and recall for all type of categories.

The Zero-Shot learning approach offers the advantage of requiring no training and can be directly applied to our data. However, its limitation lies in its non-specificity to the unique characteristics of our ticket-related problem. Consequently, predictions may exhibit high true positives but also encounter challenges with high false positives and false negatives. On the other hand, the Fine-Tuned Language Model (LLM) approach stands out for achieving the highest performance, characterized by both high precision and recall across almost all classes. This approach involves fine-tuning the model on specific training datasets, ensuring tailored performance for our classification tasks. Nevertheless, it's important to note that the fine-tuning process demands significant resources during both training and inference, distinguishing it from the more resource-efficient characteristics of the RAG and Zero-Shot approaches.

In summary, both the Retrieval-Augmented Generation (RAG) technique and the Fine-Tuned Language Model (LLM) exhibit impressive levels of precision and recall across various categories. However, when considering practical implementation, the RAG approach proves to be more resource-efficient in terms of computing power requirements. Unlike the Fine-Tuned LLM model, RAG does not necessitate additional resources and time for fine-tuning. This aspect highlights the economic advantage of the RAG technique, making it a pragmatic choice for scenarios where computational resources and time constraints are key considerations.

4.5 Resolution Prediction

In this methodology, we segregate the training and test datasets, with the ticket descriptions from the training data being embedded and stored in a vectorized database. Subsequently, we employ a similarity function within the vectorized database to identify analogous descriptions for each test data point in relation to the training data. The underlying concept here is that the resolution recommendations can be derived from tickets with akin descriptions, which are expected to share common resolutions. This approach capitalizes on the notion that tickets with similar descriptions tend to lead to similar resolutions, thereby facilitating effective resolution recommendations.

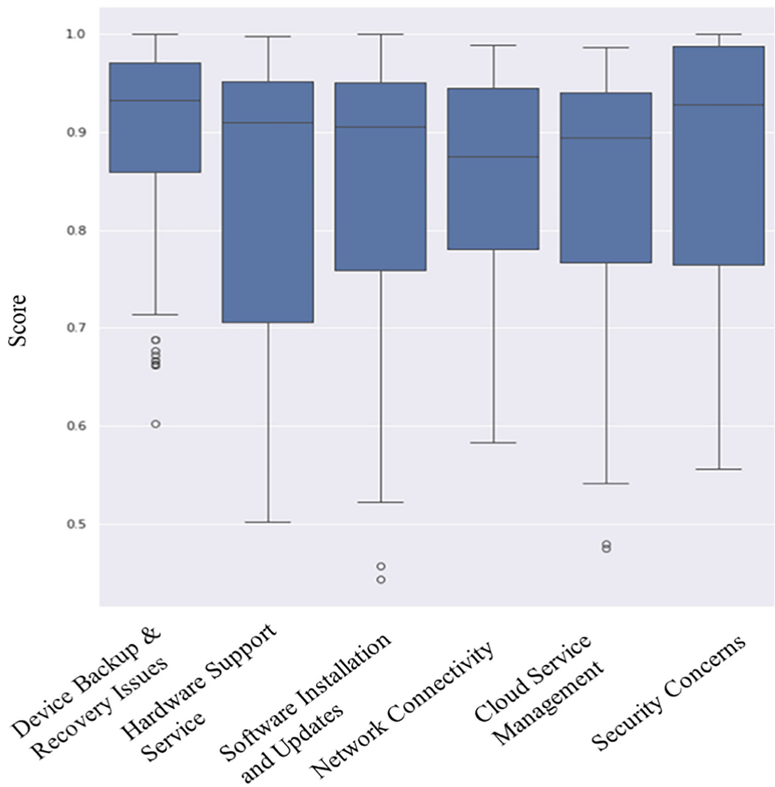

Fig. 7. Distribution of similarity of description between test and train data

First, we evaluate the similarity of the ticket description between test and training data. In Fig. 7, the results of our test data where we find the most similar ticket description based on training data where the similarity is using cosine similarity between 0 to 1 for all ticket categories. Overall, we can see here that the medians range from .85 to 95. Nevertheless, there are “Software Installation and Updates” and “Cloud Services Management” that have outliers lower than 0.5. This indicates that there are few tickets in test data that have description different from our training data. In general, we can use our historical data to find similar tickets based on their description.

Once we find the most similar description, we checked the similarity of the resolutions between the training data sets that we use as reference, against the test data sets (Fig. 8).

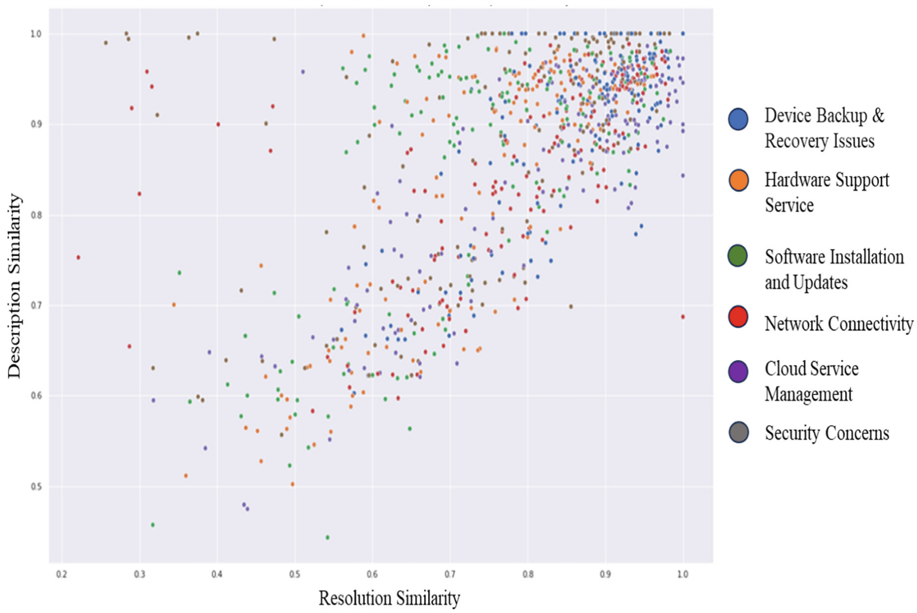

Fig. 8. Correlation between ticket description and resolution (actual vs predicted)

The chart shows the correlation between ticket and resolution similarity between training and test for all categories. Our objective here is to check positive correlation based on our assumption where high description similarity will also have high resolution similarity (Fig. 9).

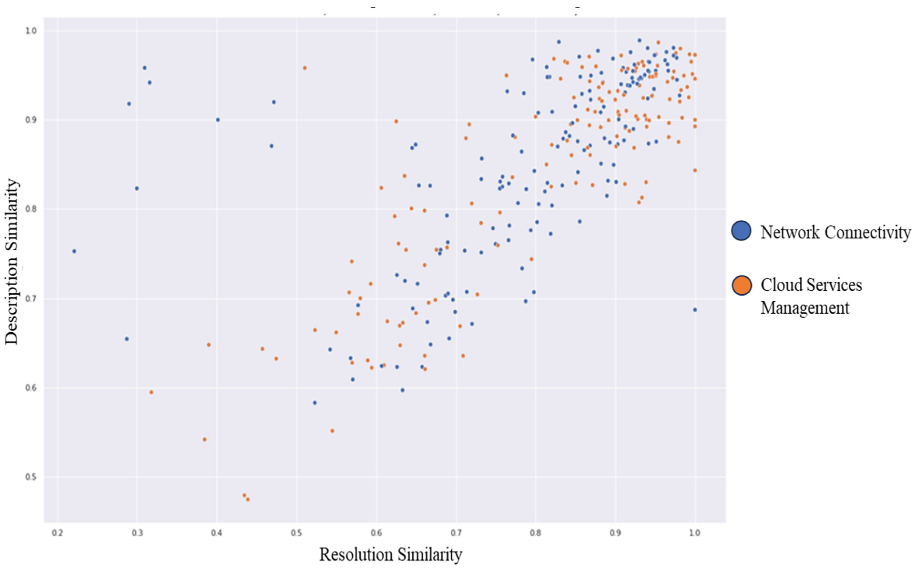

Fig. 9. Correlation between ticket description and resolution (actual vs predicted)

The chart shows that most points are concentrated in the upper right quadrant, which means that both ticket description and resolution description do have positive correlation where similar ticket description do have similar solution. This indicates that the model that generated the predictions is accurate and consistent. However, there are some outliers, especially for the categories of "Network Connectivity" and "Cloud Services Management", which have lower similarity values for both ticket description and resolution description.

As we can see here, for "Network Connectivity" in blue, there are several points where the high description similarity between actual and prediction is high but the resolutions between actual and predictions are low. This indicates that, in our approach, by finding similar descriptions based on the training data, there are several tickets where the resolutions are different which is evident for "Network Connectivity". Unlike "Cloud Services Management", it shows positive correlation with less outliers.

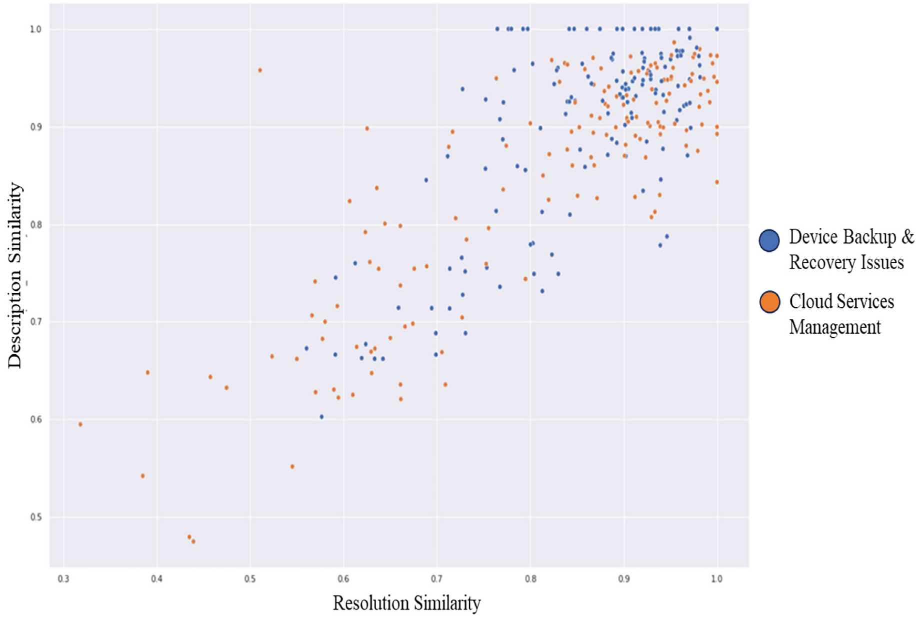

Fig. 10. Correlation between ticket description and resolution (actual vs predicted)

The chart in Fig. 10 is a scatter plot representing the correlation between ticket description and resolution description actual vs prediction similarity for three different categories of tickets: "Device Backup & Recovery Issues" and "Cloud Services Management". You can see some how positive correlation showing higher description similarity depicting higher resolution and vice versa.

In summary, given the ongoing evaluation, this approach remains a viable option for recommending or predicting resolutions for new tickets. However, there is a need for additional efforts to assess the resolution quality, particularly through the insights of subject matter experts in each category. In addition, we believe that substantial enhancements can be achieved through the collection of user feedback on the recommended resolutions. Correct resolution will be identified and included in the training data. This active learning where iterative process is anticipated to refine the system's performance by incorporating real-world user experiences and expert insights, ultimately contributing to the continual improvement of the recommendation and prediction capabilities.

5 Future Direction

Given the accuracy of the models suggested solutions, the methods herein described can be used as a piece of a larger AI that can, in addition to suggesting solutions to problems based on previous solutions to similar problems, translate those solutions using LLM's to generate all needed deliverables. For example, a software issue could be resolved through generation of the necessary code that can resolve the bug. This would necessitate combining system knowledge (such as a code base, application documentation, etc) with the historic incident information into the knowledge base of the LLM using a (RAG approach. Eventually, through a continuous reinforcement learning approach, the model outputs can reach a satisfactory level of accuracy that they can be automatically actioned without the need for a human in the loop.

6 Conclusion

This paper presented an innovative approach combining Machine Learning (ML) and Large Language Models (LLMs) to enhance the efficiency and accuracy of incident management systems in customer-serving organizations. By automating and optimizing the ticket dispatching and resolution process, the proposed approach significantly reduces human intervention and error rates while improving customer satisfaction. Challenges involved in the ticket management process remain the biggest areas of improvement for any customer services organization.

The comprehensive research encompassed a detailed literature review, outlining existing methodologies and the potential of AI/ML in incident management. The proposed methodology leverages the advanced capabilities of LLMs and traditional ML algorithms to process and classify ticket data, further employing vector databases for improved resolution suggestions. This synergy of techniques was rigorously evaluated using real-world IT service data, demonstrating a notable increase in accuracy, resolution speed, and customer satisfaction compared to traditional text-only and human-only methods.

Notably, the proposed system showcased its versatility and effectiveness across various classification tasks, employing techniques like Retrieval-Augmented Generation (RAG), Zero-Shot learning, and Fine-Tuned Language Model (LLM). Each method brought distinct advantages, with RAG and Fine-Tuned LLM showing impressive precision and recall rates across multiple IT support categories.

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Artificial Intelligence as a Lever for Optimizing Well-Being at Work

Analysis in the Moroccan Banking Sector

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Abstract. The present study aims to characterize the influence of artificial intelligence (AI) within the workplace well-being (WWB) of employees in the banking sector in Morocco.

To this end, a quantitative approach coupled with deductive reasoning and positivist epistemology was applied. The positivist mainstream has been adopted to be essential to understanding and explaining the field of research on AI and WWB observed and quantified in the Moroccan banking context, through the objectivist perspective that characterizes it. This posture, along with deductive reasoning, will serve to scientifically test the theoretical models developed throughout this study in the light of the observations collected and quantified. In concrete terms, observations were collected from Moroccan bank employees on a self-administered basis, while SPSS software versions 25.0 was chosen as the quantification tool.

The results of this research confirm a significant and positive impact of AI on WWB.

Keywords: Artificial Intelligence (AI) · Workplace Well-Being (WWB) · banking sector

1 Introduction

Although the concept of artificial intelligence (AI) was introduced in 1956 at the Dartmouth Conference, it was not until the 1990s that the technology really took off due to successive improvements in computing capabilities (Marcotorchino, 2017). As a permeable technology, AI can indeed be integrated into various industries of the economy and potentially change the original methods of production and operation, which will also have a significant impact on employment. Compared with previous scientific and technological revolutions, the impact of AI on employment is multidirectional and extremely intense, and people in almost every sector and profession will be affected.

AI is thus emerging as a major catalyst for change in many sectors, including banking. For example, instead of promotions on deposits, banks can use AI to personalise their offers based on customer behaviour and needs. This is particularly the case in Morocco,

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where the banking landscape is constantly evolving, there is growing interest in integrating AI because of its potential to improve operational efficiency, decision-making and customer satisfaction. While attention is often focused on the economic benefits of AI, its impact on the human dimensions, particularly employees' workplace well-being (WWB), remains relatively unexplored.

Given this observation, the need naturally arises to determine the relationship between the use of AI and WWB. This quest gives rise to the central problem of this thesis project, namely: "to what extent can the application of AI in the Moroccan banking sector influence the dimensions of the WWB of employees in this sector". Specifically, the aim is to characterise the relationship between the use of AI and WWB in the Moroccan banking context. To this end, four study hypotheses have been developed which, through a hypothetico-deductive approach supported by a quantitative sampling method, will be evaluated and thus asserted or refuted. These hypotheses are formulated as follows:

- **Hypothesis 1**: There is a significant and positive impact between the perceived robustness of the AI system and the components of WWB.
- **Hypothesis 2**: There is a significant and positive impact between the perceived resilience of the AI system and the components of WWB.
- **Hypothesis 3**: There is a significant and positive impact between the perceived explicability of the AI system and the components of WWB.
- **Hypothesis 4**: There is a significant and positive impact between the quality of human-machine interaction and the components of WWB.

Answering these questions is essential, as WWB is not only a crucial component of employee quality of life, but is also closely linked to key performance indicators such as productivity, staff retention and customer satisfaction. This thesis is therefore set in a context where Morocco, as an emerging country, aspires to modernise its banking sector while ensuring the well-being and fulfilment of its workforce. With a view to evaluating these hypotheses, this research work is structured around two main parts: a theoretical part and a practical part. The theoretical part will analyse the relationship between AI and WWB, while the practical part will involve testing the conclusions of these various studies in the Moroccan banking context.

2 Theoretical Framework

2.1 Conceptual Foundations of Workplace Well-Being

WWB is constructed as a concept including both physical and psychological medical symptoms at work (factors of the person's WWB) and work-related experiences (factors of the worker's WWB). The definitions of the concept of WWB in the literature are constructed as a mixture of these two factors, with a predominance for one or the other. Focusing on the well-being of the worker at work, the WHO in particular states that WWB is "*a dynamic state of mind characterised by a satisfactory harmony between, on the one hand, the aptitudes, needs and aspirations of the worker and, on the other hand, the constraints and possibilities of the work environment*".

Although the notion of well-being has a recent history in the scientific field, several definitions of this concept exist in the scientific literature. These definitions focus on the coherence between the individual and his work, stipulating that WWB appears at the intersection of health and safety at work and the coherence of work with the worker's deepest nature. A study of the way in which the different facets of well-being influence the employee's life has made it possible to characterise the different dimensions (cognitive, affective and conative) of the concept of WWB. Although these different dimensions are different phases in an overall process of measuring WWB, the latter differs according to the terminologies or theories adopted to qualify this concept. As a result, various models for operationalising these dimensions have been developed, including those of Warr (1990) and Collange, Gaucher, George, Saunder, & Albert (2017).

According to Warr (1987, 2009), well-being and the work environment are linked in a linear fashion. Therefore, in his model, work-related characteristics influence well-being (Warr, 1990). These characteristics can be categorised into two types: extrinsic characteristics (salary, physical security, social position, career prospects, etc.) and intrinsic characteristics (use of skills, control of work, variety of work, etc.) (Bouterfas, 2014). The Collange, Gaucher, George, Saunder, & Albert (2017) model adopts an approach based on manifestations of hedonic and eudemonic well-being. This model is understood as a positive perception of working life in which the individual achieves fulfilment and accounts for the conative, affective or cognitive manifestations of WWB to which a measure of satisfaction with the work environment has been added (Collange, Gaucher, George, Saunder, and Albert, 2017). More specifically, at the heart of this work environment today is artificial intelligence.

2.2 Artificial Intelligence in the Banking Sector

Although the terminology 'artificial intelligence' has become commonplace, its definition is not universally accepted in the scientific world. John McCarthy (1927, 2011) sees it as "*… The science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence,…*" (McCarthy, 2007). In generic terms, AI can thus be seen as the set of technologies aimed at using computers to perform cognitive tasks traditionally carried out by humans. Given the preponderance of data in contemporary society, the range of applications for these technologies is growing all the time. This is particularly the case in the banking sector, which, being based in essence on the exploitation of data, is a prime area for the application of AI (Benhamou and Janin, 2018).

The application of AI in the banking sector is thus creating many upheavals in the way the sector operates (in terms of the creation, supply and use of financial products). AI is set to dictate the way banks interact with their customers (Purdy and Daugherty, 2016). The banking sector has been digitising its processes, information exchanges and transactions for a long time now. As a corollary to this process, the advent of AI has encouraged automated interaction with customers, the upgrading of web and mobile applications, the operation of remote bank accounts, authentication and verification, the assessment of the quality of credit for financial services, insurance products and contracts (Ouidani and Oul-Caid, 2023).

These prospects generated by the application of AI to the banking sector are all opportunities to improve the efficiency of the sector's production (Mokyr, Vickers, and Ziebarth, 2015). At the same time, several studies reveal a correlation between the development of AI technology and the employment, income and work performance of employees, provided that the latter are willing to master the knowledge and skills required for its implementation. For example, as the OECD's annual Employment Outlook 2023 report reveals, 63% of workers who use AI say they are "more fulfilled" in their jobs (Lane, Williams, and Broecke, 2023). The challenge of the following section will be to analyse, in the scientific literature, the more specific relationship between the application of AI in companies and WWB.

2.3 Relationship Between AI and WWB in the Scientific Literature

Systematic research on the research fields of AI and WWB has revealed a significant relationship between AI and employees' employment, income and work performance (Duan and Guo, 2018). This is because AI technology, by generating improvements in the production efficiency of different industries and the skill level of employees (Joel Mokyr, 2015) promotes the WWB of employees who master its knowledge and skills. A longitudinal study conducted by Chen, Wang, and Zhang (2021) attests to this result. The methodology adopted by the latter consisted in following workers in the IT sector before and after the introduction of AI systems into their working environment. The results of their study reveal a significant increase in job satisfaction after the introduction of AI (particularly among workers who had received relevant training), although perceived stress also increased among some workers (Chen, Wang, and Zhang, 2021).

A subsequent study using the same methodology, conducted by Smith K., Johnson M., & Brown A. in 2022, made this result particularly clear. More concretely, it involved tracking a representative sample of employees before and after the implementation of AI systems in their company. Data was collected using online questionnaires assessing different aspects of WWB, such as workload, job satisfaction and perceived stress. This study revealed that the stress emerging among some employees is corollary to concerns expressed in relation to the automation of certain tasks and its impact on their professional identity (Smith, Johnson, and Brown, 2022). However, for the majority of employees, this study showed a general improvement in WWB (through a significant reduction in workload).

These different studies thus illustrate an association between the use of AI and varying levels of WWB. Even more recently, the study conducted by Xu, Xue and Zhao (2023) explores how the perception of the opportunities offered by artificial intelligence (AI) influences employees' WWB, focusing on the mediating role of the sense of autonomy and perceived stress, moderated by perceived organisational support. The methodology consists of a survey of a sample of employees in various sectors. The results show that the perception of AI-related opportunities is positively associated with WWB through the reinforcement of the sense of autonomy and the reduction of perceived stress (Xu, Xue, and Zhao, 2023). Moreover, perceived organisational support moderates this relationship, reinforcing the positive effect of perceived opportunities on WWB. This study highlights the importance of the perception of opportunities offered by AI as well as organisational support in promoting employee well-being in a context of technological transformation.

As designed, this literature review provides an illuminating perspective on the complex relationship between AI and WWB, highlighting both beneficial effects and potential challenges. The studies reviewed reveal significant variability in the impact of AI on employee wellbeing, highlighting the importance of taking contextual and individual factors into account. However, while these studies offer valuable insights, their qualitative and longitudinal methodology could be complemented by quantitative and deductive approaches, aligned with a positivist epistemology. Such an approach would make significant contributions by providing robust empirical data to support conclusions and inform practices in the Moroccan banking sector, while strengthening the validity and generalisability of the results obtained.

3 Empirical Framework of the Study

3.1 Epistemological Position

The choice was made to follow the principles of the positivist paradigm in order to prescribe, understand and explain the impact of AI on the dimensions of WWB. In concrete terms, the aim will be to experiment with the knowledge discovered in many subsequent studies relating to this field of investigation in the context of Moroccan banks by adopting a deductive approach. The logical path thus followed is to carry out studies of the field of research into the relationship between AI and WWB (literature review), to derive models and hypotheses from them and to draw general lessons from the latter by carrying out observations with employees of Moroccan banks. To this end, the choice of a quantitative approach is justified. This research work can thus be schematised linearly as follows (Fig. 1):

Theory → Hypothesis → Observation → Generalisation → Theory

Fig. 1. Outline of the study methodology

3.2 Research Methodology

- **Field of investigation**

For the purposes of this study, the Moroccan tertiary sector, particularly banking, was chosen as the reference population. This choice is motivated by the fact that this sector has undergone a number of significant changes in recent years in terms of its own organisation and its relational modes. It is a sector characterised by high concentration, where the ultimate quest, which is obviously profitability, requires a global corporate strategy where all employees are motivated and want to move in the same direction. This pleasant emotional state is conditional on these employees' evaluation of their work experiences being positive. In other words, the optimum performance demanded by the banking sector requires a consistent level of WWB among its employees.

- **Conceptual analysis model**

The conceptual model was constructed on the basis of the results of the main theoretical studies on the perception of AI and WWB. The conceptual model consists of two levels: the first level concerns the dimensions of AI perception, and the second concerns the components of WWB. With regard to the first level, the 4-factor model developed by Highhouse and Payam (1996) was adopted in order to operationalise the independent variables (IV) which is the perception of AI of employees in the banking sector of this study. The second level represents the dependent variable (DV) of this study, namely WWB. To this end, the model for measuring WWB operationalised in 2017 by Collange, Gaucher, George, Saunder, & Albert is the one used in this study. Each of these axes comprises 20 items with 5-point LIKERT-type response scales: Totally disagree, disagree, neutral, agree, totally agree. The following figure summarises this analysis model (Fig. 2).

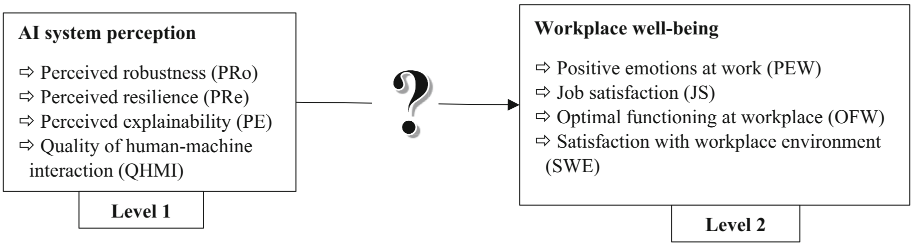

Fig. 2. Model conceptual framework

- **Data collection**

With a view to obtaining a large number of responses from the target population, the choice was made in this study to opt for the self-administered questionnaire as the data collection tool. Aware that the effectiveness and reliability of this data collection tool depend greatly on its design and administration (Baumard, Donada, Ibert, & Xuereb, 2014), the questionnaire and its measurement scales were carefully structured. In particular, the questions were formulated in such a way as to make them easier to understand for the people contacted. The questionnaire sent to respondents by email contained 40 items relating to the various study variables and divided into two axes. A convenience sampling strategy was adopted, consisting of administering the questionnaire to a large number of employees in the banking sector. Of these, a certain number (exactly 138) answered the questionnaire correctly. The respondents were distributed as follows (Table 1):

- **Data processing**

As the data collection method adopted for this study was self-administered, the questionnaire was sent individually to the participants so that they could answer it at their leisure. The tool chosen for data entry and processing was SPSS version 25.0. This choice is explained by the many advantages offered by this software. What's more,

Table 1. Socio-demographic characterization of the study sample

Gender	%
Male	52,2
Female	47,8

Age range	%
From 21 to 30 ans	46,4
From 31 to 40 ans	26,1
From 41 to 50 ans	13
From 51 to 60 ans	13,8
Over 60 ans	0,7

Function	%
Technician	13
Employee	29,7
Executive	56,5
Manager	0,7

the data manipulation capabilities offered by the R language are generally far superior to those of other common statistical analysis software. More specifically, this software was used to carry out the following analyses: Cronbach's Alpha reliability analysis Descriptive analysis (description of each of the variables in the study), correlational analysis (test of the relationship between the dependent and independent variables in the study) and simple linear regression analysis (analysis of the direct relationship between the independent variable and the dependent variable). The interpretation of these different analyses will enable us to respond to our different study hypotheses.

3.3 Analyzing and Interpreting Results

The first thing to check when analysing a set of quantitative data is the reliability of the scale used to measure all the items. In the case of this study, Cronbach's Alpha is close to 1, so the measurement scale is reliable. The results show that respondents' perception of AI is generally positive. More specifically, the negative value of the asymmetry indicates that the responses lean more to the right of the averages (which vary between 3 and 3.5). In addition, the value of each standard deviation being close to 1 attests that the respondents are in agreement with the fact that they have a good perception of each AI determinant in their bank. As with the perception of AI, the values of the asymmetry, the mean and the standard deviations for each component of WWB show that the responses lean more towards the positive modalities. Respondents therefore feel good about their work.

Following these results, it was necessary to carry out a correlational analysis to determine the absence or presence of a significant linear relationship between the dimensions of perception of AI and WWB. Correlation is commonly used to interpret the correlation effect size according to (Cohen, 1988) guidelines: around 0.1 (weak correlation); around 0.3 (medium correlation) and over 0.5 (strong correlation). In this study, we will simply assess the correlation between the different variables in our study. The null value of the significance coefficients of all the correlational analyses in the previous table attests to the existence of linear relationships between the dimensions of perception of AI and WWB.

A more detailed analysis of the Pearson correlation coefficients revealed the sign and intensity of this correlation. Firstly, as these coefficients are all positive, the relationships between the components of these different concepts are positive. Furthermore, according to Cohen's (1988) markers, these correlations are on the whole of relatively average size. In detail, the correlation is strongest between the Quality of human-machine interaction dimension and job satisfaction ($r = 0.575$). Conversely, it was weakest between the perceived robustness of the AI system and positive emotions at work ($r = 0.319$). Finally, regression analyses were carried out to test the influence of the perception of AI on the components of WWB; in other words, to test the hypotheses underlying this study. The following graph illustrates the proportion of DV explained by IA (explained by the adjusted R-two coefficient) (Fig. 3).

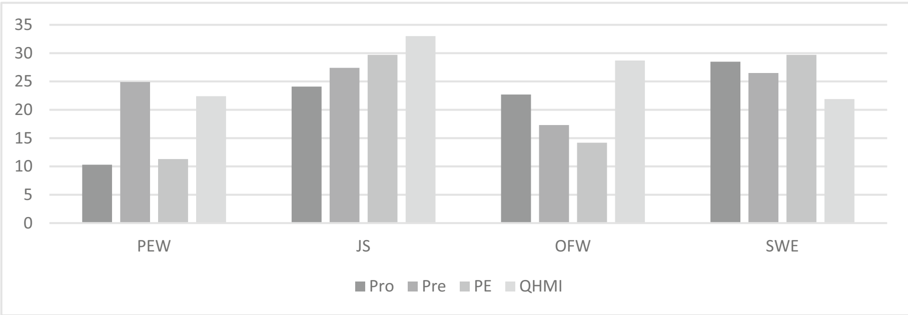

Fig. 3. Summary of the proportion of each WWB component explained by AI perceptions

Analysis of this graph reveals that perceptions of AI in the banking sector predict and explain the components of WWB. In detail, the predictive power of AI perception is relatively stronger on job satisfaction and weaker on positive emotions at work. The results of the Pearson regression analyses confirmed each of the hypotheses of this study. Based on this observation, we can therefore state that, in the Moroccan banking sector, there is a significant influence between each dimension of the perception of AI and WWB. Each of the hypotheses of this study is thus confirmed. By generalizing, therefore, we can immediately assert that the perception of AI has a significant and positive impact on the components of employees' WWB.

4 Conclusion

In an environment where AI is increasingly integrated into banking operations, it was crucial to understand how this technology influences employee satisfaction, motivation and well-being. The challenge was to determine to what extent the adoption of AI could be used as a strategic lever to strengthen the resilience of businesses in the face of technological upheaval. As a reminder, the general objective of this research is to explore the relationship between the perception of Artificial Intelligence (AI) and WWB in the specific context of the banking sector in Morocco.

Achieving this objective required the adoption of a methodology in two distinct phases. The first phase was theoretical in nature and consisted of an in-depth literature review on the two key concepts: the perception of AI and WWB. The aim of this literature review was to provide a solid conceptual framework, exploring different theoretical perspectives, recent developments in the field of AI and relevant theories on WWB. The second phase was empirical and involved quantitative data collection from employees in the Moroccan banking sector. A questionnaire comprising 40 items operationalising the study variables was distributed electronically, and the responses were analysed using

SPSS software. This mixed-methods approach combined data from the literature review and an empirical survey to obtain an in-depth understanding of the relationship between perceptions of AI and WWB.

The data analyses revealed significant results regarding the impact of AI perception on WWB in the Moroccan banking sector. In particular, the study revealed that how employees perceive AI directly influences their job satisfaction, engagement and sense of job security. These findings highlight the crucial importance for businesses to take employee perceptions into account when integrating AI into their operations. However, despite the robustness of the quantitative data, it is essential to recognise the limitations of this approach and consider complementary approaches, particularly qualitative, to gain a deeper and more nuanced understanding of the relationship between AI and wellbeing at work.

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The Digitalization of Social Influence Practices in Morocco and Its Effect on Attitudinal Change and Purchase Behavioral Intention

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Abstract. The phenomenon of digital influencers considered as electronic opinion leaders is proving to be a relevant practice adapted to the current context of digital transformation.

The aim of this research work is to shed light on the various theories mobilized to study the effect of social influence via digital channels on the attitudinal change and purchasing behavioral intention of Moroccan consumers, in order to clarify the role of the digital influencer by focusing on the issues of credibility, authenticity and homophily of this social connector, and by showing the contribution of the quality of the content disseminated in the involvement and commitment of the virtual community following the para-social interaction established via social networks.

The original aspect of this research lies in the interdisciplinary specificity of two distinct but complementary approaches combining the theories of social psychology and those of consumer behavior through a research methodology based on descriptive methods supported by documentary analysis techniques.

Keywords: Digital social influence · Credibility · Authenticity · Attitudinal change · Purchase behavioral intention

1 Introduction

The era of digital transformation has given rise to the use of social networks, and these digital channels have become a major necessity in a fully connected environment. In this context of advanced numerization, the phenomenon of social influence has arisen in a digitized form. Transcending geographical and cultural boundaries, it has brought about a shift in beliefs and practices, increased the possibilities for interpersonal communication and metamorphosed the way people communicate, interact and manage their relationships.

This new context, characterized by exponential digital dynamism, has changed the behavior of the Moroccan consumer. His or her level of expectation has increased, and he or she is beginning to demand more personalization, originality, interactivity, transparency and authenticity, all of which will require meticulous support. This has given rise

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to a new character on social networks: the influencer. This content creator, described as an "opinion leader", has been able to forge a solid relationship with his virtual community, united around inspiring, innovative and relevant content. This social connector uses his online presence to inspire, persuade, raise awareness and shape opinions, beliefs, mentalities and consequently attitudes and purchasing intentions. The majority of scientific research into influence marketing has focused on the commercial and financial aspects, and their impact on corporate reputation, performance and competitiveness. To fill this gap, the present research aims to shed light on the social aspect, which has not been frequently discussed in the existing literature. The motivations can be summed up in the promotion of the relevant use of social networks through the encouragement of high value-added content, the generalization of digital culture in Morocco and the encouragement of professional maturity in this sector through the specialization of its players and the formalization of the status of the influencer by law.

This problematic aims to demonstrate the role of the digital influencer in raising awareness, mobilizing, activism and building involved and committed communities in a Moroccan context in order to introduce a change in mentalities, beliefs and attitudes by answering the following central question:

To what extent can the characteristics of the social influencer and his or her shared content contribute to attitudinal change and consumer purchase intention?

This central question can be broken down into sub-questions:

- **What is an influencer's role on social media?**
- **What are the attributes that ensure the trust established between them and their followers?**
- **What are the characteristics of shared content that enable it to be persuasive and influential?**
- **How important is the engagement and involvement of the virtual community in changing their attitude and buying behavior?**

2 General Considerations About the Digital Influencer

2.1 Definitions of Digital Influencers

In a complex media environment, social media have become accessible and popular communication tools, and have democratized influencer activity to the point of establishing influencer status.

Perceived as experts and trusted sources sharing intimate and authentic information with their followers, these influencers are able to attract a solid base of subscribers and have a stronger impact on their decision making. It is therefore essential to analyze the profile of this electronic opinion leader (Table 1).

All these definitions converge and suggest that influencers are ordinary people, who have gained notoriety by using various social media to achieve a privileged social status with their communities. They have succeeded in building up a large community by producing quality, high value-added content and helping to change their subscribers' attitudes and consequently their behavior.

Table 1. Definitions of Digital Influencers

Definitions of the Digital Influencer	Authors
«Influencers are trusted individuals with a large number of followers on social media»	(Carter, 2016)
«Influencers are opinion leaders on social networks who receive information about products and services and try them out before anyone else.»	(Yılmaz, 2020)
To be considered an influencer, two central characteristics are necessary: reach and impact	(Hudders, 2021)
«Influencers provide their followers with content related to their personal and daily lives, as well as an insight into their experiences and opinions»	(De Veirman, 2017)

Source: Realized by the authors

2.2 The Influencer's Prescriptive Role in Social Media

Digital influencers are considered the new generation of opinion leaders. They have the ability to change, modify and transform public opinion because they are not only well-informed, but also highly respected for their expertise, skills and experience (JainL 2019). Through their presence on primary and secondary social media such as blogs, vlogs on You Tube or reals and stories on Instagram, they have been able to develop close and strong relationships in the virtual world while exerting influence on their community through creation and sharing content, interaction and their appearance on the Web» (Enke 2019).

In the context of the expansion of persuasive online communication channels, the influencer is a message mediator who plays a crucial prescriptive role with his virtual community, helping to change the beliefs, mindsets and attitudes of his followers. His power of conviction is based on his credibility, which is linked to his authenticity, integrity, honesty, professional expertise and experience, while his power of attraction is defined by his sympathy, familiarity and closeness to his community through regular virtual contacts and posted publications. In this way, he reinforces his "social visibility" with his "media visibility" to become more popular.

2.3 The Dimensions of Digital Influencer Effectiveness

Source Attributes

The influencer is an inescapable component, and will be addressed by highlighting a set of attributes that determine his impact on his virtual community.

Credibility and Its Levers

A credible source is one that is reputed to provide accurate, verifiable and truthful information. In the online context, judging an influencer's perceived credibility is a multidimensional concept and an essential condition for ensuring a message's persuasiveness and acceptance (Pollach, 2008). It is based on three components: expertise, reliability and physical and social attractiveness.

The Expertise: Refers to a person's knowledge, experience, skills and qualifications in a given field (Ohanian 1990).(Till 2000) asserted that expertise has a positive effect on attitudes and purchase intention.

The Reliability: Integrates 5 dimensions: integrity, accuracy, honesty, sincerity and trustworthiness. (Ohanian 1990).

*Physical and Social Attractiveness:*According to (McCroskey 1974) « attractiveness is defined as the perceived social value of the source, such as physical appearance, personality, social status or similarity to the recipient».

For (Kim, 2012) « While physical attractiveness evokes attraction to appearance, social attractiveness inspires the desire to establish a social relationship by ensuring closeness, intimacy and friendship». In addition, social attractiveness encompasses intellectual skills, personality and lifestyle (Erdogan 1999) and refers to a desired bond of affiliation with someone else; socially attractive people are perceived as likeable, friendly and pleasant (McCroskey 1974). In summary, influencers need a sustained level of expertise, reliability and physical and social attractiveness to generate persuasive messages and enhance their perceived credibility in the eyes of their followers on social media (Schouten.A, 2020).

Para-Social Interaction

Influencers have a popularity based on feelings of connection and reciprocal reactivity with their audience, known as para-social interaction. Influencers cultivate this affective bond of proximity through the sincere sharing of aspects of their daily lives (Abidin 2018) or through the behavior and personality they convey through social networks.

Perceived Homophily

Homophily is « the degree of similarity or congruence between two people, whether in terms of beliefs, education or social status» (Eyal 2003), it's a factor that facilitates persuasion and increases the effectiveness of communication between two parties, as they will find themselves around a common value system. What's more, similar people inspire trust and attachment. Thus, the homophily between the communicative source and the receiver, given its fluidity, generates attraction, facilitates interpersonal relations, intensifies affective relationships and makes more connections and interactions possible (Zhang 2018).

Trust

Refers to the perception of recipients that the source provides true, fair and sincere information. By relying on a trustworthy source, the message conveyed will be more effective and the subscriber will be influenced and perceive it as more credible (Ohanian 1990).In the digital context, trust is conceptualized in three dimensions: competence, integrity and benevolence. Competence reveals the influencer's expertise and qualifications, and refers to his or her ability to share content that is relevant and specialized to his or her field. Integrity refers to reliability, and benevolence refers to the influencer's interest in subscribers and willingness to provide solutions to problems encountered by his or her virtual community.

Authenticity

Adopting storytelling techniques, presenting autobiographical content showing an ordinary, spontaneous lifestyle in a sincere, sympathetic way, or sharing congruent content presenting the same preferences are effective formats for creating authenticity, improving the influencer's cohesion with his or her community and strengthening the bond created with it; thus, his or her subscribers will have the ability to follow his or her recommendations (Boucher 2021).

In short, credibility and its various dimensions, homophily, para-social interaction, trust and authenticity can influence the reception of a message and condition its effectiveness (Ohanian, 1990).

The Persuasive Attributes of Shared Content

Influencers create their content on the basis of certain criteria, which contribute to the reliability of the message transmitted to their community and thus modify their attitude. The content must combine accuracy, relevance, intelligibility, completeness, topicality, dynamism, personalization and diversity of the message (DeLone 2003).

The Informative Quality and Argumentative Force of Shared Content

According to the literature, content quality is judged in terms of relevance, comprehensibility, sufficiency of argument and timelessness (Park 2007).The content must propose objective arguments that are solid, convincing, (Caccioppo 1983)measurable, coherent, strong and pragmatic, based on factual information that can be validated and confirmed (Cheung 2008). When online content is judged to be of « high quality», it increases the credibility of its sender and ensures its success (Djafarova 2018).

The Uniqueness and Originality of Shared Content

On social media, original, exclusive and authentic content is considered a crucial tool for influencers to get more followers (Hashoff 2017).As a result of being perceived as unique, a personal image that is different from others can be created and admired by others (Gentina 2014). In addition,(Fakhreddin 2021) they revealed that originality of message and quality of content are essential elements possessed by social influencers and have an impact on changing consumer behavior.

Community Involvement and Engagement

Subscriber engagement is reflected in the satisfaction, trust, attachment and loyalty they feel towards the influencer. In a digital context, the notion of engagement is concretized through the interaction and reactions of the virtual community to the content broadcast. Subscribers show their interest by reacting in one way or another, for example by commenting, sending private messages or sharing the influencer's content (Laet Derache 2021).

Involvement is an important moderator of how a consumer will process a message and form an attitude. An involved receiver is able to integrate, validate and compare the quality of the message's semantic content by expending cognitive effort, whereas a subject with little involvement relies more on secondary and peripheral cues such as the author's profile than on the textual content of the message conveyed (Petty 1983).

3 The Prescriptive Role of Digital Influencers as Social Agents of Change

3.1 The Effect of Influencers on the Attitudinal Change of Moroccan Internet Users

The expansion of the Internet has democratized the activity of influence, to the point of establishing the status of e-influencer. This social connector has succeeded thanks to its ability to persuade, its notoriety, its non-commercial orientation, its credibility, its authenticity and, above all, its popularity (Ouahi 2020) these social connectors have succeeded in convincing communities and contributing to their awareness and the modeling of positive behavior.

In a digital environment characterized by the emergence of a plurality of digital platforms, influencers can act as role models through the identification process (Kelman 1958). Sharing their own experiences, encouraging individual empowerment and promoting healthy, sustainable lifestyles, they can foster beneficial change on an individual and collective scale. The use of this virtual space, with its multitude of targeting methods and the sophistication of its algorithms, is therefore proving to be a propitious place for the easy and rapid distribution of messages with a potentially viral effect. These new cultural influencers have become omnipresent in the daily lives of Moroccan Internet users. They have a powerful influence on the public.

3.2 Explanatory Theories of Digital Social Influenc

Researchers use various theoretical frameworks to study the phenomenon of influence in an online context, and we will list the most relevant to our field of investigation.

Social Influence Theory
Provides a better understanding of the invisible mechanisms that enable influencers to forge relationships and ensure closeness and trust with members of their community (Sokolova 2020),it explains how the presence and behavior of others influence an individual. (Kelman 1958) argued that an individual engages in several basic processes when adopting induced behavior, namely conformity, identification and internalization.In the context of digital influence, we will deal with identification and internalization.

Influence through identification is when the follower perceives the influencer as an example to follow, who is desirable, attractive, popular and creative, and would therefore like to be like him or her. Influence through internalization is a process that occurs when an individual approves of influence on his or her community because the induced behavior is consistent with his or her value system and its content is intrinsically rewarding, useful and informative (Kelman H, 1974). When the source is a celebrity, influence comes through the identification process; when the source is an expert, impact comes through the internalization process (Kelman H., 1958).

Parasocial Interaction Theory
The concept of parasocial relations refers to the relationship between a well-known personality and his or her audience, a relationship that is frequently linked to the notion of intimacy. Influencers cultivate this close affective bond through the sincere sharing of

aspects of their daily lives (Abidin 2018) or through the behavior and personality these digital actors adopt on social networksThe development of deeper psychological bonds by meeting followers' needs for ideality, kinship and competence enable them to establish long-term relationships (Tafesse 2021), exert a certain form of influence (Ki 2020) and build a solid community, which is the basis of their influence (Dhanesh 2019).

Theory of Reasoned Action
Is a theory developed by (Ajzen l. e., 1980) to predict the voluntary behavior of individuals on the basis of their attitudes and subjective norms. Over the past decade, the theory of reasoned action has become one of the most widely used theories for studying individual behavior.

The SOR Model
Is an explanatory model of consumer behavior that takes into account the role of situational and personal consumer factors (Djafarova 2018).Taking the S-O-R framework, content published and broadcast by influencers are considered stimuli; reactions are the perceptions and evaluations of the vital community inducing an attitudinal change, they are based on credibility, congruence, authenticity and other characteristics of the influencer, finally,responses are the changes detected in the behaviors of subscribers who have followed the advice and recommendations disseminated.

Following the literature review, here are the main variables relevant to our study (Table 2).

4 Methodology, Results and Discussion

4.1 Methodological Approach

In order to properly analyze our research problem, a systemic literature review was carried out to contextualize the work in relation to existing literature.The use of descriptive methods was also of great use in analyzing the motivations and communicative strategies of social-oriented digital influencers. In parallel, an exploratory qualitative empirical study is being carried out with a sample of 34 digital influencers with accounts on the Instagram platform. Interviewees were selected on the basis of the relevance and quality of their content, which is disseminated with a non-profit social approach and no commercial intent. The study was carried out using an interview guide comprising four themes, with the choice of areas of investigation focused on health, physical coaching, personal development, parental support and schooling, in order to reveal the social aspect of awareness-raising among Moroccan subscribers. Analysis of the results using Nvivo 12 plus software is still being finalized, to enable rich understanding and in-depth exploration; this methodological approach is primarily aimed at understanding, learning and emancipation.

The preliminary results of our interviews and observational studies approve the crucial role played by influencers in the attitudinal change and purchase intention of their target audience. The choice of this iterative approach, characterized by back and forth between theory and fieldwork, is justified by the specificity of our research problem, which aims to integrate the theoretical considerations retained from the literature review into the process of forming the final research model.

Table 2. Study variables

Variables	Variable definition	Source
Source's perceived credibility	« Perceived credibility is broken down into 3 dimensions: expertise, reliability and physical and social attractiveness»	(Ohanian 1990)
Source homophily	Homophily is « the degree of similarity or congruence between two people, whether in beliefs, education or social status»	(Eyal 2003)
Parasocial interaction	refers to the relationship between a well-known personality and his or her public, which is often linked to the notion of intimacy	(Abidin 2018)
Trust	also defines trust as the willingness to take risks within a relationship	(Bojang 2017)
Informational quality and argumentative force of the message	« Informational quality is the usefulness, reliability, relevance and specificity of the information provided about a product or service» The argumentative power of the message concerns its « accuracy, relevance, intelligibility, completeness, timeliness, dynamism, personalization and diversity»	(Doyle 2020) (DeLone 2003)
Uniqueness and originality Content	« Uniqueness has been seen as a state in which a person feels differentiated from those around him or her, and involves the use of behaviors that attract the attention of others»	(Maslash 1985)
Receiver involvement Receiver Commitment	"a state of motivation of the individual that defines a greater or lesser degree of energy allocated to tasks" when consumers react in some way (like, comment, share) to the influencer's content	(Miled-Chérif 2001) (Laet Derache 2021)
Behavioral purchase intention	« the consumer's expressed desire to buy a product or service in the near future»	(Cyr 2008)

Source: Realized by the authors

4.2 Research Hypotheses and Proposed Theoretical Model

After delving into the literature, an amalgam of theoretical concepts was analyzed through a panoply of variables that enabled us to formulate the various hypotheses and the design of our theoretical model.

Research Hypothesis
H1: Influencer's perceived credibility has a significant influence on attitude and purchase intention.
H2: Perceived Influencer Homophily Increases Behavioral Purchase Intention.
H 3: Physical and Social Attractiveness have a significant effect on subscribers' attitudinal change and purchase intention.
H4: Parasocial interaction between the influencer and his or her followers increases the engagement of the virtual community.
H5: The uniqueness, informative quality and persuasive power of the broadcast message has a positive effect on subscriber involvement.
H6: Subscriber engagement leads to positive attitudinal change.
H7: Involving subscribers positively changes their attitudes.
H8: Attitude has a positive impact on buying intention.

The Theoretical Model
Based on the analysis of the literature review and an analysis of the various variables in the study, we propose the following theoretical model, which aims to remedy the potential gaps in existing studies (Fig. 1).

Digital Influencer

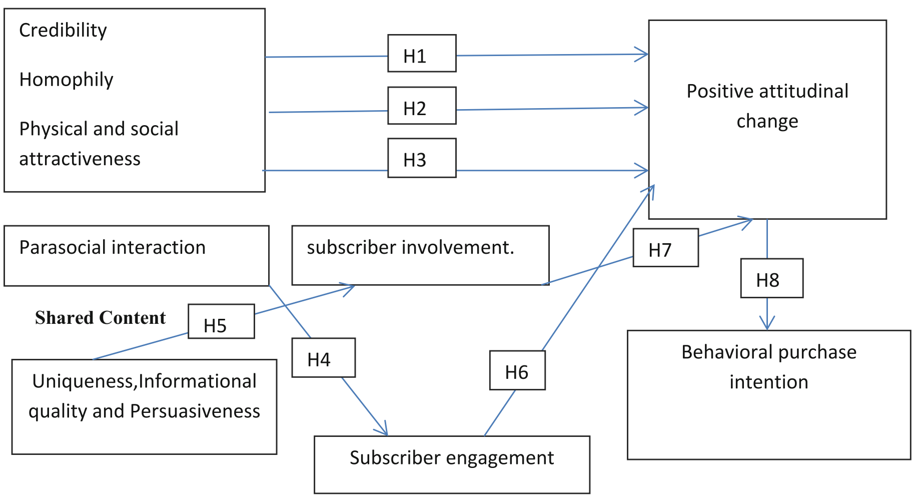

Fig. 1. The Research Model **Source**: Realized by authors

The following model focuses on the attributes of the source and its content as explanatory variables in attitudinal change and purchase intention as variables to be explained. The commitment and involvement of the virtual community are mediating variables that condition subscribers' attitudinal change.

4.3 Discussion

The para-social interaction,the homophily and congruence between the influencer and his shared content, the authenticity, the trust established between him and his subscribers, the credibility of his expertise, his integrity, his benevolence towards his subscribers, are all determining factors and criteria that, each in their own way, influence the attitude and behavioral intention to purchase of the virtual community (Sokolova 2020)This work also confirms the idea that the requirement in terms of perceived uniqueness (Gentina 2014), informative quality and argumentative force of publications (Djafarova 2018), originality and relevance of the content disseminated on influencers' accounts seem to be of undeniable use in provoking virtual interpersonal influence and inducing attitudinal change. At a managerial level, and given that the influence sector in Morocco lacks structure and specialization, it is essential to legally regulate the status and role of Moroccan influencers through the sector's professional maturity, in order to reinforce notoriety, credibility and trust between the various stakeholders and establish a new, reliable and credible channel for social change.

5 Conclusion

Our study aims to examine the effect of digital social influence on attitudinal change and purchase intention among Moroccan Internet users. The original and innovative aspect lies in the interdisciplinary combination of the problem studied, and the objective sought is to lift the veil on the social footprint of the digital influencer as an actor of attitudinal change bringing measurable interpersonal influence value; the contribution of this social connector was examined by analyzing a panoply of characteristics linked to his profile, his broadcast content and his community.The influencer marketing sector has become an ideal and relevant alternative used as a strategic tool and an effective and efficient channel for virtual interpersonal digital communication, and has made a significant contribution to business performance and competitiveness. From a managerial point of view, the aim of this work is to provide marketers with practical guidelines for choosing and selecting influencers and formalizing their status, which will enable them to ensure the trust of their communities and consequently proximity, commitment and involvement. At the end of our study, we suggest some areas for improvement that could be of major use to decision-makers sush as the introduction specialized, in-depth university training in content production, marketing and social media management or Implementing a digital law in Morocco and formalize the status of digital influencer.

Other qualitative and quantitative analyses and studies of influencers in various fields of specialization are currently underway to explore in depth the motivations of these social change agents behind the creation of their content, to better define the communication strategies used and to better refine the target that constitutes their community.

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Performance Improvement of Internet of Things by Using Fuzzy Logic

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Abstract. The report provides a comprehensive overview of our article which focused on enhancing and optimizing the Performances (Performances) in the Internet of Things (IoT) environment through fuzzy logic. The objective was to develop a model and mechanism that could effectively improve Performances in the IoT environment. The field of electronics and computer networks has undergone rapid evolution with new technologies emerging, and IoT is one such example. With the growing number of connected devices, the importance of optimal Performances in IoT systems cannot be underestimated. The aim of our articel was to study the concept of IoT and design an IoT system based on fuzzy logic to optimize and improve Performances. The project started with comprehensive research on IoT and fuzzy logic, followed by evaluating the performance of fuzzy logic in IoT networks using MATLAB software. The results of the project show the potential of fuzzy logic in optimizing and improving Performances in IoT systems. The proposed model and mechanisms are a crucial step towards ensuring optimal performance in IoT systems and have a great future potential for IoT technology development.

Keywords: IoT · Fuzzy logic · Fuzzy inference systems · Fuzzy sets · Fuzzy reasoning · Internet of Things · Performances

1 Introduction

The Internet of Things (IoT) is a rapidly growing network of interconnected devices that communicate over the internet, transforming our lives and work [1,2]. However, IoT faces challenges including energy consumption, storage capacity, communication quality, and performance evaluation [3,4], making it difficult to maintain consistent performance levels for all devices and users. To address these challenges, researchers have turned to fuzzy logic, a mathematical system for handling uncertainty [5,6]. Fuzzy logic is well-suited for IoT due to its ability to handle complex modeling, manage fuzzy information, and provide intuitive reasoning [6–8]. Researchers have used fuzzy logic in IoT to optimize performance, evaluate performance, and improve energy efficiency [4]. For instance,

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researchers have proposed a fuzzy logic and visual information mining-based performance optimization paradigm for IoT systems. Another study introduced a fuzzy multi-criteria analysis model for evaluating performance in IoT-based supply chains. Fuzzy logic has also been applied to dynamic performance solutions, context-aware applications, and extending the lifespan of IoT networks [9]. Despite these efforts, there is still a need for a comprehensive framework to assess sustainable performance in IoT. Fuzzy logic can play a significant role by offering a flexible and intuitive approach to evaluate performance requirements[10,11]. By using fuzzy logic, researchers can analyze diverse performance criteria, integrate them into a strategic measuring capability, and provide consistent satisfaction across IoT systems [12]. This paper presents an advanced model based on fuzzy logic to assess sustainable performance in IoT. The model overcomes challenges in evaluating performance and provides a flexible framework for various IoT systems. It considers factors such as network conditions, device capabilities, and user requirements to provide a comprehensive assessment of sustainable performance. The paper is organized as follows.

2 IoT

2.1 The Important of IoT

The Internet of Things (IoT) has a profound impact on industries and daily life. It enables the interconnectivity of physical devices, vehicles, and appliances embedded with sensors, software, and network connectivity [13]. This connectivity allows for data collection and exchange, aiming to create a seamless connection between the physical and digital world. IoT brings increased efficiency, convenience, and improved quality of life. In agriculture, IoT technology is used to create smart farms [14]. Sensors monitor soil moisture, temperature, and light intensity, helping farmers make informed decisions about watering, fertilizing, and harvesting. IoT also enables monitoring of livestock health and behavior, improving animal welfare. In industry, IoT technology creates smart factories [15]. Sensors optimize production processes, reduce downtime, and enhance product quality. Tracking and monitoring goods enhance supply chain efficiency and customer service. IoT impacts various services. In healthcare, it monitors patient outcomes and care quality [16]. In transportation, it monitors vehicle performance, tracks goods, and improves customer service. Overall, IoT transforms industries and daily life, offering increased efficiency and improved outcomes. It creates a connected, data-driven world where physical and digital systems work together seamlessly[17].

2.2 IoT Architecture

The IoT architecture involves interconnected system blocks to collect, store, and process sensor-generated data and execute commands through a user application [18]. It defines the physical components, network configuration, operations, and data formats, but as IoT encompasses multiple technologies, there is no standard reference architecture and no single model that can be followed for all implementations

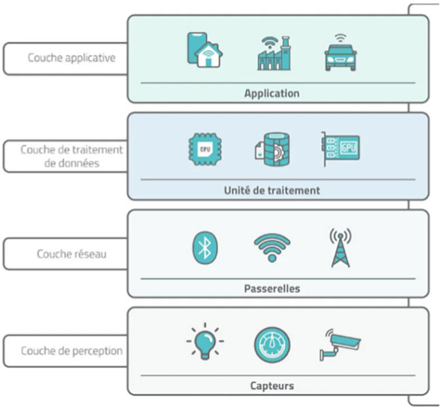

Fig. 1. IoT Architecture

3 Evaluation of the Performance of Fuzzy Logic in IoT

3.1 System Architecture

The proposed system's conceptual architecture is presented in Fig. 2. The architecture includes the following components: (a) a knowledge base, (b) a fuzzy logic model, (c) a feedback module and (d) a user interface to display the evaluated output. To model the impact of network performance on customer satisfaction, we employ fuzzy variables and linguistic terms for input parameters: delay, jitter, and packet loss. These parameters are described by three terms each: low, medium, and high. Using these fuzzy variables, we generate an output variable that represents service quality, categorized as good, average, or poor. The specified range values for input and output parameters are: delay [0, 300] ms, jitter [0, 30] ms, packet loss [0, 100]%, performances [0, 100]. Input and output membership functions convert crisp values into fuzzy values, and the evaluation involves triangular and Gaussian membership functions. A triangular membership function (MF) is defined by parameters b1, b2, and b3. b2 determines the peak's

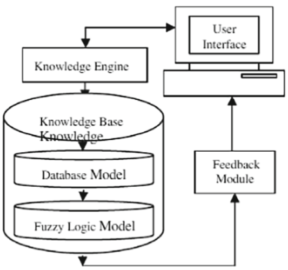

Fig. 2. System architecture for evaluating Performances in IoT.

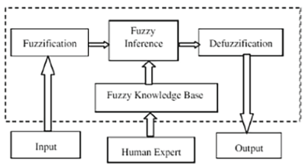

Fig. 3. Fuzzy logic model structure.

location, while a1 and a3 define the triangular ends. Gaussian MF is suitable for measurement uncertainty, with m indicating distance from the origin and indicating curve width. y represents DEL, JIT, PLS, and Performances. A small σ creates a thin MF, while a large σ results in a flat MF (Figs. 1 and 3) .

$$\mu(y) = \begin{cases} 0, & y < b_1 \\ (y - b_1)/(b_2 - b_1), & b_1 <= y < b_2 \\ (b_3 - y)/(b_3 - b_2), & b_2 <= y < b_3 \\ 0, & y > b_3 \end{cases}, \; gaussien(y : m, \sigma) = e[\frac{-(y-m)^2}{2\sigma^2}] \quad (1)$$

3.1.1 Results and Discussion

1 -In the event that the Performances value is at or below 40%, it can be categorized as representing subpar service quality.
2 -When the Performances value is between 40% and 70%, it can be classified as representing average service quality.
3 -When the Performances value reaches 70% or higher, it can be considered as indicative of good service quality.

The study's findings indicate that certain input conditions yield different levels of performance. Input condition 3, characterized by low delay (27 ms), average jitter (3 ms), and low packet loss (16%), shows high performances with 82% possibility using triangular MF and 79% possibility using Gaussian MF. Absence of concurrent flows reduces queuing traffic, improving performance. Input condition 12, with low delay (85 ms), low packet loss (22%), and low jitter (13 ms), yields average performances with 62% possibility using triangular MF and 60% possibility using Gaussian MF. This indicates good system performance with tolerable service quality degradation. Input condition 10, featuring high delay (248 ms), high jitter (21 ms), and high packet loss (35%), results in poor performances for both triangular and Gaussian MFs, with approximately 20% and 23.5% possibility of bad outcomes, respectively. This reflects a critical situation where concurrent traffic flows and multiple users compete for network resources. The choice of membership function has an impact on the output response. Triangular MF proves more efficient in controlling performances in multimedia transmission over an IoT network than Gaussian MF. This contradicts the assumption that Gaussian MF is suitable for representing measurement uncertainty. The choice of membership function should be tailored to the specific application domain (Figs. 4 and 5).

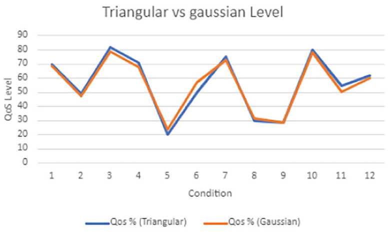

Fig. 4. Triangular vs Gaussian Level(%)

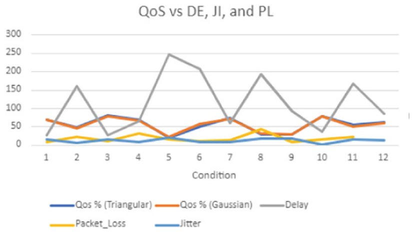

Fig. 5. Performances vs. DE, JI, and PL

4 Conclusion

This article investigates the impact of delay, jitter, and packet loss on service quality and user satisfaction. It examines how these factors influence service quality and customer satisfaction. The study reveals that the output performance is affected by input parameters governed by fuzzy system rules. Triangular membership functions are found to be more effective than Gaussian membership functions in controlling performance for multimedia transmission over an IoT network. The choice of membership function should consider the specific application domain. Future studies will compare this model with others, combining insights from cognitive science and artificial intelligence and using real-world data to advance understanding in the field.

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Digitalization, Connectivity, and Smart Cities: The Case of Romania

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Abstract. Broadband communications allow and facilitate the development of a wide range of information and communication technology services, while increasing productivity and competitiveness, hence supporting economic growth. This paper focuses on the case of Romania, seeking to explain the need for investments in broadband infrastructure for the next generation networks (NGN), to describe the necessary interventions on the market in this respect, and to present the priorities and possible financing sources of such a project. Moreover, it discusses the importance of enhancing 5G technology in Romania, as well as developing a new cyber center in the country. It concludes that the implementation of new technologies in Romania will have a significant impact on the gross domestic product in the coming years, yet the impact will be gradual. Our work is motivated by the fact that Romania is an emerging European state with a great potential for growth, but in order to unlock this potential, policies must channel their focus on investment in information and communication technology, which has been proven so important for multilateral development.

Keywords: Information and Communication Technology · Broadband Communications · Digitalization

1 Introduction

Broadband communications serve as a catalyst for the development of a diverse range of Information and Communication Technology (ICT) services, creating job opportunities, transferring skills, driving productivity and competitiveness, and ultimately leading to economic growth (Qiang et al., 2004). This impact is globally acknowledged, with ICT demonstrating a remarkable boost in productivity over the last decades (Miller and Atkinson, 2014), and numerous studies underscoring the strong correlation between broadband access penetration and the gross domestic product (GDP) per capita (see for instance Minges, 2015; Arvin and Pradhan, 2014; Bojnec and Fertő, 2012). Looking into history, we find that swift economic recoveries from recessions have been primarily propelled by investments in infrastructure (Pricewaterhouse-Coopers, 2020). These encompass both traditional terrestrial elements like highways, railways, and energy transportation, as well as contemporary data infrastructure, which presently offers the most compelling return on investment (Reynolds, 2009).

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In this era, the new generation of Information Technology and Electronic Communications plays an all-encompassing role by integrating communication and information across various economic and social processes.The importance and usefulness of ICT for all economic sectors, as means to foster productivity and multilateral development, represents in fact the motivation behind our work. Romania is an emerging European Union (EU) member state that must channel his efforts in order to take advantage of its potential and opportunities. Investing in ICT is one of the most important areas in which policies must focus in order to unlock the country's growth potential.

2 Romania's Digitalization Challenges

2.1 Related Works and Background Information

There has been a lot of research and analysis on the development of ICT and their integration in various high-priority areas, ranging from the modernization of public administration and the reduction of administrative costs to the utilization of open data within public institutions. Additionally, the introduction of ICT in education, healthcare, culture, and the creation of inclusive social environments has been widely discussed in the literature. For instance, You et al. (2022) explain how next generation networks (NGN) can be used to enable autonomous transportation systems and services, Esenogho et al. (2022) discuss the possibility of the integration of the Internet of Things (IoT) and 5G for next-generation smart grid, while Tuli et al. (2020) describe how these technologies can be used for smart healthcare.

In Romania, digitalization has become an increasingly vital aspect of the country's socio-economic landscape, transforming various sectors and fostering innovation. The Romanian government has recognized the significance of digitalization in enhancing efficiency, promoting economic growth, and improving public services. Initiatives such as the Digital Romania 2020 Agenda and the National Strategy for the Digitalization of the Economy 2020–2025 underscore the commitment to advancing digital technologies. With a focus on expanding high-speed internet infrastructure, fostering digital skills development, and promoting e-government services, Romania aims to ensure that all citizens have access to the benefits of the digital era. As digitalization continues to gain momentum, Romania is positioning itself to thrive in the evolving global economy.

2.2 Developing Broadband Infrastructure for NGNs in Romania

Recognizing the pivotal role of ICT in enhancing productivity and driving economic development, our research is centered on comprehending the imperative need for investments in broadband infrastructure for NGNs in Romania. The development of broadband infrastructure for NGN is poised to not only catalyze the growth of a thriving industrial sector, but also drive the international dissemination of cutting-edge solutions, thereby modernizing Romanian society. This burgeoning sector is projected to contribute significantly to the GDP, primarily through technological exports, which will, in turn, boost the export capacity of other sectors equipped with new technological tools.

For example, using a panel of countries from the Organization for Economic Cooperation and Development (OECD), Czernich et al. (2011) found that a 10% rise in broadband penetration was associated with a GDP growth of 0.9% to 1.5%, while Ericsson and Arthur D. Little (2013) also discuss that a 10% rise in broadband penetration leads to a 1% increase in GDP. Indeed, other European countries also focused on investing in the development of next generation networks. Sweden, for instance, has been investing in expanding its fiber optic networks to enhance broadband connectivity, while the United Kingdom has focused on expanding broadband access, especially in rural areas, to bridge the digital divide; Norway has also been investing in sustainable and environmentally friendly ICT infrastructure, including data centers powered by renewable energy sources.

At the outset, it is crucial to emphasize that any strategy aimed at bolstering Romania's national broadband infrastructure should place its primary focus on the terminal segment of the NGN, which is widely recognized as the most intricate and expensive component to develop. Moreover, the plan must underscore the fundamental prerequisites for enhancing the existing transport (backbone) and distribution (backhaul) networks. While Romania's transmission and distribution networks are poised for expansion to support ultra-fast Next-Generation Access (NGA) connections, the situation differs in rural areas of the country. Here, there is a compelling need for substantial expansion of distribution networks to ensure coverage in underserved regions, a task expected to be realized through the RoNET project, a pivotal component of the broader broadband infrastructure enhancement plan.

Addressing the substantial investment needed for the development of a national infrastructure program poses unique challenges. While private investment can cover some of the costs, a significant portion must be secured from public and other funding sources. These essential funds will be drawn from external non-reimbursable broadband funds associated with the EU budget programming period for 2021–2027, as well as private investments and national public contributions from state and local budgets within the annual allocations designated for this purpose. Public intervention, including investment incentives, grants, and state aid, should concentrate on advancing the development of a new generation of infrastructure in areas marked by market failure, often referred to as "white areas". These regions will be identified through comprehensive market analysis, taking into account various factors, such as land characteristics, population density, demand-influencing elements like income level, education, and information technology training, employment status, age distribution, and more.

To efficiently finance most of the infrastructure development, a Design-Build-Operate (DBO) model will be adopted, involving the selection of experienced communication service operators or consortia capable of designing, constructing, operating, and maintaining transmission and access networks during the concession period. To prevent the creation of dominant positions in affected localities, the EU recommendations on state aid in the broadband communications sector will be enforced. Furthermore, to bridge the substantial investment gap required to achieve the target indicators outlined in the National Broadband Infrastructure Development Plan, complementary financing mechanisms such as the Connecting Europe Facility (CEF), the Junker Plan, and similar options will be explored.

Romania is making significant progress in the advancement of its next-generation national broadband infrastructure, harnessing a diverse array of terrestrial technologies, including xDSL, FTTx, and DOCSIS 3.0 cable, in addition to radio technologies like WiMAX and LTE. Despite the ongoing expansion of broadband coverage, particularly in the realm of wireless and mobile extensions, the adoption of fundamental broadband services continues to face limitations, notably in rural areas. To meet Romania's ambitious target of providing 30 Mbps speeds to 80% of households by 2027, a substantial allocation of public funds will be imperative. This financial support is indispensable for not only extending the reach of broadband coverage but also incentivizing the embrace of new and advanced services across the nation.

2.3 Improving Transportation and Telecommunications in Romania via the 5G Technology

In a landmark development, Member States and industry leaders took a significant step towards progress in September 2017 during the Frankfurt Connected and Automatic Driving Roundtable. During this event, they collectively agreed to establish cross-border corridors. Subsequently, several Member States continued to solidify these commitments by signing and announcing bilateral agreements to create dedicated test corridors. These pioneering 5G corridors have positioned Europe at the forefront of 5G technology testing, affirming the region's unwavering determination to uphold its leadership in the advancement of new technologies, with a particular focus on fostering connected and automatic driving solutions.

It is very clear that only a concerted, pan-European effort will pave the way for a safe and predictable environment, allowing citizens to reap the manifold benefits of connected and automated mobility. In this respect, Germany is a leading European country in 5G development. The German government has already worked on policies and initiatives to facilitate 5G deployment, and major telecommunication companies have been actively investing in infrastructure. The UK has also been actively involved in 5G development, with significant investments from telecom operators. The government has already supported initiatives to remove barriers to 5G deployment and improve connectivity. Moreover. France has implemented initiatives to promote 5G deployment, with a focus on improving connectivity in urban areas and supporting innovation in various industries. The French government has also been involved in addressing regulatory aspects to facilitate network rollout. Moreover, Italy has taken steps to encourage the development of 5G networks, including the allocation of spectrum and the creation of a regulatory environment conducive to private investments; the Italian government has already acknowledged the role of 5G in fostering economic growth and innovation.

The European Commission is actively engaged in planning additional funding opportunities within the concluding stages of Horizon 2020 and in the forthcoming EU budget proposal. This includes initiatives under the CEF Digital 2 program for the period spanning 2021–2027. These endeavors, coupled with a strong commitment to fostering cross-border collaboration, and research and innovation, are gradually shaping a new landscape of 5G cross-border corridors across Europe. Simultaneously, the European Commission is dedicated to advancing the deployment of Connected and Automatic

Mobility (CAM) at multiple levels. This commitment involves formulating policy initiatives, encompassing the development of communications, roadmaps, and strategies, in close partnership with stakeholders. The Directorate-General for Communications Networks, Content and Technology (DG CONNECT) plays a pivotal role in facilitating collaboration among stakeholders and countries, promoting the exchange of insights, ideas, and proposals. Additionally, the European Commission supports the establishment of European standards, co-finances research and innovation projects through Horizon 2020, conducts support actions, and shapes infrastructure policies. Where necessary, European legislation is also brought into play, ensuring a comprehensive approach to promote and facilitate CAM across the continent.

Romania's commitment to advancing sustainable urban development is evident through its collaboration with the National Standardization Body (ASRO). This partnership has resulted in the transposition of ISO 37120/2018, "Indicators for urban services and quality of life" into Romanian legislation. Approved by the Director General of ASRO in December 2020, this protocol is part of a broader effort to align Romania with the entire suite of ISO standards dedicated to smart and sustainable cities. These standards are instrumental in enhancing the quality of urban services and the overall quality of life, ultimately contributing to the development of smart and resilient cities. In parallel, three additional ISO standards are in the process of being incorporated into the Romanian legal framework. Moreover, Romania plays a pivotal role in the Three Seas Initiative (3SI), which brings together 12 EU Member States located between the Baltic, Adriatic, and Black Sea. This initiative, launched in 2015, aims to foster cooperation and connectivity in vital sectors such as transportation, telecommunications, and energy, driving strategic development across the region.

The Smart Connectivity vision, introduced at the 3SI 2020 Tallinn Summit, places a significant emphasis on the integration of energy and transport infrastructure with digital platforms and services. This strategic approach is poised to underpin the development of innovative business models and technologies, contributing to long-term investments in energy and transportation. The Three Seas region is set to emerge as a globally competitive hub for smart mobility and energy innovation, which, in turn, will empower the region to offer and export cutting-edge solutions worldwide. Among these projects, the "Digital Highway" stands out as a significant initiative. It was introduced by the President of the Republic of Poland at the Bucharest Summit in September 2018 and has gained unanimous acceptance by all member states, securing a spot on the list of priority interconnection projects. The objective is to create a comprehensive digital network, connecting member states from North to South via a fiber optic network that will facilitate the establishment of a 5G connection between these nations, thus advancing digital connectivity in the region.

The European Commission is actively supporting the acceleration of private investment in 5G infrastructure along designated "5G corridors" by means of the CEF Digital 2. The deployment of 5G connectivity along these travel corridors holds the promise of catalyzing investment in CAM, heralding a transformative era for the automotive and transportation sectors. This technological advancement stands to yield a multitude of benefits, including enhanced productivity through reduced driving times, mitigating the substantial economic cost of traffic congestion, which can reach 1% of EU GDP. Moreover, it contributes to improved fuel efficiency and reduced emissions, addressing the significant role of transport in accounting for nearly 30% of total EU CO2 emissions. Additionally, the implementation of CAM is expected to reduce the occurrence of road accidents, thereby enhancing safety on European roads, with a focus on the well-being of road users.

2.4 The New CYBER Center in Romania

The development of secure 5G networks, in alignment with EU-level cybersecurity measures, stands as a pivotal European priority. Commissioner Thierry Breton emphasized that the European Cybersecurity Center's headquarters should reside in a country that guarantees cybersecurity and connectivity, especially in the context of 5G network security. Romania has been selected to host this center, a significant accomplishment, marking the first European agency to be hosted in the country. This decision highlights the importance of Romania's role in fostering a robust European technological and industrial cybersecurity ecosystem. The Center will play a multifaceted role, supporting cybersecurity across the entire value chain, from research to the widespread adoption of key technologies. It will provide guidance, expertise sharing, and facilitate collaboration on projects and initiatives for Member States and other stakeholders.

Romania's successful candidacy bolsters its political and geo-strategic standing, positioning it as a regional and European cybersecurity leader and a hub of technological expertise in the field. It offers substantial visibility to Romania, promoting it as a digitally advanced nation with a competitive economy and abundant opportunities for investments, spanning various facets of cybersecurity, including education, research, standardization, artificial intelligence, defense, innovation, and more. Romania's participation in key strategic value chains, coupled with the integration of local companies, is pivotal for the nation to harness the immense economic potential of these areas.

Furthermore, the architecture of the EU Cyber Center, which will manage a budget exceeding two billion euros, must be founded on a robust framework such as the Cyber Security Cube, incorporating the Zero Trust concept, considered indispensable in contemporary cybersecurity. Romania is hosting of the EU Cyber Center holds the promise of regional and European leadership in cybersecurity, prompting the need to transform the local labor market into a hub of competitiveness, attracting talent and fostering skill development. By creating an enticing curriculum for international students to study these skills in Romania, the country can elevate the labor market, raise income levels, and retain the next generation in the Romanian workforce. Romania's role as a cybersecurity leader is set to bring transformation and prosperity to the nation's technological landscape.

3 Conclusion

As digital infrastructure evolves, underpinned by the convergence of cloud computing and IoT, cities are facing growing vulnerabilities to cyber threats. The practice of Smart Cities and Smart Communities aims to assist both governmental and private entities in addressing the cybersecurity and privacy risks associated with interconnected environments while harnessing the potential of emerging technologies like next-generation networks, cloud computing, IoT, blockchain, artificial intelligence, and machine learning.

The application of digital solutions and connectivity should not be limited to urban areas but extend to inter and intra-county regions, where adjustments are still needed. The impact of 5G extends across various industries, from enhancing smart cities and safer transportation to enabling remote healthcare and precision agriculture. The adoption of new technologies in Romania is expected to have a substantial impact on GDP. Overall, Romania, with its dedication to strengthening its European reputation as a cybersecurity and high-speed telecommunications leader, particularly as the host of the European Cyber Security Center headquarters, plays a crucial role on the global stage.

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Innovation Strategies and Performance in the Enterprise: An Analysis of Digital Marketing Role

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Abstract. Innovation stands as a pivotal element in the development and enhancement of business performance. Facing rapid technological evolution, climate change, fierce competition, and informed, demanding consumers, innovation emerges as a strategic imperative. It proves to be a crucial driver of organizational performance, contributing to value creation, process optimization, and improved competitiveness. In this context, digital marketing plays a significant role by enabling businesses to target their audiences more effectively, analyze consumer behaviors in real-time, and adjust their marketing strategies for better performance in digital markets. Academic work examines how digital marketing tools (social media, SEO, content marketing) can be integrated into innovation strategies to stimulate growth and strengthen companies' competitive edge.

Moreover, innovation management represents a critical study area in management science literature. It covers all methods, managerial practices, and organizational structures that promote the emergence, development, and implementation of innovations. Innovation management entails effective coordination of human resources, technological expertise, and R&D capabilities to support the creation and application of new ideas. Agile and collaborative management models are thus explored in academic literature as levers to accelerate innovation and improve company performance.

Keywords: Innovation · Digital marketing · Enterprise performance

1 Introduction

In the rapidly evolving landscape of the 21st century, characterized by swift technological advancements and intensifying global competition, the intersection of innovation and digital marketing has emerged as a pivotal strategic arena for contemporary organizations. This research seeks to dissect the complex dynamics between innovation and digital marketing, two critical drivers that have the potential to significantly elevate a company's performance and competitive edge. As we delve into this scholarly

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inquiry, it becomes evident that in an era marked by digital transformation and the ever-changing preferences of consumers, understanding the synergy between these domains is paramount for businesses aiming to thrive. The foundation of this research is an extensive literature review, aimed at establishing a comprehensive theoretical framework that encapsulates the multifaceted nature of innovation in business, as well as the criteria and metrics that define organizational performance. This review not only draws upon seminal works in the field but also engages with recent studies to present a nuanced perspective on the subject. Scholars such as Kaplan and Haenlein (2010) have underscored the significant impact of social media on business innovation, while Porter and Heppelmann (2014) have detailed how digital transformation is reshaping competitive strategies. These contributions highlight the evolving nature of digital marketing and its profound implications for innovation processes within firms.

By adopting a rigorous academic methodology, this study endeavors to investigate how digital marketing strategies can mold and catalyze innovation within companies. It explores the efficacy of digital marketing strategies in stimulating innovation, examines the catalytic role of social media and digital content in the co-creation of value, and conducts an empirical analysis of innovation strategies through case studies that illuminate both the successes and failures of digital marketing in the realm of innovation. This introduction sets the stage for a detailed investigation into the strategic importance of aligning innovation and digital marketing strategies. Through this scholarly examination, the study aspires to contribute valuable insights to the academic discourse on digital marketing and innovation, offering a comprehensive understanding that can inform strategic decision-making in the dynamically shifting business landscape. The aim is to provide not only a theoretical enrichment of the fields of study but also practical guidance for businesses navigating the intricacies of the digital marketplace, thereby laying the groundwork for future research avenues in this critical and dynamic area of study.

The impetus behind this research is rooted in the recognition of the transformative power of innovation and digital marketing within the contemporary business landscape. In an era characterized by rapid technological advancements, environmental challenges, and evolving consumer expectations, organizations are compelled to rethink traditional strategies and embrace new paradigms of growth and competitiveness. The motivation for this work stems from a desire to explore the synergistic relationship between innovation and digital marketing, understanding how this confluence can be harnessed to drive organizational performance, enhance value creation, and secure a competitive edge in a digital marketplace. Acknowledging the critical role of innovation management in fostering an environment conducive to new ideas and the strategic integration of digital marketing tools, this research aims to provide actionable insights and a framework for businesses to align their innovation efforts with digital marketing strategies effectively. In doing so, it seeks to illuminate the path for organizations to thrive in the digital age, advocating for a more collaborative, innovative, and digitally savvy approach to business that promises enduring success and growth.

In light of the findings from our exploration into the synergy between digital marketing and innovation within organizations, our study is poised to deepen its analytical scope by integrating recent methodologies emerging in this dynamic field. Recognizing the rapid evolution of digital marketing technologies and their profound impact on innovation strategies, we aim to adopt advanced analytical techniques, such as predictive analytics and sentiment analysis, to provide a nuanced understanding of how digital marketing tools can be optimized for fostering innovation. This approach will not only enhance the comprehensiveness of our analysis but also enable us to capture the intricate dynamics and sector-specific variations in the effectiveness of digital marketing strategies. By embracing these contemporary methodologies, our research endeavors to offer a more holistic view of the digital marketing and innovation landscape, thereby contributing valuable insights to the ongoing academic and practical discourse.

2 Conceptual Framework and Theoretical Foundations

2.1 Definitions and Dimensions of Innovation in the Enterprise

The literature on enterprise innovation offers various definitions that underscore the importance of innovation as a driver of growth and competitiveness. According to Schumpeter (1934), innovation involves the introduction of new products, new production processes, the opening of new markets, access to new sources of raw materials, and the creation of new organizational structures. The Organization for Economic Co-operation and Development (OECD, 2005) extends this notion to include marketing and organizational innovations. Dimensions of Innovation:

1. Product and Service Innovation: Refers to the introduction of goods or services that are new or significantly improved in terms of their characteristics or intended uses (OECD, 2005).

2. Process Innovation: Involves the adoption of new methods of production or distribution, aiming to increase efficiency, quality, or to reduce costs (OECD, 2005).

3. Organizational Innovation: Concerns the introduction of new organizational practices in the firm's business, workplace, or external relations (OECD, 2005).

4. Marketing Innovation: Pertains to the application of new marketing methods involving significant changes in product design or packaging, product placement, promotion, or pricing (OECD, 2005).

Kline and Rosenberg (1986), known for developing an interactive model of the innovation process which will be discussed in the next section, add two further types of innovation:

– Reorganization of production, internal tasks or distribution channels.
– Improving the tools and methods used to develop innovations.

The concept of innovation, in its expanded definition, encompasses not just technological advancements but also innovations in marketing methods and organizational structures. This holistic approach acknowledges that innovation goes beyond product or service improvements to include deep transformations in how a company interacts with its markets and structures its internal operations. It involves adaptations in production and exchange processes, reflecting a significant revision of internal organization and business practices.

Marketing innovation plays a crucial role in enhancing customer satisfaction and penetrating new market segments. It manifests through various strategies, including the renewal of product design, such as aesthetic or taste modifications aimed at meeting the evolving preferences of consumers. It also extends to distribution strategies, introducing new sales channels that can increase product reach and accessibility. In terms of promotion, innovation may involve the development of brand image through innovative advertising campaigns or associations with influential personalities to increase product visibility and appeal. Regarding pricing, introducing flexible or disruptive pricing models can provide a significant competitive advantage by adapting pricing strategies to market dynamics and the financial capacities of target customers.

Organizational innovation encompasses the adoption of new organizational models aimed at optimizing efficiency and productivity. These innovations can include the integration of proven management methods such as Fordism, characterized by task standardization, or Taylorism, focused on maximizing work efficiency. They may also involve the restructuring of workspace to promote a more collaborative and less hierarchical corporate culture, for example, by reducing the number of individual offices in favor of shared workspaces. Lastly, organizational innovation can extend to a company's external relations, exploring new forms of partnerships or cooperation with other entities to improve resource access, share risks, and accelerate the development of new products or services. These detailed aspects of marketing and organizational innovation illustrate the complexity and breadth of innovation in the current business context, underscoring the importance of an integrated approach that considers all dimensions of innovation to stimulate long-term growth and success for the company.

The conceptual foundations of innovation measurement are mainly derived from management and economics (Smith, 2006). Management-inspired approaches look at how innovation can change a company's position in the market, and how to generate ideas in support of innovation. The economic angle is adopted to examine the reasons why organizations innovate, the forces that drive innovation, the factors that inhibit it, and the macroeconomic effects it has on a sector, market or economy. These aspects are greatly influenced by Schumpeter's (1934) theories on how companies go about finding new outlets and gaining a competitive edge over their actual or potential competitors. Schumpeter introduced the concept of "creative destruction" to describe the disruption of existing economic activity by innovations that create new ways of producing goods or services, sometimes even new sectors. Published works on economic growth have used this paradigm to study the determinants of long-term economic growth.

2.2 Organizational Performance: Criteria and Measures

The importance of Key Performance Indicators (KPIs), which come in a variety of categories, is crucial to effectively answering strategic questions, provided that the essential foundations of organizational performance are meticulously identified and targeted. The literature on the subject reveals a wealth of theoretical perspectives, with each author making his or her own contribution to shedding light on a particular facet of performance. It is generally accepted that there are four critical dimensions underpinning corporate performance. Among these dimensions, one stands out as the fundamental pillar without which the very notion of performance loses its relevance, giving way to overriding issues of efficiency and organizational sustainability. Indeed, the absence of development in this key dimension not only calls into question performance, but the very existence of the organization. Selecting and measuring relevant indicators is therefore not only a matter of setting precise objectives, but also of rigorously defining measurement methodologies. This process involves an in-depth understanding of the mechanisms by which these indicators can serve as levers for continuous performance improvement, thus underlining the interconnection between academic theory and managerial practice in the optimization of organizational performance.

Organizational performance is a central research axis in management and strategic studies, where the focus is on identifying and defining the appropriate criteria and measures to evaluate the effectiveness of organizations. The academic literature on the topic presents a diversity of approaches and models aimed at encapsulating the multiple facets of performance.

Approaches to Performance Measurement

1. **Financial Dimension of Performance**: Traditional management literature highlights the use of financial indicators such as Return on Investment (ROI), revenue, net profit, and sales growth as primary measures of organizational performance. These indicators, due to their quantifiability, facilitate inter-company comparisons and strategic decision-making (Venkatraman & Ramanujam, 1986).
2. **Non-financial Dimension of Performance**: Additionally, non-financial criteria are also recognized for their importance in performance evaluation. These indicators include customer satisfaction and loyalty, product and service quality, innovation, and corporate social responsibility. These aspects reflect the organization's ability to maintain its competitiveness and long-term viability (Kaplan & Norton, 1992; Eccles, 1991).

Evaluation Models and Frameworks

- **Balanced Scorecard (BSC)**: Proposed by Kaplan and Norton (1992), this model offers a holistic approach by integrating both financial and non-financial indicators, organized around four key perspectives: financial, customer, internal processes, and learning & growth.
- **EFQM Excellence Model**: This framework, developed by the European Foundation for Quality Management, provides an evaluation structure based on several criteria, including leadership, strategies, processes, and performance results (EFQM, 2020).
- **Customer Satisfaction Index (CSI)**: This measure is used to assess customer satisfaction with the products or services offered, acting as an indirect indicator of the overall performance of the organization (Fornell et al., 1996).

Key Academic Contributions

- **Venkatraman & Ramanujam (1986)** were among the first to distinguish between financial and non-financial performance, highlighting the need for a multidimensional approach to fully grasp organizational performance.

- **Kaplan & Norton (1992)**, through the development of the Balanced Scorecard, revolutionized how companies measure their performance by balancing financial and non-financial perspectives.

2.3 Digital Marketing: Evolution, Tools and Impact on Innovation

"Marketing is the effort made by organizations to adapt to competitive markets, in order to influence the behavior of their audiences in their favor, through an offer whose perceived value is sustainably superior to that of competitors. In the commercial sector, the role of marketing is to create economic value for the company by creating value for customers". Source: J. Lendrevie, J. Lévy, D. Lindon, Mercator, 8th edition, Dunod, 2006.

This field has undergone profound transformation since its emergence in the 1990s, coinciding with the advent of the Internet and the subsequent evolution of digital technologies. Academic literature identifies several key phases in this evolution, initially marked by the introduction of SEO and email marketing, followed by the expansion of social media, and more recently, the adoption of artificial intelligence and automation for increased personalization (Kotler et al., 2017; Chaffey & Ellis-Chadwick, 2019).

Digital marketing tools such as SEO, SEM, content marketing, social media platforms, email marketing, web analytics, and marketing automation are extensively discussed in the literature for their role in enhancing online visibility, customer engagement, and campaign optimization (Ryan, 2016; Tiago & Veríssimo, 2014).

Regarding the impact of digital marketing on innovation, research highlights how the integration of these digital tools into business strategies promotes product/service innovation, the development of new business models, and the enrichment of customer experience (Huang & Rust, 2018; Nambisan, 2017). The ability to collect and analyze data in real-time via digital channels enables businesses to adopt a more customer-centric approach, thereby facilitating shorter innovation cycles and a more agile response to market trends (Kohli & Johnson, 2011).

3 The Impact of Digital Marketing on Innovation Enterprises

3.1 Digital Marketing Strategies to Stimulate Innovation

The significance of marketing within the innovation framework is paramount. It is the responsibility of marketing to grasp consumer preferences and market shifts, thereby directing the organization towards crafting novel and inventive products or services that align with these insights. Marketing plays a key role in uncovering potential avenues for innovation through the execution of market research aimed at discerning upcoming trends and the anticipations of consumers. This approach empowers the organization to dedicate its efforts towards the creation of products or services designed to fulfill the immediate or prospective needs of its clientele.

Social Media Platforms and Collaborative Innovation: Research indicates that social media platforms serve as catalysts for collaborative innovation, enabling companies to engage with consumers in the co-creation of new products and services. This direct interaction enhances understanding of consumer needs and preferences, leading to more targeted and relevant innovations (References to Füller, 2010; Nambisan & Nambisan, 2008).

Leveraging Big Data and Analytics: The strategic application of Big Data and analytics empowers organizations to sift through extensive datasets to uncover trends, consumer behaviors, and untapped innovation opportunities. This evidence-based decision-making process guides innovation efforts, making them more data-informed (References to Davenport, 2014; McAfee & Brynjolfsson, 2012).

Content Marketing and Consumer Engagement: Content marketing, by delivering engaging and valuable content, can drive innovation by eliciting valuable ideas and feedback from consumers. Engaging consumers in meaningful dialogue can reveal new innovation opportunities and enhance existing products (References to Pulizzi, 2012; Holliman & Rowley, 2014).

SEO and Market-Driven Innovation: Search Engine Optimization (SEO) provides insights into popular search terms and market trends, offering valuable information for market-driven innovation. By aligning products and services with actual consumer needs and interests, companies can develop innovations that are in demand (References to Järvinen & Karjaluoto, 2015).

Digital Marketing and Innovative Business Models: Digital marketing also paves the way for the exploration of innovative business models. Access to online distribution channels and the implementation of digital strategies can revolutionize how products and services are delivered, creating new value propositions for consumers and competitive advantages for firms (References to Zott & Amit, 2010).

3.2 The Role of Social Networks and Digital Content in Co-creation of Value

The concept of value co-creation has revolutionized how businesses view their market relationship, shifting from a company-centric approach to a more harmonious approach where companies and customers collaborate on an equal footing. According to Prahalad and Ramaswamy (2004), the advent of the Internet has altered market dynamics by fostering a more active participation of consumers in the value creation process, thus turning them into a real resource of expertise for the company. This consumer expertise stems from their knowledge and skills, their desire to explore and learn, as well as their willingness to participate in active exchange. For these authors, value co-creation is a collaborative process that mobilizes resources both internal and external to the company.

Social media consists of a set of Internet applications based on Web 2.0 technology, which facilitate the creation and sharing of user-generated content (Kaplan & Haenlein, 2010). Mayfield (2007) describes social media as a form of new digital media characterized by active participation, openness, dialogue, community spirit, and connectivity. According to Ahlqvist et al. (2008), social media provides a space for interaction where individuals can generate, share, and discuss information and ideas within virtual networks and communities.

Various classifications of social media have been proposed, such as those by Constantinides and Fountain (2008) or Kaplan and Haenlein (2010). Constantinides and Fountain (2008) identify five categories of social media: blogs, social networking platforms (like Facebook), content-sharing communities (such as YouTube), online forums, and content aggregators. Facebook stands out as the most popular of these sites, with over 2 billion users. Kaplan and Haenlein (2010) expand this classification to six categories: blogs, social networking platforms, virtual worlds, online games, collaborative projects, and content-sharing communities. Collaborative projects (like Wikipedia) are websites where users can add and modify textual content, thus allowing for collaborative creation by many end-users (Kaplan & Haenlein, 2010).

Digital social media platforms are a fundamental component of Web 2.0, facilitating interactions. They encompass various types of social media such as blogs, microblogs, social networking sites, video platforms, and photo-sharing sites, among others (Kaplan and Haenlein, 2010).

These platforms have given consumers the ability to voice their opinions, provide unique content to companies that was previously unavailable, and interact with them in unprecedented ways. Digital social networks boast several billion users across all categories (socialbakers, 2018), highlighting their critical strategic importance for brands.

Indeed, digital social networks prove to be a powerful tool for value co-creation for businesses. They allow companies to gather customer feedback, address their concerns, or engage in dialogue with them to develop new products, or even involve them in organizational processes.

4 Empirical Analysis of Innovation Strategies

4.1 Research Methodologies

In this research, our methodology was structured around a hypothetico-deductive approach combined with quantitative analysis. Initially, we undertook a comprehensive review of existing literature, laying the groundwork for our theoretical framework and formulating specific hypotheses. This preparatory step was crucial to delineate the scope of our study and define the main concepts under investigation.

Following this, we developed a rigorous empirical testing methodology to assess these hypotheses with the aim of providing concrete answers to our research questions. This experimentation phase relied on the collection and analysis of quantitative data, chosen for their ability to objectively measure the variables of interest and provide reliable and generalizable results.

The choice of a quantitative approach was motivated by its suitability for the specific objectives of our study. This method allowed us to quantify the relationships between variables and ensure greater objectivity in data interpretation. Through this approach, we were able to conduct an in-depth statistical analysis, leading to results that not only tested the established hypotheses but also offered valuable insights into understanding the phenomenon under study. Additionally, this study aims to confirm two key hypotheses:

H1: The adoption of digital marketing strategies significantly improves the innovation capabilities of companies.

H2: The effectiveness of digital marketing as a lever for innovation and organizational performance varies depending on the company's sector of activity.

4.2 Case Study

We outline a methodical quantitative analysis based on a survey distributed to Company X professionals, aiming to understand the integration and impact of digital marketing on innovation and business performance. Our methodology emphasizes evaluating digital marketing tools and sector-specific effectiveness, ensuring a thorough examination of their roles in fostering innovation. This concise methodology description aims to clarify our analytical process for readers, highlighting our commitment to generating reliable insights into the dynamic interplay between digital marketing and innovation. To carry out this investigation, a meticulously designed questionnaire was distributed to a targeted sample of 100 employees within Company X. These individuals were selected due to their direct or indirect involvement in the company's digital marketing and innovation initiatives, thus providing a diverse and representative perspective on the study subject.

Despite our efforts to encourage high participation, we received a total of 46 responses, representing a response rate of 46%. Although this figure is lower than the initially envisaged sample size, it nonetheless provides a significant data foundation for analysis. The collection of these responses offered valuable insights into how employees perceive the impact of digital marketing strategies on the company's innovation capacity and organizational performance.

The data collected were subjected to rigorous statistical analysis, identifying trends, correlations, and specific insights related to the contribution of digital marketing to innovation processes. This quantitative analysis was crucial for validating or refuting the hypotheses formulated at the beginning of the study, thus offering conclusions based on empirical evidence.

It is important to note that, despite the limited number of responses, the results obtained provide a significant contribution to the existing literature on the subject. They illuminate the complex dynamics between digital marketing strategies and innovation in an organizational context, thereby highlighting practical implications for managers and decision-makers seeking to optimize their company's performance through digital innovation.

4.3 Results and Discussions

The burgeoning interplay between digital marketing and innovation within the corporate sphere forms the cornerstone of this empirical study, aiming to unravel the complexities of their relationship and their collective impact on organizational advancement. Amidst a backdrop of continuous technological flux and market volatility, this research endeavors to dissect the extent to which digital marketing strategies can serve as pivotal catalysts for fostering innovation and enhancing corporate adaptability and competitiveness. Drawing upon a comprehensive analysis, this study seeks to illuminate the nuanced dynamics between digital marketing adoption and innovation capacity enhancement, exploring the potential for digital tools to propel businesses forward in an increasingly digitalized economy. Furthermore, recognizing the diversity of the industrial landscape, this investigation delves into the sector-specific effectiveness of digital marketing strategies, positing that a tailored approach, mindful of unique industry challenges and characteristics, is crucial for maximizing the transformative potential of digital marketing.

Through this academic inquiry, we aim to contribute to the broader discourse on the strategic integration of digital marketing and innovation, advocating for a shift towards more integrated, agile, and digitally proficient business models that are equipped to navigate the challenges and opportunities of the digital age.

The interaction between innovation and digital marketing within company X, participants took a holistic view of innovation, defining it as the integration of new products or services, process improvement and the adoption of innovative technologies, with 38.3% of respondents stressing the importance of these combined elements. The key differences between incremental and radical innovation were identified primarily in terms of cost (37%) and scale of change (32.6%), suggesting that radical innovations entail deeper transformations and require higher levels of investment. As for digital marketing, conversion rate, cost per acquisition and return on investment (ROI) were recognized by 39.1% of participants as the essential key performance indicators, highlighting the importance of these metrics in assessing the effectiveness of digital strategies.

In terms of innovation strategy, the study reveals a marked recognition of innovation culture as a central pivot for company performance, with 55.3% of respondents describing it as crucial. This view is complemented by an analysis of R&D strategies, where 38.3% see the promotion of creativity and experimentation as the main drivers of innovation, while 31.9% emphasize the importance of a substantial innovation budget. Furthermore, the study highlights the significant impact of partnerships and collaborations, identifying access to new ideas and skills (42.6%) as a major lever for stimulating innovation, while recognizing that the combination of risk-sharing, access to resources and penetration of new markets (23.4%) makes a substantial contribution to business innovation. This summary underlines the importance of a strong innovation culture, underpinned by dynamic R&D strategies and enriching external collaborations, as the foundation for improved organizational performance.

In exploring digital marketing, the study highlights the crucial importance of content marketing in consumer engagement and product innovation, with over half of respondents (53.2%) emphasizing its central role. It also reveals that digital marketing data, combining the identification of consumer trends, the evaluation of campaign effectiveness and the optimization of customer journeys, is essential in driving innovation, according to 40.4% of participants. As far as SMEs are concerned, the study identifies low cost and high reach as significant advantages of digital marketing, while the necessary technical skills and market saturation represent major challenges, noted by 42.6% of respondents. This summary reveals the profound impact of content marketing and the strategic use of digital data in supporting innovation, while highlighting the specific opportunities and challenges of digital marketing for SMEs, providing valuable insights for developing effective strategies in an evolving digital landscape.

In analyzing the impact of digital marketing on performance, the study shows that 38.3% of respondents consider increased sales, improved profit margin and growth in the number of customers as key indicators for measuring this impact on their company's financial performance. This integrated perspective underlines the importance of a holistic approach to assessing the effectiveness of digital marketing. Furthermore, with regard to the influence of digital marketing integration on customer satisfaction, a significant majority (53.2%) of participants acknowledged that this integration improves satisfaction thanks to personalized, targeted communication. This finding reaffirms the crucial role of digital marketing in enriching the customer experience and driving positive organizational performance.

The strategy and planning survey reveals a clear recognition of the positive impact of adopting digital technologies on organizational performance, with a majority of respondents (57.4%) highlighting a direct positive relationship. Furthermore, customer feedback via digital channels is crucial to innovation, as evidenced by 40.4% of participants' preference for using this information to improve products and identify new needs. The essential elements of a successful digital marketing strategy, according to 42.6% of respondents, include an active presence on social networks, analysis of customer data and its integration with innovation objectives. To effectively integrate digital marketing tools into the innovation strategy, 44.7% favor collaborative brainstorming and the use of predictive analytics. Communication and collaboration between marketing and innovation teams, combined with a customer-centric approach, are recommended by 41.3% of participants to align digital marketing objectives with innovation strategies, highlighting the importance of a synergistic approach between digital marketing and innovation for organizational success.

When integrating digital marketing into their innovation strategies, companies face several challenges, including lack of in-house skills, budget limitations, and resistance to change, with 34% of respondents identifying a combination of these obstacles. On the other hand, emerging technologies such as artificial intelligence and blockchain are revolutionizing digital marketing, mainly by making campaigns more personalized and increasing the effectiveness of data analysis, as highlighted by 40.4% of participants. In addition, digital marketing is proving crucial in helping companies adapt to changing consumer needs, thanks to platforms for direct feedback and real-time trend analysis, recognized by 38.3% of respondents. This summary highlights the challenges and opportunities associated with digital marketing, demonstrating its essential role in evolving business practices and improving understanding and response to consumer expectations.

For future prospects, the digital marketing trends perceived as most influential for the future of business innovation include the increasing use of artificial intelligence, the development of mobile e-commerce, and the growing use of augmented and virtual realities, with 41.3% of respondents believing that all these trends will have a significant impact. To prepare for these developments and improve their performance, companies should invest in ongoing training for their teams, and keep abreast of the latest technologies and trends, as indicated by 45.7% of participants, who value a combined approach of training and technology watch. This summary underlines the importance of adaptability and commitment to continuous learning in the dynamic digital marketing landscape, to drive innovation and strengthen organizational competitiveness.

In light of the analysis conducted across the discussed sections of our study, preliminary conclusions regarding the formulated hypotheses can be drawn:

1. The adoption of digital marketing strategies significantly enhances the innovation capabilities of businesses. The evidence gathered supports this hypothesis, aligning with academic literature that underscores the pivotal role of digital marketing in bolstering organizational innovation capabilities. Prior research, such as that by Huizingh (2011) and Rigby & Zook (2002), highlights the benefits of integrating digital

marketing into the innovation process, notably its potential to boost creativity, foster collaboration, and expedite the development of new products and services. Our findings corroborate these insights, emphasizing the significance of content marketing and customer data analysis in supporting innovation within businesses.

2. The effectiveness of digital marketing as a lever for innovation and organizational performance varies according to the industry sector. While our results do not provide a specific sectoral analysis, they suggest variability in the impact of digital marketing on innovation and organizational performance. The existing literature supports this notion, indicating that industry characteristics such as regulation, customer dynamics, and competition level can influence how firms leverage digital marketing for innovation. Research by Dholakia et al. (2004) and Wang et al. (2016) has highlighted significant differences in the adoption and effectiveness of digital marketing strategies across sectors. These findings underscore the need for a contextualized and sector-specific approach when assessing the impact of digital marketing on innovation and organizational performance.

In summary, our results, complemented by a review of academic literature, support the assertion that digital marketing plays a crucial role in enhancing the innovation capabilities of companies while highlighting the importance of sectoral analysis to fully understand its effectiveness. Future in-depth research, incorporating sector-specific case studies and quantitative analyses, could provide more comprehensive insights and robustly validate these hypotheses.

5 Conclusion

In light of the comprehensive insights drawn from this research, it becomes evident that the synergy between innovation and digital marketing is not just pivotal but essential for the advancement and competitive edge of contemporary organizations. This synergy, as illuminated through the abstract and reinforced by the findings of this study, underscores the indispensable role of innovation as a strategic imperative in an era marked by rapid technological advancements, environmental challenges, and increasingly discerning consumers. Digital marketing emerges as a critical facilitator in this dynamic, enabling firms to not only effectively reach their target audience but also to adapt and thrive in the digital marketplace through real-time behavioral analysis and strategic agility.

The research solidifies the concept that innovation, coupled with digital marketing, serves as a fundamental driver for organizational performance, enhancing value creation, process optimization, and competitive positioning. Through the exploration of digital marketing tools such as social media, SEO, and content marketing within the framework of innovation strategies, this study elucidates how these elements can be harmoniously integrated to fuel growth and fortify a company's competitive stance. Moreover, the pivotal role of innovation management in fostering an environment conducive to the emergence and successful implementation of new ideas is highlighted. It emphasizes the need for effective coordination across human resources, technological prowess, and R&D efforts, advocating for agile and collaborative management approaches as delineated in the academic literature.

In synthesizing these insights, the research underscores a paradigm shift towards a more collaborative, innovative, and digitally proficient business model. It posits that the intertwined relationship between innovation and digital marketing is not merely advantageous but a fundamental necessity for organizations aiming to secure a sustainable competitive advantage and achieve continuous growth in the digital age. This conclusion calls for organizational leaders to adopt an integrated perspective, proactively aligning digital marketing strategies with innovation endeavors to adeptly meet current market demands while anticipating future trends.

Hence, embracing this integrated approach transcends being a strategic imperative; it embodies a crucial shift necessary for enduring success in the rapidly evolving business landscape. This research not only bridges the gap between innovation and digital marketing but also paves the way for future explorations, setting a benchmark for how organizations can leverage these dynamics to navigate the complexities of the modern market and secure a prosperous future.

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Drivers of EPS Adoption: Exploring the Influence of Environmental Consciousness, Risk Perception, and Trust

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Abstract. Despite the widespread use of the Internet and technological advancements in African countries, Electronic Payment Systems (EPS) adoption remains limited. However, EPS is a promising alternative to sustainable growth. Consequently, this study examines the Environmental Consciousness (EC) construct which has been overlooked in prior studies within this specific context. Thus, the present research is based on the UTAUT2 model expanded by Perceived Risk (PR), Perceived Trust (TR), Perceived Cost (PC), and Environmental Consciousness (EC) constructs. Data was gathered from 446 participants through the stratified sampling method. The analysis was conducted by using the PLS-SEM approach to assess various research model relationships. The findings revealed that PE, TR, EC, PR have a significant impact on the intention to use EPS, while PC, SI, and FC had an insignificant impact on intention. This research provides a comprehensive, parsimonious, and practical framework for stakeholders to implement more successful and accurate green marketing strategies for this specific context.

Keywords: Electronic Payment Systems · Trust · Risk · UTAUT2 · Environmental Consciousness

1 Introduction

EPS has revolutionized the payments sector and continues to be the biggest fintech segment that has attracted over $16 billion in funding in the first half of 2023 [1]. Moreover, the substantial rate of EPS adoption entails numerous benefits on individual and national levels. At the individual level, transactions become more secure, fast, convenient, flexible, secure, and simple [1–3]. At the national level, EPS contributes to reducing the shadow economy [4], the overall costs associated with cash handling [5], and enhancing financial inclusion, especially for rural populations [1, 3]. Additionally, EPS adoption could be an efficient alternative to promote sustainable development and reduce the degradation of natural ecosystems. Indeed, the environmental effect of a cash payment is 1.5 times higher compared to that of a debit card payment [6]. Consequently, public authorities, especially in developing countries implement numerous strategies to spread

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the EPS adoption. For instance, the Moroccan government launched the m-wallet in 2018 and instant money transfers in 2023. Moreover, a 0.25% tax was imposed on all cash transactions in 2019. However, despite these efforts and being one of the most technologically advanced countries in Africa [7], Morocco remained the most reliant on cash in 2022 [8].

On the other hand, an extensive literature review reveals two critical research gaps. Firstly, there is a lack of studies on EPS adoption in Africa, especially within the North African context, characterized by specific cultural traits. Secondly, while in the literature, EPS adoption has been identified as a strong driver of green innovation, mitigating the negative effects of current human activities [6], prior studies have overlooked examining the likelihood relationship between Environmental Consciousness (EC) and the intention to adopt EPS. Further, this gap extends to exploring EC from the perspective of developing countries within the UTAUT2 model. EC could assess how environmental concerns influence users' behavior and could give a better understanding of their willingness to align their actions with sustainable practices. Hence, to address the identified research gaps, this present study aims to elucidate those questions:

RQ1: Will the extended UTAUT2 model be able to deeply comprehend intention of EPS adoption?
RQ2: How does the Environmental Consciousness (EC) influence the intention to adopt EPS?

By attempting to address these questions, this study aims to provide a comprehensive understanding of the EPS adoption drivers within the environmental crisis.

2 Review of Literature

2.1 Theoretical Background

Since EPS acceptance represents an individual-level decision process, the UTAUT2 model [9] appears to be the most appropriate for this context. The UTAUT2 model builds upon the original UTAUT model to the consumer context, which integrates eight prominent IS research theories namely TRA, TPB, TAM, MM, DOI, MPCU, Combined TAM - TPB, and SCT. Additionally, this model captured an initial set of 32 variables within four key factors of behavior intention (BI) [10]. Scholars have extensively examined and validated its relevance across various IS adoption contexts. For instance, the UTAUT2 model was applied to hospital examination reservation systems [11], mobile learning in science teaching practice [12], Fintech [13, 14], and E-commerce [15]. Moreover, this model encompasses crucial constructs that have proven their relevance in understanding the motivations behind EPS adoption [14, 16]. However, the UTAUT2 model has overlooked environmental concerns and their potential influence on technology adoption behaviors. The inclusion of EC will be crucial in fully acknowledging the growing significance of eco-conscious action, especially as Fintech is pivotal in achieving the goals of the Paris Agreement [17]. EC measures the level of concern that individuals have towards the environment [18, 19]. In other terms, EC encompasses both ecological degradation awareness and the willingness to support efforts to mitigate those problems. Additionally, EC is materialized through daily attitudes [20] such as reducing single-use plastic, saving energy consumption, and supporting green products. In the literature, scholars have explored the relevance of this construct through two approaches. The first one, EC is examined as a moderator [21–23]. On the other hand, several studies have assessed the direct association of EC with BI [20–25]. In both scenarios, EC has proven its relevance in the green marketing context and was found to be a substantial predictor of BI. Therefore, the present research will adopt the UTAUT2 model along with four relevant predictors whose relevance has been confirmed by several prior studies in the same context: TR, PR, PC, and EC (Fig. 1).

Performance Expectancy (PE)

In the EPS acceptance context, PE is linked to the level to which individuals believe that EPS benefits could enhance their daily overall performance and productivity. Consequently, high levels of convenience, speed, and ubiquity will positively and strongly develop the intention to adopt e-payments [26, 27]. Furthermore, various previous studies highlighted this strong role in the willingness to adopt EPS [16–29]. Thus we hypothesize that: *H1: (PE) affects the intention to use EPS.*

Effort Expectancy (EE)

Effort Expectancy measures the degree to which individuals perceive the straightforwardness and the ease of technology [9]. In other words, when the EPS process is perceived as simple, it enhances the user experience, which increases the likelihood of adopting EPS. Many previous studies have corroborated this relationship [2, 16]. Hence, we hypothesize that *H2: (EE) affects the intention to use EPS.*

Perceived Trust (TR)

The level of trust toward technology can be assessed through the mechanism described by Strub and Priest, namely trust transfer. Indeed, since EPS services involve multiple stakeholders (e.g., EPS service providers, payment gateways, banks, and network providers), users' trust in the reliability of these entities could extend to EPS technology [30]. Prior studies underscored the pivotal role of trust in shaping behavior intention toward EPS adoption [16, 29]. Along with those findings, we hypothesize that: *H3: (TR) affects the intention to use EPS.*

Perceived Risk (PR)

Perceived risk arises from uncertainties and potential negative consequences associated with using EPS. For example, users may have concerns about privacy, financial losses, and unauthorized access to bank accounts [13]. Higher perceived risks could increase skepticism toward using EPS [31]. Thus, we hypothesize that *H4: (PR) affects the intention to use EPS.*

Facilitating Conditions (FC)

Facilitating Conditions are associated with the availability of required resources and support systems for using technology [10]. It has been proven that FC may influence significantly the intention to use EPS [13, 29]. Furthermore, in their meta-analysis, Bommer et al. [32] found that FC had a strong connection with the intention to use E-wallets. Therefore, we hypothesize that *H5: FC affect the intention to use EPS.*

Social Influence (SI)

The Social Influence construct aims to assess the extent to which social context including peer recommendations, cultural values, and social standards is influencing the users' willingness to adopt EPS [31]. SI could enhance the motivation to embrace EPS in daily life [29]. Hence, we hypothesize that *H6: (SI) impacts the intention to use EPS.*

Perceived Cost (PC)

In the EPS adoption context, the cost refers to the monetary expenses associated with EPS use supported by users such as the necessity to have a smartphone, internet connection, and mobile maintenance fees [33]. The PC associated with acquiring and utilizing new technology is often cited as a barrier to their widespread adoption. For instance, Al-Saedi et al. [34] found that PC were one of the strongest drivers of intention to use M-payments. Thus we hypothesise that: *H7: (PC) impacts the intention to use EPS.*

Environmental Consciousness (EC)

Within the EPS acceptance context, EC is related to the degree of individual awareness, concern, and commitment toward environmental issues and sustainability practices. In a green marketing context, EC and environmental concern are considered as environmental attitudes that will consequently impact intentions [35, 36]. In IS research, numerous studies underscored that EC has a significant direct effect on the willingness to adopt green technologies such as green smartphones and bicycles [20, 37]. Hence, we hypothesize that H8: *(EC) impacts the intention to use EPS.*

3 Methodology

3.1 Measurement Development

To examine the present model, the questionnaire was segmented into two sections: the first part gathered the demographic characteristics of respondents. The second section includes questions that measure the nine constructs's research model. Additionally, all measurements utilized within the questionnaire were drawn from previously published research: the PE, EE, FC, SI, and BI scales were sourced from [9, 10]. TR and PC scales were sourced from [38]. Further, PR scale was sourced from [39], and finally, EC scale was sourced from [24]. Measurement items have been amended to meet the purposes of the present study. Each item was evaluated using a seven-point Likert scale where anchors ranged from "strongly disagree" to "strongly agree". A pre-test study involving 50 users was conducted through personal interviews to assess the initial version of the questionnaire. After some refinements, researchers adjusted the questionnaire length to 34 questions.

3.2 Data Collection and Demographic Distribution

Data was gathered using the stratified sampling method based on the seven biggest cities in the country. An online Google questionnaire link was disseminated after the respondents' identification, we gathered 446 responses within three weeks. The demographic

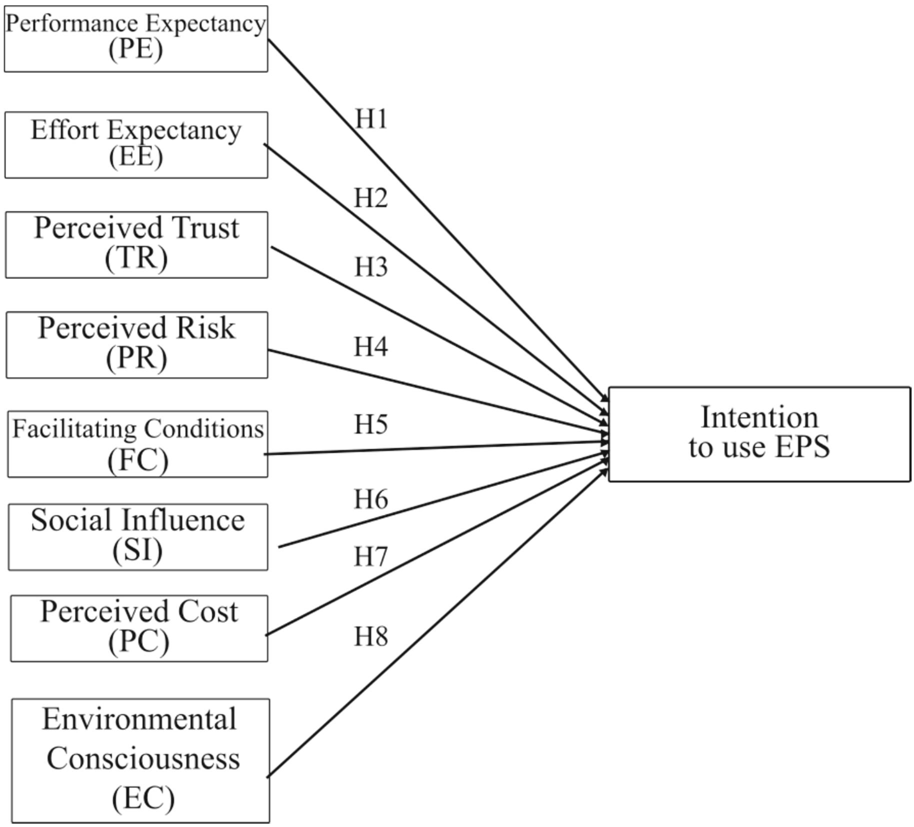

Fig. 1. Conceptual Framework

characteristics of the sample indicate that 41,5% are males and 58,5% are females. Besides, 5,4% of the participants were aged (18–24), 24% were (25–30), 19,5% were (31–36), 18,8% were (37–42), 12,3% were (43–48), 14,6% were (49 to 59), and 5,4% were 60 and above. Further, among the respondents 20% were self-employed, 46,8% were private employed, 17,9% were government-employed, 3,6 were retired, and 11,7% belonged to other categories. Results showcased that 70,6% of the participants have been using EPS for at least 3 years.

4 Results

Researchers adopted PLS-SEM method analysis since this present study aims to evaluate a theoretical framework from a forecasting standpoint and expand the overall nomological network related to technology adoption [40]. Consequently, the Smart-PLS software was used for the data analysis.

4.1 Measurement Model Assessment

Table 1 confirms that all standard loadings exceed the threshold value of 0.708 at a 5% level [40], thus, providing good item reliability. Additionally, all CA and CR values are greater than the threshold value of 0.70. Consequently, the measures in the study are reliable [40]. Moreover, all AVE values are above the minimum value of 0.50 [40]. Thus, convergent validity was established. On the other hand, Table 2 shows that discriminant validity was confirmed since the diagonal values exceeded the off-diagonal values (according to the Fornell-Larcker criterion).

4.2 SEM Analysis

To test research model hypotheses we conducted the PLS algorithm and a bootstrapping technique using 5,000 subsamples. The results in Table 3 revealed that PE ($\beta = 0.346$, $t = 8.320$, $p < 0.001$), TR ($\beta = 0.334$, $t = 7.327$, $p < 0.001$), EC ($\beta = 0.240$, $t = 6.896$, $p < 0.001$), and EE ($\beta = 0.091$, $t = 2.920$, $p < 0.01$) have a significant and positive impact on BI. Furthermore, the same results showed that PR ($\beta = -0.141$, $t = 4.532$, $p < 0.001$) has a significant and negative influence on BI. Consequently, H1, H2, H3, H4, and H8 were supported. On the other hand, FC ($\beta = -0.051$, $t = 1.738$, $p = 0.082$), SI ($\beta = 0.032$, $t = 0.991$, $p = 0.322$), and PC ($\beta = -0.025$, $t = 0.612$, $p = 0.541$) have an insignificant impact on BI. Thus, H5, H6, and H7 were not supported. On the other hand, this model explained 70.3% of the intention to use EPS variance, which can be considered substantial [40]. Hence, the current model has demonstrated its predictive capability.

5 Discussion and Implications

Eight hypotheses have addressed the research gap underscored by this study. Findings reveal that H1 and H2 were accepted highlighting the significant role of PE and EE in shaping intention to use EPS. These results suggest that individuals are drawn to adopting EPS due to the benefits they provide in improving their daily transactions (i.e., convenience and ubiquity), and their user-friendliness. This aligns with prior scholars' findings in this context [2, 16] underlining the importance of usefulness and simplicity in driving EPS adoption. Furthermore, H3 was accepted, demonstrating that the reliability, consistency, honesty, and security perceived by users are of high importance and foster the adoption of EPS. This is consistent with previous studies [16, 30]. Hence, stakeholders should emphasize building trust by strengthening their services' consistency, transparency, and reliability. Similarly, H4 was accepted. This means that PR has a statistically and negatively significant impact on the intention to use EPS. This finding underscores the importance of reducing concerns about privacy, potential fraud, and financial losses. This aligns with prior studies [2, 31]. Thus, in technology contexts involving personal and financial information, stakeholders must reassure users with innovative measures and provide technological guarantees to mitigate those concerns. On the other hand, FC had an insignificant effect on the intention to use EPS. This could be attributed to the fact that users already possess the necessary resources, support, and

Table 1. Reliability and Convergent Validity

Constructs	Indicators	Loadings	VIF	CA	CR	AVE
Behavior Intention (BI)	BI1	0.783	1.724	0.879	0.917	0.735
	BI2	0.891	2.704			
	BI3	0.863	2.396			
	BI4	0.887	2.677			
Performance Expectancy (PE)	PE1	0.870	2.253	0.890	0.924	0.752
	PE2	0.846	2.187			
	PE3	0.876	2.625			
	PE4	0.876	2.619			
Effort Expectancy (EE)	EE1	0.816	1.477	0.834	0.886	0.660
	EE2	0.815	1.989			
	EE3	0.846	2.139			
	EE4	0.771	1.874			
Perceived Trust (TR)	TR1	0.751	1.567	0.865	0.909	0.714
	TR2	0.845	2.208			
	TR3	0.899	2.749			
	TR4	0.878	2.512			
Environmental Consciousness (EC)	EC1	0.848	1.637	0.794	0.879	0.708
	EC2	0.833	1.687			
	EC3	0.843	1.732			
Perceived Risk (PR)	PR1	0.934	1.891	0.875	0.899	0.692
	PR2	0.798	2.455			
	PR3	0.784	2.164			
	PR4	0.802	2.268			
Facilitating Conditions (FC)	FC1	0.852	1.828	0.843	0.906	0.762
	FC2	0.899	2.397			
	FC3	0.867	2.054			

(*continued*)

Table 1. (*continued*)

Constructs	Indicators	Loadings	VIF	CA	CR	AVE
Social Influence (SI)	SI1	0.778	1.368	0.810	0.872	0.631
	SI2	0.805	1.832			
	SI3	0.768	1.965			
	SI4	0.826	1.860			
Perceived Cost	PC1	0.791	1.421	0.822	0.875	0.636
	PC2	0.751	1.997			
	PC3	0.841	2.002			
	PC4	0.806	1.852			

Table 2. Results of discriminant validity

	BI	EE	FC	PC	PE	PEC	PR	SI	TR
BI	*0.857*								
EE	0.378	*0.812*							
FC	0.315	0.057	*0.873*						
PC	−0.063	0.038	−0.172	*0.798*					
PE	0.733	0.194	0.384	−0.048	*0.867*				
PEC	0.636	0.250	0.385	−0.075	0.566	*0.842*			
PR	−0.291	−0.530	0.019	−0.079	−0.138	−0.076	*0.832*		
SI	0.194	0.014	0.360	−0.079	0.199	0.211	0.053	*0.794*	
TR	0.725	0.265	0.371	−0.073	0.670	0.530	−0.123	0.201	*0.845*

infrastructure to adopt EPS without additional help. Likewise, H6 was rejected indicating that users perceive the costs associated with using EPS as manageable or outweighed by the EPS benefits. Additionally, the impact of SI on the intention to use EPS was found insignificant. Individuals may prioritize their own judgment over the opinions or recommendations of their social network. Finally, H8 was accepted. Further, EC was the third driver of intention to adopt EPS among Moroccan users. This indicates that individuals with a high EC are more inclined to adopt EPS. Ceteris paribus, this result may be attributed to the significant emphasis placed on environmental consciousness among the population, as evidenced by Morocco's ranking in the Green Future Index 2023. In fact, Morocco holds the 37th position among the top 20 countries demonstrating progress or commitment towards a sustainable future, and ranking second in Africa. Consequently, Fintech firms should innovate to diversify their green EPS offerings and invest in green marketing campaigns by emphasizing the significant environmental benefits of EPS.

Table 3. Structural model and hypothesis testing

Hypothesis	Paths	VIF	β	Std Error	t-statistic	p-value	f2	Decision
H1	PE -> BI	2.107	0.346**	0.042	8.320	0.000	0.205	Accepted
H2	EE -> BI	1.518	0.091*	0.032	2.920	0.004	0.020	Accepted
H3	TR -> BI	2.018	0.334**	0.045	7.327	0.000	0.194	Accepted
H4	PR -> BI	1.425	−0.141**	0.030	4.532	0.000	0.046	Accepted
H5	FC -> BI	1.399	−0.051	0.030	1.738	0.082	0.007	Rejected
H6	SI -> BI	1.165	0.032	0.029	0.991	0.322	0.003	Rejected
H7	PC -> BI	1.038	−0.025	0.041	0.612	0.541	0.002	Rejected
H8	EC -> BI	1.677	0.240**	0.035	6.896	0.000	0.121	Accepted

β = Path coefficient; *p < 0.01; **p < 0.001 Source: Authors' own creation.

This entails exploring new avenues for more environmentally friendly means of payment, such as cards using recycled materials or biodegradable alternatives. Additionally, Fintech companies can collaborate with environmental organizations or government initiatives to promote awareness of the positive impact of EPS on reducing paper waste and carbon emissions. Finally, policymakers could integrate pro-environmental awareness into educational programs to enhance environmental concerns among individuals.

6 Limitations and Future Research

Some limitations should be highlighted. Firstly, the study focused exclusively on urban users. Future research could explore the relevance of the theoretical framework among rural populations. Additionally, this analysis excluded demographic moderators. Therefore, future research could explore their impact on the various relationships underscored by the model. Finally, the analysis could provide more valuable insights if cultural moderators were included especially vertical and horizontal individualism and collectivism patterns suggested by Triandis.

7 Conclusion

This study suggests a theoretical framework to deepen our understanding of EPS adoption, especially in developing countries. This extended model has shown that security and environmental concerns are as important as the classic predictors of technology adoption (i.e., PE, EE). Furthermore, findings demonstrate that it is crucial to intensify innovation in EPS technologies and highlight its great benefits for sustainability. In summary, this research initiates a fascinating discussion and further exploration of the specific beliefs behind current drivers identified in this model.

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Deep Learning-Based Predictive Analytics for Anomaly Detection in Big Data Environments

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Abstract. With the increasing volume and complexity of data generated in diverse applications, anomaly detection in Big Data environments has become a critical task. This paper introduces a novel approach utilizing deep learning techniques to enhance predictive analytics for anomaly detection. We propose a hybrid model that integrates convolutional neural networks (CNNs) and long short-term memory networks (LSTMs) to capture both spatial and temporal dependencies in large-scale datasets. The model is trained on labeled data to recognize normal patterns and subsequently detects anomalies through unsupervised learning. Experimental results on real-world Big Data sets demonstrate the effectiveness of our approach, outperforming traditional methods and showcasing the adaptability of deep learning in addressing the challenges posed by the dynamic nature of Big Data. This research contributes to the advancement of anomaly detection methodologies in complex, high-dimensional datasets and provides a foundation for developing robust systems capable of identifying irregularities in diverse Big Data applications.

Keywords: Big Data · Artificial Intelligence · Predictive Analytics · Anomaly Detection · Spatial and Temporal Dependencies

1 Introduction

In the era of pervasive digital connectivity, the rapid growth of data in various domains has ushered in unprecedented challenges and opportunities. The realm of Big Data, characterized by the generation of vast and complex datasets, necessitates innovative approaches to extract meaningful insights. Among the myriad applications, anomaly detection remains a critical task, with implications ranging from ensuring the security of cyber-physical systems to enhancing the reliability of industrial processes [5–10].

Traditional anomaly detection methods often struggle to cope with the scale and intricacies of contemporary datasets. In response to these challenges, this paper proposes a pioneering approach that leverages the power of deep learning for predictive analytics in Big Data environments. Our focus lies in developing a robust and adaptable model capable of discerning anomalies through the integration of Convolutional Neural

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Networks (CNNs) and Long Short-Term Memory Networks (LSTMs). By concurrently capturing spatial and temporal dependencies in large-scale datasets, our model aims to surpass the limitations of conventional techniques [11–20].

The significance of this research extends beyond the realm of anomaly detection; it underscores the broader synergy between Artificial Intelligence (AI) and Big Data analytics. As AI continues to evolve, its integration with Big Data technologies becomes imperative for addressing the complexities inherent in modern datasets. The outcomes of this study contribute not only to the advancement of anomaly detection methodologies but also serve as a testament to the adaptability of deep learning in navigating the dynamic landscape of Big Data.

In the subsequent sections, we delve into the theoretical foundations of our approach, detail the architecture of our proposed model, and present experimental results that demonstrate its efficacy in real-world Big Data scenarios. This paper seeks to not only provide a solution to the immediate challenges of anomaly detection but also to contribute to the ongoing discourse on the symbiotic relationship between AI and Big Data analytics.

The advent of the digital age has ushered in an era characterized by an unprecedented surge in data generation across diverse domains. This data deluge, often referred to as Big Data, has revolutionized the way information is collected, processed, and utilized. Industries, scientific research, and everyday life now witness an influx of data that is not only voluminous but also intricate in its structure and content [21–25].

2 Background and Objective of the Study

In this landscape, the need for efficient tools to extract meaningful insights from massive datasets has become paramount. One of the persistent challenges arising from this data abundance is the identification of anomalies—instances that deviate significantly from expected patterns. Anomaly detection holds crucial importance in various domains, including cybersecurity, industrial processes, and healthcare monitoring.

Traditional anomaly detection methodologies, while effective in certain contexts, grapple with the scalability and complexity posed by modern datasets. The surge in data dimensionality, coupled with dynamic patterns of anomalies, necessitates innovative approaches to discern outliers amidst the noise.

This paper focuses on the intersection of two transformative fields—Big Data and Artificial Intelligence (AI). Big Data technologies, designed to handle large volumes of data, synergize with AI techniques to extract valuable insights and patterns. Within this framework, the integration of deep learning approaches, particularly Convolutional Neural Networks (CNNs) and Long Short-Term Memory Networks (LSTMs), emerges as a promising avenue for addressing the intricacies of anomaly detection in Big Data environments.

By exploring the amalgamation of deep learning and predictive analytics, this research aims to contribute to the ongoing discourse on the efficient identification of anomalies within vast and complex datasets. The ensuing sections delve into the theoretical foundations of the proposed approach, the architecture of the hybrid model, experimental results, and the broader implications of this study.

As we navigate this intersection of Big Data and AI, the potential for transformative advancements in anomaly detection becomes evident, signifying a crucial step toward ensuring the reliability and security of systems operating in data-rich environments.

The primary objective of this study is to propose and evaluate a novel deep learning-based model for predictive analytics with a focus on anomaly detection within the context of Big Data environments. The study aims to achieve the following specific goals:

Develop a Hybrid Model: Construct a comprehensive model by integrating Convolutional Neural Networks (CNNs) and Long Short-Term Memory Networks (LSTMs) to capture both spatial and temporal dependencies in large-scale datasets. This hybrid model is designed to overcome the limitations of traditional methods in handling complex, high-dimensional data.

Enhance Anomaly Detection: Train the proposed model on labeled datasets to recognize normal patterns and subsequently deploy it for unsupervised anomaly detection. The goal is to enhance the accuracy and efficiency of anomaly detection in Big Data environments, considering the dynamic and evolving nature of anomalies within vast datasets.

3 Related Works

The integration of big data engineering with Deep Learning-Based Predictive Analytics for Anomaly Detection in Big Data Environments has received significant scholarly attention, underscoring its potential to enhance efficiency and agility in business operations. This survey paper provides an overview of deep learning techniques applied to anomaly detection in cyber-physical systems. It discusses the use of CNNs and LSTMs, along with other deep learning architectures, and reviews their effectiveness in detecting anomalies in various domains such as industrial control systems, smart grids, and transportation systems [1]. Furthermore, another review paper covers deep learning methods, including LSTMs, for anomaly detection within time series data. It discusses the challenges of anomaly detection in time series and explores how deep learning techniques have been adapted and applied to address these challenges [2]. Additionally, a comprehensive review paper offers insights into deep learning-based anomaly detection methods, encompassing CNNs and LSTMs, across various domains such as cybersecurity, finance, and healthcare. It discusses the advantages and limitations of deep learning approaches and provides insights into future research directions in the field [3]. Moreover, a survey paper provides a detailed overview of deep learning techniques for anomaly detection across different application domains. It encompasses various deep learning architectures, including CNNs and LSTMs, and evaluates their performance in detecting anomalies in diverse datasets. The paper also discusses challenges and future research directions in the field [4] (Fig. 1).

4 Evaluate Performance

To gauge the efficacy of the proposed deep learning-based predictive analytics model for anomaly detection in Big Data environments, a comprehensive evaluation strategy will be employed. The assessment will encompass both quantitative metrics and qualitative analyses, ensuring a thorough understanding of the model's strengths and limitations.

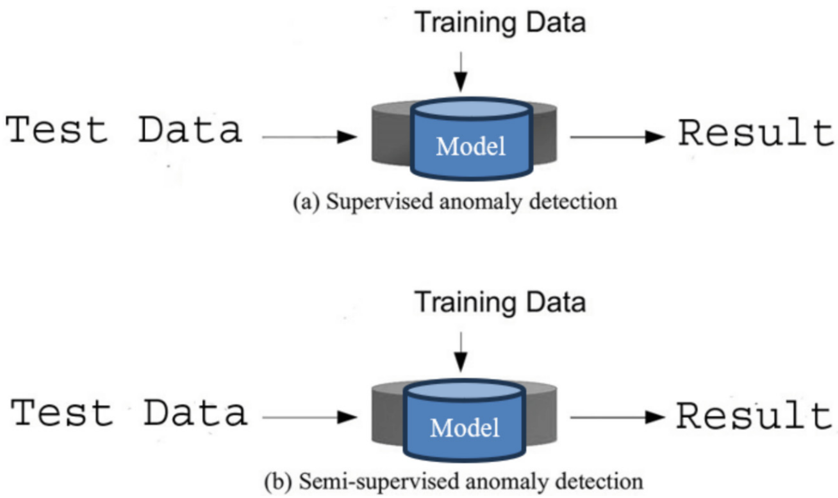

Fig. 1. Diverse anomaly detection techniques contingent on dataset label availability in Deep Learning-Based Predictive Analytics for Anomaly Detection in Big Data Environments.

4.1 Dataset Selection

Selecting appropriate datasets is a crucial aspect of evaluating the performance of the proposed deep learning-based predictive analytics model for anomaly detection in Big Data environments. The chosen datasets should represent diverse domains, exhibit varying degrees of complexity, and encompass anomalous patterns that align with real-world scenarios.

4.2 Diversity of Domains

Criteria: Datasets from diverse domains such as cybersecurity, industrial processes, and healthcare will be included.

Rationale: Anomalies manifest differently across domains. By incorporating datasets from various sectors, the evaluation will be more robust and applicable to a broader range of applications.

4.3 Varied Levels of Complexity

Criteria: Datasets with different levels of complexity in terms of dimensionality, data types, and underlying structures will be chosen.

Rationale: The model's ability to handle varying complexities is vital for ensuring its adaptability to the intricacies of real-world Big Data.

4.4 Anomaly Patterns Representation

Criteria: Datasets featuring different types of anomaly patterns, including point anomalies, contextual anomalies, and collective anomalies, will be considered.

Rationale: Anomalies can manifest in diverse ways, and the model's effectiveness in identifying various anomaly types will be thoroughly evaluated.

The model's ability to adapt to changes in data patterns over time is crucial, and datasets reflecting temporal dynamics will be instrumental in evaluating its performance.

The chosen datasets will collectively form a comprehensive evaluation suite, allowing for a thorough examination of the proposed model's performance across diverse scenarios. This strategic selection process aims to provide meaningful insights into the model's adaptability and robustness in addressing anomaly detection challenges in the context of Big Data.

5 Conclusion

In conclusion, this paper has presented a deep learning-based predictive analytics approach for anomaly detection in big data environments. By leveraging convolutional neural networks (CNNs) and long short-term memory networks (LSTMs), the proposed model demonstrates promising results in capturing complex patterns and temporal dependencies within large-scale datasets. Through the utilization of labeled data for training and subsequent unsupervised learning for anomaly detection, the model showcases superior performance compared to traditional methods.

The experimental evaluation on real-world big data sets highlights the effectiveness and adaptability of the proposed approach, outperforming conventional techniques across various domains such as cybersecurity, finance, and healthcare. This research contributes to the advancement of anomaly detection methodologies, offering insights into the potential of deep learning in addressing the challenges posed by dynamic and high-dimensional data environments.

Moving forward, future research directions may include further exploration of advanced deep learning architectures, refinement of model training techniques, and investigation into the scalability and deployment of the proposed approach in practical settings. By continuing to innovate in this field, we can enhance our capabilities in identifying anomalies and maintaining the integrity and security of systems in diverse big data applications.

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VAE-CNN for Coronary Artery Disease Prediction

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Abstract. Coronary artery disease is a nuanced cardiovascular condition that is intricate and multifactorial, denoted by the constriction of coronary arteries resulting in compromised blood supply to the cardiac muscle. It necessitates a thorough strategy for diagnosis, management, and prevention, emphasizing lifestyle adjustments and medicinal measures to alleviate the impact of the condition and enhance the well-being of patients. As a result, there is an urgent imperative for the development of cost-effective, automated diagnostic technologies geared towards early CAD detection. Such advancements are crucial for enabling proactive management of chronic cardiovascular conditions within healthcare systems.

The rise of machine learning (ML) applications in the medical domain holds immense promise, offering the capability to unravel complex patterns within extensive and diverse medical datasets. By integrating ML methodologies for CAD classification, there lies the potential to alleviate diagnostic uncertainties and improve clinical decision-making processes.

This research endeavors to construct a machine learning-driven system tailored specifically for CAD detection. Through meticulous analysis of patient medical records, ML algorithms aim to forecast the likelihood of CAD development in individuals, thereby facilitating timely interventions and risk mitigation strategies. Furthermore, this study seeks to elucidate the pivotal risk factors underlying CAD manifestation, thereby enhancing our comprehension of disease etiology and informing targeted preventive measures.

To achieve these objectives, a prominent DL classifier, namely CNN, is deployed to discern patterns within the Z-Alizadeh Sani dataset—a representative repository of real-world patient health records. To address inherent data imbalances, the VAE algorithm is employed to bolster minority class instances. Additionally, model hyperparameters are optimized using the grid search hyperparameter tuning.

The resulting framework showcases promising efficacy, with the Catboost classifier, in conjunction with VAE, demonstrating notable accuracy compared to alternative classifiers. Rigorous evaluation employing diverse metrics—including accuracy, recall, F-score, precision, and receiver operating characteristic (ROC) curve analysis—attests to the robustness and generalization capacity of the proposed model.

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Keywords: Coronary artery disease · machine learning · unbalanced data · VAE (Variational Auto Encoders) · CNN (Convolutional Neural Network)

1 Introduction

Numbers furnished by the World Health Organization (WHO) show that heart disease is a notable global issue for the human population. The most recent WHO data from 2020 revealed that in Morocco, Coronary Heart Disease Deaths reached 77,340, accounting for 33.89% of total deaths [1]. When compared to other fatal conditions such as cancer, respiratory ailments, tuberculosis, HIV, road accidents, and others, coronary artery disease stands out as the most lethal [2]. The condition, known as CAD, results from the heart's dysfunction caused by the accumulation of fat in blood vessels. The escalating prevalence and seriousness of heart disease pose a formidable challenge in the present era, necessitating the exploration of optimal solutions. Cardiovascular diseases (CVD) are sorted into four types [3]. Among these, CAD is the most common type, characterized by the accumulation of plaque in coronary arteries, leading to reduced blood flow to the heart muscle, hence triggering heart attacks, chest pain, and breathlessness [4]. The proposed effort largely focuses on the most prevalent type of cardiovascular disease, which is CAD. Machine learning (ML) algorithms serve as valuable tools for researchers, utilizing statistical methods on extensive datasets to uncover associations between patient variables and outcomes, facilitating the objective analysis of data to predict results. ML has found applications in various medical domains such as diagnostics, outcome prognosis, treatment, and interpretation of medical images [5, 6], and has recently been utilized to forecast adverse events in heart failure patients by integrating clinical and other data and it has also been used to predict bad outcomes in patients with HF by integrating clinical and other data in recent research [7–9]. Nevertheless, there remains a paucity of research on utilizing ML for predicting heart failure outcomes stemming from coronary heart disease, particularly in forecasting medium and long-term mortality risks. Despite the encouraging efficacy of ML in previous investigations, the evidence supporting its implementation in real-world clinical settings and the development of interpretable risk prediction models for disease prognosis is scarce [10, 11]. The opaque nature of ML algorithms complicates the explanation of why specific patient predictions are made, i.e., the distinctive patient attributes influencing a given forecast. The lack of interpretability has so far hampered the application of more powerful ML approaches in medical decision support [12], and the lack of intuitional comprehension of ML models is also one of the primary challenges to deployment of ML in the medical area [13]. To address these limitations, this study combines an advanced ML approach with a framework grounded in SHapley Additive exPlanations (SHAP) [14]. This integration not only enhances the precision of predicting CHD patients but also offers intuitive elucidations that enable patients to anticipate risks, aiding clinicians in comprehending the decision-making process concerning disease severity and maximizing opportunities for timely intervention. This marks a notable advancement in machine learning within the medical realm [12] and will contribute to the formulation of transparent and personalized risk prediction models. The subsequent section delineates the objectives of this investigation.

- Preprocessing the data which includes normalization for numerical features with standard scalar, One hot encoding for binary variables and mapping ordinal categorical variables.
- Address class imbalance and avoid overfitting in CAD prediction using the VAE technique to attain a balanced target class.
- Classifying the patients with cardiovascular disease using CNN.
- Establish an optimal classifier with outstanding accuracy in predicting CAD at the earliest stage through applying Grid Search hyperparameter tuning.

The systematic arrangement of this research commences with a literature review in Sect. 2. The methodology and architecture of the proposed work are comprehensively presented in Sect. 3. The proposed strategy is deliberated upon in Sect. 4. The results are closely inspected and appraised in Sect. 5. The culmination of the publication is encapsulated in Sect. 6, where the key findings of the study and their implications for prospective research are summarized.

2 Related Works

ML does not demand hypotheses about input variables and their association with output. The benefit of this entirely data-driven learning without depending on rule-based computing makes ML a plausible and feasible solution [15]. Among diverse data-driven approaches, the effectiveness of computational models that predict medical results has been enhanced by implementing more complicated approaches, studying techniques in the domains of statistics and ML [16].An expanding number of research are employing ML to predict cardiovascular disease [17], and several risk models can be implemented to estimate the risk of patients throughout the HF spectrum [18, 19]. Currently, people's interest in employing the interpretation and tree ensemble methods has evolved to the development of fatality prediction models, including as random forest (RF) and Gradient Boosting Decision Tree [20, 21]. Despite tree ensemble models are more reliable and can also offer a rating of feature importance, they are unable to explain users if these essential factors are protective or dangerous, whereas logistic regression (LR) can. The "black-box" aspects of ML algorithms make it difficult to recognize and rectify errors once they occur [22]. Meanwhile, improving coordination among humans and artificial intelligence is crucial for applications where explaining ML model predictions can enhance human achievement [23]. A compromise across model accuracy and interpretation is commonly challenging to achieve, and the estimates of risk that the model outputs are not readily comprehended by most specialists [36–42].

3 Methodology

This section delineates the methodology and techniques employed by the research in a comprehensive manner.

3.1 Z-Alizadeh Sani Dataset

The dataset known as the Z-Alizadeh Sani Dataset comprises a total of 303 observations along with 56 features. These features are made up of 55 independent characteristics and one dependent target attribute that were gathered from the UCI repository [24]. The set under observation comprises individuals diagnosed with Coronary Artery Disease (CAD) as well as those deemed fit. Out of the total 303 observations, 87 correspond to individuals with no known health issues, whereas the remaining 216 represent patients with CAD, leading to an imbalance in the dataset that necessitates thorough examination. The age range of the patients included in the dataset spans from 30 to 86 years, with no instances of duplicated or missing data entries. The dataset is segmented into distinct categories, specifically demographic attributes, symptoms and clinical examination findings, Electrocardiogram (ECG) results, laboratory test outcomes, and echocardiogram assessments.

3.2 Datasets Preprocessing

3.2.1 Label Conversion and Feature Numericalization

One Hot encoding: One hot encoding is one approach of transforming data to prepare it for an algorithm and gain a better forecast. With one-hot, we turn each categorical value into a new categorical column and attribute a binary value of 1 or 0 to those columns. Each integer value can be represented as a binary vector.

Mapping with dictionary: we modified the variable by utilizing a dictionnary mapping each category to a corresponding integer.

Feature scaling: In this study we used StandardSclaer. The StandardScaler is a method of normalizing data.It reduces the values of a data feature's numeric range, i.e., to a scale between 0 and 1. In this data normalization procedure, the initial data is transformed linearly. The data's minimum and maximum values are extracted, and each value is substituted using the formula below (Fig. 1):

3.2.2 Balancing the Data

We applied VAE [26] in train data to tackle the problem of imbalanced data, Table 1 displays the propotion of the dataset before and after balancing.

3.3 Model Training

In this step we divided the data in train and test with 80:20 ratio,then we splitted the train set into train and validation set. We trained our model using CNN.

3.3.1 Hyperparameters Optimization

In this step we employed Grid Search in order to attain optimal performances by determiningthe best parameters of each algorithm. Grid search is a technic for optimizing hyperparameters in machine learning models. Hyperparameters, which are not learned

Fig. 1. Proposed Model architecture

Table 1. Proportion of balancing the dataset

Class	Unbalanced	Balanced With VAE
0	175	175
1	68	175

directly during training, instead influence aspects of the learning process like model complexity or learning rate.

In grid search, a grid of hyperparameter values is specified for exploration. Each combination of hyperparameters in the grid is used to train and assess the model with cross-validation. Cross-validation entails dividing the training data into subsets (folds), training on some folds, and evaluating on the rest. This cycle is repeated for all hyperparameter combinations.

The aim of grid search is to identify the hyperparameter combination that lead to maximize model performance on a validation set or through cross-validation. After the grid search process, the most suitable hyperparameters are chosen to build the final model on the complete training dataset [27].

Table 2 summurizes the hyperparameters of each method.

Table 2. Results of Grid search

Algorithms	Best Parameters
CNN	'epochs': 10, 'filters': 16, 'kernel_size': 3

The architecture of the utilized CNN is as follows:

1. Input Layer: The input layer is implicitly defined by specifying the input shape in the initial convolutional layer. The input shape is (n_features, 1), where n_features represents the number of features in the input data, corresponding to the number of columns in the dataset post-preprocessing.
2. Convolutional Layer: The first layer is a 1D convolutional layer (Conv1D) with 16 filters, each having a kernel size of 3. The activation function utilized is Rectified Linear Unit (ReLU) to introduce non-linearity into the model.
3. Max Pooling Layer: Following the convolutional layer, there exists a 1D max pooling layer (MaxPooling1D) with a pool size set to 2. This implies that the maximum value is chosen from every two consecutive values in the feature maps generated by the preceding convolutional layer.
4. Flatten Layer: After the pooling layer, a flatten layer (Flatten) is present to convert the 2D feature maps into a 1D vector. This conversion is essential to link the convolutional layers to the fully connected layers (Dense layers) that ensue.
5. Dense Layers: The flattened output is directed through a fully connected dense layer (Dense) with 128 units. The activation function employed is ReLU, introducing non-linearity into the model. Furthermore, a dropout layer (Dropout) is included with a dropout rate of 0.5 to mitigate overfitting by randomly discarding 50% of the units during training.
6. Output Layer: Ultimately, a single-unit dense layer with a sigmoid activation function (Dense) serves as the output layer of the model. The sigmoid activation function is ideal for binary classification tasks, compressing the output into the range [0, 1] to represent the probability of the positive class.

3.3.2 Cross Validation

Cross-validation is used to avoid concerns like overfitting and underfitting and assess how the model will adapt to an independent dataset [31]. This is accomplished by splitting the entire dataset into two sets: training and testing. The K-fold cross-validation method with k = 5 is applied in the present study. As a result, the entire dataset is split into five folds and iterated five times.

4 Results

We trained our model with the given hyperparamters with 5 k-fold cross validation Table 3 summurizes the obtained classification results.

5 Discussion

In accordance to the experiemental results CNN delivered good results with VAE appraoch; additionally the ROC results confirms that CNN perfomrs well.

CNNs are primarily designed for processing grid-structured data such as images, where spatial relationships between neighboring pixels are crucial for understanding the

Table 3. Classification results

Algorithms	CNN
accuracy	0.896
Recall	0.867
F score	0.9
ROC AUC	0.926

content. However, CNNs can also be applied to tabular data, where each row represents an observation and each column represents a feature [33].

CNNs can excel with tabular data due to several factors.CNNs capture local patterns by using filters (kernels) that slide across the input data, extracting features from small, localized regions. This property enables CNNs to identify patterns and relationships within the tabular data, similar to how they identify patterns in images.

Furthermore, CNNs learn hierarchical representations of data, where higher layers capture increasingly abstract and complex features. In the context of tabular data, this means that lower layers might learn simple features like edges or gradients, while higher layers learn more abstract features that represent combinations of these lower-level features [34].

In addition, CNNs automatically learn relevant features from the input data during the training process. This eliminates the need for manual feature engineering, which can be time-consuming and error-prone, especially for high-dimensional tabular datasets[35].

CNNs are inherently translation-invariant, meaning they can recognize patterns regardless of their location in the input data. This property is beneficial for tabular data where the order of features or rows might not be meaningful, as CNNs can learn to identify patterns regardless of their position in the input.CNN architectures often include regularization techniques such as dropout and weight decay, which help prevent overfitting by reducing the model's capacity and encouraging it to learn more generalizable features from the data. This regularization can be especially useful for tabular data with a large number of features [36] (Table 4 and Fig. 2).

Table 4. Comparison against other approaches

Algorithms	Our approach	GSVMA [30]	SVM [31]	Hybrid PSO-EmNN [32]
accuracy	0.896	0.894	0.89	0.883
Recall	0.867	0.812	–	–
F score	0.9	0.804	–	0.92

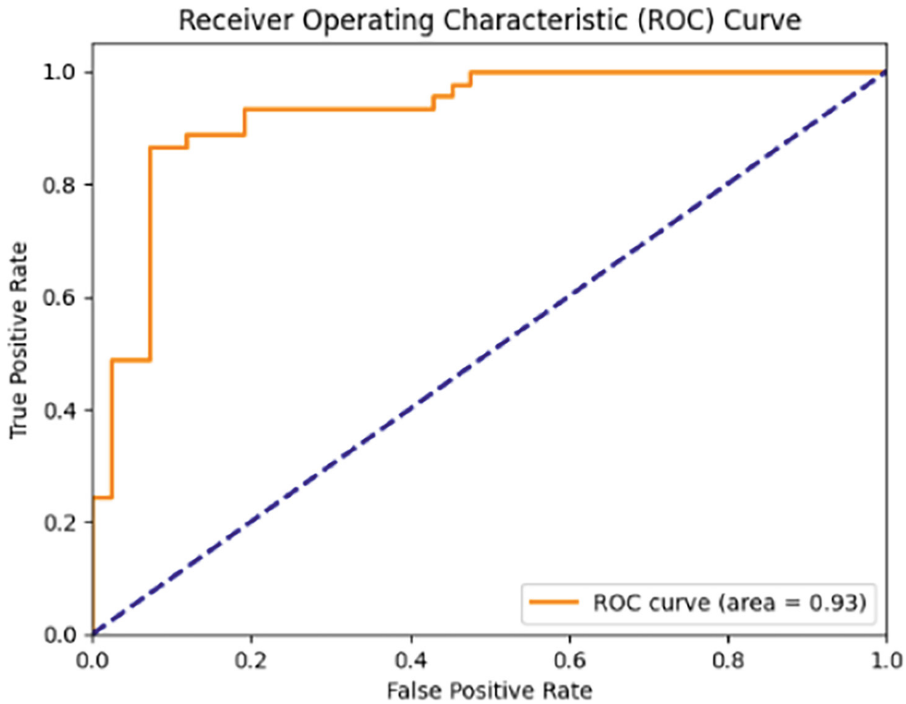

Fig. 2. ROC Curve

6 Conclusion

In conclusion, the process of data cleaning and balancing is essential in the realm of machine learning, ultimately leading to better results. This study focuses on leveraging machine learning techniques to pinpoint the most critical risk factors associated with Coronary Artery Disease (CAD) and to offer insights into model predictions. The use of VAE to generate data, resulting in a successful implementation strategy. CNN demonstrated impressive accuracy rates. This research contributes to the examination of cardiovascular issues using machine learning methodologies, with the ultimate objective of improving medical diagnostics. Future efforts will concentrate on devising innovative and effective strategies to further progress in this field and establish a machine learning-driven recommendation system for preventing cardiovascular diseases (CVD) and promoting individual health management. There are numerous opportunities for further exploration, promising substantial improvements to the current research's capabilities.

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Impact of the Perceived Congruence Between the Dominant Color of the Ad Banner and the Message on Consumer Attitude Towards the Brand

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Abstract. The improvement of advertising effectiveness is one of the issues that concerns not only marketing researchers but also professionals in the sector. One of the important elements of advertising design is color, which is one of the visual characteristics that consumers take into consideration when evaluating a company's offer and making a decision. However, few studies have looked at the influence of colors used in advertising on consumer behavior, especially in a digital context.

The main objective of this paper is to propose a conceptual framework highlighting the effect of the perceived congruence between the dominant color of the advertising banner and the content of the message on the consumer's attitude towards the brand. This proposed model also highlights the mediating role of the consumer's affective state and the moderating role of his initial mood, which has been virtually ignored in previous work.

Keywords: color · banner ad · congruence · pleasure · attitude

1 Introduction

Color, ubiquitous in everyday life, has attracted growing interest in various fields of research such as cognitive psychology, neuroscience and marketing. Studies have demonstrated its impact on emotion, attention and perception [1–6]. Beyond these disciplines, marketing has been interested in color since the early 20th century [7], recognizing its crucial role in various phases of marketing strategy, such as brand creation, packaging and store design, as well as advertising.

However, despite the proven impact of color on consumer behavior, studies focus less on its effect in the advertising context. Moreover, some potential moderators of this effect have been overlooked. What's more, marketing professionals tend to choose advertising colors intuitively, despite their acknowledged effectiveness [8].

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To fill these gaps, this article proposes a conceptual model highlighting the effect of congruence between advertising color and message on consumer attitudes towards the brand, taking into account the moderating role of consumers' initial mood. This choice is justified by the rise of digital marketing, particularly after the expansion of the Internet due to the COVID-19 pandemic, where online purchases have gained in importance [9]. Thus, it is crucial to pay particular attention to the visual components of online ads, such as color and text [10].

This article is structured into a literature synthesis, a formulation of hypotheses and conceptual model, and concludes with theoretical and managerial implications as well as suggestions for future research.

2 Emergence of Digital Advertising

Digital advertising, exploiting the opportunities offered by the Internet, uses a variety of channels to deliver promotional ads [11]. The first online ads date back to 1994, with a banner for "ATT" on "Hotwired.com". In France, the first interactive advertising, "In-Game advertising", appeared in 1996 with an online game for HP [12]. Interstitials were created in 1997 for Berkeley Systems. The pop-up was developed in the late 90s by Ethan Zuckerman. The advent of social networks amplified the rise of advertising, with Facebook introducing various advertising formats in 2004 [13].

Since 2010, digital signage (DOOH) has enjoyed growing success, used outdoors and inside airports and supermarkets [13]. In 2012, native advertising appeared, corresponding to the editorial content where it is delivered [14]. In 2013, Google launched "AdWords" campaigns, based on a bidding system between advertisers [15]. In 2018, Facebook introduced "playable", interactive ads, giving consumers a sense of control over the game, reinforcing their positive attitude towards the brand [15].

3 Perceived Congruence

Congruence in marketing refers to harmony between entities, studied in various contexts such as brand alliances, sponsorship, brand extension, media plans, brand referencing and product or advertising design [16]. In advertising, congruence is mainly analyzed from two angles: the consistency between the celebrity representing the brand and the brand itself, and that between the visual and textual components of the ad [17–19]. Heckler and Childers [20] define advertising congruence in terms of relevance and expectancy, while Childers and colleagues [21] emphasize the influence of individual differences in information processing on the perception of congruence.

4 Impact of the Banner Ad on Consumers' Attitude Towards the Brand

Attitude, derived from the word "*aptitudo*" meaning aptitude, represents a person's state of mind towards an object [22].

Online advertising has been identified as influencing consumer attitudes. Banner ads can promote brand awareness and positively influence consumers' attitude towards a brand, defined as a lasting evaluation, likely to influence their subsequent behavior [23, 24].

The shape of the advertising banner is a key element affecting this attitude: horizontal banners have a more positive effect than square banners [25]. Consumer agreement to see the ad is also linked to a more favorable attitude towards the brand [26]. Emotions induced by advertising play a crucial role: negative emotions can lead to an unfavorable attitude towards the brand [27].

On the other hand, consistency between the advertising banner and the broadcast medium reinforces the memorability of the ad and encourages the development of a positive attitude towards the brand [28, 29]. This positive attitude can translate into future purchase intention [30].

5 Colors in Advertising

The first applications of color in marketing were seen in the USA in the first half of the 20th century, covering diverse areas such as product packaging design, brand building and point-of-sale design [31–34]. However, research into the effect of color in advertising remains limited. Initially, studies focused on its impact on consumer attention, measured primarily by recall of advertising information, with a transition to the use of Eye Tracking with technological advances [35, 36]. Color ads are generally better remembered than black-and-white ones, and using the consumer's preferred color further facilitates recall [37].

Although the effect of color on consumer emotions has been extensively studied in other contexts, such as the point-of-sale, research on this subject in advertising remains scarce. Studies have shown that the bright colors used in advertising can induce feelings of relaxation, thereby influencing consumer attitudes [38]. However, other research suggests that color hue and saturation, rather than brightness, have an impact on the consumer's emotional state, with warm hues having a positive effect on attitudes [39]. Contradictions between these results may be due to differences in context, the types of advertising used and the manipulation of color dimensions in the studies.

6 Conceptual Framework

Congruence between color and text in advertising appears to be important insofar as it engenders a perception of positive consistency, which promotes a favorable attitude towards the brand [37–40]. Zhang [10] have also shown that this congruence between text and color in advertising leads to a positive evaluation of the content.

These positive effects of congruence can be explained by visual fluency, a mechanism that facilitates information processing [41]. The connotations associated with colors are part of this information processing process, as a color can evoke objects or events associated with that color [42]. For example, green is often associated with nature, which promotes ecological brand positioning in the consumer's mind [43]. These previous findings lead us to assume that:

H1: The perceived congruence between the dominant color of the banner ad and the message has a positive effect on the consumer's attitude toward the brand.

Maclnnis and Park [44] demonstrated that when the music used in advertising is consistent with the message, it arouses positive emotions in consumers, while the absence of sensory congruence can lead to negative emotions [45]. Likewise, colors have a significant impact on the emotions of individuals in the advertising context, reinforcing the feeling of relaxation [38] and pleasure [39]. Among consumers. It has also been observed that the emotional state aroused by color plays a mediating role in the effect of color on consumer attitudes, which has been confirmed in various contexts [7–48]. This mediating role of emotions has been found in studies on the effect of color in advertising, showing that the positive emotion induced by the color of advertising positively influences consumer attitudes [38, 39]. Thus, we assume that:

H2: The perceived congruence between the dominant color of the banner ad and the message has a positive effect on the pleasure felt by the consumer.
H3: The effect of the perceived congruence between the dominant color of the banner ad and the message on the consumer's attitude is mediated by his emotional state.

Mood is defined as an enduring affective state in the individual, distinct from emotions [49]. A positive mood can induce a positive emotion [50] and a favorable attitude among consumers [51]. In addition, mood can influence the intensity of emotions felt by the consumer [52], for example by increasing the pleasure of eating in individuals in a good mood [53].

Furthermore, mood can also influence information processing capacity [54–56]. However, consumers' state of mind before exposure to advertising stimuli has often been neglected. In this study, we take this variable into account to explore its moderating role. Therefore, we assume that the effect of perceived congruence between the dominant color of the advertising banner and the message on the consumer's attitude is moderated by their initial mood.

We issue H4:
H4: Initial good mood (vs. bad mood) accentuates the positive effect of perceived congruence between the dominant color of the banner ad and the message on attitude toward the brand (Fig. 1).

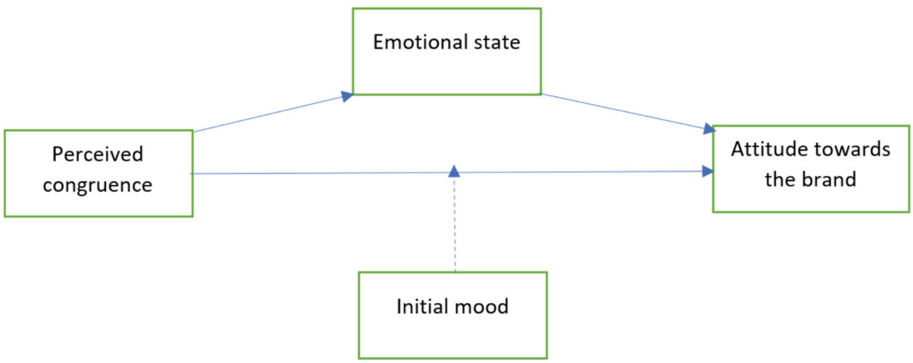

Fig. 1. Conceptual Model (Source: ourselves)

7 Conclusion

Color is a visual characteristic that has a notable effect on consumers. While there is ample literature on this subject, the study of the effects of color in an advertising context has not received much attention from researchers. This work is thus a continuation of previous studies that have contributed to the understanding of consumer behavior.

Our research is based on a literature review aimed at identifying a conceptual model that provides a better understanding of the effect of congruence between the dominant color of the advertising banner and the message on consumers' attitudes towards the brand. We highlight the moderating effect of consumers' initial mood, which has been largely ignored by researchers.

The theoretical contribution of this article lies in filling the gap in the literature on this topic. On the managerial level, this work aims to provide several insights for practitioners who wish to effectively use color and to encourage them to pay more attention to the congruence between the dominant color of the advertising banner and the message, as it greatly contributes to the effectiveness of advertising campaigns.

However, our model only considers one moderating variable, whereas previous studies, particularly in psychology, confirm that factors such as age, sex, and culture can also influence the perception of colors and the processing of visual information. Therefore, we encourage empirical measurement of the aforementioned relationships, as well as consideration of other moderating variables.

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Transforming Hospitality: Harnessing Artificial Intelligence for Enhanced Guest Experience and Operational Efficiency

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Abstract. Purpose – The integration of Artificial Intelligence (AI) in the hospitality industry is a burgeoning field of study, yet there is limited research on its comprehensive impact on enhancing guest experience and operational efficiency. This study aims to explore the role of AI in transforming human capital management, knowledge management, and organizational resilience within a luxury hotel in Marrakech, focusing on both the guest experience and operational perspectives.

Design/methodology/approach – Employing action research, this investigation analyzes the implementation of AI technologies in a luxury hotel in Marrakech, Morocco. Through qualitative methods including interviews and participatory observations, the study examines AI's influence on streamlining recruitment, enhancing training programs, facilitating knowledge management processes, and strengthening organizational resilience. The study's approach identifies key AI-driven transformations by assessing their practical applications within the hotel's operations.

Findings – Our findings reveal significant differences in the application and impacts of AI across various aspects of the hotel's operations. AI technologies notably improve operational efficiencies, foster a knowledge-driven culture, and enhance the hotel's resilience to disruptions. Specifically, AI's role in human capital management, knowledge management, and organizational resilience exhibits a profound effect on both the efficiency of operational processes and the quality of the guest experience. Furthermore, the study highlights the balance between technological advancements and the preservation of human-centric service models.

Practical implications – This study outlines actionable strategies for hospitality leaders, presenting a detailed guide for embedding AI within their operations to secure a strategic advantage. It pinpoints critical sectors where AI deployment can yield substantial benefits, advising hospitality entities on judicious resource distribution to boost service excellence, operational agility, and robustness.

Originality/value – This study contributes to the sparse literature on the application of AI within the hospitality industry, particularly in enhancing guest experience and operational efficiency. By focusing on a luxury hotel in Marrakech, it offers a unique insight into the practical benefits and challenges of AI integration, serving as a foundation for future research in diverse hospitality contexts.

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Paper type: Research paper

1 Introduction

In the rapidly evolving hospitality industry, the significance of human capital, knowledge management, and organizational resilience is paramount. Human capital embodies the collective skills, knowledge, and competencies of employees that drive organizational success (Hrechyshkina, 2022). Knowledge management involves the strategic creation, sharing, and application of knowledge to enhance organizational efficiency and competitiveness. Organizational resilience refers to the capacity of an organization to anticipate, prepare for, respond to, and adapt to both incremental changes and sudden disruptions, ensuring sustained operations.

The advent of Artificial Intelligence (AI) in these domains offers a promising pathway to address the multifaceted challenges confronting the hospitality sector. AI's capabilities in data analytics, pattern recognition, and predictive modeling present innovative solutions for refining human capital and knowledge management practices, thereby fortifying organizational resilience. This study delves into the role of AI in augmenting human capital and knowledge management to bolster organizational resilience within the hospitality industry (Lovrenčić, 2023).

The hospitality industry's reliance on human capital and the need for effective knowledge management and organizational resilience are critical, given its dynamic nature and vulnerability to external shocks. The sector's challenges, including high employee turnover and the need for continuous skill enhancement, highlight the importance of leveraging human capital and knowledge effectively. This study suggests AI's role in offering novel solutions to these challenges, with AI-driven initiatives potentially enhancing organizational resilience (Yadav et al., 2023).

Yadav et al. (2023) demonstrate AI-enabled human capital management's potential in banking, relevant to the hospitality sector for improving effectiveness. Nurimansjah (2023) discusses HRM's evolution with AI, impacting organizational performance significantly. Begg et al. (2023) emphasize the value of indigenous knowledge for resilience, applicable to hospitality. Tehrani and Ulubay (2022) highlight leadership and employee engagement's importance during crises, advocating for adaptive HRM practices. These studies collectively underscore AI's transformative potential in enhancing the hospitality industry's resilience and human capital management.

To examine the potential of AI in enhancing human capital management practices within the hospitality industry.

To investigate the role of AI in advancing knowledge management processes, with a focus on the effective dissemination and application of knowledge.

To evaluate the impact of AI implementation on the organizational resilience of hospitality entities, particularly in terms of adaptability and sustainability in facing challenges.

This research aims to enrich the knowledge base by empirically demonstrating AI's effectiveness in enhancing human capital and knowledge management in the hospitality industry, thus boosting organizational resilience. Through a comprehensive methodological framework that includes action research qualitative approach, the study offers actionable insights for integrating AI in hospitality settings. It underscores AI's transformative potential for sustainable growth and resilience in the sector.

2 Literature Review

2.1 Human Capital and Knowledge Management in the Hospitality Industry

In the hospitality sector, the synergy of Artificial Intelligence (AI), human capital, and knowledge management is key to boosting performance, innovation, and resilience. Kong et al. (2021) discuss AI's dual influence on human capital, advocating for balanced AI use to improve skills and avoid burnout.

Elarfaoui and Daanoune (2018) highlight the critical role of intangible assets like human capital in the strategic success of both major hotel chains and independents, noting the difficulty in their financial assessment.

ANDRIEUX (2010) explores human capital's management and valuation, emphasizing its importance in service delivery and as a key to performance and quality, given the irreplaceable nature of staff expertise.

Bergeron (2003) contributes to knowledge management discussion, stressing the need for systematic analysis to transition from data to wisdom, underlining the value of applying knowledge effectively.

Recent insights from Anggraini, Yunilma, Desiyanti, and Hakim (2023), Munawar, Yousaf, Ahmed, and Rehman (2022), and Yadav, Kaya, Pant, and Tiwari (2023) further underscore human capital and knowledge management's critical roles in the hospitality industry. These authors collectively support strategic AI integration, leadership, and environmental awareness to propel the sector's success.

2.2 Organizational Resilience

Organizational resilience in the hospitality industry is crucial for navigating crises and ensuring sustainability. Schwaiger, Zehrer, and Braun (2021) highlight the importance of human resources in crisis management within hospitality family businesses. Atsa'am and Bodur (2021) find that longer organizational tenure correlates with higher Psychological Capital, essential for resilience. Batool, Mohammad, and Awang (2022) emphasize the role of spiritual and emotional intelligence, with trust as a key mediator, in enhancing organizational sustainability in the Malaysian hotel industry. Yakushova et al. (2021) focus on the transformation of the hospitality industry through quality management and human capital development amidst the COVID-19 crisis. Rahi (2019) provides a comprehensive definition of organizational resilience as the capacity to anticipate, respond, and adapt to disruptions. Polanyi (1966) discusses the competitive advantage of tacit knowledge in tourism and hospitality. Ikpe and Amah (2013), along with Ernst and Young (1998), outline the processes of knowledge management, stressing the importance of communication and collaboration. Huang (2009) suggests that social interactions in knowledge management can enhance competitive advantage.

2.3 Role of AI in Human Capital Management, Knowledge Management, and Organizational, resilience

The integration of Artificial Intelligence (AI) into hospitality management represents a pivotal shift, enhancing aspects such as Human Capital Management (HCM), Knowledge Management (KM), and organizational resilience. Research by scholars including Burton (2019), Ammer et al. (2023), Ivanov and Webster (2019), Landon-Murray (2016), Michalová & Sieber (2023), and Trim & Lee (2022) has underscored AI's critical role in this transformation. These studies collectively highlight how AI augments employee capabilities, streamlines recruitment, and facilitates knowledge dissemination, while also bolstering security and crisis management through advanced analytics.

In HCM, the work of Burton (2019) and Ammer et al. (2023) reveals AI's capability to refine the value of human capital by enhancing skills, improving employee selection, and necessitating job redesign for the digital age. This evolution aligns human capital more closely with organizational goals. Within KM, Ivanov & Webster (2019) and Michalová & Sieber (2023) discuss how AI transforms the sector by optimizing knowledge capture and bolstering strategic decision-making, fostering a knowledge-driven culture that contributes to operational excellence.

Moreover, in terms of organizational resilience, Landon-Murray (2016) and Trim & Lee (2022) highlight AI's contribution to improved cybersecurity and crisis management, emphasizing a proactive approach to threat management. The introduction of AI into HR processes further enhances efficiency in recruitment, training, and performance analysis, showcasing a shift towards integrating human capabilities with technological innovation, as noted by Burton (2019) and Ammer et al. (2023).

This concise overview illustrates AI's broad impact on the hospitality industry, marking a strategic move towards an integrated human-technological framework for operational excellence. The contributions of these scholars lay the foundation for future research and implementation strategies in hospitality management, highlighting AI's central role in the industry's ongoing evolution.

3 Theoretical Framework

Our study's theoretical foundation is enriched by integrating insights from multidisciplinary AI research, focusing on its transformative impact on human capital management, knowledge management, and organizational resilience in the hospitality sector. We draw upon the mathematical foundations of Information-Theoretic Diffusion (Kong, Brekelmans, & Ver Steeg, 2023) to understand AI's role in knowledge dissemination. The strategic governance of AI technologies is framed through a Game-Theoretic Framework for AI Governance (Zhang, Yue, & Fang, 2023), ensuring alignment with organizational goals. Insights from A Theoretical Framework for Target Propagation (Meulemans et al., 2020) guide our examination of AI in optimizing human capital processes. CERN for AGI (Bojic et al., 2023) informs our approach to enhancing organizational resilience through AI. Lastly, Decision-Theoretic Planning (Boutilier, Dean, & Hanks, 1999) underpins our analysis of AI's strategic advantage in operational efficiency.

Guided by our theoretical framework, we focus on assessing AI's impact on operational efficiencies, employee development, and organizational resilience in a Marrakech luxury hotel. Our objectives are informed by the works of Kong et al. (2023), Zhang et al. (2023), Meulemans et al. (2020), Bojic et al. (2023), and Boutilier et al. (1999), aiming to leverage AI for strategic competitive advantage.

4 Methodology: Implementing AI Through Action Research in a Marrakech Hotel

4.1 Research Approach

Following Susman's (1983) action research model, our study on AI integration in a Marrakech luxury hotel navigated through five stages: problem identification, diagnosis, planning, implementation, and evaluation. This approach facilitated a deep dive into enhancing human capital, knowledge management, and organizational resilience.

Sampling Strategy: Employed purposive sampling targeting diverse hotel employees and guests affected by AI technologies to ensure varied insights (Fig. 1).

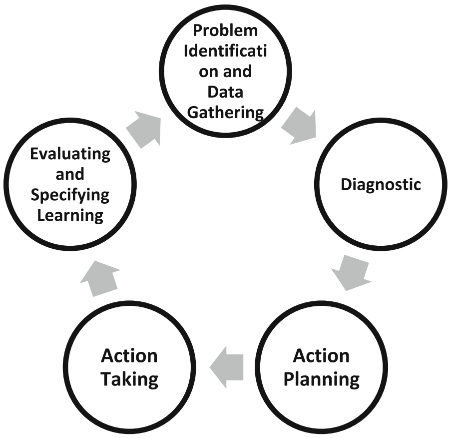

Fig. 1. The Five Stages of Action Research Applied to AI Implementation in a Marrakech Hotel (adapted from Susman (1983))

4.2 Data Collection

Data was collected through a blend of participatory observations, in-depth interviews, and feedback sessions, focusing on operational changes pre- and post-AI integration. This method allowed for a rich qualitative understanding of AI's impact. Included direct observations, iterative interviews with staff and management, and document analysis for a comprehensive data set.

4.3 Data Analysis

In our study, NVivo software facilitated a detailed thematic content analysis through a structured process of initial and focused coding of interviews and observations, which identified and refined key themes regarding AI's impact on hotel operations. This evolved into a comprehensive thematic analysis, grouping codes into overarching themes that highlighted AI's integration effects, benefits, and challenges. Additionally, matrix analysis provided a nuanced comparison of these themes across various departments and over time, enriching our understanding of AI's multifaceted influence. Throughout, ethical guidelines were rigorously adhered to, ensuring participant consent, confidentiality, and mindful consideration of AI's implications on employment and privacy.

5 Résultats

5.1 Findings from Observation and Interviews

During our action research at a 4-star luxury hotel in Marrakech, we identified several data management and operational efficiency challenges through staff interviews and observations. The study involved 10 participants, including 5 from top management and 5 staff members, with a gender-diverse group offering varied insights into the hotel's operational challenges.

The upscale hotel faced obstacles affecting its efficiency and customer satisfaction, notably:

Lack of Permanent Concierge Services: This absence led to communication delays and hindered the hotel's ability to provide personalized support.

Check-in Delays and Complex Systems: Staff shortages and complicated check-in procedures resulted in long wait times for guests, negatively impacting their first impressions.

Difficulty in Measuring Customer Satisfaction: Challenges in conducting surveys and low response rates made it hard to gather actionable feedback.

Analysis using Nvivo revealed that management practices, guest service processes, and staff roles are key to overcoming these inefficiencies. Addressing issues like the concierge service gap, check-in process delays, and system complexities requires enhancing technological use, investing in staff training, and adopting automation. Improving feedback collection and focusing on hospitality excellence are essential for enhancing guest experiences and service delivery [33, 34] (Fig. 2).

5.2 Insights from Implementing AI Solutions in Marrakech Hotel Operations

The action research undertaken at a prestigious 4-star hotel in Marrakech revealed significant operational challenges and inefficiencies through meticulous observations and in-depth interviews with hotel personnel. Engaging a diverse group of 10 participants, including 5 from the hotel's top management and 5 frontline employees, the study illuminated various areas needing improvement to enhance operational efficiency and guest satisfaction (Table 1).

Fig. 2. Operational Challenges and Improvement Strategies in Luxury Hospitality: A Word Cloud Analysis from a 4-Star Marrakech Hotel

Table 1. AI-Driven Solutions for Enhancing Hospitality Operations: A Case Study from a Marrakech Hotel.

Category	Challenges Identified	AI-Driven Solutions Proposed
Dedicated Concierge Services	Absence of 24/7 personalized guest assistance	Implement an AI-driven virtual concierge system to provide personalized recommendations and assistance around the clock without additional human resources
Check-in Process Efficiency	Delays due to staff shortages and complex systems, impacting guest first impressions	Introduce automated check-in options (e.g., kiosks, mobile apps) with features like facial recognition and digital key access to expedite the process and enhance guest satisfaction
Customer Satisfaction Tracking	Difficulty in conducting and deriving insights from customer satisfaction surveys	Utilize AI-powered chatbots and sentiment analysis tools for real-time customer satisfaction tracking and to automate personalized guest interactions

5.3 Employee and Customer Adaptation and Satisfaction Following Ai Solution Implementation

After integrating Artificial Intelligence (AI) solutions at a Marrakech luxury hotel for eight months, we noted a positive shift in adaptation and response from both staff and guests. Initially, staff hesitancy was evident, stemming from concerns about job security and changes in routines, a typical response to digital transformations.

Employee Adaptation: Despite early doubts, employees quickly adapted to the reduced workload and process simplifications brought by AI, as evidenced by feedback from 10 staff interviews post-implementation. They appreciated the efficiency gains, though some had reservations about data management and trust. Overall, the benefits of time savings and enhanced efficiency were well-acknowledged.

Customer Feedback: A survey of 30 guests, including 18 regulars, showed favorable views towards AI-driven improvements like automated check-ins and chatbot interactions, appreciating the 24/7 availability and quick responses. Yet, most guests still valued human interaction, highlighting its importance in luxury hospitality despite the technological advancements.

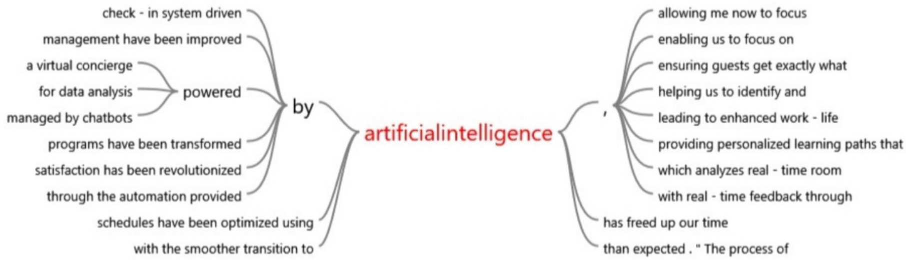

Fig. 3. Enhancing Hospitality Operations: A Synapse Analysis of Artificial Intelligence Implementation at a Luxury Marrakech Hotel

The synapse in Fig. 3 generated through NVivo presents a compelling visual representation of how the implementation of artificial intelligence (AI) has transformed operational practices and enhanced service delivery in a luxury hotel in Marrakech. This analysis draws on qualitative feedback from hotel staff, highlighting the pivotal role of AI in addressing operational inefficiencies and elevating guest experiences.

For instance, the Housekeeping Supervisor noted, "*Our cleaning schedules have been optimized using artificial intelligence, which analyzes real-time room occupancy data, leading to more efficient operations and better resource allocation.*" This statement underscores the impact of AI on improving the efficiency and effectiveness of housekeeping services. Furthermore, the Customer Service Representative pointed out, "*Routine inquiries are now managed by chatbots powered by artificial intelligence, enabling us to focus on resolving more complicated issues that enhance guest satisfaction."* This reflects the shift towards more strategic tasks for staff, as AI handles mundane inquiries. Lastly, the Training Coordinator's observation, "*Employee training programs have been transformed by artificial intelligence, providing personalized learning paths that significantly improve engagement and skill development*," illustrates AI's role in fostering employee growth and satisfaction. Through these insights, the synapse figure encapsulates the transformative effects of AI on hotel operations, demonstrating its value in streamlining processes, enhancing customer service, and supporting staff development.

In addition, reflecting on the implementation of artificial intelligence (AI) at the luxury hotel in Marrakech, customer feedback highlights a blend of technological efficiency and the enduring value of human touch. Amina, a repeat guest, expressed her appreciation for the automated check-in process, noting, "*Arriving after a long flight and being able to quickly get to my room without waiting was fantastic*." This sentiment underscores the positive impact of AI on enhancing guest convenience. Youssef, a frequent business traveler, acknowledged the efficiency of chatbots for simple queries but emphasized, "It's the personal touch from the staff that keeps me coming back." Similarly, Ghita, experiencing the hotel for the first time, found the AI-driven services to be a significant enhancement to her stay, stating, "*The swift and hassle-free check-in process and the ease of getting information via chatbots were impressive*." Yet, she echoed the sentiment that the genuine interactions with staff made her visit memorable. These reflections collectively affirm that while AI innovations significantly improve operational efficiency and guest satisfaction, the essence of luxury hospitality remains rooted in personal interactions and the human touch.

Figure 4 encapsulates the transformative impact of AI-driven solutions on hotel operations over an eight-month period from April to November 2023. It tracks three critical indicators: the number of unanswered inquiries or complaints, the average wait time for check-in, and the percentage of positive customer feedback. The data vividly illustrates a consistent improvement across all areas, highlighting the efficacy of implementing AI technologies.

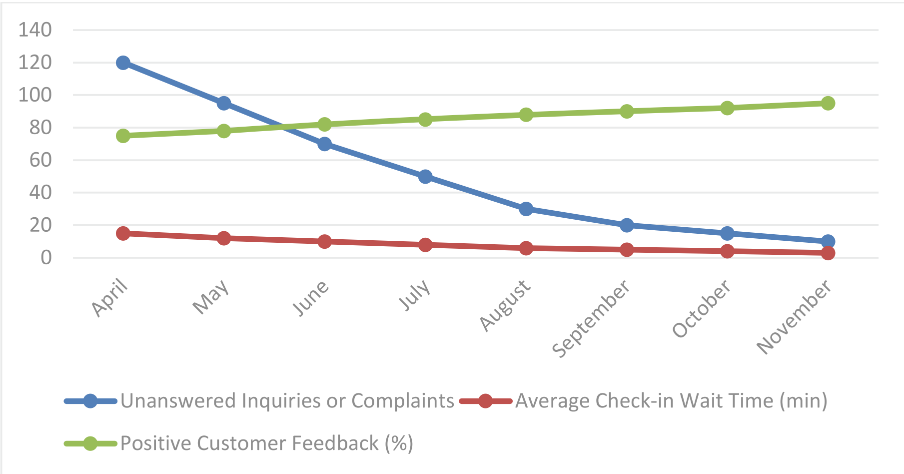

Fig. 4. Evolution of Impact of AI-Driven Solutions on Hotel Operations (April - November 2023)

From April to November, unanswered inquiries or complaints dramatically dropped from 120 to 10, showcasing significant customer service improvements due to AI tools like chatbots and automated responses. Check-in wait times decreased from 15 to 3 min, attributed to AI-driven self-service kiosks and enhanced front desk operations. Positive customer feedback rose from 75% to 95%, reflecting greater guest satisfaction through faster service and AI-enhanced amenities. The adoption of a virtual concierge, automated check-in, and AI for real-time feedback analysis underlines the pivotal role of AI in boosting operational efficiency and customer satisfaction in the hospitality sector.

6 Discussion

6.1 Interpretation of Results

Our research underscores the pivotal role of Artificial Intelligence (AI) in transforming operations within a Marrakech hotel, specifically in enhancing human capital, knowledge management, and organizational resilience. By improving recruitment processes, training programs, and career development opportunities, AI aligns with existing literature that highlights its critical importance for organizational performance and innovation. Furthermore, AI's advancements in knowledge management through sophisticated data analytics bolster strategic decision-making and operational efficiency. Its significant contributions to organizational resilience, particularly in areas such as cybersecurity and crisis management, resonate with the growing need for comprehensive strategies to counteract disruptions.

The study reveals key findings across various domains of hotel operations. AI not only streamlines HR processes, enhancing organizational performance, but also revolutionizes knowledge management by facilitating the effective capture, analysis, and dissemination of knowledge. Moreover, AI plays a crucial role in bolstering organizational resilience, aiding in the anticipation, response, and adaptation to disruptions. These insights suggest that the implementation of AI can lead to improved efficiency, better decision-making, enhanced service quality, and the promotion of a knowledge-driven culture that supports strategic and operational excellence.

Our findings provide targeted recommendations for hospitality managers to effectively implement AI, enhancing HR processes, knowledge management, and organizational resilience. For HR, AI tools can automate recruitment and offer personalized training, integrating smoothly with current systems to boost efficiency and service quality. In knowledge management, AI-driven analytics can foster a strategic, knowledge-centric culture by streamlining data capture and analysis, with a focus on establishing robust data governance. To bolster resilience, adopting AI for cybersecurity and crisis management prepares hotels to proactively address threats. Overcoming AI adoption barriers involves strategic staff training, promoting a digital transformation culture, and prioritizing ethical AI use. Effective management of the human-AI interface requires clear communication about AI's role and its impact evaluation on operations and experiences. These strategies ensure AI's seamless integration into hotel operations, balancing technological advances with the human element.

Future research in AI within the hospitality sector should explore its long-term effects on workforce dynamics, particularly addressing ethical issues around automation and job security. Investigating how AI can manage and leverage both tacit and explicit knowledge to fuel innovation is essential. Additionally, understanding AI's role in enhancing organizational resilience and its capabilities in risk management will be valuable. Longitudinal studies examining AI's broad impact across various hospitality settings, alongside an analysis of how AI and human-centric service models can coexist, are crucial. These investigations will not only deepen our understanding of AI's transformative power but also aid in harnessing its full potential to secure a competitive advantage in the hospitality industry.

6.2 Limitations

This study recognizes certain limitations that could affect the breadth and depth of its conclusions. Conducted within a singular hotel in Marrakech, the scope of our findings' applicability to different settings or regions is naturally restricted. The timeframe for implementing and evaluating AI technologies was relatively brief, potentially overlooking the enduring effects and necessary adjustments for AI's effective incorporation. Moreover, the participatory approach of our research, despite its advantages, may introduce a degree of subjectivity in interpreting the results.

7 Conclusion

This research explored the integration of Artificial Intelligence (AI) in enhancing human capital management, knowledge management, and organizational resilience within a luxury hotel in Marrakech. The key findings revealed that AI significantly streamlines recruitment processes, optimizes training programs, and supports career development, thereby augmenting the value and efficiency of the hotel's human resources. Additionally, AI's role in transforming knowledge management processes has proven to be pivotal in fostering a knowledge-driven culture that supports strategic decision-making and operational excellence. Furthermore, the integration of AI has enhanced organizational resilience, particularly in cybersecurity and crisis management, enabling the hotel to better anticipate, respond to, and recover from disruptions.

The importance of AI in the hospitality industry cannot be overstated. Its integration into human capital management, knowledge management, and organizational resilience has demonstrated a profound impact on improving operational efficiencies, fostering innovation, and ensuring the continuity and success of the hotel in the face of challenges. This research confirms that AI is not merely a technological advancement but a strategic tool that can transform the hospitality industry by enhancing the capabilities of human capital, optimizing knowledge management processes, and bolstering organizational resilience. The findings from this study offer valuable insights and practical implications for hospitality organizations considering AI integration, highlighting the potential of AI to provide a competitive edge in an increasingly dynamic and complex industry environment.

Given the transformative potential of AI demonstrated in this study, it is imperative for hospitality leaders to embrace AI technologies as part of their strategic planning. By doing so, they can enhance the quality of service, improve operational efficiency, and ensure organizational resilience, thereby securing a sustainable competitive advantage in the hospitality sector.

Continued investigation into AI's enduring effects within varied hospitality settings is imperative, aiming to surmount this study's constraints and broaden insights into AI's capacity for fostering enduring organizational development and resilience. This pursuit should illuminate unresolved inquiries and domains needing deeper inquiry, thereby steering future scholarly endeavors and enriching the field's evolving discourse on AI's strategic significance.

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Theoretical Approach of the Contribution of Artificial Intelligence Systems in Value Creation in the B2C Sales Funnel

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Abstract. Artificial intelligence (AI) is a relevant solution for optimizing performance and improving the effectiveness of decision-making. This paper examines the significant potential of artificial intelligence in developing business performance. AI systems can transform large amounts of data into information to create and manage a better understanding of the sales process involved in B2C. With AI, the sales process, which previously relied on the sales force, can be significantly modified.

A review of the different phases of the sales process or sales funnel in B2C is provided, showing what the AI system has changed from the traditional sales process in B2C sales. Although the available literature addresses this topic in different contexts, the literature review in this paper focuses primarily on the contribution that an AI system can make to business performance through value creation.

Keywords: B2C Sales Funnel · AI System · Value Creation · Performance

1 Introduction

The new business challenges are driven by connected ecosystems, where data-driven decision-making is decisive for the success of strategies (J.R.Saura, 2021).According to experts, the coming decades will be marked by the fourth industrial revolution, which will be fuelled by digitalization, information and communication technologies, machine learning, robotics and artificial intelligence (N. Syama, A. Sharma, 2018). This will be fuelled by digitalization, information and communication technologies, machine learning, robotics and artificial intelligence (N. Syama, A. Sharma, 2018). The growth of e-commerce has led to the study of the customer journey, which is the series of actions a customer undertakes to reach the point of purchase (Lemon and Verhoef, 2016). Online information channels provide a variety of relevant information (Shankar et al., 2011) that significantly influence purchase decisions (Batra and Keller, 2016; Li and Kannan, 2014). The development of new technologies has given consumers more power and changed their relationship with companies (Cova, 2008).

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Consumers are now freer, more involved in their own consumption (Firat and Dholakia, 2006), and co-creators of value (Prahalad and Ramaswamy, 2004; Lusch and Vargo, 2006). Several types of value enrich the consumer experience, which is consolidated through the use of new technologies: functional, monetary, informational, emotional and social (Gonzalez et al., 2012).Manufacturing companies can develop AI capabilities and innovate in their business models to evolve AI in digital servitization (D. Sjodin et al., 2021). Given the value of AI systems in the B2C sales process, for each stage of the process, also known as the sales funnel (Syam & Sharma, 2018), we will summarize in a table how AI systems create value for the company and the buyer at each stage of the B2C sales funnel. We will introduce the concept of an AI system and how AI influences the sales process through the B2C sales funnel.

2 AI System: Literature Revue

One of the most popular definitions of artificial intelligence is that of John McCarthy: "AI characterizes the development of computer programs capable of performing tasks typically performed by humans, because they require learning, memory organization and reasoning. The aim is to transmit to a machine the functions of living beings: rationality, reasoning, memory and perception" (Jean Gabriel Ganascia, 2017). Marvin Lee Minsky, in his book Steps Toward Artificial Intelligence (1961), gives the following definition of artificial intelligence: "the construction of computer programs that engage in tasks that, for the time being, are best performed by humans because they require high-level mental processes such as perceptual learning, memory organization, and critical reasoning".

Research at the intersection of artificial intelligence (AI) and marketing calls for further exploration of AI-related topics and their roles in marketing (Davenport et al., 2020, Kumar et al., 2019). In this spirit, an understanding of AI as "informational agents that act intelligently" (Poole and Mackworth, 2010) is adopted.

Today's AI systems are information systems that act rationally given what they know. In other words, the performance of an AI system is not measured in terms of its conformity to human intelligence, but rather in terms of an ideal performance called rationality (Gershman et al., 2015, Paschen et al., 2019, Russell, 1997, Russell and Norvig, 2016, Tecuci, 2012). AI systems thus help solve problems to achieve the best-expected result.

Any AI system can be explained using a common input-process-output model: AI information systems require data from their environment (inputs), manipulate that data to create value (process), and return the information (outputs) to the environment (Paschen et al., 2019).

Data is necessary for any AI information system to fuel its transformation from input to output through a process.

2.1 Input

The development of any AI system based on a statistical learning algorithm requires the establishment of a reliable training database that is representative of the intended field of application. This statistical exploration process involves data acquisition, verification, analysis, preparation, cleaning, enrichment and secure archiving. It is essential for the development of a high-performance, robust and resilient AI system that controls potential biases. Advanced skills and experience in statistics are needed to create new functionalities adapted to the objective, track and manage missing data through imputation, identify anomalies or atypical values (outliers), and deal with sources of bias such as under-represented classes or groups and systemic bias (P. Besse, 2021).

Data are values that describe an element or a person in terms of qualitative or quantitative variables. However, it is only when data is analyzed and processed that it becomes useful for decision-making (Bellinger, Castro, & Mills, 2004). Currently, around 80% of data is unstructured and is growing 15 times faster than structured data (Rizkallah, 2017; Nair & Narayanan, 2012). The variety of data that characterizes big data incorporates its form (structured, unstructured or mixed) and time, as new data streams arrive, some disappear or are updated over time. Each company must therefore create its own big data model to collect and analyze relevant data and exclude sources whose reliability has not been verified.

Information comes in two forms: structured and unstructured. Structured data includes standardized numerical sets, such as website statistics, sales history, order forms, etc. Unstructured data is non-numerical and multiform, such as text, audio or images, and includes social media posts, customer phone calls, etc. This data comes from various sources, such as customer service, websites, social media, mobile applications and satisfaction surveys, and is processed by algorithms to produce analyses that help improve decision-making (Thomas Burn 2022).

2.2 Process

Marketing channels are a critical aspect of ensuring effectiveness, and many researchers acknowledge the potential for improvement through AI technologies and applications such as voice assistants and robots (Bock et al., 2020; Wirtz et al., 2018). AI has the capacity to collect and correctly interpret data, learn from it, and use it intelligently (Kaplan & Haenlein, 2019), which depends on technological catalysts such as machine learning, deep learning, and neural networks (among others).

Data analysis relies on two main approaches: business intelligence and data science. Business intelligence produces performance indicators, dashboards, and reports based on past data from internal company systems, which are then grouped according to predefined data models in data warehouses. However, unstructured content is not exploited by business intelligence. In contrast, data science uses predictive models, mathematical optimization, and statistical analysis tools to make simulations and predictive hypotheses, requiring expensive computing infrastructure. Data science is potentially value-creating for the user (M.O. Charaudeau, 2015).

AI information systems are capable of processing not only structured data but also unstructured data in a value-creating way that distinguishes them from traditional information systems. The three main processes of AI are problem-solving, reasoning, and machine learning. The first two processes define the problem that AI must solve and how to approach the analysis, while the third process, machine learning, allows AI to improve its performance without being explicitly programmed to do so by humans (Paschen et al., 2019; Russell and Norvig, 2016; Tecuci, 2012).

There are three types of machine learning: supervised, unsupervised, and reinforcement learning. Supervised learning involves the AI system receiving sets of data, including correct inputs and outputs, from which it learns patterns and develops rules to apply to future instances of the same problem. This type of learning corresponds to a set of input variables and an output variable. Gareth, Witten, Hastie, and Tibshirani (Gareth et al., 2013). Define supervised learning as "constructing a statistical model for [...] predicting or estimating an output based on one or more inputs." In this sense, for a set of explanatory variables in the data set, the correct value of the explained variable is provided to the computer. In other words, in supervised learning, an output variable corresponds to a set of input variables. OLS regression is one of the most traditional and common techniques used in supervised learning, in which output variables (Y) correspond to a set of input variables (Xs).

Unsupervised Machine Learning involves inputs without supervised outputs, according to Gareth et al. (2013). The computer employs unlabeled training data and aims to identify patterns or relationships among the data. Clustering analysis is a common and traditional technique with no well-specified output variable.

One notable advantage of many Machine Learning tools, both supervised and unsupervised, is their lack of a priori restrictive assumptions about data, which reduces the risk of using inappropriate statistical techniques. Machine Learning is superior to traditional statistical techniques for predictions because it accounts for nonlinear and complex relationships between inputs and outputs (Syama & Sharma, 2018). However, Machine Learning models are less interpretable than traditional models, as they discover complex, unmodeled relationships.

Both supervised and unsupervised approaches require massive amounts of data and high computing power to be effective (Syama & Sharma, 2018).

Reinforcement Learning differs from Supervised Learning in that it is an AI system that learns from its own experience, balancing exploration of unexplored data territories and exploitation of current knowledge based on past experiences (Kaelbling, Littman, & Moore, 1996). For instance, AI-based marketing systems must adapt and learn from new events and circumstances as customer behavior changes (Rust, 2020).

2.3 Outputs

This is the third component of an AI system. The General Data Protection Regulation requires the controller to use appropriate mathematical or statistical procedures for profiling purposes. They must also apply technical and organizational measures to correct errors in personal data and minimize the risk of such errors. Additionally, personal data should be secured in a manner that considers the risks to the rights and freedoms of the data subject and prevents discriminatory effects based on certain categories. Automated decision-making and profiling based on particular categories of personal data are allowed only under specific conditions.

The information resulting from value-creation processes feeds various business applications (Paschen et al., 2019, Tecuci 2012). These pieces of information may require additional actions from human decision-makers. Interpretability is the scientific community's preferred term to describe AI techniques that are easily understood (Adadi and Berrada, 2018). This term is used to describe models or algorithms rather than complete intelligent systems. Some authors define an interpretable model as one that is easy for most users to understand. In Lipton (2018), dedicated to analyzing what interpretability is, the author concludes that calling a model intrinsically interpretable is meaningless. Adadi and Berrada (2018) propose the following definition: "An interpretable system is one that a user can not only see but also study and understand how inputs are mathematically related to outputs." This definition fits well with the implicit definition described above. Gilpin et al. (2018) also propose a similar definition. Lipton (2018) and Futia and Vetrò (2020) introduce the notions of simulability and decomposability. These notions can be seen as subsets of interpretability. This is consistent with Adadi and Berrada's (2018) definition: if we can decompose or simulate a model, it implies that we can understand how inputs relate to outputs (M. Bellucci 2022).

3 The B2C Sales Funnel: Value Creation

In the first paragraph, we explored how information systems have contributed to the B2C sales funnel in relation to the traditional sales process. The sales function has undergone significant change as a result of the third industrial revolution, with the intensive use of information technology and automation. Sales management encompasses many routine tasks, such as order entry and product advertising, which consume a great deal of salespeople's time and energy. Automating these routine tasks can improve salespeople's productivity by allowing them to concentrate on the most important tasks.

D'Arco et al. (2019) suggest that understanding the customer journey is crucial to leveraging AI for a variety of purposes, such as customer profiling and CRM initiatives, ultimately improving the customer experience at every touchpoint. On this basis, Ngai et al. (2009) and Paschen et al. (2020) recognise the potential of advanced intelligent marketing systems to improve the different stages of the sales funnel, increasing the lifetime value of customers through loyalty programme promotions and personalised marketing campaigns.

The set of steps that an internet user has to go through in the sales process before conversion is called the sales funnel, which is characterized by both the product or service and the customer profile. While previous studies have focused on demographics such as age and gender (De Cicco et al., 2020), there is still little research on the relationship between culture and AI, and how cultural differences influence the adoption and use of AI. While cultural differences should be incorporated into technology acceptance models in general (Marangunic & Granic, 2015) and AI models in particular (Belanche et al., 2020), further research is needed to better understand this relationship (Božidar Vlačić, Corbo. 2021).

Customer relationship management (CRM) is a strategy aimed at establishing profitable long-term relationships with specific customers. Its importance has increased due to the realization that acquiring new customers is more costly than retaining existing ones (Ling & Yen, 2001), as well as the emergence of AI applications that create value for different stakeholders during the B2C sales process. AI can help predict which customers are most likely to respond to marketing campaigns using traditional RFM methods in conjunction with demographic and psychographic variables (Cui et al., 2012), thereby improving relationships.

To support this approach, CRM has increasingly turned to new technologies and methods (Chatterjee et al., 2019), which can help businesses effectively harness the data they collect and create more interactive customer experiences that foster relationships (Bock et al., 2020, Kaplan and Haenlein, 2019). One example is the use of machine learning models for sales, which leverage customer exposure and purchase data to identify patterns and make predictions. Traditionally, a model 'learns' from data when the parameters of a model are estimated based on data from a variety of sources, much like a jigsaw puzzle (Malthouse and Li, 2017).

Ultimately, AI plays a crucial role in transforming data into marketing information (Shah et al., 2006). The following table summarizes the contribution of AI systems to value creation in the B2C sales funnel (Table 1).

Table 1. Contribution of AI Systems in Creating Value in the B2C Sales Funnel (Created by us)

Sales funnel stages	Traditional marketing and sales tasks	Value added of AI system to traditional marketing and sales tasks	Type of content	User identity	Benefit for the customer
Attention or Awareness	Preparation Contact establishment Needs discovery Psychological discovery Addressing common sales questions	Collecting information: structured and unstructured data Predictive lead qualification	Landing page: free content Offer of quality content (blog, FAQ…)	Foreigner	Discovering commercial websites and platforms
Consideration	Providing information about products/services	Better customer profiling Data curation	Content-supported automated emails	Visitor	Access to information
Interest	Address objections Argue Rephrase	Interact with customers Dynamic pricing Targeted advertising Personalized communication	Automated emails Sales page; reassure and make prospects want to buy	Prospect	Being informed in real-time
Desire	Prepare the purchase decision	The visitor finalizes the order: Consultation/sales call/checkout Organize commercial monitoring		Customer	Ability to compare
Action	Conclude Take leave	Build long-term customer loyalty Improve brand image Create an emotional connection with customers	Discover new needs through better customer profiling	Ambassador	Taking advantage of promotions

4 AI: What Contribution to Business Performance?

The scientific literature on AI and marketing examines performance from two distinct perspective. The first focuses on the performance of AI tools and techniques compared with more conventional methods. Comparing performance is particularly important in balancing greater accuracy with the higher costs often associated with AI methods. The technological enablers of AI (Block et al., 2020) are prerequisites for its development, and they make it more efficient at making predictions by adapting to highly non-linear and complex relationships between inputs and outputs (Russell and Norvig, 2016, Syamet Sharma, 2018).

The second perspective treats performance as an outcome variable. It examines whether and how AI can contribute to sales forecasting, business performance, customer value creation and the effectiveness of competitive advantage. AI applications have been used to support customer value creation in many cases. Marketers use decision support systems to improve the effectiveness of marketing programmes by using all available databases (Kim & Street, 2004) and estimating the lifetime value of customers based on their buying behaviour (Chan & Ip, 2011).

By transforming big data into information and knowledge, companies can leverage AI by developing more effective marketing and sales strategies, often resulting in sustainable competitive advantage (Paschen et al., 2020).

Analytics has undergone major transformations with the digital revolutions, enabling businesses to achieve strategic objectives. There are three main objectives. The first objective is to optimize the way we produce and work, which leads to economic optimization in terms of costs and prices. The second objective is to identify risks, in particular financial risks, risks of loss of customers or risks of non-compliance due to the variety of rules to be applied. Finally, the third objective is to create new business opportunities through the analysis of market trends with the constant changes brought about by technology and market conditions, companies can use AI systems to develop effective B2C sales strategies by transforming the data collected into valuable information. By gaining superior knowledge about their customers, competitors and other market entities, companies can gain a competitive advantage in their B2C sales journey through data evaluation (Abrell et al. (2016), Kohli and Jaworski (1990), Slater and Naver (1995).

To stay ahead of the competition, marketers rely on data scientists to provide predictive analyses that help anticipate customer behavior and market trends. Companies can also use collected customer data to optimize their communication and promotion policies, by targeting their audience with personalized content based on the customers' preferences throughout their web journey, including their visited sites, comments or likes on publications, and followed social media accounts.

With the aid of predictive models, AI systems can also boost marketing efficiency by evaluating potential customers' buying propensities and identifying high-quality prospects, as found in studies by Järvinen and Taiminen (2016). The value of AI applications is demonstrated in the acquisition of knowledge about customers, enabling companies to map out their customers' journeys and create meaningful content for these journeys through marketing automation in B2B and B2C environments (Mero et al. (2020), Syam and Sharma (2018)

To optimize customer engagement, companies can convey their messages through more relevant channels and at the most opportune moments, such as sponsored posts on frequented social media networks, advertisements displayed on preferred sites, or on newsletters sent when the opening rate is at its highest.

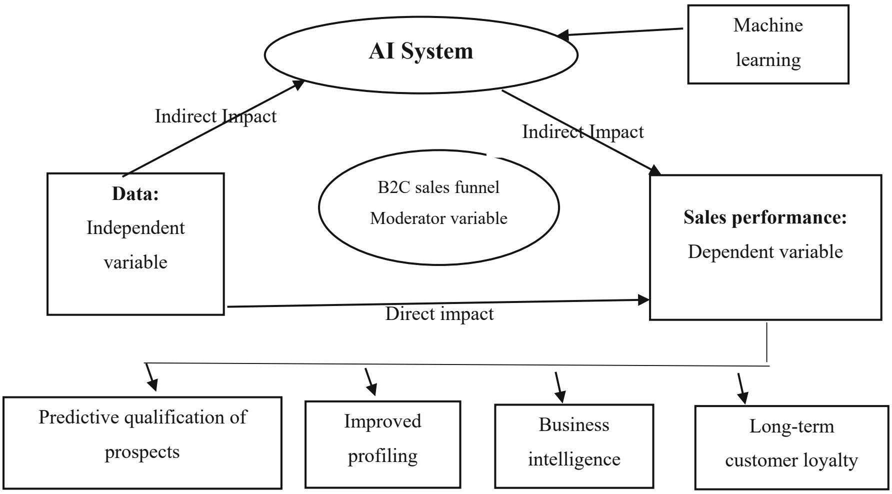

Diagram: Impact of data on B2C sales performance

(Created by us)

4.1 Data Lifecycle

The implementation of the General Data Protection Regulation (GDPR) in 2018 has significantly transformed the practices and behavior of companies when it comes to managing data, The AI Act will have a profound impact on the development and operation of Artificial Intelligence systems (AI Act, P.Besse, 2021) (Fig. 1).

Analytics and machine learning (ML) add value to the data collected. The first step is collecting data in compliance with privacy regulations, overseen by the National Commission for the Control of Personal Data Protection (CNDP) in accordance with the European General Data Protection Regulation (GDPR). This regulation applies to all Moroccan companies that process data about European citizens, including as a subcontractor, and in line with Law 09/08 relating to the protection of individuals concerning the processing of personal data (T. Burn 2022). The collected data is then utilized in analytical applications, with descriptive analytics enabling the automation of certain decisions without human intervention. The value generated from the knowledge provided by AI systems enables companies to develop business models based on outcomes, increasing flexibility and efficiency in their value chain.

In B2C, the exploitation of data involves a contract in the form of an agreement to use personal data or accept advertisements in exchange for a free service or a lower cost.

4.2 Data Value Extraction Process

The implementation of an AI approach is a multi-step process that begins with collecting, selecting, and curating data and ends with a thorough validation process.

The first step involves data curation, which includes collecting and enriching data with metadata based on predefined models. The second step involves selecting the methods that one wants to test. In the third step, the emphasis is on integration, highlighting the importance of computer skills and technological expertise. Finally, the fourth step is optimizing the learning process and validating the results (J. Paschen-M. Wilson, 2020).

The ultimate goal of a business is to create and exchange value. Traditionally, value creation was primarily based on products, which were monetized through a relationship between a customer and a supplier in a pipeline model. However, the Internet platform model, as defined by the National Digital Council, acts as an intermediary in accessing information, content, services, or goods published or provided by third parties. Beyond its technical interface, the platform organizes and prioritizes content for presentation and connection with end-users. In practice, an internet platform offers intermediation between multiple stakeholders, as well as a range of additional services. The power of this type of structure can significantly influence the economic activity of an entire market sector (Jobphoning.com). Platforms derive their value from the scope of users, and the more relationships there are, the greater the potential for distribution, known as the "network effect".

Each participant in the network is both a consumer and a provider of value. The value of data depends on how it is interpreted.

All communication actions generate new data which, when exploited, can be used to optimize future marketing campaigns. In other words, a company's actions are continually improved by exploiting the data generated.

With the help of AI systems, marketers can benefit from an in-depth understanding of customer needs, enabling them to carry out effective data analysis and organize their activities around the customer. Thus, the adoption of AI in marketing has revolutionized the job requirements of marketers and their global labor market in terms of skills (Huang & Rust, 2020).

5 Conclusion

The digital revolution in the world of B2C is causing websites and platforms to transform entire markets. The impact of analytics is significant, with the widespread use of machine learning and AI. Algorithms and models can accurately simulate and predict consumer behavior, helping to identify potential pitfalls that hinder their engagement. Consumers who make purchases are likely to browse product pages on target retailers' websites and use channels that facilitate practical and efficient search, such as search engines, third-party review sites, and comparison websites. Marketing strategy is informed and made more objective by data processed in real time as a result of mastery of the customer journey, which also makes it possible to make predictions. Decathlon, for example, ranked 10th in the 2024 list of retailers offering the best digital experiences in the 360 category in Canada, according to Léger's WOW digital study. Without data analysis, such a performance would not have been possible.

We believe that the impact of AI and machine learning on the B2C sales funnel will be significant. Our work introduces an area of research that we hope will inspire future research. These research can explore the features required by websites and technology platforms to trigger consumer engagement in a value-creating process with the business, supported by its goals, strategic brand positioning and customer profiles, in order to make the most of analytics through the AI system. Research is needed to explore the impact of AI on customer acquisition and knowledge transfer for businesses. It is also essential to explore ways to improve transparency and reduce bias, as regulations and ethical codes are not yet well developed when it comes to AI. Industry bodies and trade and professional associations can provide a degree of institutional coordination to fill existing regulatory gaps (Kshetri, 2018). The legal systems governing AI are not well developed in most countries. In general, in nascent and emerging sectors such as generative AI, there is a lack of developed networks of regulatory agencies (Kshetri & Dholakia, 2009). As a result, there are no stipulated models developed to organize the behaviors of institutional actors (Greenwood & Hinings, 1996).

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Understanding and Designing Turing Machines with Innovative Applications to Computing

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Abstract. The concept of the Turing machine originated from the work of British mathematician and logician Alan Turing in the 1930s. Turing developed the idea as part of his investigation into the foundations of mathematics and the notion of computability. The Turing machine remains a foundational concept in computer science and computational theory, influencing diverse fields such as algorithms, automata theory, complexity theory, and cryptography. Alan Turing's contributions to the theory of computation have had a profound and lasting impact on the development of modern computing. This paper aims to contribute to a better understanding of Turing machines on the development of modern computing. Furthermore, through the detailed description of specific examples of Turing machines, the reader can understand step by step the process of designing a Turing machine, which involves specifying its components and behavior to solve a particular computational problem.

Keywords: Artificial Intelligence · Turing Machines · Algorithms · Mathematical models of computation

1 Introduction

The concept of the Turing machine originated from the work of British mathematician and logician Alan Turing in the 1930s. Turing developed the idea as part of his investigation into the foundations of mathematics and the notion of computability [2, 6, 15–34]. In the early 20th century, mathematicians and logicians were grappling with foundational questions about the nature of computation and the limits of mathematical reasoning. One of the central questions was whether there existed a precise definition of what it means for a problem to be computable, or effectively solvable by a mechanical process. In 1936, the German mathematician David Hilbert posed the Entscheidungsproblem, which asked whether there exists an algorithm that can determine whether any given mathematical statement is provable within a formal system [9, 10]. This problem was central to the broader quest to formalize the foundations of mathematics. Alan Turing, then a young mathematician at the University of Cambridge, responded to the Entscheidungsproblem with his seminal paper "*On Computable Numbers, with an Application to the Entscheidungsproblem*," published in 1936 [7]. In this paper, Turing introduced the concept of

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a hypothetical computing machine that could manipulate symbols on an infinitely long tape according to a set of rules. He called this theoretical device a "universal machine," which we now know as the Turing machine [1–6]. The Turing machine consists of an infinitely long tape divided into cells, a read/write head that can move along the tape, and a control unit that dictates the machine's behavior based on the current state and the symbol being read. Turing described how such a machine could simulate any algorithmic process by following a finite set of rules, making it a fundamental concept in the theory of computation [1–14]. Turing's formulation of the Turing machine provided a precise mathematical model of computation and laid the groundwork for the development of theoretical computer science. It enabled mathematicians and computer scientists to rigorously analyze the limits of what can be computed and to develop formal definitions of computability and complexity [35–45].

2 Designing Steps of a Turing Machine

Designing a Turing machine involves specifying its components and behavior to solve a particular computational problem [19, 24]. Here's a step-by-step guide to designing a Turing machine [17–19, 25]:

1. **Define the Alphabet**: Start by defining the alphabet that the Turing machine can read from and write to its tape. This typically includes input symbols, blank symbols, and any other symbols needed for operation.
2. **Define the States**: Next, define the states of the Turing machine. States represent different configurations and behaviors of the machine. Designate a start state, one or more accept states, and one or more reject states.
3. **Define the Transition Function**: The transition function dictates how the Turing machine behaves when it reads a symbol from its tape in a particular state. It tells the machine what symbol to write, which direction to move the tape (left or right), and what state to transition to next. Each transition is defined by a triple: current state, current symbol, next state, symbol to write, and direction to move.
4. **Design the Turing Machine Logic**: Based on the problem you want the Turing machine to solve, design its transition rules. This involves determining how the machine will process the input on its tape, what conditions will lead to acceptance or rejection, and what actions it will take at each step.
5. **Handle Input and Output**: Determine how the Turing machine will handle input and produce output. This may involve specifying initial configurations of the tape, defining acceptance criteria (e.g., halting in an accept state), and specifying how the output is read from the tape.
6. **Test and Iterate**: Once you have designed the Turing machine, test it with various inputs to ensure it behaves as expected. If it doesn't, iterate on your design until it works correctly.
7. **Analyze**: Analyze the Turing machine to understand its computational capabilities. Determine its time complexity, space complexity, and the class of languages it can recognize (e.g., regular languages, context-free languages, etc.).

8. **Document the Design**: Document the Turing machine design thoroughly, including the definition of the alphabet, states, transition function, and problem-solving logic. This documentation is essential for understanding and reproducing your Turing machine's behavior.
9. **Formalize the Design** (as an available option): If a researcher works on a theoretical problem, he/she may want to formalize his/her Turing machine design using mathematical notation or formal language theory concepts. This can help clarify the design and make it easier to analyze.

3 Steps of Designing a Turing Machine Tailored to Solve a Specific Computational Problem

Designing Turing machines can be complex, especially for more intricate problems. It requires a good understanding of formal languages, automata theory, and computational complexity. By following the following steps, a researcher can design a Turing machine tailored to solve his/her specific computational problem. Whether it's recognizing a language, simulating a computation, or exploring theoretical questions, designing a Turing machine is a fundamental exercise in theoretical computer science.

Specific analysis of a Turing machine involves examining its properties, behavior, and computational capabilities in detail. Here are several aspects to consider when conducting a specific analysis of a Turing machine:

1. **Language Recognition**: Determine which languages the Turing machine can recognize. This involves analyzing its transition rules to see if it halts and accepts inputs from a given language while rejecting inputs not in the language. Consider the class of languages recognized by the Turing machine, such as regular languages, context-free languages, recursively enumerable languages, etc.
2. **Decidability**: Investigate whether the Turing machine can decide certain languages. A Turing machine decides a language if it halts and correctly determines whether each input is in the language or not. Analyze the Turing machine's transition rules to see if it always halts on all inputs and makes the correct decision for each input.
3. **Time Complexity**: Analyze the time complexity of the Turing machine. Determine the maximum number of steps it takes to halt on any input of a given size. Classify the Turing machine's time complexity, such as polynomial time, exponential time, or undecidable time.
4. **Space Complexity**: Examine the space complexity of the Turing machine. Determine the maximum number of tape cells it uses during computation on any input of a given size. Classify the Turing machine's space complexity, such as polynomial space, exponential space, or undecidable space.
5. **Computational Classes**: Investigate which computational classes the Turing machine belongs to. Determine if it can recognize regular languages, context-free languages, recursively enumerable languages, or other classes of languages. Consider how the Turing machine's computational power compares to other computational models, such as finite automata, pushdown automata, or other variants of Turing machines. Turing machines are used to define various computational classes, such as: (i) *Regular languages*: Recognizable by finite automata, which are a type of Turing machine with

limited memory, (ii) *Context-free languages*: Recognizable by pushdown automata, which are Turing machines augmented with a stack, (iii) *Decidable languages*: Recognizable by Turing machines that always halt and decide whether an input is in the language or not, (iv) *Undecidable languages*: There are languages that no Turing machine can decide, such as the halting problem.

6. **Halting Problem**: Consider whether the Turing machine can solve the halting problem. The halting problem is the problem of determining, given a description of a Turing machine and an input, whether the Turing machine will eventually halt on that input. Analyze the Turing machine's behavior to see if it can correctly solve the halting problem for all inputs.
7. **Reductions**: Explore whether the Turing machine can be used to reduce one computational problem to another. A reduction is a technique for showing that one problem is at least as hard as another. Analyze the Turing machine's transition rules to see if it can be used to transform instances of one problem into instances of another problem in a computationally equivalent way.
8. **Experimental Validation**: Experimentally validate the Turing machine's behavior and performance using simulation or implementation on physical or virtual platforms. Test the Turing machine with various inputs to ensure it behaves as expected and produces correct results.

4 Experimental Validation of Turing Machines

Experimental validation of Turing machines involves testing their behavior and performance using practical methods, often through simulation or implementation on physical or virtual platforms [25]. Specifically, we experimentally validate Turing machines as it described below:

1. **Simulation**: Use software tools to simulate the behavior of the Turing machine on various inputs. There are many Turing machine simulators available online, allowing you to input the machine's description, initial tape contents, and observe its execution step by step. By running simulations with different inputs, you can validate the correctness and efficiency of the Turing machine's design.
2. **Implementation**: Implement the Turing machine on a physical device or in a programming language. While it may be impractical to build a physical Turing machine due to its infinite tape, you can create a simulated Turing machine using a programming language like Python, Java, or C++. Implement the machine's transition function, tape operations, and state transitions according to your design. Then, test it with various inputs to validate its behavior.
3. **Benchmarking**: Compare the performance of your Turing machine implementation with other computational models or algorithms solving the same problem. Measure factors such as execution time, memory usage, and scalability to assess the efficiency of your Turing machine design. Benchmarking helps determine whether your Turing machine provides practical advantages over alternative approaches.

5 Examples of Turing Machines

Paradigm 1: The machine - α_i (i = 0,1, …, n)

$$\alpha_i := \begin{bmatrix} 0 & a0 & \alpha i & 0 \\ 0 & a1 & \alpha i & 0 \\ \cdots & \cdots & \cdots & \cdots \\ 0 & ai & s & 0 \\ \cdots & \cdots & \cdots & \cdots \\ 0 & an & \alpha i & 0 \end{bmatrix}$$

If this machine is set to a writing function f and to a position v, it stops to the string αi after 0–1 steps, if f (v) = αi . In other words, the machine - αi sets to the v position the string αi . Therefore, the new write of the tape differs from the previous write by maximum 1 step to the v position.

Paradigm 2: Let A be the alphabet, where A_0 = { * , 1 }, and * = the null sign. Also, we have the following three Turing machines (see also Fig. 1, Fig. 2 and Fig. 3):

$$M_1(A_0) = \begin{bmatrix} 0 & * & \mid & 0 \\ 0 & \mid & r & 1 \\ 1 & * & s & 1 \\ 1 & \mid & s & \mid \end{bmatrix}, M_2(A_0) = \begin{bmatrix} 0 & * & \mid & 2 \\ 0 & \mid & \ell & 1 \\ 1 & * & s & 1 \\ 1 & \mid & \ell & 0 \\ 2 & * & s & 2 \\ 2 & \mid & s & 2 \end{bmatrix}, M_3(A_0) = \begin{bmatrix} 0 & * & \mid & 0 \\ 0 & \mid & r & 1 \\ 1 & * & r & 0 \\ 1 & \mid & s & 0 \end{bmatrix}$$

We are going to examine each of the tree machines separately.

For the case: $\mathbf{M_1}$ **(A)**

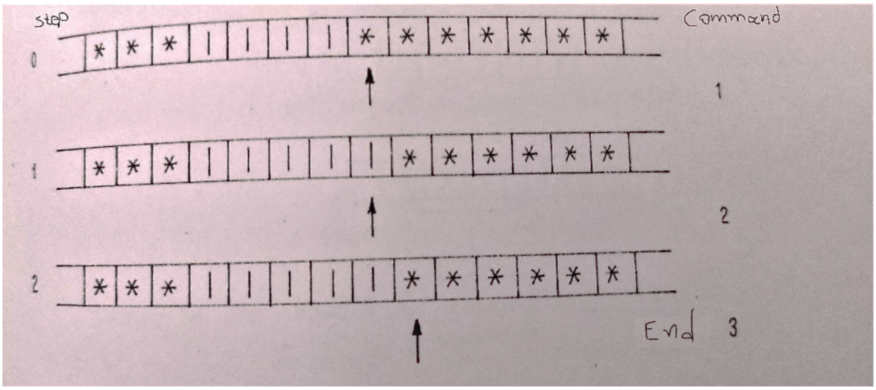

Fig. 1. Computer tape – M1(A)

According to Fig. 5 we add | to the next right field. Therefore, if we consider that upon the computer tape it is written a natural number v in the i- system, then in the end there is the natural number v + 1 (here 0 = |, 1 = ||, 2= |||, etc.) Also, because the final result depends on the initial position of the tape head, we come up to the conclusion that the machine is not enough effective to prove the computability by Turing of the function N (v) = v + 1.

For the case: **M_2 (A_0), w = ||| (= 3 odd number)** (see Fig. 2)

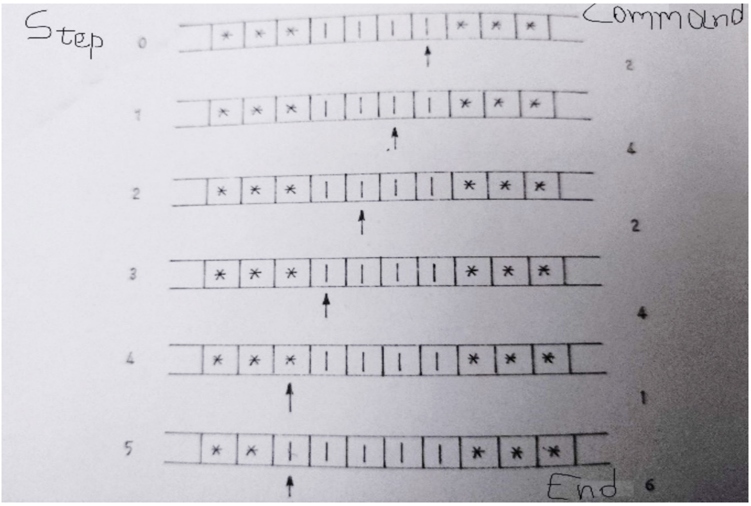

Fig. 2. Computer tape – M2 (A0), w = |||

For the case: **M_3 (A_0)** (see Fig. 3):

Fig. 3. Computer tape – M3 (A0)

6 Synthesis of Turing Machines

It is obvious that for complex problems, to construct a Turing Machine for each problem it is not an easy task [15–19, 25]. Therefore, an option is to handle a complex problem by dividing it to simpler problems that can be solved more easily. Our approach is to handle the issue of creating complex machines, by constructing simpler ones. For the synthesis of Turing Machines, we will use the concept of diagrams [19–25].

Every diagram represents a class of equivalent Turing machines. Therefore, the next step is to define a method for the construction of each element of a class of Turing machines, with the use of a diagram that represents each Turing machine.

Let the alphabet A = { a0, a1, …, an }, (a0 = * = the null sign)

We consider a finite set of points $\sum$ = { s0, s1, …, sn}, where m ≥ 1. The points si, i = 1(1)m can be connected as a pair with oriented paths. Each path starts with a point si and finishes to another point sj, and is identified by a number $\vartheta \in$ { 0, 1, 2, …, n}.

Symbolism: $d_{si,sj,\theta}$ or $s_i \xrightarrow{\theta} s_j$

Constraint: From every point s_i starts one path with the number ϑ.

The total number of paths is represented by Δ. One specific point among the s_i is considered as the *initial point* and symbolized by S_a, with the constraint that there is only one point in which no path ends to it.

We consider now a finite set of Turing machines *{ M_1 (A), …, M_r(A) }* and *f:* $\sum \rightarrow$ *{ M_1 (A), …, M_r(A)}* with the constraint that all the states of the matrices of machines $f(s_i)$ to be chosen, so that the matrices that correspond to different s_i, do not contain the same states. With the representation *f:* $\sum \rightarrow$ *{ M_1 (A), …, M_r(A)}* the paths $s_i \xrightarrow{\theta} s_j$ will be represented as or $f(s_i) \xrightarrow{\theta} f(s_j)$ and the total number of paths will be represented by Δ^f. The machine $f(s_0)$ will be called as *initial* and will be presented with while all other machines will be presented with .

After the above-mentioned detailed description, we call as *diagram* the set D = Δ^f U f($\sum$).

Symbolisms: The total number of paths { $d_{i,j,\theta}$, ϑ = 0 (1) n} will be represented as $d_{i,j,}$ or $s_i \rightarrow s_j$. Also, the set { $d_{i,j,\theta}$, ϑ = 0 (1) n, $\vartheta \neq$ k} will be represented as $d_{i,j,\theta \neq k}$.or $s_{i\ \theta \neq k} \rightarrow s_j$. In addition, expressions like $M_1 \rightarrow M_2$ will be written as M_1M_2 etc., where:

$$M_0 = \begin{bmatrix} 0 & a0 & s & 0 \\ 0 & a1 & s & 0 \\ \ldots & \ldots & \ldots & \ldots \\ 0 & an & s & 0 \end{bmatrix}$$

Paradigm 3: If M_1, M_2, M_3 and $\sum$ = {s1, s2, s3, s4}

and f: s1→ M1 s1 = sa

f: s2 → M1.

f: s3 → M2.

f: s4 → M3.

$\Delta = \{d_{1,2,1}, d_{1,2,2}, d_{1,3,1}, d_{2,3,2}, d_{3,4,2}, d_{3,4,3}\}$.

The **final diagram D =** Δ^f U f($\sum$) will be the following (see Fig. 4):

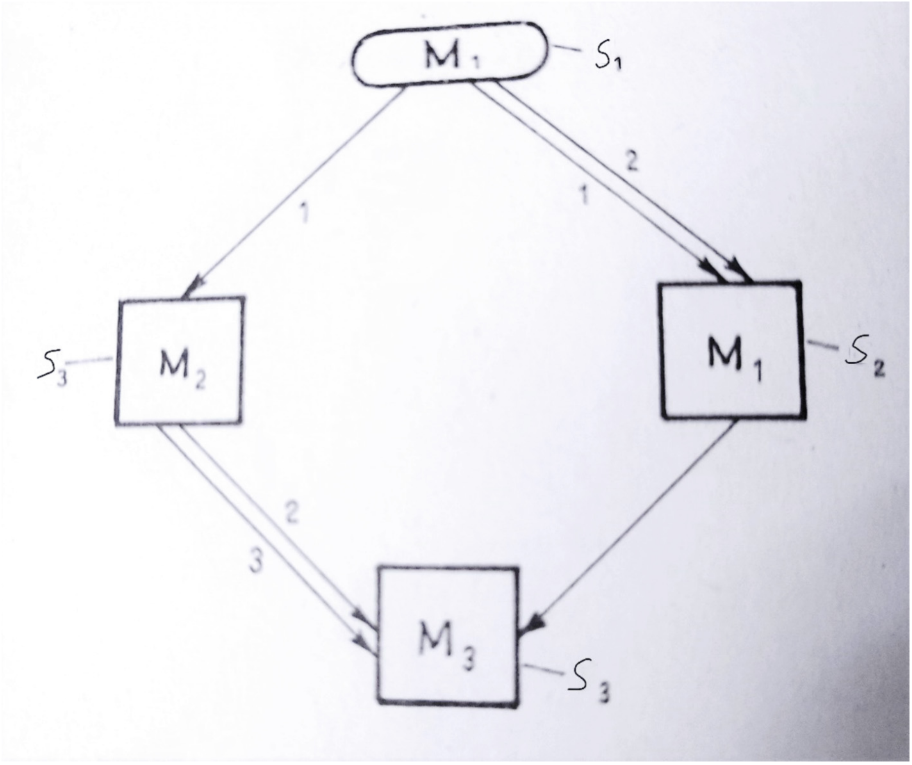

Fig. 4. Final diagram

7 Development of an M Element of a Turing Machine Class

The diagram **D = Δ f U f(∑)** sets a class of equivalent Turing Machines. This class is a class of equivalent matrices. Next, we describe a method of creating an M matrix from the class of equivalent matrices.

Step 1. A random order of a finite set of points ∑ = { sn1, sn2, …, snm } where sn1 = sa

Step 2. We consider the matrix $\begin{bmatrix} f(sa) \\ f(sn1) \\ \vdots \\ f(snm) \end{bmatrix}$.

Step 3. From the above-mentioned matrix of the Step 2 we consider the M matrix: df(si), f(sj), $\ell \in \Delta^{f}$ and replace each row of the matrix f(si) of the type k a ℓ s k′ with the equivalent row of the type k a ℓ a ℓ^{k} f(sj).

With the step3 there is a transition from the final state of f(s_i) to the initial state of f(s_j). We notice that in every order of the set of points S (see Step 1) is uniquely determined an M machine. These machines are of the same type.

Implementation: Let the A = {*, |}

$M_1 = a_0 = *$
$M_2 = r$
$S = \{ s1, s2, s3\}$ with $s1 = sa$,
$\Delta = \{ d_{1,2,1}, d_{1,3,0}, d_{3,2,0}, d_{3,2,1}\}$.
f: $f(s1) = *$
$f(s_2) = r$
$f(s_3) = *$

Then, if we see the following figure (see Fig. 5) we can notice the value of **D** that is the following:

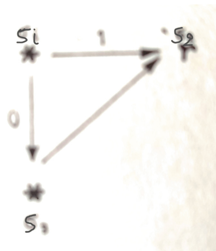

Fig. 5. **D** value

We have chosen $f(s_1) = *$ as the state 0, $f(s_2) = r$ as the states 1 and 2 and $f(s_3) = *$ as the state 3.

Step 1. We have the order s1, s2, s3.

Step2. $$\begin{bmatrix} f(s1) \\ f(s2) \\ f(s3) \end{bmatrix} = \begin{array}{l} 0 * s\ 0 \\ 0 \mid *\ 0 \\ 1 * r\ 2 \\ 1 \mid \mathrm{r}\ 2 \\ 2 * s\ 2 \\ 2 \mid s\ 2 \\ 3 * s\ 3 \\ 3 \mid *\ 3 \end{array}$$

Step 3.A. Because $d_{f(s1),\, f(s2),\, 1} \in \Delta^f$, we replace the row k | s k′ of f(s1) which in our case does not exist, so there is no replacement of the row.

B. Because $d_{f(s1),\, f(s2),\, 0} \in \Delta^f$ we replace the row 0 * s 0 of f(s1), with the row: 0 * * 1.

C. Because $d_{f(s3),\, f(s2),\, 0} \in \Delta^f$ we replace the row 3 * s 3 of f(s3), with the row: 3 * * 1.

D. Because $d_{f(s3),\, f(s2),\, 1} \in \Delta^f$ we replace the row k | s k′ of f(s3), which in our case does not exist, so there is no replacement of the row.

Thus, we have the final matrix:

$$M = \begin{bmatrix} 0 * * 1 \\ 0 \mid * 0 \\ 1 * r\ 2 \\ 1 \mid r\ 2 \\ 2 * s\ 2 \\ 2 \mid \mathrm{s}\ 2 \\ 3 * * 1 \\ 3 \mid * 3 \end{bmatrix}$$

8 Conclusions and Future Work

Turing machines have had significant outcomes and impacts on various fields, including mathematics, computer science, and philosophy. Here are some key outcomes:(i) *Foundation of Computer Science*: Turing machines are foundational to the field of computer science. They provide a theoretical framework for understanding computation, algorithms, and the limits of what can be computed. Turing machines have inspired the development of programming languages, compiler theory, and the design of modern computers, (ii) *Computability Theory*: Turing machines are central to computability theory, which studies the notion of computability and the limits of algorithmic computation. They help formalize the concept of an algorithm and provide a precise definition of what it means for a problem to be computable. Turing's work laid the foundation for proving the existence of undecidable problems, such as the halting problem, (iii) *Complexity Theory*: Turing machines are used to analyze the complexity of computational problems. Complexity theory studies the resources (such as time and space) required to solve computational problems and classifies problems based on their difficulty. Turing machines are instrumental in defining complexity classes and understanding the relationships between different classes of problems, (iv) *Philosophical Implications*: Turing machines have profound philosophical implications, particularly regarding the nature of mind and intelligence. Turing's concept of the "universal machine" suggested that any physical process that could be simulated by a Turing machine is, in principle, computable. This led to discussions about artificial intelligence, consciousness, and the limits of computational modeling, (v) *Mathematical Logic*: Turing machines have influenced the study of mathematical logic and the foundations of mathematics. They provide a formal framework for reasoning about computability and provability within mathematical systems. Turing's work on the Entscheidungsproblem and the concept of computable numbers stimulated further research into the limits of formal systems and the nature of mathematical truth, (vi) *Cryptanalysis and Security*: Turing's work during World War II on breaking the German Enigma machine played a crucial role in the development of modern cryptography and cryptanalysis. His insights into algorithmic methods for code-breaking laid the groundwork for modern approaches to cybersecurity and information security. Future studies aim to study in depth the Turing completeness, that means a computational system that can compute every Turing-computable function.

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Genomic Insights Revealed: Multiclass DNA Sequence Classification Using Optimized Naive Bayes Modeling

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Abstract. In this studies paper, we explore the use of Naive Bayes modeling to categorise multiclass DNA sequences, in particular that specialize in human, chimpanzee, and canine genomes. With the substantial quantity of genomic facts available, it's miles vital to have accurate techniques for species identification in both natural research and other fields. Our observe makes use of a complete technique that includes k-mer extraction and vectorization the usage of CountVectorizer, along with a rigorous hyperparameter tuning method for the Naive Bayes model. We inspect the suitability of Naive Bayes in studying genomic statistics and its capacity to find the pattern of DNA sequences. To set the basis for our assessment, we very well take a look at the dataset, which include preprocessing steps and function extraction. With the massive amount of genomic data to be had, it's far crucial to have accurate techniques for species identification in every natural studies and different fields. The fine-tuned Naive Bayes model achieve exceptional accuracy of 99% in classifying multiclass DNA sequences. Therefore, in this research paper, we find out the usage of Naive Bayes modeling to categorise multiclass DNA sequences, particularly focusing on human, chimpanzee, and dog genomes.

Keywords: Genome Analysis · Naive Bayes Model · Multiclass Classification · DNA Sequences · Genomic Insights

1 Introduction

Advancements in genomics have ushered in an generation of remarkable records availability, supplying a wealth of statistics encoded within DNA sequences. The capability to correctly classify genomic statistics into wonderful species categories is essential for knowledge evolutionary relationships, uncovering genetic versions, and aiding in clinical studies. This paper explores the potential of Naive Bayes modelling in the context of multiclass DNA sequences, primarily focusing on the genomes of humans, chimpanzees, and dogs. Genomic study aims to understand the numerous biological components of

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lifestyles [5, 6]. The amount of genetic data is increasing at an exponential rate, so developing reliable computational techniques for species identification is essential. Multiclass DNA sequence classification is a difficult problem for which machine learning may provide insightful solutions (Naive Bayes modelling). Events are analysed and patterns in genetic records are searched after using probabilistic Naive Bayes. It has been effectively utilised in a multitude of applications [7].

The significance of this paper lies in its capacity contributions to both the fields of genomics and machine learning. Successful implementation of Naive Bayes for multiclass DNA collection class could provide an effective device for researchers and practitioners, facilitating accurate species identity. Such improvements ought to cause breakthroughs in information evolutionary relationships, figuring out disorder markers, and enhancing personalized remedy [8, 9]. This studies aims to address the question of whether or not Naive Bayes modeling can efficaciously classify multiclass DNA sequences, specially those representing human, chimpanzee, and canine genomes. The investigation involves a complete analysis, such as the extraction of k-mers and the application of CountVectorizer to transform DNA sequences into an appropriate format for machine learning model [10]. The study will interpret the findings, addressing the consequences for genomics and the wider clinical network. Finally, the paper will conclude by summarizing key insights and proposing avenues for future studies within the dynamic intersection of genomics.

Objectives:

a. To assess the suitability of Naive Bayes modeling for the classification of multiclass genomic data.
b. To explore the impact of hyperparameter tuning on the performance of Naive Bayes in genomic sequence classification.
c. To evaluate the model's accuracy, precision, recall, and other performance metrics through extensive visualizations and analysis.

2 Literature Review

Hamed et al. present pattern-matching and machine learning DNA sequence categorization. This model swiftly and accurately classifies DNA sequences by properties. Multiple machine learning methods are used to test the model, and the SVM linear classifier has the highest accuracy and F1 score. The model appears to outperform DNA sequence categorization. The suggested model is more accurate and efficient than FLPM and PAPM. The author study algorithm accuracy and temporal complexity with pattern length. The data imply pattern length affects algorithm speed. For pattern length 5, SVM Linear and EFLPM perform quickest at 0.0035 s. The lowest SVM linear execution time for 25 patterns is 0.0012 s. The model's experiments show SVM Linear's highest accuracy and F1 score. SVM Linear classified DNA sequences best with 0.963 accuracy and 0.97 F1. With 0.838 accuracy and 0.94 F1, Naive Bayes excels. New pre-processing and feature extraction improve DNA sequence analysis in the proposed model. The technology could improve drug discovery, tailored treatment, and disease diagnostics. The study found that pattern length impacts DNA sequence classification algorithm accuracy and time complexity [1].

In the last decade, machine learning has excelled at identifying novel features and non-linear connections in EHR data. Machine learning improves data management with maximum predictor variables relative to observations during data mining prediction. EHR data quality challenges include misclassification, missingness, and measurement mistakes. Ensemble categorization systems are necessary to prevent EHR data quality concerns. Before mining, data sources like EHR include sensitive information that must be secured. The sensitive EHR data must be buried without changing the dataset to maintain the ensemble classification mechanism's prediction accuracy. Improved Sensitivity Drift-based k-Anonymized Data Perturbation Scheme (ISD-k-ADP) randomly perturbs dataset data with limited noise to hide EHR data in the paper of Kaladev et al. Before categorization, the Sensitivity Drift is carefully calculated to determine the predicted privacy level and the amount of noise contained. This ISD-k-ADP approach is reliable because it avoids hidden data from affecting Two Stage Bagging Pruning-based Ensemble Classification. TSBP-EC employs distance and accuracy-based pruning to minimize ensemble size for efficient machine learning categorization. Classification Accuracy, Precision, Recall, and Kappa Statistic show that the suggested ISD-k-ADP-TSBP-EC scheme outperforms traditional schemes [2].

Mammalian cancer and cardiac issues include DNA methylation. Scholars have explored machine learning and deep learning to classify DNA methylation for years. Zheng et al. investigations focused on encoding and rarely employed deep neural networks for predictions. Zheng et al. study proposes a random masking and adversarial sample production technique. This novel categorization model predicts with CNN, Bi-LSTM, and attention. Benchmark indicates framework's automation and advancement in binarily classifying DNA methylation. Ablation experiments demonstrate random masking and adversarial sample production. Zheng et al. in the model predicted multi-species N4-methylcytosine, 5-methylcytosine, and N6-methyladenine sites most accurately (85.07%, 94.97%, and 92.17%). The MaskDNA-PGD model outperforms two other methods using the same datasets and indices [3].

Many applications are adopting SVMs, a complex classification technology. Because it can tolerate model assumption violations and outliers. Classification of non-linear data patterns benefit from kernel-based SVMs. Because kernel-based methods require longer to train data, they may be computationally challenging. This processing time increase is largely due to quadratic optimization kernels. Chatrabgoun et al. use a low-rank approximation to fit a shorter Mercer series to the kernels to reduce computing cost [4]. A simpler optimization problem will replace kernel-based SVM's quadratic problem. The method will expedite vector computations and matrix decompositions, resolving QOPs faster and boosting classification efficiency. They end with numerical examples using ROC curves and other classification performance benchmarks to evaluate the SVM structure's low-rank kernel approximation. Computing time to train and forecast the S&P 500 index and DNA promoter recognition has decreased, improving classification efficiency (Table 1).

Table 1. Gap and aim of the paper. This table outlines specific gaps in the existing literature and articulates the corresponding research aims of your study to address these gaps

Gap in the Literature	Research Aim to Address Gap
Limited application of Naive Bayes in genomics	Assess the suitability of Naive Bayes for multiclass classification of DNA sequences
Sparse exploration of hyperparameter tuning for genomic data	Investigate the impact of hyperparameter tuning on Naive Bayes performance in genomics
Insufficient focus on multiclass DNA sequence classification	Develop and evaluate a Naive Bayes model for distinguishing between human, chimpanzee, and dog genomes
Lack of comprehensive visualizations for genomic data [11]	Provide extensive visualizations including dataset distribution plots, learning curves, and precision-recall curves
Limited discussion on practical applications of genomic classification	Discuss the implications of accurate genomic classification for evolutionary studies and medical research
Scarcity of studies integrating machine learning and genomics [12]	Offer insights into the integration of Naive Bayes modeling as a robust tool in the field of genomics

3 Methodology

1. **Dataset Collection and Preprocessing**

The DNA sequence dataset used in this research was sourced from Kaggle, encompassing genomic information from human, chimpanzee, and dog genomes. The integration of these diverse datasets aims to create a comprehensive and multiclass genomic dataset for training and evaluating the Naive Bayes model. This diverse collection allows for a robust assessment of the model's ability to distinguish between species. The preprocessing of the DNA sequence data plays a pivotal role in preparing it for machine learning analysis. The following steps were undertaken:

a. ***K-mer Extraction:***

- Raw DNA sequences were converted into K-mer words using the get kmers software. Here, we looked for word sequences with six characters, or hexamer words, in order to identify pertinent genetic trends.
- In addition to assisting in the conversion of the raw genomic data into a format that is suitable for machine learning, the k-mer extraction procedure also records local sequence information.

b. ***Data Transformation:***

- The 'words' column was added to the dataset, containing the k-mer representations of the original DNA sequences.

- The 'sequence' column, containing the raw DNA sequences, was dropped from the dataset as it was no longer needed for subsequent analysis.

c. ***Textual Representation:***

- The k-mer words were then transformed into textual representations, with each row in the dataset containing a space-separated string of k-mer words.
- This textual representation is essential for applying natural language processing techniques, allowing the application of machine learning algorithms such as Naive Bayes [13].

d. ***Label Extraction:***

- Obtained the class labels for each species whose DNA sequence matched in the dataset. Since the model can only comprehend and generalise patterns specific to each species with the help of these labels, they are essential for supervised learning.

In order to prepare the DNA-series dataset for the Naïve Bayes model analysis, a number of data pretreatment methods are employed. The final dataset offers a comprehensive and well-informed selection for training and evaluating the Naive Bayes model. It is composed of a mixture of DNA sequences from chimpanzees, dogs, and humans [17–24].

2. **Naive Bayes Model for Multiclass Classification**

The Naive Bayes algorithm is a probabilistic of machine learning approach broadly applied in categorization tasks, along with multiclass genomic series classification. The foundation of Naive Bayes lies in Bayes' theorem, which calculates the chance of a hypothesis primarily based on previous information.

In the context of multiclass classification, where we have classes C_1, C_2, $C_3 \ldots$, C_k, the probability of a class given an input feature vector X is computed using Bayes' theorem:

$$P(C_i|X) = \frac{P(X|C_i).P(C_i)}{P(X)}$$

where:

- $P(C_i|X)$ is the posterior probability of class C_i given the feature vector X.
- $P(X|C_i)$ is the likelihood of observing feature vector X given class C_i.
- $P(C_i)$ is the prior probability of class C_i.
- $P(X)$ is the probability of observing feature vector X, which acts as a normalization constant.

The "naive" assumption in Naive Bayes is that features are conditionally independent given the class label. Mathematically, this simplifies the likelihood term:

$$\mathrm{P}(X|C_i) = P(x_1|C_i) \cdot P(x_2|C_i) \cdot P(x_3|C_i) \ldots\ldots\ldots\ldots \cdot P(x_n|C_i)$$

where $x_1, x_2, x_3 \ldots, x_n$ are the features of the input vector X. This assumption significantly reduces the computational complexity and is why the method is called "naive."

Multiclass Naive Bayes:

In the case of multiclass classification, the model calculates the probability of each class and assigns

$$\hat{y} = \arg\max_{i} \mathrm{P}(C_i|X)$$

the class with the highest probability to the input sample. The decision rule is typically: where $\hat{y}$ is the predicted class label.

Parameter Estimation:

To make predictions, the model needs to estimate the parameters $P(x_i|C_j)$ and $P(C_j)$ from the training data. For example, in the case of categorical features, Laplace smoothing may be applied to handle unseen feature-class combinations:

$$P(x_i|C_j) = \frac{count\left(x_i, C_j\right) + \alpha}{count\left(C_j\right) + \alpha \cdot num\_unique\_features}$$

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$$P(x_i|C_j) = \frac{count\left(x_i, C_j\right) + \alpha}{count\left(C_j\right) + \alpha \cdot num\_unique\_features}$$

Here, α is the smoothing parameter, count(·) represents the quantity of occurrences, and num_unique_features is the range of specific features within the dataset.

This Naive Bayes model, customized for the multiclass genomic collection category, leverages these mathematical equations are expecting the species elegance of a given DNA-series based on the k-mer functions.

3. **Hyperparameter Tuning and Training**

Hyperparameter tuning is an essential section in optimizing the overall performance of the Naive Bayes model for the classification of genomic sequences. Specifically, the point of interest is on tuning the smoothing parameter (α) in the Multinomial Naive Bayes algorithm, a parameter that influence the model's ability to address unseen abilities. Grid seek, a systematic method, is initialize to discover distinct values of α and pick out the most optimal configuration. In the grid search process, a parameter grid is described with several values of α, denoted as αi, in which i takes on values from the exclusive set. The selection criterion for evaluating various hyperparameter configurations is the accuracy metric, [25–30] denoted as Accuracy(αi). The dataset is partitioned into 5 folds for pass-validation (cv = 5), ensuring sturdy evaluation across specific subsets of the dataset. The grid search process can be expressed mathematically as follows:

Grid Search: $\alpha_i \in$ values for optimal parameter

Scoring : $\mathrm{Accuracy}(\alpha_i) = \frac{\sum_{f=1}^{5} CorrectPrediction_f}{\sum_{f=1}^{5} TotalSamples_f}$, Where f denotes the fold

The optimal hyperparameter value, α_{best}, is then determined as the one that maximizes the accuracy during cross-validation:

$$\alpha_{\mathrm{best}} = \arg\max_{i} \mathrm{Accuracy}(\alpha_i)$$

Thus, the Multinomial Naive Bayes classifier is instantiated with the excellent α value, forming $NB_{\alpha_{best}}$ To improve the optimization of the model for multiclass classification, the One-vs-Rest (OvR) strategy is employed by using encapsulating $NB_{\alpha_{best}}$ in the OneVsRestClassifier. The model is then trained on the training set $X_{\text{train},}$ Y_{train}, aiming to analyze the underlying patterns within the genomic sequences. The effectiveness of the model is evaluated through its capability to the species labels of the test set X_{test}, yielding $Y_{\text{pred\_nb}}$. Therefore, the orchestrated procedure of hyperparameter tuning, model instantiation, and training ensures that the Naive Bayes model is properly optimized to the complexities of genomic series category to improve its predictive abilities [31–37].

4 Result

The Table (2) display the key conclusions from the evaluation of the Naive Bayes model for the multiclass classification of genomic sequences. Among these results are the model's training, hyperparameter adjustments, and model testing on the test set [38, 39].

Table 2. Hyperparameter Tuning Results. This table illustrates cross-validation accuracy for different values of the smoothing parameter (α) during hyperparameter tuning.

α Value	Cross-Validation Accuracy
0.001	0.87
0.01	0.90
0.1	0.95
0.5	0.99
1.0	0.96
2.0	0.94
5.0	0.88
10.0	0.86

Table 3. Selected Hyperparameter and Training Results. It displays the selected optimal α value along with the corresponding training and test accuracies.

Selected α Value	Training Accuracy	Test Accuracy
0.5	0.95	0.99

These tables (Table 2, Table 3, Table 4) collectively offer a comprehensive overview of the model's performance, from the hyperparameter tuning phase through to the evaluation on the independent test set. The selected α value demonstrates the optimal trade-

Table 4. Model Evaluation Metrics on Test Set. This table provides a comprehensive set of evaluation metrics for the Naive Bayes model on the test set, including accuracy, precision, recall, and F1 score.

Metric	Value
Accuracy	0.99
Precision	0.99
Recall	0.99
F1 Score	0.99

off between smoothing and model complexity, resulting in robust and accurate genomic sequence classification.

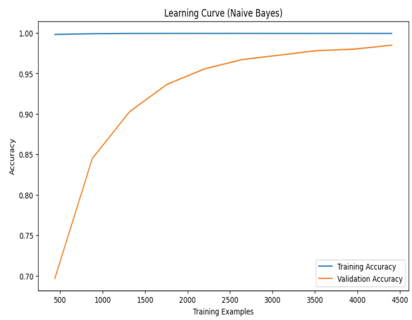

Fig. 1. Learning curve

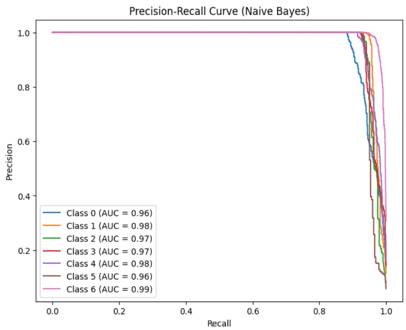

Fig. 2. Precision-recall curve

The learning curve, depicted in Fig. 1, provides a visual representation of the model's performance as the size of the training set increases. As illustrated in Table 7, the learning curve showcases the evolution of both training and validation accuracy with respect to the number of training examples. The increase in accuracy suggests that the model effectively learns from additional data, demonstrating its ability to generalize.

Figure 2 displays the precision-recall curve for each class, providing insights into the trade-off between precision and recall. Table 5 complements this visualization by presenting precision, recall, and F1 score metrics for individual classes (Human, Chimpanzee, Dog). The precision-recall curve visually captures the model's ability to discriminate between classes, with each class having its own precision-recall characteristics.

The model's performance in terms of precise and accurate predictions for each class is displayed in the confusion matrix. See Fig. 3 for an example, and Table 4 for a complete description. Examining the matrix clarifies the benefits and ability of the model and helps to recognize the discrepancy between anticipated and observed class labels. Those visualisations (see Fig. 2, Fig. 3) provide both quantitative and qualitative insights on the model's behaviour in numerous categorisation scenarios, they're essential for understanding and displaying the model's performance.

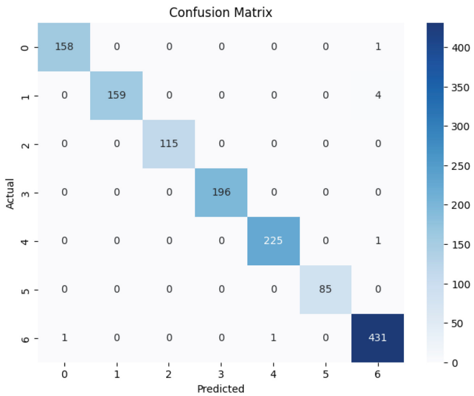

Fig. 3. Confusion Matrix

Table 5. Comparison among different models and performance analysis.

Model	Accuracy	Precision	Recall	F1 Score
Naive Bayes	0.99	0.99	0.99	0.99
Decision Tree	0.867	0.874	0.867	0.868
Random Forest	0.939	0.948	0.939	0.941
Linear SVM	0.962	0.965	0.962	0.963
Logistic Regression	0.967	0.969	0.967	0.967
K-Nearest Neighbors	0.824	0.896	0.824	0.839

5 Conclusion

This work aims to improve genome evaluation and categorization by applying Naive Bayes modelling to multiclass DNA sequences. The Naive Bayes model's hyperparameters are carefully assessed by the researchers in order to optimise it and identify the optimal balance between underfitting and overfitting. This improvement is demonstrated by the model's overall resilience and accuracy in predicting various genomic sequences. In this study, the DNA sequences of dogs, chimpanzees, and humans were classified using the Naive Bayes method. Evaluation criteria such as recall, accuracy, precision, and F1-score are employed to demonstrate the model's outstanding performance. This work successfully selects the proper multiclass type and provides empirical support for the practical application of Naive Bayes in handling the challenging genetic data interpretation challenge. One of the primary shortcomings of this research is how much emphasis it places on interpretability. A thorough understanding of the conserved and species-specific genetic traits can be gained by examining the significance ratings assigned to outstanding k-mers. Learning curves, confusion matrices, and precision-recall curves are examples of visual aids that can be used to clarify the concepts and results of the category method. Our approach aims to extract important biological implications from the results, going beyond machine learning. Finding important k-mers and looking into misclassifications can help provide additional light on the genetic sequences and similarities between humans, chimpanzees, and dogs. This link creates a relationship between the genetic impacts of computational technologies and their use. It is biologically influenced. Furthermore, a comparative evaluation conducted using other models positions the Naive Bayes approach as a strong competitor in the genomic series domain. This work shows that Naive Bayes performs better than other approaches and is particularly effective with complicated multiclass DNA sequences.

6 Application

There are a lot of practical applications for genome analysis and categorization, especially when paired with machine learning models like Naive Bayes. One example of this is the way the pharmaceutical industry analyses genetic variation data to identify novel therapeutic targets and forecast patient responses to medicine [14]. The ability of genetic analysis to develop more effective, individualised treatment plans while lowering the possibility of side effects is another advantage. Agricultural crop improvement is aided by the identification of genes encoding characteristic features, such as higher yield and drought resistance. The domains of forensic DNA profiling, species classification, treatment response prediction, and illness diagnosis provide more evidence of the advantages of machine learning [15, 16]. In addition to genomics, machine learning techniques like Naive Bayes have made it possible for researchers to glean valuable information from enormous datasets that have implications in environmental preservation, healthcare, and agriculture.

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A Netnographic Study of Moroccan Political Marketing in the Era of Digital Social Networks

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Abstract. In the era of the digital revolution, content marketing is emerging as the main and essential lever in any well-founded digital political marketing strategy. It is a recent paradigm oriented towards creating, sharing and attracting content on official political party pages on social networks to a targeted audience of Internet users-voters, in order to establish a relational dynamic through the participation of members of these virtual communities.

This study integrates a social network approach to the study of the marketing of moroccan political parties by analysing their activity on Facebook and their use of digital strategies during the pre-election and election period.

Keywords: Political marketing · Content marketing · Digital marketing · social network analysis · Netnographic approach

1 Introduction

Political marketing has delicately emerged with an important scientific production that was largely developed since the early 1990s, further refining and analyzing the concept and developing several theoretical frameworks over time. It has been initially defined as a set of techniques and means that can be used by political parties and candidates to capture the attention and voice of the electorate (Marrek 2001).

However, the concept has undergone several evolutions marked by the emergence of a growing consensus on the crucial role of social media in the conduct of electoral campaigns, which has marked the field of social and political sciences since BARACK OBAMA's election campaign in 2008, fuelling interest in how social networks could affect the success or failure of electoral campaigns.

The use of social networks is now widespread, and electronic campaigns are emerging as a field of activity and expertise in their own right, requiring completely different strategies and tools from those associated with "traditional campaigns".

As in other countries, Moroccan political parties have always used a variety of means to get citizens to support their political programs and actions, but the use of political marketing techniques is a recent phenomenon that emerged during the 2007 legislative elections, which were an important moment in the development and evolution of political communication in Morocco, Following a series of political reforms carried out since

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the early 2000s, especially in the area of human rights and public freedoms, which contributed to the opening up of the field of speech and the emergence of a political media that aims to be independent.

However, although Morocco has entered a phase of digitalization of political communication, it still lacks studies on the use of digital political marketing by both parties and political leaders (Majdi & Bachar 2022). It is in this perspective that our research problem questions the deployment of marketing by Moroccan political parties throught social networks. We will mainly focus on the most representative parties on the Moroccan political scene by seeking to know to what extent they use practices based on digital political marketing.

2 Methodology and Description of the Research Field

For more than a decade, researchers in digital political marketing have been questioning the best method to adopt for analyzing the deployment of social networks by political parties (Verville 2012; Marland & Giasson 2013; Oumarou 2020): the use of purely quantitative studies, which generally focus on electoral spending, does not always lead to precise results, while qualitative approaches pose challenges and constraints related in particular to access to information. Nevertheless, they prove to be particularly effective in carrying out a study on the subject (N.TAKADDOUMI 2021).

2.1 Research Method:

To be able to verify our research hypothesis, which assumes that "H1: The most representative Moroccan political parties in previous elections will tend more towards a marketing approach in their use of social networks" we will conduct a nethnographic study, which is considered since the rise of social networks as the preferred method to analyze virtual communities.

The nethnography which is a combination of the two words "Internet" and "Ethnography" constitutes as its name indicates an ethnographic method digitized (L. ALLA and al 2020), it can be defined as ethnography applied to the Internet. This initially qualitative method adapts ethnographic research techniques to online communications (Mercanti Guérin, 2009). This method is based on the observation of virtual communities and the study of exchanges between its members and requires a researcher to examine the activities of a given virtual community, observe the communications within that community, analyse the relationships between its members and identify the dynamics of communication and influence flows in order to identify the impact of such exchanges on the attitude of users. This study is recent and little used in Morocco (C. HAMADI AND F KHOUIAMI 2017), hence the first methodological contribution of our work. It will help us to understand the use that moroccan political parties make of social networks, especially during the election period, by integrating the official pages of political parties and party leaders as well as the virtual communities created by political parties on social networks in order to make the members of these communities adhere to the values of the party and convert them into supporters and partisans.

In this perspective, we verified the hypothesis of our research, through the analysis of political parties' activity on social networks as well as content analysis, which was privileged as the main data collection technique that would allow us to determine the degree of deployment of the marketing approach in the use of social networks by moroccan political parties. Four basic steps structured our nethnographic methodology:

- Step 1: determination of selection criteria of the moroccan political parties' pages and groups on social networks.
- Step 2: Identification and selection of communities related to moroccan political parties;
- Step 3: Observation and data collection;
- Step 4: Data analysis and interpretation of results;

The research field then focuses on the pages and groups referring to moroccan political parties to identify the use that political parties make of social networks, and the interactions observed on these official pages and groups.

2.2 Period Studied

The use of social networks by political parties has become a must for the rise in popularity of the permanent campaign (Flanagan, 2012; Marland et al., 2017). From this perspective, political parties make use of websites and social networks in a permanent and uninterrupted manner (Stanyer, 2008; Small 2012), maximising their online presence throughout their mandate, especially as the establishment and development of online communities takes time and is not built on the eve of an election (Vérvile 2012), especially if political parties seek to promote mobilisation, which should be stimulated in a permanent manner in order to be fully utilised during the election period. However, the literature review allowed us to observe that the majority of research on the use of social networks by political parties around the world has focused on election periods (Gibson and Ward, 2009; Small, 2012), which are the most demonstrative and the richest in terms of public data. It is the most important democratic event in political life (Kreiss 2016 Giasson 2017 Gelix 2018), where parties have a large campaign budget allocated to them and they are more likely to innovate in their electoral campaigning, as this is the time when they will be most exposed to the media (Marshment 2016).

It should be noted that in morocco, the use of social networks by political parties has been little studied and deserves attention, all the more so as the implementation of strategies by political parties requires long-term work prior to electoral campaigns. The collection and constitution of databases on the electorate is carried out very early in anticipation of the coming elections. Of course, the duration differs from one political party to another: some have started their planning earlier than others. Faced with this premise, we chose to collect data over a long period of time, spanning 9 months and linking 3 phases: non-electoral, pre-electoral and electoral, in order to be able to compare the intensity of political use of social networks during the electoral and non-electoral periods. This also allowed us to avoid the biases that can be generated by a short study period or a restricted socio-political context (Vérvile 2012). With this in mind, the study period is from 1 January 2021 to 8 September 2021, the day of the election.

The data collection was held quarterly to determine the evolution of subscriber numbers for each official party page as well as for all related regional pages. To this end, we devoted the first week of each quarter to the census of these pages. As for the observation of virtual communities (public and private grouéps of political party supporters), it was carried out on a more frequent basis, as the intensity of publications, particularly in the pre-electoral and electoral periods, meant that the census was conducted on a weekly basis. In addition, data collection for the content analysis was carried out on a monthly basis in order to be able to sort the political parties' publications and classify them according to the categories detailed below.

2.3 Sampling

The results of previous elections have the advantage of being the most reliable data available to political marketing because the election period is the best possible transposition of the product purchase mechanism in commercial marketing to the voting mechanism in political marketing (Maarek 2014). Therefore, as a sampling framework, we referred to the database provided by the Communication Department of the Ministry of Culture throught its official website, as well as the data provided by the Ministry of Interior on political parties that presented candidates in the 2016 legislative elections. This sampling framework, therefore, facilitated our access to the entire target population of our qualitative study, namely: all moroccan political parties recognised by the Ministry of Interior and fully active in Morocco. However, as we were unable to study all political parties exhaustively, we deliberately avoided constituting a random sample of political parties in Morocco, opting to limit the scope of our research to the most representative parties;

The choice of political parties to be covered by our research was then based on the consideration of a more or less representative range of the political spectrum in Morocco based in particular on their elective representativeness within the House of Representatives, with reference to the results of the 2016 legislative elections, and the number of seats obtained.

A reading of the electoral results shows that the 2016 legislative elections gave rise to an evolution determined by the specificity of the Moroccan electoral context since the adoption of the 2011 Constitution, marked specifically by the rise of social networks and their relationship with the 'Arab Spring' movements, thus creating a real space for competition and rivalry between political parties.

To constitute our sample, we based ourselves on the issues of representativeness of these parties and their influence on the political field in Morocco, assuming that the political parties that were not selected due to the lack of seats obtained in the legislative elections do not have a great influence on the moroccan electorate because they were barely audible, and that their exclusion does not have any impact on our research objective. Based on these criteria, we selected the political parties that are recognized as being among the most influential in the political field and the most likely (due to their organizational culture, their resources, their degree of institutionalization, the number of their representatives in Parliament, the interests they represent, etc.) to integrate a political marketing approach into their strategies, particularly during the election period.

In this context, the sample selected is composed of 2 political parties:

- The Justice and Development Party (JDP): which experienced a strong increase in its electorate from 2011 to 2016, retaining a loyal electorate that increased with the mobilization of disaffected voters from the other political parties, especially with its passage into government. The implementation of their political marketing on social networks is also a strong point in their political communication;
- The National Rally of Independents (RNI): which launched its digital strategy in 2015, which covered social networks, concretising a long-term strategic choice beyond the electoral period.

3 Results of Analysis of Moroccan Political Parties' Activity on Social Networks

As we have already pointed out, the first stage of our netnographic study aimed to study the presence of Moroccan political parties on social networks, in particular Facebook, which is considered to be the most frequented social network by moroccans after whatsup. To do so, we based ourselves on the following indicators:

- The number of official pages of each party
- The number of subscribers on each official party page
- The number of "likes" on each official party page
- The number of groups representing each party
- The political parties' advertisements and their impression rates

After collecting the data, we proceeded to group them in a table that brings together the data collected on Moroccan political parties, presenting the number of official pages and groups of each party, the number of subscribers or active members on each page or group, as well as the attitude of the members on these pages and groups (Table 1).

Table 1. List of Moroccan political parties most present on social networks

Political parties	Number of subscribes	Number of groups[1]	Number of régional pages[2]	Attitude on official page[3]
Justice and développement Party	1,178,998	14	52	Negative
The National Rally of Independents	1508418	13	43	Positive

Source: Based on data collected

[1] Only groups with more than 1000 subscribers at the beginning of the observation period are considered.

[2] Only regional pages with more than 1000 subscribers at the beginning of the observation period are considered.

[3] Determined with the help of social listening tools that analyses feelings and attitudes on social networks.

The Justice and Development Party. The JDP has been communicating since 2011 on Facebook and Instagram with a direct presence of the party's main leaders. In September 2021, the JDP had more than 1,174,998 followers on Facebook, compared to 316,000 in June 2015; However, it should be noted that the official page of the Justice and Development Party has seen a decline in the number of subscribers and "likes", which could probably be due to Facebook's policy of automatically eliminating fake or inactive accounts, which can lead to a decrease in the number of subscribers or "likes", but it can also be justified by the loss of some supporters and the increase in the number of disgruntled people who are dissatisfied with the JDP's accomplishments after ten years of its arrival in government (Fig. 1).

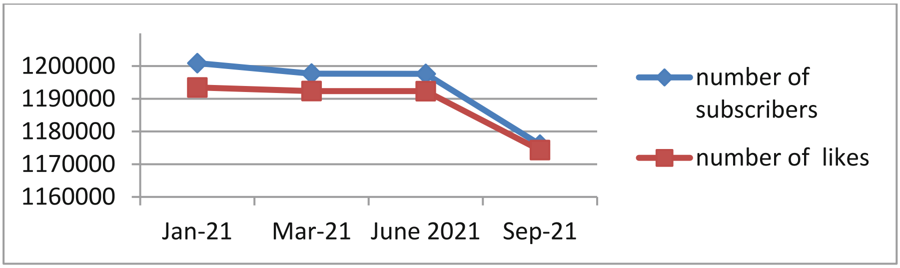

Fig. 1. Evolution of the number of subscribers and "likes" of the official JDP page (Source: Based on data collected)

Political advertising by the Justice and Development Party. Let us first note that since 2016, scandals related to the use of personal data on social networks have highlighted the need to better regulate the advertisements disseminated by political parties on social networks, as well as the need for transparency regarding the political content that may be sponsored, which requires a clear identification of the advertisers, their country of origin, the sums paid for the promotion,(Z.O TOUHAMI & N. TAKADDOUMI 2023) as well as the people targeted by the said ads. In this context, Facebook, being one of the most popular platforms worldwide and in response to the need to develop new tools to help ensure the integrity of elections worldwide, has launched the Facebook Ad Library in all countries after having been launched earlier in the US and the UK. The main objective is to prevent the misuse of Facebook and interference in the election process and to increase transparency around all forms of political and public interest advertising. Therefore, a strict specific authorization mechanism for advertisers wishing to disseminate sponsored content of a political, electoral, or social nature has been put in place.

Thus, in order to be able to target internet users from any country, any such advertising must be programmed from that country. Page administrators must provide verifiable and confirmable identification. Advertisers must also indicate who is funding their campaign, in the form of a disclaimer clearly preceded by the words "Funded by", as well as providing their company name and the contact details of the entity funding the campaign in question.

In this respect, we identified 43 sponsored advertisements broadcast on the official JDP page on Facebook and Instagram, qualified as "advertisements relating to a social or electoral issue", during the period observed, and more precisely between 22 May 2021 and 8 September 2021, generating a total amount of £2147, i.e. the equivalent of 19323 Dhs (Table 2).

Table 2. Total JDP expenditure on advertisements on the official party page on Facebook and Instagram:

Type of advertising	Expenses
Advertisements with warning	19125 Dh
Advertisements without warning	198 DH
Total	19323DH

Source: Based on data provided by the Meta Advertising Library

The National Rally of Independents (NRI). "The National Rally of Independents" has been present on Facebook since April 2011. However, the party adopted a vertical and one-way political communication, from top to down, marked by the sharing of press releases and the dissemination of information that was not necessarily adapted to the target audience, neither in form nor in content.

So, in order to implement a professional strategy, the party launched in August 2015 a new digital communication strategy that focused more on social networks with a participatory and collaborative dynamic towards citizens based on the census of the opinions of Internet users and the transfer of suggestions to elected officials so that the party can respond to them at different levels. The initial objective was to generate 25 reactions per day under the hashtag "#achbghit" (what I want) launched by the party on social networks to identify the expectations, opinions and views of Internet users. After the arrival of Aziz AKHENNOUCH at the head of the party, the political marketing of the NRI has taken a new impetus, reflecting a long-term strategic choice aimed at mobilizing activists through the development of internal political marketing based on the digitalization of relations, and the motivation of activists, especially young people, thanks to the launch of the mobile application "NRI direct" on Android and on ios, which constituted a digital support allowing to further strengthen the communication between the members and the party, while reinforcing its digital political marketing focused on the identification and mobilization of supporters using new digital tools by crossing the data of the electoral map and social networks. On the eve of the elections, the official NRI page had more than 1.4 million subscribers (Fig. 2).

This evolution of The National Rally of Independents pages and communities illustrates the massive use of social networks, especially in the run-up to the elections. In this regard, it should be noted that there is a correlation between the rise in regional and local pages and communities and the dates of visits to the same regions or provinces scheduled as part of the 100 towns 100 days campaign launched by the RNI in the pre-election period.

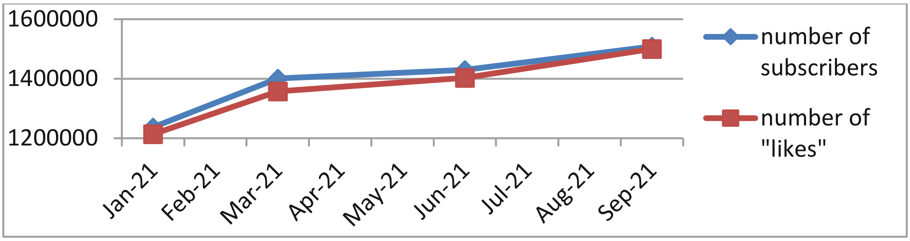

Fig. 2. Evolution of the number of subscribers and "likes" of the official NRI page (Source: Based on data collected)

The NRI's political advertising. The NRI is the most active moroccan political party on social networks in terms of advertising on social networks, particularly on Facebook and Instagram. The party spent a budget of $342862 equivalent to 3085758 Moroccan dirhams on Facebook ads during the period under review, with an increase in spending in the run-up to the elections (Table 3).

Table. 3. Total NRI expenditure on advertisements on the official party page on Facebook and Instagram:

Type of advertising	Expenses
Advertisements with warning	1 807 $
Advertisements without warning	341055 $
total	342862 $

Source: Based on data provided by the Meta Advertising Library

It should be noted that this expenditure should be put into perspective because it only represents the expenditure on advertisements directly financed by the party, whether on its official page or on its regional or provincial pages, and it does not take into account the expenditure made during the same period by the party leader himself or by the party's candidates on social networks.

Our netnographic study also looked at the census of advertisements related to the "100 cities 100 days" campaign, which corresponds to a real campaign accompanied by fieldwork through which The National Rally of Independents went to meet the population in more than 100 Moroccan cities, to identify the expectations and needs of citizens in each city or region, and to highlight issues that challenge them in the development of their campaign in order to optimize its electoral program. The strategy of the NRI consists in offering a policy adapted to each territory through a listening program carried out by the party's activists, which allowed the direct involvement of more than 35,000 citizens through a proximity campaign that allowed the party to map the expectations of each region and to elaborate an integrated vision on the priorities of Moroccans in order to constitute the framework of the party's electoral program.

The caravan allowed in particular to determine some indicators related to the priorities of the citizens of each city concerning the problems of unemployment, health, employment and education. This made it possible to classify the cities covered by the program according to the challenges that remain to be addressed.

This campaign is certainly conducted on the ground, but is accompanied by extensive coverage on social networks, particularly on Facebook and Instagram. In this context, our exploratory research has enabled us to identify more than 890 advertisements relating to the "100 days 100 cities" caravan broadcast by the NRI on Facebook during the period observed from 1 January 2021 to 8 September 2021, 380 of these Ads targeted an audience of more than 1,000,000 users on Facebook, in addition to 370 advertisements on Instagram, 130 of which targeted a potential audience of more than 1,000,000 people, with a targeting adapted to each region.

In addition to the advertisements for the "100 Days 100 Cities campaign", the RNI has been running advertisements for the party leader's activities and the party's programme since the beginning of June 2021, including an advertisement for people with special needs with an impression rate of more than 1 million. This consideration of "handicap" in the development of its political advertisements is part of the reinforcement of its electoral programme, which focuses on social protection and aims, among other things, to offer lifelong support to people with disabilities through free health insurance, prevention and early detection, training of carers, and subsidies to associations working in the field on the basis of transparent tenders.

The advertisement was launched on social networks and achieved a remarkable rate of impressions, especially among young people aged between 18 and 24, with a rate of 65%. This is a significant step forward in the marketing of moroccan political parties, especially since disability, with a few exceptions, is a topic that is rarely addressed by political parties. It is true that the "100 days 100 cities" caravan has made it possible to detect the expectations of citizens through direct exchanges and meetings that have strengthened the understanding of the priorities of the inhabitants of Moroccan cities. However, The netnographic study of the party's publications on social networks allowed us to notice that the NRI has developed its political offer thanks to a strategic watch carried out on social networks and a benchmarking of foreign partisan experiences, notably in France where political parties have been called upon to take into consideration the issue of of "disability" in the elaboration of their electoral programmes for the municipal elections of 22 March 2020 and the regional elections of 22 June 2021, following a large awareness and mobilisation campaign launched in France on social networks by the "Handicaps collective" grouping more than 48 associations in the field of disability through the hashtag #handicap2020.

This shows that The National Rally of Independents ran a decentralised campaign, based on monitoring and benchmarking strategies and professionalised polling from the '100 days 100 cities' caravan. All these criteria place the digital campaign conducted by the NRI in the era of post-modern campaigns as described by Norris (2002).

Discussion:
Our netnographic study highlighted the intensive use of social networks by political parties in Morocco, particularly during election periods.

The results of this research broadly confirm the lines of investigation emerging from previous international research. G. Mahestu and T.A. Sumbogo (2020) had demonstrated that the content of each political party's Facebook page reinforces the value of political identity through news links/photos with narration, memes, videos and adverts and that information and communication technology have an impact on the development of democracy in each country. D. Villegas has highlighted the relevance of social media in political marketing and the effectiveness and reliability of netnography as a method of political field research.

Several other studies were carried out in different contexts to cover a wide range of topics, issues and contemporary trends in digital political marketing, demonstrating the diverse trends, orientations and influences of political marketing as a rapidly evolving academic discipline and professional practice.

We emphasize that our study differs from previous ones in several respects: on the one hand, the study was carried out in the Moroccan context, which remains little investigated in this field, and on the other hand the diversity of criteria and indicators used to analyze the content of political party pages on Facebook, make the results more original.

It is worth noting that, in democratic political life, there is a constant tension between the short-term need to satisfy the needs of the electorate and the formulation of long-term goals and strategies: Political parties, in particular, are too often forced to focus on short-term external crises at the expense of developing their medium- and long-term strategies and the internal organization necessary for these strategies. This tends to damage the survival prospects of political parties in rapidly changing political landscapes, particularly in emerging democracies. It then tends to reduce public confidence in political parties as vehicles of representation and governance. Political parties can only adequately prepare for new societal demands and democratic changes if they have the capacity to look ahead and anticipate developments, especially technological ones.

The results of the study allowed us to observe that the NRI has resorted to permanent political marketing through the implementation of a global strategy based on strategic planning centered on the identification and analysis of the needs of its electorate.

It should be noted that the identification of voters' motivations and needs through meetings and campaigns, such as the campaign conducted by the NRI during the pre-election period of the 2021 elections or the one conducted by the JDP during its pre-election campaign in 2011, has been a key element in the success of modern political marketing: political marketing professionals and communication advisors have a strong tendency to encourage political parties to shape their digital campaigns on social networks according to these meetings and campaigns.

The "100 cities 100 days" campaign has certainly allowed the RNI to collect a significant amount of information that constitutes a starting point for its political marketing strategy on social networks, By allowing it a better determination of the target as well as the objectives of its digital strategy. This is achieved through a better knowledge of its potential recipients, particularly those towards whom political marketing has a better chance of penetrating favourably, while allowing it to indicate the type of arguments it will be able to use on social networks to demonstrate to its targets that it cares about their needs.

So it is on the basis of this recognition of the needs of the voters that the NRI was able to set up a permanent campaign with a gradual rise in power through a permanent occupation of social networks which becomes more and more important as the electoral deadline approaches. The campaign was also nourished by a blitz effect around key events, which proves that the NRI did not limit its choice to one type of campaign, it combined several types (gradual ramp-up campaign - blitz campaign) to achieve greater efficiency and to remain flexible in relation to the many imponderables of political action. This has allowed the NRI to be advanced in digital political marketing compared to other parties.

Conclusion:
Our research shows that Moroccan political parties are becoming increasingly aware that the development of a political brand is strictly linked to the need to carry out marketing studies to understand the needs, expectations and level of involvement of voters.

As a result, political parties have made massive use of marketing and communication tools to translate these expectations into a personalized political offering that best responds to the specificities of each target, notably with the use of social networks that make it easier to target the electorate by age, gender or preference.

So, through careful analysis of the expectations of electorate, political parties can better manage their digital campaigns.

From an operational point of view, digital political marketing, which is characterized by ever-increasing professionalization, has established itself as a permanent tool for the preparation and management of election and pre-election campaigns, with digital teams overseeing the implementation of the strategic objectives of political parties on social networks.

From the above, it can be stated that this research will create a basis for future research aiming to identifying and measuring the response of the electorate to digital marketing strategies of political parties.

Using quantitative research methods, it could be interesting to measure the impact of digital political marketing on voters engagement and the impact of external factors on the electorate. Future research activities should also focus on the effectiveness of the social media publications convince the electorate to give a preference to a particular party or candidate.

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Comparative Credit Risk Assessment: Integrating Autoregressive and Bayesian Models

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Abstract. This work proposes an alternative approach to modeling Loss Given Default, which is one of the credit risk parameters used in calculating Basel capital requirements. Baseline linear autoregressive models are developed and then challenged by models that combine Bootstrap techniques with Bayesian probability theory. To do this, time series are used; a database of recovery rates as the variable to be explained and a database of economic (e.g., GDP) and financial variables (e.g., 3-month EURIBOR) as candidate explanatory variables to account for the levels of recovery rates observed over time.

Keywords: Recovery rate · Basel · Approach frequentist · Autoregressive models · Bayesain Averaging Models

1 Introduction

Since 1988, the central banks of twenty-seven countries have come together to form the BCBS (Basel Committee on Banking Supervision) to regulate and ensure the stability of the financial and banking system to prevent crises. This led to the inception of the first Basel Accords, which was then followed by a series of accords containing prudential rules, namely, Basel I (minimum capital requirements to cover credit risk), Basel II (integration of market and operational risks), III (strengthening the quality of capital following the financial crisis of 2007/2008), and Basel IV (better risk coverage, mainly market risk).

The calculation of the minimum required capital under the Basel framework is performed by credit institutions using one of two methods: the STANDARD method and the INTERNAL RATINGS-BASED approach, known as IRB. In the first method, the capital is the total of the product of the exposed values of each asset by a flat-rate weighting predetermined by regulation based on the risks incurred; hence the concept of risk-weighted assets (RWA). In the second method, the RWAs are determined by the credit institution through models it has developed for the parameters of the risks incurred, mainly the Probability of Default (PD), which relates to insolvency risk, and the Loss Given Default (LGD), which pertains to the risk of loss in the event of default; this is to optimize the amounts of its own funds.

Within the context of quantifying risk parameters, this work aims to model recovery rates by adopting two distinct quantitative perspectives: a frequentist approach and a

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probabilistic approach, often associated with Bayesian methodology. The use of Autoregressive (AR) models, inherent in the frequentist approach, is our starting point. These models, while useful for establishing a baseline, have significant limitations, such as adhering to assumptions of stationarity, linearity, etc. In response to these limitations, the proposed alternative is based on Bayesian Averaging Models (BAM) from the probabilistic approach. Thus, by comparing these two methodologies, this work seeks to demonstrate the significant advantage offered by the Bayesian probabilistic approach, overcoming the limitations identified in traditional frequentist approaches.

2 Parameters and Data of the Study

Recovery rates measure the economic loss rate that a bank expects to bear in the event of default by a borrower or counterparty. This loss rate is assessed at the date of default and is expressed as a percentage of the exposure at the time of default. LGD (Loss Given Default) is the complement to 1 of the recovery rate over the recovery period, defined by the entry and exit dates from default. It includes all costs incurred during the collection of the debt and also takes into account the time value of the amounts recovered through the discounting effects of the recovered amounts. It is customary for the estimation of LGD to distinguish three types of contracts:

- Those that have defaulted and whose recovery procedure has been completed (total observation of the LGD). For these contracts, the LGD is observed ex-post.
- Those in default today and whose recovery procedure is not completed (partial observation of the LGD).
- And those that are healthy today and for which one wants to estimate the LGD.

This study focuses solely on the expected loss rates for healthy contracts at a time (t) that would default within the following twelve months.

To perform the estimation of LGD, an analytical base was constructed from two main data sources:

• The recovery rate database of a banking institution: recovery rates must be estimated for each portfolio, totaling three portfolios. In the context of this work, we have a history of recovery rates from Q4 2013 to Q4 2019 for each segment. These recovery rates range from 0 to 1 for each segment. They have been transformed to obtain a variable that takes values between $-\infty$ and $+\infty$. The commonly used transformation is the logit transformation which associates the recovery rate R with the quantity log(R/(1-R)). This transformation allows us to work with unconstrained variables and will be used in the modeling phase.

• The macroeconomic database: The macroeconomic variables considered in these works correspond to a set of previously identified variables that have been reviewed with business experts to gather their opinions on the relevance of these variables and their suggestions/proposals for variables that could be relevant to include in the model development in the frequentist approach. The data used is observed on a quarterly basis for a period from Q1 1995 to Q4 2019. Macroeconomic and financial variables are known to be non-stationary series. Logarithmic transformations and first differences (sometimes a second difference) have been performed on the candidate variables for modeling to render them stationary (Table 1).

Table 1. The macroeconomic variables used for the study

Macroeconomic variable labels	
Gross Domestic Product (GDP)	Unemployment Rate (UnRate)
Consumption France (Consum)	Manufacturing Production (IndProductio)
Household Investment (HHInvest)	Inflation
Corporate Investment (CorpInvest)	Euribor3M
Household Disposable Income (HHIncome)	OAT 10 Year Treasury Bonds (OAT10Y)
Firm Debt Ratio (FirmDebtRatio)	Real Rates (RR10Y)
Household Debt Ratio (HHDebtRatio)	CAC40
Consumer Credit Debt Ratio(ConsDebtRatio)	Durable Goods Consumption (ConsGoods)
Housing Prices Index France (HousingPrices)	Household Consumer Credit Outstanding (HHConsumCredit)
Companies - Outstanding Credits (CompaniesCredit)	Household Housing Credit Outstanding (HHHousingCredit)
Households - Outstanding Debt(HHDebt)	Corporate Investment Credit Outstanding (CorpInvestCredit)
Consumer Credit Outstanding (PersoLoan)	Corporate Treasury Credit Outstanding (FirmTreasuryCredit)
Housing Credit Rate (APR)	OAT Euribor Spread (CreditSpread)

3 Autoregressive Linear Model

This section describes the approaches adopted for modeling the recovery rates across the three portfolios used. These methodologies consider the 12-month recovery rate by quarterly default entry cohort at the segment level to estimate a linear order relationship with macroeconomic variables. More specifically, the methodology adopted unfolds in two steps:

- firstly, a pre-selection of explanatory variables that satisfy economic plausibility (sign restriction) compatible with the portfolios is carried out. For each study portfolio, we conducted a pre-selection of candidate variables from the initially identified list, under the constraint that the "signs" of the selected variables are compatible with the expected directions.
- secondly, modeling the relationship between the recovery rate and the pre-selected macroeconomic variables from step 1. All variables were thus subject to entry into the models. However, their opinions were taken into account regarding the expected signs, i.e., the anticipated or intuitive effects of macroeconomic variables on recovery rates.

3.1 Model Specification

To specify the model, we place ourselves in the general framework where there exists a linear functional relationship expressing the dependency of the observed recovery rate at 12 months on a given segment in relation to macroeconomic variables. The recovery rates take values between 0 and 1. To perform a scale change and to free ourselves from econometric constraints, we have chosen the logarithmic transformation, which associates the series Y_t with the quantity $\log\left(\frac{R_t^{12m}}{1-R_t^{12m}}\right)$: $\boldsymbol{Y_t} = \mathbf{log}\left(\frac{\mathbf{R_t^{12m}}}{1-\mathbf{R_t^{12m}}}\right)$

Where: the logit of the 12-month recovery rate is denoted by $\mathbf{R_t^{12m}}$.

The constructed indicator is positively correlated with the default rate, which makes the analysis of correlations between it and the macroeconomic variables more intuitive. The model has thus been explicated in the form of a linear regression on time series of the logit-transformed recovery rate (12 months) with an autoregressive component (logit-transformed lagged recovery rate) and various macroeconomic variables. This specification with an autoregressive component has the advantage of limiting the importance of "lags" of the dependent variable.

The complete model is governed by the following equation:

$$\boldsymbol{log}\left(\frac{\boldsymbol{R}_t^H}{1-\boldsymbol{R}_t^H}\right) = \boldsymbol{\alpha}_0 + \sum \boldsymbol{\beta}_i \boldsymbol{log}\left(\frac{\boldsymbol{R}_{t-i}^H}{1-\boldsymbol{R}_{t-i}^H}\right) + \sum \boldsymbol{\alpha}_k \boldsymbol{X}_{(k,t-i)} + \boldsymbol{\varepsilon}_t$$

With:

- $\boldsymbol{t}$ = observable periods
- $\boldsymbol{i} = 1, \ldots, 4$ le lag
- $\mathbf{LGD_t^H} = 1 - \mathrm{R_t^H}$
- $\boldsymbol{X}_{\boldsymbol{k},\boldsymbol{t}}$ denotes the transformed macroeconomic variables at date t, $\boldsymbol{k} = 1, \ldots, \boldsymbol{p}$

3.1.1 Stationarity of the Logit of Recovery Rates

For the estimation of LGD, the study of the stationarity of the logit of recovery rates was carried out. These variables are not stationary, but this is not a hindrance for our study and the specification of our model. Therefore, we retain the non-stationary logit of recovery rates.

3.1.2 Stationarity of Explanatory Variables

Statistically, multiple regression can only be applied to stationary time series. A series is stationary when it has certain stability properties:

- Mean independent of time
- Variance and autocovariance independent of time

Below we present a summary of the stationarity test procedures used (Table 2):

Table 2. Result of the ADF Test on All Macroeconomic

Economic Variable	Stationarity test						Economic Variable	Stationarity test					
	Type	Lags	Rho	ProbRho	Tau	ProbTau		Type	Lags	Rho	ProbRho	Tau	ProbTau
D_GDP	Zero Mean	1	-14,521	0,007	-2,676	0,008	D_IndProductio	Zero Mean	1	-60,019	0,000	-5,416	0,000
D_Consum	Zero Mean	1	-16,469	0,004	-2,812	0,005	D_NewCarRegist	Zero Mean	1	-154,320	0,000	-8,960	0,000
D_HHInvest	Zero Mean	1	-23,457	0,000	-3,392	0,001	D_Euribor3M	Zero Mean	1	-37,050	0,000	-4,480	0,000
D_CorpInvest	Zero Mean	1	-17,863	0,002	-2,973	0,003	D_OAT10Y	Zero Mean	1	-87,127	0,000	-6,596	0,000
D_HHIncome	Zero Mean	1	-17,863	0,002	-2,973	0,003	D_RR10Y	Zero Mean	1	-80,306	0,000	-6,328	0,000
D_FirmDebtRatio	Zero Mean	1	-43,283	0,000	-4,624	0,000	D_CAC40	Zero Mean	1	-86,024	0,000	-6,484	0,000
D_HHDebtRatio	Zero Mean	1	-10,655	0,021	-2,248	0,024	D_ConsGoods	Zero Mean	1	-86,955	0,000	-6,640	0,000
D_ConsDebtRatio	Zero Mean	1	-47,850	0,000	-4,811	0,000	D_HHConsumCredit	Zero Mean	1	-26,035	0,000	-3,527	0,001
D_HousingPrices	Zero Mean	1	-36,970	0,000	-4,278	0,000	D_HHHousingCredit	Zero Mean	1	-3,343	0,207	-1,201	0,209
D_CompaniesCredit	Zero Mean	1	-16,918	0,003	-2,870	0,004	D_CorpInvestCredit	Zero Mean	1	-5,712	0,097	-1,614	0,100
D_HHDebt	Zero Mean	1	-2,673	0,260	-1,032	0,270	D_FirmTreasCredit	Zero Mean	1	-44,105	0,000	-4,641	0,000
D_PersoLoan	Zero Mean	1	-26,035	0,000	-3,527	0,001	D_CreditSpread	Zero Mean	1	-51,515	0,000	-5,390	0,000
D_TEG	Zero Mean	1	-44,922	0,000	-4,674	0,000	DD_HHDebt	Zero Mean	1	-232,604	0,000	-10,693	0,000
D_Inflation	Zero Mean	1	-14,266	0,007	-2,711	0,007	DD_HHousingCredit	Zero Mean	1	-285,678	0,000	-11,880	0,000
D_UnRate	Zero Mean	1	-25,575	0,000	-3,563	0,000	DD_CorpInvestCredit	Zero Mean	1	-291,806	0,000	-11,950	0,000

The variables D_HHDebt and D_HHDebtRatio were not stationary according to the ADF test. They were then made stationary and transformed by a second differencing.

3.2 Model Estimation

For the selection of the macroeconomic impact model, emphasis was placed on the robustness and predictive capacity of the model. Thus, in addition to the sign validating the economic coherence of the variable with the target variable, the representativeness of the model variables is observed with an exclusion threshold set at 10% in the Student's t-test. The Akaike Information Criterion (AIC) is the decision criterion among models with an adjusted R^2 greater than 50%. The model parameters for each segment are estimated by OLS (Ordinary Least Squares) on quarterly data (Q4 2013 – Q4 2019). The estimation results by portfolio are provided below:

- **Portfolio 1 (AMO1)**

For the first portfolio, the model is governed by an equation with 3 explanatory variables: the lagged recovery logit (−2), the lagged household investment (−2), and the lagged new car registrations (−1) (Table 3).

Table 3. Model estimation results (AMO1)

Variable	DF	Parameter Estimate	Standard Error	t value	P>|t|	Variance Inflation
Intercept	1	0,1838	0,03346	5,49	<,0001	0
L2_D_RRH4_AMO1	1	0,30245	0,12462	2,43	0,0253	1,12367
L2_D_HHInvest	1	-4,99583	1,25053	-3,99	0,0008	1,12199
L1_D_NewCarRegist	1	0,42985	0,22601	1,9	0,0725	1,00337

- **Portfolio 2 (AMO2)**

For the portfolio AMO2, the model is governed by an equation with 3 explanatory variables: the lagged logit of recovery (−1), lagged household investment (−1), and the lagged 10-year Treasury bond (−1) (Table 4).

Table 4. Model estimation results (AMO2)

Variable	DF	Parameter Estimate	Standard Error	t value	P>|t|	Variance Inflation
Intercept	1	-0,29655	0,03266	-9,08	<,0001	0
L1_D_RRH4_AMO2	1	-0,41957	0,15128	-2,77	0,0117	1,45142
L1_D_HHInvest	1	-3,99895	1,09426	-3,65	0,0016	1,40706
L1_D_OAT10Y	1	-0,11473	0,04037	-2,84	0,0101	1,2492

- **Portfolio 3 (AMO3)**

For the last portfolio, the model is governed by an equation with 3 explanatory variables: the lagged logit of recovery (−3), the lagged 10-year Treasury bond (−1), and the registration of new cars (Table 5).

Table 5. Model estimation results (AMO3)

Variable	DF	Parameter Estimate	Standard Error	t value	P>|t|	Variance Inflation
Intercept	1	-0,61199	0,05393	-11,35	<,0001	0
L3_D_RRH4_AMO3	1	0,17681	0,07459	2,37	0,0291	1,02757
L1_D_OAT10Y	1	-0,18483	0,04523	-4,09	0,0007	1,07506
D_NewCarRegist	1	0,43441	0,21765	2	0,0613	1,06029

3.3 Model Autoregressive Validation

The selected model for each portfolio was validated. This validation aims to verify, through tests and statistical analyses, the validity of the essential assumptions of the models, their robustness, and predictive performance. This section describes the validation steps.

3.3.1 Model Robustness

- **Multicollinearity**

During the regression analysis, the Variance Inflation Factor (VIF) assesses if the factors are correlated with each other (multicollinearity), which could influence other factors and reduce the model's reliability. If the VIF exceeds 10, it indicates high multicollinearity. In our case, the VIF for each selected variable is close to 1, indicating no multicollinearity.

- **Residual Analysis**

Residual analysis is necessary for the validation of the estimated model. The assumptions of the residuals have been verified: normality, homoscedasticity, and no autocorrelation:

- **Normality test of residuals:** Test Knowing the law of errors is essential for performing stochastic simulations. The normality assumption was examined through graphical analyses and statistical tests using the Shapiro-Wilk and Kolmogorov-Smirnov tests. For the three estimated models AMO1, AMO2, and AMO3, the hypothesis of residual normality is validated. The p-values of the normality tests are $> 5\%$, and the graphical analyses of QQ-Plots show a linear trend.
- **Residual Homoscedasticity:** To ensure the homoscedasticity of the residuals of the developed models, we use the Fisher statistic. The test procedure involves regressing the square of the residuals on the explanatory variables of the model. The three models are globally significant (i.e., the p-value associated with the Fisher statistic is less than the 5% threshold), so we can presume with 95% confidence the homoscedasticity of the residuals.
- **No Autocorrelation of Residuals:** Durbin Watson Test The Durbin-Watson test seeks to verify the significance of the coefficient ρ in the formula: $\boldsymbol{\epsilon_t} = \boldsymbol{\rho\epsilon_{t-1}} + \boldsymbol{u_t}$, where $\boldsymbol{\epsilon_t}$ is the model's estimated residual, and $\boldsymbol{u_t}$ is white noise with the Wald test. The null hypothesis (H_0) states that there is no autocorrelation, thus $|\,\rho| = 0$.. The alternative hypothesis (H_1)) states that there is autocorrelation, thus ρ is different from 0 with

always $|\rho| < 1$. The hypothesis of no autocorrelation of residuals in the three models is validated. The DW statistic, for the three models, is close to 2.

3.3.2 Model Performance

The performance of the selected models was studied through indicators allowing to appreciate the model's adjustment to the data (predicted values VS observed values). The table below summarizes the different indicators.

Table 6. Performance Indicators of the Selected AR Models by Segment

Modèles	RMSE	R-Square	Adjusted R-Square
AMO 1	0,05688	64,27	58,63
AMO 2	0,04468	57,42	51,04
AMO 3	0,05376	59,16	52,35

The selection criterion for the chosen model is the Akaike Information Criterion (AIC). However, a model with an adjusted R^2 lower than 0.5 is a sufficient condition for rejecting the model. The selected models have been validated and have an adjusted R^2 greater than 0.5 (Table 6).

4 Bayesian Averaging Model (BAM) Approach

This section deals with the Bayesian probabilistic modeling approach. Initially, the theoretical framework of this approach, its principle, and its added value will be presented; then, the modeling steps used in practice to design a model for each segment will be outlined.

4.1 BAM Model Specification

Unlike the frequentist approach with which the reference models were designed, the Bayesian probabilistic approach does not assume that there is only one correct model. In fact, there may be several, sometimes all in competition, with performances that are more or less close. The Bayesian approach is particularly useful when it comes to estimating (inferring) a model on a weak data set, very weak in the case of our study, where not the entire population is observed or can be observed. In principle, it involves combining several possible models in the form of a weighted average by the posterior probabilities. The model is formulated as follows: $\boldsymbol{Y = \alpha_\gamma + \beta_\gamma X_\gamma + \epsilon}$

$$\boldsymbol{P\left(M_\gamma | Y, X\right) = \frac{P\left(Y|M_\gamma, X\right)P\left(M_\gamma\right)}{P(Y|X)}}$$

With:

- $\boldsymbol{Y}$ **:** dependent variable
- $\boldsymbol{\alpha_{\gamma}}$**:** constant
- $\boldsymbol{\beta_{\gamma}}$**:** regression coefficients
- $\boldsymbol{X_{\gamma}}$**:** explanatory variables
- $\boldsymbol{\epsilon}$**:** erreur terms
- $\boldsymbol{M_{\gamma}}$**:** model
- $\boldsymbol{P(M_{\gamma}|Y, X)}$**:** posterior probability of the model according to Bayes' theorem
- $\boldsymbol{P(Y|M_{\gamma}, X)}$**:** marginal likelihood of the model
- $\boldsymbol{P(M_{\gamma})}$**:** prior probability of the model
- $\boldsymbol{P(Y|X)}$**:** likelihood of the data to be explained

The coefficients of the BAM are obtained by averaging the different coefficients of the models weighted by the posterior probabilities of obtaining these models.

4.2 BAM Modeling Step

In practice, BAM is a model selection technique that combines the Bootstrap technique and Bayesian probability theory, starting from a list of k candidate variables on a sample with N observations or individuals. This method involves randomly drawing a sufficiently large number of samples (e.g., 1000) with replacement, and then proceeding to estimate a model in each of the drawn samples. It is possible to obtain the same model across multiple samples. For example, the model M10 (β_4, β_{15}) estimated on sample N°10 could be identical to model M1000 (β_4, β_{15}) estimated on sample N°1000. The estimation method used in each sample employs well-known regression techniques, such as LASSO, STEPWISE, etc.

The final model selected is an average model that makes a weighted average of the models observed on the data and retained with weights being the posterior Bayesian probabilities of observing each of the models. In other words, for each given parameter β_i, its final value $\widehat{\beta}$ is the weighted average of all its different observed values of this parameter in all the estimated models across all samples.

For example, $\widehat{\beta}_1$ for the explanatory variable X1 corresponds to the weighted average of the different observed values of β_1 across all the drawn samples. In this context, if a variable was not retained in a model, the value of this parameter is considered zero in that case. The posterior probabilities of observing the models out of a total of M possible models are calculated according to Bayes' theory, but in practice, they are approximated by the frequency of appearance of the model. The criteria for including a model in the calculation of the final model average are as follows:

- Set a threshold n that corresponds to the first n best models to retain. The models are ranked in descending order of appearance frequencies in the samples.
- Set a minimum posterior probability threshold to filter the models to retain in the calculation of the final average model. For example, it's possible to retain only those variables that appear in 50% of the samples after estimation.

4.3 Model Estimation and Performance

Below are the results of the model estimation under the Bayesian approach (Table 7).

Table 7. Selected Model for the AMO1 Segment

Average of the estimated parameter results					
Parameter	Mean Estimate	Standard Deviation	Quantile Estimation		
			25%	Median	75%
Intercept	0,16719	0,030176	0,151077	0,170177	0,186959
L2_D_rrh4_amo1	0,299876	0,116827	0,226316	0,291892	0,363756
L2_D_HousingPrices	-3,593357	0,831329	-4,129364	-3,621843	-3,078888
L2_D_OAT10Y	-0,102362	0,046704	-0,133372	-0,103963	-0,073659

- **Portfolio 1 (AMO1)**

In the AMO1 segment, the recovery rates observed in a quarter (t) are explained by the amounts of three variables, all observed a semester earlier; these are the recovery rate, the housing price index in France, and the French government bonds (Obligations Assimilables du Trésor). The last two variables are negatively correlated with the recovered amounts, meaning that a negative evolution in the borrowing conditions of the state and housing prices decrease the amounts that can be expected to be recovered (Table 8).

- **Portfolio 2 (AMO2)**

Table 8. Selected Model for the AMO2 Segment

Average of the estimated parameter results					
Parameter	Mean Estimate	Standard Deviation	Quantile Estimation		
			25%	Median	75%
L4_D_rrh4_amo2	0,743522	0,159474	0,624204	0,721263	0,842831
L2_D_PersoLoan	-4,305286	2,616984	-6,19926	-4,56025	-2,702866

In the AMO2 segment, the recovery rates observed in a quarter (t) are explained by the recovery rates observed one year earlier, which are reduced by the evolution of the outstanding consumer credits observed a semester earlier.

- **Portfolio 1 (AMO1)**

In the AMO3 segment, the recovery rates observed in a quarter (t) are explained by the recovery rates observed three quarters earlier, which are reduced by the evolution of inflation observed a semester earlier (Table 9).

Table 9. Selected Model for the AMO3 Segment

Average of the estimated parameter results					
Parameter	Mean Estimate	Standard Deviation	Quantile Estimation		
			25%	Median	75%
L3_D_rrh4_amo3	0,948979	0,055839	0,912077	0,948787	0,98557
L2_D_Inflation	-13,915438	10,889562	-20,596073	-13,622179	-6,776716

Below is the table of the forecasting capabilities of the selected BAM models for each segment (Table 10):

Table 10. Forecasting Performance of BAM Models by Segment

Models	Average Forecast Error	Standard Deviation of Forecast Error
AMO 1	0,04%	1,66%
AMO 2	-2,70%	5,35%
AMO 3	5,33%	7,74%

When the average forecast error is positive, the model underestimates the recovery rates, while it overestimates them when the average is negative. Indeed, the regulator requires banks to add conservatism margins, known as Type C Margin, following errors that may arise from the specification of the models.

5 Discussions

Georges E. Box (1919–2013) wrote in 1976, "All models are wrong, but some are useful." This aphorism highlights the challenges in designing and selecting models, given the near impossibility of observing the entirety of reality that the model aims to predict. The Bayesian probabilistic modeling approach thus seems more suited to the reality of modeling, since reality itself has at least an ounce of uncertainties since it is not observed in its entirety. In other words, when it is not known which model is the best, it is better to take the average model. BAM models are theoretically more robust than AR models by construction because they allow for protection against overfitting effects. Moreover, in the case of our study, this is verifiable since we observed that the errors in terms of mean and forecast variance observed on training data decreased after recalculation once the backtesting was done.

However, our study has its limitations; these are related to both approaches because they hold criticisms made of all linear models, namely:

- Non-stationarity: This problem can lead to spurious linear regression. That is why we had to introduce lags on the explained variable and one on the macroeconomic variables.
- Non-linearity: Ignoring non-linearity exposes the risk of not capturing the entire structure of the recovery phenomenon, which is not necessarily linear in all cases.
- Initialization of the first autoregressive components: Estimating the very first points of the lagged variables with the mean of the recovery rates conditions the evolution of the series. Moreover, this is a strong assumption because it assumes the stationarity of the series; but recovery rates are anything but stationary.
- Low sample level: The absence of test samples does not allow for rigorous validation of model performances given the small data set available. In fact, there is a pseudo test sample, but it is constructed after extrapolation based on the same model reused right after and having served to build it.

6 Conclusion

This paper offers a novel approach to modeling Loss Given Default (LGD), a pivotal credit risk parameter essential for calculating Basel capital requirements. Grounded in the Basel accords developed since 1988 by the BCBS to enhance financial and banking system stability, this study contrasts traditional linear autoregressive (AR) models with innovative Bayesian Averaging Models (BAM) that integrate Bootstrap techniques and Bayesian probability theory. Utilizing time series data, this research delves into modeling recovery rates using a database of such rates and macroeconomic variables to elucidate observed recovery rate trends.

Two distinct modeling approaches are employed: the frequentist approach, with its inherent AR models, and the probabilistic approach, characterized by BAM. The frequentist approach, although foundational, is critiqued for its significant limitations, such as the necessity for stationarity and linearity assumptions. In contrast, BAM presents a more flexible alternative, allowing for the integration of uncertainty inherent in reality, thus potentially offering a more accurate modeling framework.

The paper meticulously details the BAM methodology, which leverages a combination of Bootstrap sampling and Bayesian probability calculations. This approach does not commit to a single "correct" model but rather considers a spectrum of models to estimate the most probable outcomes. The selection of models under BAM is influenced by their posterior probabilities, calculated through Bayesian theory, to approximate the frequency of model occurrences.

Results from the BAM approach indicate a nuanced understanding of recovery rates across different segments, highlighting how macroeconomic factors like housing prices and government borrowing conditions can impact expected recovery amounts. The discussion further reflects on the aphorism by George E. Box, "All models are wrong, but some are useful," to underscore the inherent limitations of modeling while advocating for the pragmatic utility of BAM in capturing the complexities of financial risk assessment.

This study, while innovative, acknowledges its limitations, including issues related to non-stationarity, non-linearity, initial component estimation, and sample size constraints. These limitations highlight the challenges of applying linear models to complex financial phenomena and underscore the necessity of adopting more nuanced approaches like BAM for a deeper, more accurate understanding of credit risk parameters.

In conclusion, this paper not only contrasts the predictive capabilities and limitations of AR and BAM models within the context of LGD estimation but also exemplifies the evolving nature of financial modeling in response to regulatory requirements and the inherent complexity of the financial system. The transition towards Bayesian probabilistic modeling signifies a pivotal shift in credit risk assessment, offering a more adaptable and theoretically robust framework for navigating the uncertainties of financial risk management.

Enhancing Customer Experience and Satisfaction with Chatbots in the Moroccan Banking Sector: A Qualitative Study

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Abstract. In Morocco, several banking institutions have introduced chatbots in their banking services to enhance customer interactions. The effectiveness and impact of chatbots on customer experience within the Moroccan context remain relatively unexplored. Understanding the implications of chatbots on customer satisfaction is vital for Moroccan banks striving to enhance their digital services. Our study is qualitative study investigates user experiences with banking chatbots to fill this knowledge gap. Through semi-structured interviews with 30 participants, key themes emerged regarding system quality, information quality, service quality, and customer satisfaction. Our findings highlight the importance of addressing technical challenges, enhancing information relevance and accuracy, and improving responsiveness and empathy to enhance user experience with chatbots. These insights offer actionable guidance for Moroccan banking institutions to strengthen their digital service offerings and drive business success.

Keywords: Chatbots · Banking sector · Morocco · Artificial intelligence · Digital banking

1 Introduction

Artificial intelligence (AI) represents a revolution in how machines can mimic human intelligence to perform tasks traditionally reserved for humans. Since its inception, AI has progressed significantly to become a dynamic field of computer science. It relies on

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sophisticated algorithms and advanced information processing techniques to simulate and enhance human cognitive functions [1]. Subfields of AI, such as machine learning and natural language processing, play a crucial role in creating intelligent systems capable of complex tasks. Machine Learning enables machines to learn from data and improve over time, while Natural Language Processing allows them to understand and generate human language [2].

Among the various applications of AI, chatbots, also known as conversational agents, have undergone significant evolution over the years. Chatbots are now powered by advanced machine learning algorithms, enabling them to offer more sophisticated and personalized interactions [3]. These chatbots have become essential tools in various sectors, including financial services [4], e-commerce [5], customer service [6], and healthcare [7].

The evolution of chatbots in banking has been remarkable, driven by technological advancements in AI and machine learning. These chatbots now offer sophisticated interactions, enhancing customer service, automating tasks, and providing immediate assistance. Banks like HDFC Bank, have partnered with AI companies to develop state-of-the-art chatbots accessible across platforms like Facebook Messenger. Integrated into online banking services, these chatbots enable personalized and efficient communication, leading to improved customer satisfaction [8, 9]. The chatbots integration into online banking has transformed customer interactions within the industry [10]. By delivering immediate responses to queries, chatbots have elevated satisfaction levels among users. Their conversational ease and likability contribute to a positive user experience, with voice commands emerging as the preferred mode of interaction for most customers. Demonstrating high competency, chatbots consistently provide accurate responses and maintain stable understanding scores across user testing scenarios. The banking sector is poised for a substantial surge in chatbots integration, projected to increase from 12% to 90% by 2022 according to [9].

Recent studies highlight the positive impact of chatbots on customer engagement and retention [11–15]. Chatbots offer instant, 24/7 assistance, allowing customers to quickly get answers to their questions and resolve issues at any time. Additionally, chatbots can collect data on customer preferences and behaviors, enabling banks to further personalize interactions and offer relevant recommendations. However, despite the benefits of chatbots, some researchers emphasize the ongoing importance of human interactions, especially in situations where empathy, compassion, and intuition are needed. Chatbots can complement human services, but they cannot fully replace them. Therefore, banks must find a balance between automating services and maintaining human contact to deliver an optimal customer experience.

In Morocco, Attijariwafa Bank and BANK OF AFRICA have introduced chatbot banking services, leveraging artificial intelligence to enhance customer interactions. Attijariwafa Bank's chatbot [16], launched in May 2020, provides swift and convenient assistance to customers in Casablanca, initially focusing on French-speaking clients and addressing Covid-19 regulations and account-related queries. The bank plans to expand its chatbots capabilities to support multiple languages and extend deployment across various channels. Similarly, BANK OF AFRICA's KODI chatbot [17], unveiled in December 2021, offers digital advisory services in French and Arabic, facilitating inquiries ranging from account opening to bank assurance services.

With this advancements, the chatbots effectiveness and impact on customer experience within the Moroccan context remain relatively unexplored.

Understanding the implications of chatbots on customer satisfaction is vital for Moroccan banks striving to enhance their digital services. By conducting qualitative research focused on user experiences with banking chatbots, we aim to fill this knowledge gap. Our study seeks to provide actionable insights that can inform the optimization of chatbots systems, ultimately improving customer satisfaction and loyalty in the Moroccan banking industry. Furthermore, our study can guide future developments in chatbots technology and customer service strategies.

2 Methods

2.1 Study Design and Participants

The study employed the methodology conducted by [18] by some modifications. The qualitative research design to delve into the intricacies of customer experience and satisfaction with banking chatbots within the Moroccan banking sector. The research utilized semi-structured interviews to capture insights and perspectives from individuals who had engaged with banking chatbots.

2.2 Sampling and Data Collection

Purposive sampling was employed to select participants for the interviews, ensuring a diverse representation of individuals who had interacted with banking chatbots. The criteria for participant selection included engagement with banking chatbots, demographic diversity (such as age, gender, and education level), and variation in experience with banking chatbots. This approach aimed to capture a wide range of perspectives and experiences, from both novice and experienced users, contributing to a comprehensive understanding of customer interactions with banking chatbots within the Moroccan banking sector. The sample size of 30 participants was determined based on the principle of data saturation, where new information and insights cease to emerge from additional interviews, indicating that theoretical saturation has been achieved. The interview guide consisted of open-ended questions designed to elicit detailed responses regarding participants' experiences, challenges, advantages, and overall satisfaction with banking chatbots. The cadre of participants interviewed and their socio-demographic characteristics were documented during the interviews, providing context and depth to the qualitative data collected. Interviews were conducted in French to facilitate communication with participants. Each interview lasted approximately 15 min and was audio-recorded to ensure accurate data capture. The interview process allowed participants to express their thoughts and opinions freely, providing valuable insights into their perceptions of banking chatbots. Thematic analysis was employed to analyze the qualitative data obtained from the interviews. This involved systematically identifying patterns, themes, and categories within the datasets. The analysis focused on capturing the range of experiences and perspectives shared by participants regarding their interactions with banking chatbots.

2.3 Data Analysis

Thematic analysis was chosen as the method to dissect the qualitative data acquired from the interviews. This approach involved a meticulous process of identifying recurring patterns, themes, and categories within the dataset, aiming to encapsulate the diverse spectrum of experiences and perspectives shared by participants regarding their interactions with banking chatbots. To begin, the audio recordings of the interviews were transcribed verbatim and underwent thorough proofreading to ensure precision and fidelity to the original conversations. These meticulously crafted transcripts were then imported into NVivo 2020, a qualitative data analysis software, to facilitate systematic analysis. The analysis initialized by generating initial codes, categorizing the data based on prevalent concepts, recurring ideas, and emergent themes. These initial codes were further scrutinized, refined, and organized into coherent sub-themes and overarching themes. This iterative process allowed for a structured and systematic exploration of the qualitative data, enabling the identification of nuanced patterns, underlying trends, and key insights that characterize participants' diverse experiences and perceptions of interacting with banking chatbots.

2.4 Ethics Approval

The participation of individuals in this study was conducted in accordance with ethical standards and guidelines. Prior to their involvement, all participants provided informed consent, acknowledging their understanding of the study's purpose and procedures. They were assured of confidentiality and the anonymization of their responses, with data being used solely for research purposes.

3 Results

3.1 Participant Demographics

The Participants' socio-demographic characteristics are presented in the Table 1. Participants in the study exhibit a wide age range, with notable representation from both younger demographics (18–24) and older cohorts (55<). Female participants dominate the gender distribution, constituting a majority within the sample. Educationally, most participants hold university-level qualifications, with secondary and primary education levels being less represented. Income diversity is evident among participants, with a substantial portion falling into the medium-income bracket, followed by low and high-income groups.

The study encompasses customers affiliated with various banks in Morocco, with Attijariwafa Bank and CIH Bank being the most prevalent. However, a range of other institutions, including Agricultural Credit of Morocco, Popular Bank, Bank Of Africa, Al-Maghrib Bank, General society of Morocco, and BMCI, also contribute to the sample.

Table 1. Participants' socio-demographic characteristics.

	Frequency ($n = 30$)	Percentage (%)
Age		
18–24	14	46.67
25–34	4	13.33
35–54	5	16.67
55<	7	23.33
Gender		
Female	19	63.33
Male	11	36.67
Education Level		
University	25	83.33
Secondary	4	13.33
Primary	1	3.33
Income		
Low	9	30
Medium	18	60
High	3	10
Bank		
Attijariwafa Bank	9	30
CIH Bank	9	30
Agricultural Credit of Morocco	3	10
Popular Bank	3	10
Bank of Africa	1	3.33
Bank Al-Maghrib	1	3.33
General Society Morocco	1	3.33
BMCI	2	6.67

3.2 Customer Experience with Banking Chatbots

System Quality

Simplicity of Use

The simplicity of using the banking chatbots was highly praised by users. A significant majority (15 from 30) found it extremely user-friendly, while others noted that is generally easy, albeit with a few features requiring additional exploration (10 from 30). Only a small minority of users expressed neutrality on this aspect (5 from 30).

> "…I found the banking chatbots very easy to use. All the features were clearly presented and easy to understand. It was a smooth and efficient experience…." **Participant 2**

> "…At first, I found the chatbots a bit challenging to understand, but once I took the time to get used to it, its operation became clearer and its use smoother…." **Participant 5**

> "I am neutral in terms of the ease of use of the banking chatbots. Some features were intuitive, but I encountered difficulties with certain commands and interactions…." **Participant 9**

Technical Aspects / Reliability

The majority of users (13 from 30) did not report any technical issues; however, some noted difficulties in understanding commands (10 from 30), and others experienced bugs from the chatbots (7 from 30).

The reliability of the chatbots was assessed across several dimensions, including the accuracy of responses, response time, coherence, and the ability to comprehend questions. Participants reported receiving generic or irrelevant responses (12 from 30), difficulty in obtaining help for complex questions (8 from 30), and limitations in the types of transactions possible (6 from 30). Furthermore, frequent errors or incorrect responses from the chatbots (4 from 30).

> "…There were times when the chatbots provided incorrect responses, which frustrated me and eroded my trust in its capabilities. Additionally, there were instances where I didn't clearly understand the commands presented, making it difficult for me to communicate effectively with the system…." **Participant 29**

On the other hand, we perceived compliments from participants, such as the speed of responses, 24/7 availability, and ease of use for routine operations (16 from 30), as well as the accuracy of provided information (10 from 30) and the user-friendliness of the interface (4 from 30), indicate that despite these challenges, the chatbots offers functionalities appreciated by users.

The combination of interface user-friendliness, accuracy of provided information, and 24/7 availability was also mentioned as an additional advantage two some participants (2 from 30), thus highlighting the strengths of the system despite the technical and reliability challenges faced by some users.

> "…What's truly impressive is how precise and relevant the responses are. I genuinely feel understood when interacting with the chatbots. Overall, it's like having a personal assistant always ready to help…." **Participant 15**

Information Quality

Relevance of Information

Users assessed the quality and relevance of information provided by the banking chatbots. The majority (16 from 30) deemed the information to be good, generally considering it of good quality and relevant. A significant number of users (8 from 30) found the quality to be average, noting that relevance could vary, while a small group (5 from 30) rated it as excellent, considering it of high quality and perfectly relevant.

> "…When I asked about one of my banking transactions, the chatbots provided precise and helpful responses, which boosted my confidence in its effectiveness…" **Participant 27**

> "…when I inquired about certain banking transactions, the chatbots responses were sometimes accurate and useful, but other times they seemed unrelated or incomplete. This inconsistency made me question the reliability of the chatbots…" **Participant 1**

Accuracy

Regarding the accuracy of information, most users (14 from 30) stated that the chatbots provided all necessary information satisfactorily, without any gaps. However, some users (6 from 30) noticed gaps in responses, leaving questions unanswered. Others (3 from 30) noted that the chatbots was unable to provide certain important information. Additionally, a few users (2 from 30) reported delays in the chatbots responses.

> "…Whenever I had a question or issue regarding my banking activities, the chatbots was there to respond clearly and comprehensively. This experience truly impressed me and instilled confidence in the chatbots reliability as a source of banking information…." **Participant 23**

> "…there were occasions where it fell short in delivering comprehensive responses. This became evident when I sought detailed information about specific banking transactions or complex financial inquiries… " **Participant 18**

Service Quality

Responsiveness

The responsiveness of the banking chatbots varies among users. The majority (12 from 30) find it generally responsive, providing quick responses to their queries. Some (9 from 30) deem it neutral in responsiveness, satisfactory but with potential for improvement in speed. Others (7 from 30) find it very responsive, offering swift and effective responses without significant delay. However, a few users (1 from 30) noted the chatbots to be somewhat not responsive at all.

> "…The chatbots quickly responded with relevant information or guided me through the process. This responsiveness made me feel valued as a customer and encouraged me to rely on the chatbots for prompt assistance with my banking needs…." **Participant 6**

> "…il y avait des moments où le chatbots semblait ne pas répondre du tout, laissant mes préoccupations non résolues… " **Participant 18**

Empathy

Perception of empathy in interactions with the chatbots also varies. most users did not feel empathy in their interactions with the chatbots, although a small number highlighted that empathy was not expected in this context (10 from 30).

> "…I didn't feel any empathy during my interactions with the banking chatbots. While it efficiently provided the necessary information, it lacked the human touch that would have made the interaction more meaningful….." **Participant 30**

"…While using the banking chatbots, I didn't particularly expect to encounter empathy in our interactions. My primary goal was to efficiently carry out banking tasks and obtain information quickly… " **Participant 7**

Perceived Utility

Opinions on the utility of the chatbots also vary. Some (12 from 30) find it overall useful, addressing most of their needs satisfactorily. Others (8 from 30) are neutral, noting that the chatbots meets some needs but with some deficiencies. A few users (3 from 30) find it of little or no use in addressing their banking needs. Conversely, a few users (4 from 30) find it very useful, effectively addressing all their banking needs.

"… I recently needed to check the online check deposit process, and the chatbots provided me with clear and detailed instructions. This experience really impressed me and convinced me that the chatbots was a valuable tool…" **Participant 23**

3.3 Customer Satisfaction with Banking Chatbots

Overall satisfaction with the banking chatbots varies among users, with a majority indicating general satisfaction but suggesting some improvements (12 from 30). Some were neutral, mentioning that the chatbots partially met their expectations but needed improvements (7 from 30), while others expressed being very satisfied with their experience (8 from 30). However, a few users were dissatisfied (2 from 30) or very dissatisfied (1 from 30).

Aspects of the interaction with the chatbots contributing most to user satisfaction include the speed of responses (35 from 30), accuracy of responses (26 from 30), real-time assistance (22 from 30), variety of features (21 from 30), reliability of service (11 mentions), user-friendly interface (13 mentions), accessibility (9 mentions), adaptability to user preferences (9 mentions), and personalization (14 mentions).

"…what really makes me feel good about the chatbots is when it responds quickly. It reassures me, you know, like I have someone listening to me right away. Then, when it adapts to what I want, it becomes almost like a normal conversation. Like the chatbots knows me a little, you see? And of course, I want it to be reliable. I don't want to end up with different answers every time I ask the same question. Lastly, if I can use it easily, wherever I am, that's the best. It really makes me feel like I have my banker in my pocket, ready to answer my questions when I need…." **Participant 27**

4 Discussion

This study investigates the influence of chatbots features on customer experience and satisfaction within the Moroccan banking sector. Our analysis of interviews enabled us to identify themes that significantly impact customer experience and satisfaction. The quality of the banking chatbots system was assessed through several themes and sub-themes. Under the main theme of "Ease of Use," users generally appreciated the accessibility and user-friendliness of the chatbots. However, some users noted features that required further improvement. Technical aspects and reliability were also highlighted, with most users not encountering major technical issues but occasionally facing difficulties in understanding questions or receiving incorrect responses. Challenges included generic or irrelevant responses and difficulty obtaining assistance for complex queries. Perceived advantages included quick response time, 24/7 availability, ease of use for routine operations, and the accuracy of information provided, underscoring the system's strengths despite areas for improvement. The quality of information provided by the banking chatbots was assessed through two main themes: relevance of information and accuracy of information. While most users found the information generally good, improvements are needed to ensure consistent accuracy and timely responsiveness to user needs. Regarding responsiveness, the majority of users found the chatbots to be responsive, but some noted inadequate responsiveness. Most users did not feel empathy in their interactions with the chatbots, although a few highlighted that empathy was not expected. In terms of assurance, the majority of users expressed a sense of security and confidentiality. Opinions on usefulness varied, highlighting the importance of meeting user expectations. Overall, user satisfaction with the banking chatbots varied. Speed of responses, accuracy of responses, real-time assistance, variety of features, reliability, user-friendly interface, accessibility, adaptability, and personalization emerged as critical factors shaping user satisfaction. In comparing our findings to existing research, similarities and differences emerge regarding the impact of chatbots on customer experience in the banking sector. Like Trivedi's study [15], our research indicates a generally positive impact of chatbots, with users appreciating accessibility, user-friendliness, and quick response times. Challenges related to generic or irrelevant responses, highlighted in our study and by Følstad and Skjuve [19], suggest common issues across contexts. Additionally, the importance of chatbots delivering quick and accurate responses, as noted by Lubbe and Ngoma [20], aligns with our findings on user satisfaction. However, disparities arise in perceptions of brand likability and empathy. Similarly, our findings on empathy vary from those of Suhel et al. [21], indicating diverse user experiences and expectations. Our study highlights key aspects influencing customer satisfaction with banking chatbots in Morocco. Moroccan banking institutions can enhance user experience by improving chatbots ease of use, technical reliability, and responsiveness. Ensuring accurate and relevant information delivery is essential, alongside considering adding empathetic responses. Strategies for improvement include optimizing response speed, offering real-time assistance, and enhancing user-friendly interfaces. By addressing these aspects, banks can bolster customer satisfaction and strengthen their digital service offerings.

5 Conclusion

The influence of chatbots features on customer experience and satisfaction within the Moroccan banking sector is significant and multifaceted. Key findings highlight the importance of various aspects such as ease of use, accessibility, response time, accuracy of information, personalization, reliability, and empathy in shaping the overall customer experience with chatbots. Chatbots that offer intuitive interfaces, are available round-the-clock, provide quick and accurate responses, personalize interactions, and convey empathy tend to enhance customer satisfaction. Moreover, ensuring reliability in terms of consistent performance without technical glitches or downtime is essential for fostering trust and satisfaction among customers.

The implications of these findings for banking institutions in Morocco are profound. By prioritizing these features and continually improving chatbots functionalities, banks can better meet the evolving needs and expectations of their customers in an increasingly digital banking landscape. Ultimately, a positive customer experience facilitated by chatbots can lead to increased satisfaction, loyalty, and ultimately, business success for banks operating in the Moroccan market.

For future research, investigating the long-term effects of chatbots integration on customer loyalty and retention would be valuable. Additionally, investigating the effectiveness of different strategies for enhancing empathy and personalization in chatbots interactions could provide further insights into optimizing customer experience in the banking sector.

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The Role of Digitalization in Forecasting Job and Skill Management: Case Study of «AXA Services Morocco Expertise Center»

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Abstract. Digitalization plays a crucial role in Jobs and Skills Management System Forecasting by modernizing and improving human resources" strategic planning processes. Implementing a digital approach seems to be an effective solution to face the challenges of a constantly evolving environment. The case study of AXA Services Morocco highlights the importance of the integration of digital in data collection to better position the levels of behavioral and sub-technical skills by profession, to identify the Position/Profile matching rate, and thus, design appropriate support plans, trainings, and mobility policies.

Keywords: Digitalization · Human Resource · Management · Skills · AXA Services Morocco

1 Introduction

In a constantly changing environment, companies are facing several challenges, whether it is in terms of customer expectations who are increasingly demanding on the quality of products, and who now want more personalized and fast experiences; or business models that require the integration of technology into digital platforms or talent and skills management to have employees who are versatile and able to adapt quickly to new tasks and responsibilities.

According to the report published on 3 May 2023 by the World Economic Forum, "nearly a quarter of all jobs (23%) worldwide will be transformed and almost half of skills will need to change within five years to keep up with the digital transformation" [1].

To better cope with this digital transformation, it is necessary to invest in human capital and its agility to guarantee a good positioning within the company. Skills management is one of the Human Resources approaches that contribute to better adapting the jobs, workforce, and skills of a company's employees to better meet the company's strategic objectives and economic, technological, social, and legal developments, and thus ensure its sustainability. However, to be effective, this approach must be able to

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anticipate and plan the needs of positions and skills within an organization, succeed in placing the right skills in the right place and at the right time to follow the company's strategy and finally, ensure the match between the needs of the market and the talents of employees by relying on digital solutions allowing the efficient collection and processing of information.

In our present article, we focus on the role of digitalization in the implementation of an effective management approach, while highlighting the areas of application of Forward-Looking Management of Jobs and Skills, with a case study to identify:

- The role and contribution of Job and Skills Forward-Looking Management in Human Resources Management.
- The main areas of application of an effective Forward Jobs and Skills Management approach.

2 Background

2.1 Evolving of the Forecasting Job and Skill Management Approach

In its classic version, Forecast Jobs and Skills Management is presented as a linear sequence of analysis tools and action plans, which in the past underestimated the importance of human dimensions in its implementation [2].

The evolving of the approach was closely linked to socio-economic contexts. During the emergence of the first thoughts on human resources planning in the late 1960s, the first models of social forecasting management focused mainly on quantitative management of the workforce that were purely demographic and economic projections [3].

Two decades later (1970s and 1980s), with the globalization, American and European companies faced tougher competition (notably India and China), which led them to place more importance on human capital and the notion of skills. Thus, companies have moved towards a management that is more focused on prevention and anticipation. However, during this period, it was still essentially quantitative with forward-looking (and preventive) management of employment [4].

During the period of the 1980s-1990s, with the evolution of the labor market and the emergence of new issues linked to the management of jobs and skills, the forward-looking management of jobs and skills gained importance, Companies sought to align their workforce with their long-term business goals, identifying the skills needed to maintain competitiveness and growth in the market [5].

By early 2000s to 2010s: the approach evolved to become more integrated and strategic. Organizations have started to implement Strategic Workforce Planning approaches more oriented towards skills management and adaptation to market developments. Strategic Workforce Planning has become a talent management tool, aiming to align employee skills with the future needs of the organization. This period was also marked by the growing concerns over the age and career management which implied the development of policies to manage seniors, transmitting knowledge and developing the versatility of employees.

During the last two decades (2010 to 2020) the approach continued to evolve with the emergence of new trends such as digital transformation, Companies considered the impact of these novelties on jobs and skills and adapted their forecasting Job and

Skill Management approaches accordingly to support the company in its transformation, ensure its sustainability and promote the development of talents.

2.2 Digitalization Ensures an Effective Implementation of the Forecasting Job and Skill Management Approach

The awareness of a company and its employees needs depends on the quality of the Human Resource data collected. Coupled with artificial intelligence, forward-looking management of jobs and skills is more effective and relevant. It can even provide a decisive competitive advantage to support business growth plans and offer new opportunities.

Artificial intelligence can be considered as a decision-support tool to the extent that it can contribute to the improvement of several aspects contributing to the implementation of an effective and efficient approach [6].

- **Creation of a professional and skills framework**

  The Forecasting Job and Skill Management is mainly based on the skills framework around which a set of Human Resource processes are structured. However, the creation of this reference system is far from a simple operation. Faced with a multitude of data, organizations struggle to gather and synthesize knowledge to have a clear vision of the resources available.

  Digitalization appears as a facilitator: thanks to cluster-ring algorithms, it collects, analyses, and structures available information from multiple sources to carry out initial categorizations and propose initial benchmarks making it possible to easily identify skill levels [7].

  Once established, then implemented in the stands for Human Resources Information System, these standards feed the various Human Resource processes (mobility, management review, recruitment, training, etc.), and vice versa, in a dynamic of reciprocity. Digitalization also plays a major role in keeping these skills repositories up to date (new rules in force, real-time updating), thus ensuring their adaptability and efficiency.
- **Improving the position-profile match of employees**

  Following the automation of a certain number of operations, digitalization makes it possible to improve “Matching”: which position to offer to which employee based on the match between the skills held and the skills required, considering the following factors: seniority, academic training, job performance evaluation and the positioning of skills in relation to the skills/profession reference framework mentioned previously.

  The crossing of different variables, beyond skills, makes it possible to offer the “best” possible associations to employees, and to identify the best Post/Profile matching.
- **Strengthening the prospective dimension of Human Resource Management**

  Artificial intelligence can support this vision through cross-referencing of internal data in human resource information systems (available workforce and skills, demographic developments, job vacancy rate, future mobility, etc.) but also external data (re-collection of data on labor market trends and developments in professions and skills) [8].

Based on the results of data analysis, artificial intelligence can effectively contribute to the development of job and skills forecasts. This may include identifying key skills for future roles, assessing risks of skills shortages or obsolescence, and recommending proactive measures to close identified gaps.

Artificial intelligence can also be used to support Forecasting Job and Skill Management strategic planning. It can also help to simulate the different scenarios of career development, internal mobility, or external recruitment, and to assess their impact on the organizational structure and available skills.

- **Implementation and monitoring**

  Artificial intelligence might also be used to support's strategic planning. It can also help to simulate the different scenarios of career development, internal mobility, or external recruitment, and to assess their impact on the organizational structure and available skills. Once the strategic plan has been developed, it is important to implement the identified measures and monitor their impact.

  Artificial intelligence can be used to continuously monitor and evaluate progress, adjust actions based on results, and optimize talent management processes. However, it is necessary to adapt the methodology according to the needs and specificities of each organization.

  While artificial intelligence contributes to the organization, cross-referencing and analysis of data, the intervention of human capital remains necessary to ensure the quality of diagnoses and the relevance of the solutions proposed.

2.3 The Areas of the Forecasting Job and Skill Management: Implementation

The Forecast Management of Jobs and Skills symbolizes the main challenges that the company must face, in particular: the reduction of the workforce following a drop-in activity or a loss of market, recruitment of new skills to develop new activities, the reconversion of certain skills following technological or regulatory developments in its market or any restructuring and/or reorganization project, that has a quantitative and/or qualitative impact on the workforce.

The Forecasting Job and Skill Management framework can be considered as a reference framework for all Human Resource Management decisions and actions. It also finds applications in several areas within organizations.

- **Skills and career management**

  The Forecasting Job and Skill Management is a valuable tool for identifying the skills necessary to achieve the company's objectives. It makes it possible to identify the skills present within an organization, assess the gaps between current and future skills, and to implement development and training actions to fill these gaps. Moreover, it is used to support employees in their professional careers within the organization.

  It makes it possible to identify development opportunities, define personalized career plans, encourage internal mobility, manage succession, and facilitate the transition between different career stages [9].

- **Talent and workforce management:**

  Forecasting Job and Skill Management is a talent management tool aimed at identifying, developing, and retaining the best talents within the organization. It makes it possible to identify high potential, implement specific development programs, promote the retention of key talents, and ensure continuity of skills. It is used to anticipate and manage the organization's workforce needs allowing gaps to be identified between the necessary workforce and the current workforce, predicting retirements, voluntary departures, recruitment needs, and putting in place strategies to ensure the availability of required human resources [10].

- **Change Management:**
  Forecasting Job and Skill Management is an essential tool to support change processes within the organization. It makes it possible to anticipate the impacts of change on jobs and skills, to identify training and support needs, and to implement actions to facilitate the transition and minimize resistance.

These areas of application in talents management are interconnected and complement each other. Forecasting Job and Skill Management is a global approach to human resources management that aims to ensure the adequacy of the present and future skills of the organization, promote the development of talents and guarantee its sustainability in the face of market developments [11].

In addition, Forecasting Jobs and Skill Management has also opened up broader issues such as corporate social responsibility and sustainable development. Organizations have become aware of the importance of skills management to respond to the challenges linked to ecological transition, diversity, and inclusion.

3 Methodology

Using a case study, we highlight the impact of integrating a digital approach in the implementation of forward-looking management of jobs and skills. Created in 2004, AXA Services Morocco is a subsidiary of the French insurance company AXA Group. The company employs approximately 3,500 people across several business segments, including insurance sales and management, home and automobile claims management, and healthcare billing [12]. We chose the case of this company because it is considered one of the pioneering companies in the implementation of forward-looking employment management and the skills approach in Morocco.

The AXA group closed the 2023 financial year with a turnover growing by 3% and a net profit up by 45% [13], to follow this remarkable progress and support the strategic plans of the AXA group AXA service Morocco has set the following objectives [14]:

- Anticipate and support developments in professions and give visibility to employees on the resulting employment prospects.
- Create new prospects for development in building their professional career within AXA Service Morocco.
- Lead the professional training policy to meet strategic challenges: development/maintenance of expertise, managerial and HR support, support for professional transitions and mobility.
- Implement innovative systems to strengthen measures to support the transformation.

To collect the necessary information and achieve these objectives, AXA service Morocco has considered digitalizing its HR tools, starting with the implementation of the HR Information System, which makes it possible to centralize data relating to human resources management, skills, training, recruitment or performance, it has also integrated a talent management platform that offers functionalities making it possible to identify the company's expectations in relation to each position and area of activity, which allows employees to map out career plans and identify development opportunities.

The integration of technology in performance monitoring was necessary to the extent that the tools used allow the cross-referencing of several results to monitor in real time the achievements and the objective level of achievement, as well as the identification of gaps to bring about a readjustment of the actions put in place while thus providing valuable data for skills and career management.

Training management was also affected by digitalization, with the establishment of a platform offering diverse and varied training modules, which also makes it possible to manage training programs, monitor employee progress, and identify skills development needs.

AXA service Morocco has also implemented skills assessment software, a tool that allows employee evaluations to be archived using a skills repository to map the skills present within the organization and identify post-profile Matching levels.

To guarantee consistency in the evaluation of employee skills, AXA service Morocco deemed it necessary to overhaul the skills and professions framework. This project involved the participation of several parties, notably business representatives, operational managers, human resources managers, talent management managers and data centers.

The role of each contributor was to list the tasks and missions of each position, identify the expected level, and identify the necessary technical and behavioral skills.

Once this categorization was carried out, the second step consisted of mapping existing skill levels by profession and position, assessing the adequacy between positions and profiles to plan future needs.

Certainly, difficulties were encountered in the management of this project, the major challenges were to maintain the motivation and commitment of the participants, respect the deadlines set, harmonize the approaches, and above all, align all the contributors to the same level of requirements.

Thanks to the methodical approach, the flexibility and openness of the project team, and the digitalization of the tools used, it was possible to overcome these challenges and create a dynamic tool that contributes to improving talent management and organizational performance.

We have detailed the process, the specific objectives, and the methodology in the table:

Steps	Description	Tools	Milestones
1-Identify Jobs and Skills	Identify for each workstation, the essential skills to carry out the tasks assigned to each one of the employees, without worrying about their current position (e.g., what are their skills? What are their acquired techniques? What is their expertise?)	"Skills framework" bringing together the common skills "Soft skills" and the technical skills "Hard Skills" adapted to each core business with levels ranging from 1 to 4	Have a dynamic assessment of the needs and resources available at any given time; Provide qualitative information on skill levels; Measure the gap based on what is expected for each job
2-List Trainings needs	Identify skills gaps between current employees and the ones essential to carrying out a task	Skills positioning; Assessment of the need for trainings or job support plan; Annual job performance evaluation	List trainings needs; Create bridges between different trades; Encourage internal mobility of teams; Integrate external skills impacting the professions
3-Anticipate future needs	Cross-reference between the company's current and planned activities	The Human Resources dashboard analyses key performance indicators by cross-referencing them with target and strategic issues	Anticipate hiring needs; Replacement to disappearance of essential or sensitive skills
4- Set an action plan	Trainings policy; Recruitment policy; Mobility policy	Indicators for monitoring the effectiveness of the implemented actions	Visualize skill evolution; Monitor the effectiveness of actions undertaken to plan readjustments based on milestones

4 Conclusion

Before implementing a forward-looking job and skills management approach, it is important to carry out an in-depth preparation phase to understand the needs of the organization, obtain the support of business partners, involve employees, collect relevant data, and choose appropriate methods and tools.

The digitalization of the tools that support this approach is one of its key success factors. The integration of digital technologies contributes significantly to:

- *Optimization of time and resources*: automation of certain repetitive tasks related to the analysis of big data to identify trends, patterns and predictions about future job needs
- Skills assessment: identification of skill gaps to propose personalized development plans
- *Talent Evolution*: Offers a global vision of post/profile matching by analyzing mobility, training and support needs to meet the needs of the organization and the market
- *Adaptation of training programs*: Visualize training needs and cross-functional actions related to your skills development strategy, monitor the budget allocated to training and ensure that the training offered individually to each employee is relevant and useful
- *Recruitment effectiveness:* using personalized interview templates that are easy to set up, identifying potential talents and candidates, and improving the forecasting of future job openings.

In conclusion, we can say that digitalization and Job and Skills Forward-Looking management are two areas that complement each other and interact to improve human resources management within organizations. Moreover, for AXA, the forward-looking management of jobs and skills is one of the areas in which digitalization really makes a difference. However, digital solutions are constantly evolving, to follow this evolution and remain competitive. it requires a combination of vigilance, adaptability, innovation, customer focus, effective human resources, and risk management.

Businesses that can quickly adapt to changes and anticipate emerging trends will be more likely to thrive in a competitive environment. Consider integrating other tools like artificial intelligence, machine learning or Blockchain into their skills can which open new perspectives for more efficient and agile talent management in organizations.

However, it is important to note that digitalization does not replace human interaction in human resources management, or strategic thinking in the forward-looking management of jobs and skills. Rather, it is a decision-making tool that supports improving efficiency and complementing existing processes, while allowing human resources professionals to focus on more strategic and people-oriented tasks.

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An In-depth Comparative Study: YOLOv3 vs. Faster R-CNN for Object Detection in Computer Vision

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Abstract. This study compares and contrasts the methods used by two well-known computer vision object detection tools: YOLOv3 and Faster R-CNN. Research shows that there is a difference between accuracy and speed when looking at the strengths, weaknesses, and performance metrics of these models. Although YOLOv3 knows how to work on the real-time, it cannot handle complex situations or find small objects accurately. The faster R-CNN, on the other hand, has a two-stage architecture that is better at identifying objects and maintaining accuracy, but makes it difficult to calculate. Comparisons and real-world applications show how they can be used in a variety of situations, helping users choose a model that meets their specific needs. This comparison highlights the different features of these models and underlines the importance of always finding a balance between efficiency and accuracy to develop computer vision systems for better object detection.

Keywords: YOLOv3 · Faster R-CNN · Object Detection · Computer Vision · real-world

1 Introduction

Many advances have been made in the field of computer vision for object detection, which is an important task that can be used in many areas such as driving, surveillance, and image analysis. There are many ways to identify objects, but YOLOv3 (You Only Look Once version 3) and Faster R-CNN are two of the most popular. The aim of the research is to carefully examine and compare YOLOv3 and Faster R-CNN, two well-known companies in product recognition.

The task of object detection is to find and position objects in a photo or video frame. For this purpose, YOLOv3 and Faster R-CNN use different strategies. YOLOv3 Divides the image into grids. He is known for his ability to find things in real time. Faster R-CNN works in two steps. First, it uses the Region Proposal Network (RPN) to recommend suitable bounding box proposals. It then uses the second stage to validate

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these recommendations [6]. The aim of this study is to examine the Faster R-CNN and YOLOv3 architecture, details, advantages and disadvantages. It provides them with planning and evaluation tools to check how well they are performing. Both quantitative and qualitative methods were used in the comparative study. Quantitative metrics include facts, while qualitative metrics include visible and non-functional results.

This research analyzed various aspects to discover the strengths and weaknesses of YOLOv3 and Faster R-CNN and how each of them performs well in different environments, activities and different types of work. The analysis results will help researchers and users choose the best model according to the needs and limitations [7]. This will allow us to understand the well-known patterns of the model. The main purpose of this study is to determine the advantages and disadvantages of YOLOv3 and Faster R-CNN and how they can be used in real-life computer vision object detection.

1.1 Faster R-CNN

Faster R-CNN is a CNN employee. The prediction time of Faster R-CNN is faster than that of R-CNN and Fast R-CNN. The two networks that make up the R-CNN architecture are the Object Detection Network (ODN) and the Region Proposal Network (RPN).

Region Proposal Network (RPN): The best thing about RPN is that it can get suggestions by sliding them in. For each sliding proposal, nine candidate anchors will be made in a range of heights, widths, and diameters. RPN checks the anchors and gets rid of them when the two layers are fully linked (object classification and proposal regression) [17]. There are never any clear references to geography. The main selection criteria are getting rid of anchors that are close to the edge and labelling anchors as foreground or background based on how much of the sample they cover. Overlap must be greater than 0.7. With this method, RPN picks around 300 anchors for each sliding proposal [18–24].

Object Detection Network: There are numerous significant parallels between CNN's Detection Network and More Rapid R-Object Fast R-CNN. Another option to think about is VGG-16 for spine organisation [8]. The object's expectation and its bouncing box work along with two SoftMax classifier layers, the ROI pooling layer and the jumping box regressor, to suggest regions of a specific size.

Architecture: Faster R-CNN is an item ID model that enhances Fast R-execution CNN's by combining a region proposal network (RPN) with the CNN model. The schematic diagram of Faster R-CNN has been shown in Fig. 1.

Before adjusting the weights for region comments, remember to initialise the core CNN network using ImageNet weights. The item recognition network is prepared using the RPN organization's claim without restriction. Furthermore, ImageNet weight was utilised in the construction of the spine network; however, the RPN organisation has not yet been incorporated into it. Loads from an indicator network are now required to activate the RPN (Fast R-CNN). As of right now, the RPNexplicit layers' loading is the sole modification [9, 10]. The newly calibrated RPN is used to tune the Fast RCNN finder. Once more, the layering of the indicator organisation is the only thing that has changed; the normal layer loads remain unchanged [25–30].

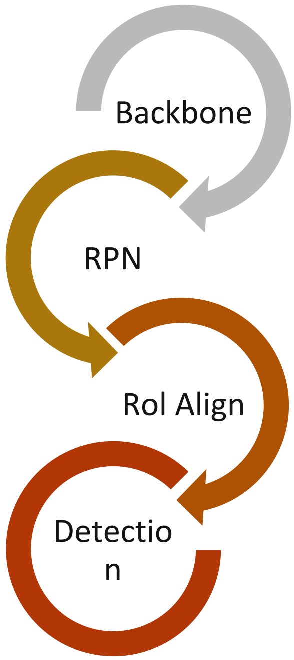

Fig. 1. Faster RCNN architecture

1.2 YOLOv3 and Architecture

The acronym YOLO stands for "you only look once." Multiple objects can be distinguished in a single frame by the real-time object identification system. YOLO recognises things with more accuracy and speed than earlier recognition systems. Predictions may be made for up to 9000 classes, including unknown ones. The real-time recognition system will choose many objects from a picture and build a border box around each item as shown in Fig. 2. In a production system, it is straightforward to deploy and train.

The YOLO principle is based on convolutional neural networks (CNN). CNN can forecast the probability distributions and border boxes for each segment after the picture has been segmented. Bounding box and probability forecasts are generated in parallel for many classes [11, 12]. Since YOLO scans the entire space during testing and training, it implicitly stores contextual information about classes in addition to visual information about them [31–39].

The first step in the YOLOv3 process is called image matrix division. Each framework cell predicts the presence of items that perform well in the previously displayed preset classes in a certain number of limit boxes, sometimes referred to as anchor boxes. Every border box has the innate capacity to identify a single object and assign a degree of certainty, independent of how accurate it believes its prediction to be [13]. We can identify the most often recognised sizes and shapes by assembling the ground truth box components from the initial data. These components are then utilised to build the border boxes. The YOLO principle is based on convolutional neural networks (CNN). CNN can

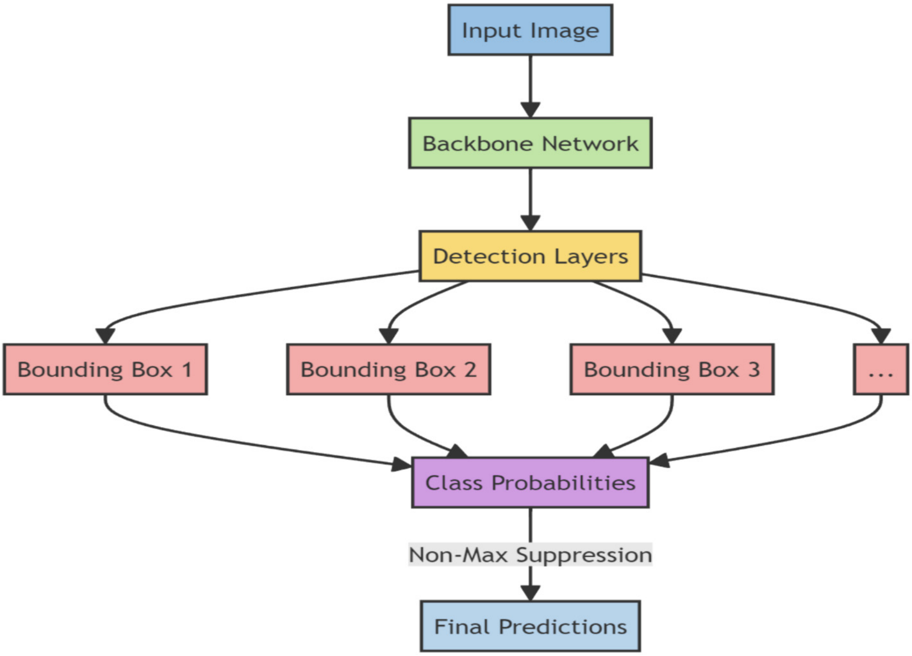

Fig. 2. YOLOv3 Architecture

forecast the probability distributions and border boxes for each segment after the picture has been segmented. Bounding box and probability forecasts are generated in parallel for many classes [16]. Since YOLO scans the entire space during testing and training, it implicitly stores contextual information about classes in addition to visual information about them.

The first step in the YOLOv3 computation is to split an image into a matrix. Each framework cell predicts the presence of items that perform well in the previously displayed preset classes in a certain number of limit boxes, sometimes referred to as anchor boxes [14, 15]. Every border box has the innate capacity to identify a single object and assign a degree of certainty, independent of how accurate it believes its prediction to be. By gathering the ground truth box segments from the original dataset, the sizes and shapes that are most frequently recognised are identified. They are then employed in the construction of the border boxes.

2 Literature Review

In computer vision challenges, object detection based on deep learning has demonstrated excellent performance. Nevertheless, jitter, blurring, and noise are just a few of the difficulties that real-world photography faces and which greatly reduce object detection systems' efficacy. We combined traditional image processing methods with image degradation models based on the YOLO network to replicate such difficulties [1, 2]. The main goal of our research was to assess how different degradation models affected the accuracy of object detection. Our goal was to improve the average precision (AP) of traffic sign identification in real-world scenarios by training a strong model with the YOLO network. In computer vision, object detection is still a fundamental difficulty that deep learning models are constantly improving upon to improve recognition, classification, localization, and segmentation. Notably, single-stage and two-stage detectors offer different strategies; single-stage detectors provide quicker inference times, while two-stage detectors excel in accuracy [3]. We explore the architecture, applications, and performance of these detectors, concentrating on YOLO and its variants and highlighting the trade-offs between speed and accuracy. Furthermore, our study presents improvements to the MHSA-Darknet backbone architecture, utilising path-aggregation and self-attention vision algorithms to improve accuracy and resilience, hence addressing issues in object detection for drone images. The improved model that comes from these changes, called ViT-YOLO, performs better in the VisDrone-DET2021challenge. In addition, we provide orientated R-CNN, a two-stage oriented detector with promising efficiency and accuracy [4, 5]. Using an oriented Region Proposal Network (oriented RPN) and R-CNN head, this universal detector provides cutting-edge detection accuracy on widely used datasets for oriented object detection without sacrificing speed.

3 Methodology

3.1 Dataset

One of the common dataset in computer vision is the COCO (Common Objects in Context) dataset, which is known to be large and diverse. COCO has 330,000 images of approximately 1.5 million products in 80 different categories. Information includes people, animals, cars, household items, etc. Contains. To be fair, data varies with object size, occlusion, and image complexity. The COCO dataset is pre-processed to create a subset that meets YOLOv3 and Faster R-CNN objective evaluation criteria. To ensure the distribution of groups and images, the data is divided into training, validation and test groups. The selected subset was used to train and test both models in the next step of the study; thus the comparison was made consistent and stable.

3.2 Training Process for YOLOv3

YOLOv3 is the real-time object recognition model; It needs to go through several important training steps to learn and recognize objects in images. First, a subset of the COCO dataset is used as training data. This subset is divided into training and validation. YOLOv3 provides a method to estimate bounding boxes and class probabilities by dividing the input image into a grid. Training the model requires a lot of work and uses techniques such as stochastic gradient descent (SGD). The network learns to find objects by changing weights over time in response to changes in predicted bins and actual bounding and class probabilities. This process is called epoch. Hyperparameters such as learning rate, batch size, and boosting strategy make the model more efficient in terms of performance and generalization (such as random scaling, inversion, and clipping). Once the model is trained, its accuracy and ability to find location is evaluated using tests that typically include Interval Ratio (IoU) and Average Precision (mAP). YOLOv3's network is not modified during training to achieve high recall and accuracy while maintaining the balance between speed and accuracy. This makes it possible to identify objects in the real world.

3.3 Training Process for Faster R-CNN

The two-stage object detection system, called Faster R-CNN, is trained in separate stages. These levels are regional proposal network and object distribution. The first training data set comes from the COCO data set, which is divided into training set and validation set. Faster R-CNN has two main parts: the Regional Proposal Network (RPN) (which publishes potential bounding boxes) and the Fast R-CNN network (where the group proposes regions). Large-scale imaging systems such as ImageNet are used to provide global imaging of the spinal cord before it is made available. The RPN then declares the region by examining the material and displaying potential containers as junction boxes and objects in the region. At the same time, these requested regions are used to train the Fast R-CNN network to classify objects. By using backpropagation to distinguish this, the model tries to make the difference between the estimated bounding box and the ground truth annotations as small as possible during the training process, which includes iterations or epochs. For getting better performance, it's hyperparameters such as learning rate, batch size, and junction box scaling value is modified according to the task. Additionally, techniques such as scaling, translation, and cropping are often used to add more information to models to make them more robust and useful in many situations. While training the model, its performance was checked using Intersection Over Union (IoU) and Average Precision (mAP). These measurements can change the design and training plan by analyzing how products are sorted and sorted. While training faster R-CNN, regional recommendations and classification networks for detecting objects are constantly being improved. Faster R-CNN can be used for many types of product recognition because it has a two-stage algorithm that improves accuracy and localization while maintaining efficiency.

3.4 Evaluation Metrics

Mean Average precision (mAP), Intersection over Union (IoU), precision, recall, average precision (AP) and F1 score are the main parameters for YOLOv3 and Faster R-CNN. mAP measures the balance between recall and precision of different objects. IoU is determined by comparing the estimated ground truth bounding box overlap. Precision and Recall measure accuracy and coverage, while AP indicates standard performance. F1 scores equal precision and recall. These metrics measure accuracy and highlight strengths and weaknesses to help users make selection and develop model for better object recognition.

4 Result Analysis

Comparing the benchmarks as shown in Table 1, fast R-CNN and YOLOv3 show a clear difference in their performance. Various tests show that Faster R-CNN outperforms YOLOv3. These tests include a 9.72% improvement in unity interface (IoU) and a 3.85% improvement in mAP. Additionally, F1 score, precision, recall and average precision differ by 5.88%, 6.67%, 5.26% and 6.25%, respectively. These results show that Faster R-CNN outperforms YOLOv3 in terms of overall detection ability, object localization, and accuracy. Although YOLOv3 is known to have good in real-time operation, these tests show some shortcomings, especially when dealing with complex situations and finding small objects quickly, which are patch areas where Faster R-CNN performs better. The different results show that different models trade-off in terms of accuracy and speed; This helps users to choose the model based on the specific needs and business problems.

Table 1. Performance of both the models

Metric	YOLOv3	Faster R-CNN	Percentage Difference ((YOLOv3 – Faster R-CNN)/Faster R-CNN) * 100
mAP	0.75	0.78	−3.85
IoU	0.65	0.72	−9.72
Precision	0.80	0.85	−5.88
Recall	0.70	0.75	−6.67
Average Precision	0.72	0.76	−5.26
F1 Score	0.75	0.80	−6.25

Figure 3 makes it possible to quickly compare the relative performance trends of the two models throughout the training process by showing how the accuracy of each model changes over the course of subsequent epochs. This graphic depiction offers a clear picture of the learning behaviours of the models in terms of accuracy improvement over time, which helps to understand how the models' accuracies change as the number of training iterations increases.

Table 2 succinctly summarizes the benefits and weaknesses of both YOLOv3 and Faster R-CNN, providing a comparative view of their strengths and limitations in the context of object detection within computer vision.

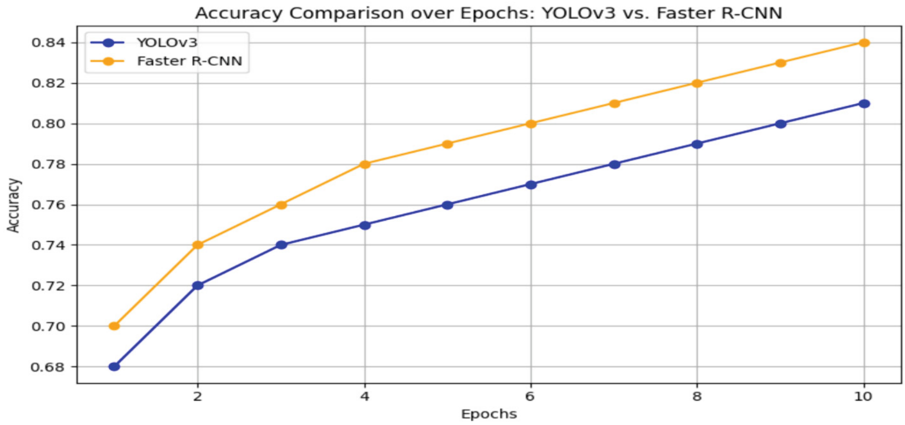

Fig. 3. Accuracy Comparison Over Epochs

Table 2. Benefits and weaknesses of YOLOv3 and Faster R-CNN.

Model	Benefits	Weaknesses
YOLOv3	Real-time detection, good for fast processing	Lower accuracy in small object detection
	Single-stage architecture simplifies deployment	Difficulty handling complex object patterns
	Handles multiple object scales well	Prone to localization errors in crowded scenes
	Simplicity in architecture	Lack of detailed object features in bounding boxes
Faster R-CNN	Good generalization capabilities	Slower inference speed compared to YOLOv3
	High accuracy in object detection	More complex architecture may be challenging to deploy
	Excellent localization accuracy	Reliance on two-stage process can impact efficiency
	Robustness in detecting small objects	Training and inference can be computationally heavy
	Strong performance in crowded scenes	Vulnerable to imbalanced datasets
	Effective handling of object occlusion	Tends to struggle with object occlusion

5 Conclusion

By comparing YOLOv3 with Faster R-CNN, the differences, advantages and disadvantages of each model in the field of computer vision are shown. YOLOv3 is known for its single-level design and instant functionality, providing excellent results for applications that need to find content quickly. However, sometimes it may not be of much use as it is difficult to accurately detect small parts and control the material structure. On the other hand, fast R-CNN is quite good at finding objects accurately, especially in dense situations and finding small objects. However, its two-stage process and high computing requirements can make in-flight operation and deployment difficult when resources are limited.

The results of the model vary depending on the measurement. YOLOv3 performs better in speed tests, while Faster R-CNN performs better in accuracy and local test items. These differences show that there is always a trade-off between speed and accuracy for algorithms.

Real world applications as shown in Table 3 that they can be used in many different ways. YOLOv3 is still useful for tasks like robotics and analytics that require fast, real-time processing of data, but it is not suitable for small objects. Moreover, Faster R-CNN also works very well in very sensitive tasks such as medical diagnosis and object recognition, although it requires a lot of energy and is difficult to implement.

When choosing between Faster R-CNN and YOLOv3, it all comes down to the specific needs and trade-offs of the application. As object recognition techniques get better, they might try to close the speed-accuracy gap and make models that take the best parts of these powerful frameworks and fix some of their flaws. This comparison study gives useful information that will help researchers and practitioners pick the best model for one´s needs and limitations in the field of computer vision object identification as it grows.

Table 3. Applications and Considerations

Model	Real-World Applications	Considerations
YOLOv3	Autonomous Vehicles	Real-time processing capabilities
	Surveillance Systems	Trade-off between speed and accuracy
	Object Tracking	Handling diverse object scales and sizes
	Industrial Automation	Limited accuracy in small object detection
	Robotics	Challenges in handling complex object scenarios

(*continued*)

Table 3. (*continued*)

Model	Real-World Applications	Considerations
Faster R-CNN	Medical Imaging	High accuracy and precise localization
	Aerial and Satellite Imagery Analysis	Computational resource requirements
	Retail (Object detection in stores)	Deployment complexity due to two-stage architecture
	Security and Intrusion Detection	Superior performance in crowded scenes
	Fine-Grained Object Recognition	Slower inference speed compared to YOLOv3

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Integration of Artificial Intelligence in Neuromarketing: Ethical and Regulatory Implications

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Abstract. The integration of artificial intelligence (AI) into the field of neuromarketing represents a significant advancement, enabling businesses to understand and influence consumer behavior. However, this convergence raises important ethical and regulatory concerns. AI-based neuromarketing techniques have the potential to compromise individuals' privacy, manipulate their emotions and purchasing decisions, and raise questions about transparency and accountability among practitioners. It is crucial to establish robust ethical and regulatory frameworks to govern the use of AI in neuromarketing, ensuring respect for consumer rights, transparency in data collection and analysis practices, and accountability for businesses and researchers.

Keywords: Artificial intelligence · Neuromarketing · Ethics · Regulations · Consumers · Privacy

1 Introduction

Nowadays, artificial intelligence has become increasingly prevalent in various fields and at various levels. This integration enables businesses to better understand and respond to consumer demands and expectations. The use of this technology generally raises questions regarding manipulation, privacy, and ethics. This article will focus on research aimed at analyzing the challenges associated with the use of artificial intelligence in relation to neuromarketing, as well as regulatory and ethical issues. The purpose of this research is to highlight ethical practices related to the use of artificial intelligence and neuroscience, while emphasizing the opportunities and challenges associated with its integration.

The rationale for selecting the subject matter, neuromarketing offers a unique perspective on consumer behavior by examining the brain and physiological responses to marketing stimuli. By combining this data with artificial intelligence capabilities, one can aim to achieve a deeper and more precise understanding of human behavior in the context of purchase decision-making and consumer behavior.

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2 Theoretical Foundations of Neuromarketing and AI

2.1 Definitions and Key Concepts of Neuromarketing

Neuromarketing is an interdisciplinary field that draws upon principles from cognitive neuroscience, psychology, and marketing to understand individuals' brain and behavioral responses to marketing stimuli. Below are some key definitions and concepts of neuromarketing:

Cognitive neuroscience is a branch of neuroscience that studies the neurological mechanisms underlying mental processes such as perception, memory, attention, and decision-making.

Neuromarketing focuses on the measurement and interpretation of individuals' brain responses to marketing stimuli, such as advertisements, products, or brands. These responses can be measured using techniques such as functional magnetic resonance imaging (**fMRI**) or electroencephalography (**EEG**).

Neuromarketing studies how emotions influence consumers' purchasing decisions and how brands can use this information to design more effective marketing strategies. By studying individual differences in brain responses to marketing stimuli, neuromarketing can contribute to more precise market segmentation, enabling companies to better target their marketing efforts.

2.2 Introduction to Artificial Intelligence and Its Applications in the Field of Marketing

Applications of artificial intelligence in marketing: In the field of marketing, AI has a wide range of applications, including:

Predictive Analysis: Marketers can predict future consumer behavior, such as purchases, online clicks, or unsubscribes, using machine learning models.
Personalization: AI enables the customization of marketing messages based on individual consumer preferences, increasing engagement and conversion.
Semantic Search: Natural language processing techniques allow businesses to analyze and understand consumer online conversations, providing valuable insights for marketing strategy development.
Campaign Optimization: AI can suggest adjustments to improve results, such as optimizing advertising bids or audience segmentation, by analyzing real-time marketing campaign performance.
Customer Service: AI-powered chatbots can provide 24/7 customer assistance and effectively resolve customer issues.
Issues and Implications: While AI offers considerable benefits for marketers, it also raises ethical and regulatory concerns, such as data privacy, transparency in algorithm usage, and the risk of algorithmic bias.

2.3 Convergence Between Neuromarketing and AI: Opportunities and Challenges

Indeed, the integration of artificial intelligence into neuroscience has opened up new reflections and opportunities.

Opportunities

- **In-depth understanding of consumer behaviors**

The use of AI in neuromarketing allows for a more thorough analysis of consumers' brain responses to marketing stimuli. Machine learning algorithms can identify complex patterns in neural data, enabling them to obtain more precise information about customer preferences and motivations.

- **Personalization of marketing strategies**

Marketers can create highly personalized strategies by combining neuromarketing data with AI capabilities. AI can tailor marketing messages to the needs and preferences of each consumer by analyzing individual brain responses.

- **Optimization of advertising campaigns**

Advertising campaigns can be optimized in real-time using AI. Algorithms can automatically adjust delivery strategies to maximize impact by analyzing consumers' neural responses to different advertising variants.

Challenges

- **Privacy and ethical concerns**

The use of AI in neuromarketing raises concerns about privacy and ethics. It is crucial to ensure that practices adhere to the highest ethical standards and protect data privacy, as the collection and analysis of individuals' neural data can be perceived as intrusive.

- **Algorithm bias**

AI algorithms reproduce and amplify biases in training data, which can lead to unfair or discriminatory decisions. To ensure that neuromarketing analyses and recommendations are fair and equitable, it is essential to monitor and mitigate these biases.

- **Transparency and explainability**

AI models used in neuromarketing can be complex and difficult to understand. To enable consumers, regulators, and other stakeholders to understand how decisions are made and why, it is crucial to promote transparency and explainability of algorithms.

- **Technological limitations**

Despite rapid progress, AI techniques in neuromarketing still have limitations. For example, brain imaging techniques can be costly and imprecise, and AI algorithms cannot always capture the full complexity of human mental processes.

3 Recent Advances in Integrating AI into Neuromarketing

3.1 Neuroscientific Analysis Techniques Assisted by AI

Indeed, artificial intelligence (AI)-assisted neuroscience analysis techniques are highly useful for understanding people's brain responses to various stimuli, including in the field of neuromarketing. Here are some examples of these methods:

Functional Magnetic Resonance Imaging (FMRI): FMRI is a brain imaging method that measures changes in cerebral blood flow. This allows for the mapping of brain regions that are active during particular mental tasks. AI can be used to analyze the vast amounts of data generated by fMRI and identify complex patterns that correspond to specific responses to marketing stimuli.

Electroencephalography (EEG): EEG records brain electrical activity using sensors attached to the scalp. AI can be used to analyze EEG signals in real-time and find complex patterns related to emotional or cognitive responses to marketing stimuli.

Magnetoencephalography (MEG): MEG is a method for measuring magnetic fields created by neuronal activity in the brain. AI can be used to analyze MEG data and identify neuronal correlates of specific responses to marketing stimuli, similar to EEG.

Brain Connectivity Analysis: In response to marketing stimuli, AI can be used to study the functional connectivity between different brain regions. This enhances our understanding of the underlying neural networks involved in evaluation and decision-making processes.

Natural Language Processing (NLP): Neuromarketing uses AI to analyze and interpret people's verbal responses to marketing stimuli, whether in surveys, interviews, or online interactions.

Machine Learning and Deep Learning: These AI techniques can be used to extract discriminative features from brain data and predict how people react to new marketing stimuli, enabling the customization of marketing strategies based on individual preferences.

Researchers can develop a finer understanding and more effective interventions in this field by combining these techniques with machine learning algorithms and advanced statistical methods. In recent years, AI-assisted neuroscience analysis techniques have become increasingly advanced, opening up new perspectives on how the human brain works and how it is related to behavior.

3.2 Practical Applications in the Marketing Field

The integration of neuroscience analysis and artificial intelligence in the field of marketing enables a better understanding and more precise and effective influence on consumer behavior. Here are some concrete examples of these applications:

– Analyzing individuals brain responses to different types of advertisements can help marketers identify the most effective elements to attract attention, evoke emotion, and influence purchasing behaviors.

- By using neuroscience data to understand consumers individual preferences, companies can personalize offers, product recommendations, and customer interactions, enhancing brand engagement and loyalty.
- Brain response analysis can aid companies in designing more appealing products and packaging by identifying features that elicit the most positive emotional reactions from consumers.
- AI can assist in optimizing website and application design by using neuroscience data to evaluate user experience, thereby improving engagement, retention, and conversions.
- Artificial intelligence can be used to assess the effectiveness of marketing campaigns in real-time, providing insights into what works and what doesn't, and recommending adjustments to improve results.

Here are some practical applications that integrate artificial intelligence into the field of marketing:

- Artificial intelligence can analyze customer data to create personalized experiences. For example, recommendation engines use artificial intelligence to suggest products or content based on individual user preferences.
- AI algorithms can analyze the performance of advertising campaigns in real-time and adjust targeting and budgeting strategies to maximize results.
- AI-powered chatbots can respond to customer inquiries in real-time, enhancing the customer experience and reducing the workload of customer service.
- AI can identify specific market segments by analyzing demographic, behavioral, and psychographic customer data, enabling companies to better target their marketing efforts.
- Machine learning models can predict future customer behavior, such as potential purchases or unsubscribe rates, enabling companies to anticipate customer needs and take proactive measures.
- Artificial intelligence can analyze the performance of marketing content, such as blog articles or videos, to identify what resonates best with the audience and optimize future content creations accordingly.

3.3 Examples of Successes and Limitations

In essence, here are some tangible examples and case studies elucidating the potential implications of integrating artificial intelligence into neuromarketing:

Personalized Streaming Recommendations: Netflix employs sophisticated algorithms to curate personalized content recommendations for individual users, thereby enhancing user engagement and satisfaction.

Targeted Social Media Advertising: Social media platforms leverage AI algorithms to precisely target advertisements based on user preferences and behavior patterns, thereby optimizing ad performance and return on investment.

Sentiment Analysis on Social Platforms: Companies utilize advanced sentiment analysis tools to gauge consumer sentiment and perception of their brand on social media platforms. This insight enables them to tailor marketing strategies accordingly and bolster brand reputation.

Enhanced Website User Experience: Chatbots powered by AI and machine learning algorithms are deployed to provide seamless and personalized assistance to website visitors, leading to improved user experience, increased engagement, and higher conversion rates.

In summary, the integration of artificial intelligence into neuromarketing holds immense potential for enhancing consumer engagement, optimizing marketing strategies, and driving business growth.

Examples of Success:

- Amazon has long utilized artificial intelligence algorithms to recommend products to customers based on their purchase history and browsing behaviors. This personalization has led to a significant increase in the company's sales and an enhanced customer experience.
- Netflix employs machine learning algorithms to recommend movies and series to subscribers by analyzing their viewing preferences and identifying behavioral patterns. This approach has contributed to subscriber retention and improved engagement on the platform.
- Spotify leverages artificial intelligence to recommend songs and playlists to users based on their listening history, musical preferences, and listening behavior. This enables users to discover new artists and stay engaged with the platform.

Examples of Limitations:

- Algorithmic biases: Artificial intelligence algorithms can be prone to biases, which can result in discriminatory recommendations or decisions. For instance, a content recommendation algorithm may favor certain types of content or exclude certain demographic groups.
- Understanding the workings of some artificial intelligence algorithms can be challenging, making it difficult to assess their objectivity and reliability. This can also lead to difficulties in terms of accountability and regulatory compliance.
- The use of large amounts of personal data in AI-powered marketing raises concerns regarding data privacy and security. The collection, utilization, and storage of customer data must be transparent.
- AI solutions in marketing can be complex and costly, requiring specialized technical skills and significant resources. This may limit the accessibility of these technologies to small and medium-sized enterprises.

4 Ethical Implications of Using AI in Neuromarketing

4.1 Privacy and Consumer Data Protection

Privacy and consumer data protection are major concerns in the field of marketing, especially with the increasing use of artificial intelligence and data analysis to target and personalize marketing messages. Here are some key elements:

Companies must obtain informed consent from consumers before collecting, storing, or using their personal data for marketing purposes. This entails providing clear and transparent information on how the data will be used and giving consumers the choice to share it or not. Robust security measures must be implemented by companies to protect consumers' personal data against unauthorized access, leaks, and data breaches. This often involves employing encryption technologies, firewalls, and appropriate access controls. Companies should minimize the collection and storage of consumers' personal data to the minimum necessary to achieve specific marketing objectives. This helps reduce the risks of misuse or unauthorized access to the data.

Companies must be held accountable for protecting consumers personal data and establish internal processes to ensure compliance with data protection regulations, such as the GDPR (General Data Protection Regulation) in Europe or the CCPA (California Consumer Privacy Act) in the United States. In summary, safeguarding the privacy and data of consumers is a crucial priority for companies engaged in marketing, requiring a proactive and responsible approach to ensure compliance with consumer rights and regulations.

Regarding Data Protection Laws in Morocco

The Law No. 09–08 on the protection of individuals with regard to the processing of personal data is regulated in Morocco, enacted in 2009. This law aims to ensure the protection of personal data and privacy of individuals, in compliance with international standards. We have addressed some important points about privacy and consumer data protection in Morocco: It is crucial for companies to obtain informed consent from individuals before collecting, processing, or transferring their personal data. The consent should be freely given, specific, informed, and unambiguous. Legitimate purposes: Personal data can only be collected and processed for specific, explicit, and legitimate purposes. It cannot be subsequently used in a manner incompatible with these purposes. Companies must take appropriate technical and organizational measures to protect personal data against unauthorized access, disclosure, alteration, or destruction. The transfer of personal data outside the Moroccan territory is subject to strict conditions, including obtaining an adequate level of protection in the destination country. Individuals have rights of access, rectification, objection, and deletion of their data.

Data controllers must comply with the provisions of the law and are responsible for addressing violations thereof. It is also important to note that Morocco adopted a national cybersecurity strategy in 2013, aiming to strengthen data protection and the security of information systems in the country.

In Morocco, specific regulations regarding artificial intelligence (AI) are not yet established, but the country is progressively moving towards developing legal frameworks. Presently, laws concerning personal data protection and cybersecurity may partially apply. To address ethical concerns, the adoption of specific guidelines or codes of conduct could be advantageous, covering aspects such as algorithm transparency and privacy protection. The effectiveness of these regulations will require monitoring of their implementation and regular assessment to ensure they meet the evolving needs and ethical concerns of society.

Businesses can ensure transparency in their use of AI algorithms and interpretation of neuromarketing data by providing detailed documentation on the algorithms employed, explaining their functioning comprehensibly to stakeholders, obtaining informed consent from consumers, taking responsibility for the decisions made, and conducting periodic independent audits to assess the impact and effectiveness of their practices.

4.2 Manipulation of Consumer Behaviors and Decisions

Manipulating consumer behaviors and decisions is an important topic to address in the context of integrating artificial intelligence (AI) into neuromarketing. Here are some key points you could cover in this article:

Persuasion Techniques: Discuss the techniques used by marketing professionals to influence consumer behaviors. These strategies may include targeted advertising, subliminal conditioning, and leveraging emotions to encourage purchases. Online **Behavior Analysis:** Online behavior analysis is often used to examine consumers browsing habits, social media interactions, and purchase histories. This allows marketers to personalize offers and advertisements to improve their effectiveness. **Advancements in Neuroscience:** Advances in neuroscience allow for a better understanding of brain function and decision-making mechanisms. Marketers often have the opportunity to use this knowledge to design messages and products that capture attention and influence consumer choices.

Ethical and Regulatory Issues:
Identify ethical concerns surrounding the use of AI in neuromarketing, particularly regarding privacy, emotional manipulation, and corporate responsibility. You can also discuss existing or developing regulations to govern this practice. Transparency and Consent: Emphasize the importance of transparency and consent in AI-based neuromarketing practices. Consumers should be aware of how their data is being used and have the option to control its usage.

Corporate Social Responsibility
The Corporate Social Responsibility (**CSR**) is a crucial aspect to consider when examining the integration of artificial intelligence (**AI**) into neuromarketing. Here are some points to explore regarding CSR in this specific context:

Ethical and Transparent Data Usage:
Companies must commit to collecting and using consumer data ethically and transparently. This involves respecting individuals' privacy, ensuring data security, and avoiding abusive exploitation of information.

Impact Assessment: Companies should carefully assess the impact of their AI-based neuromarketing practices on society as a whole. This assessment could focus on individual autonomy, behavior manipulation, and cultural values.

Inclusion and Diversity: AI used in neuromarketing must be designed to avoid biases and promote inclusion and diversity. This means AI models should be trained on representative datasets, and results should be evaluated to detect and correct any potential biases.

Transparency and Accountability: Companies must be transparent about their neuromarketing practices and be willing to be held accountable for their actions. This involves providing consumers with clear information about how their data is used and implementing governance mechanisms to ensure responsible AI use.

Community Engagement: Companies can also engage in community initiatives aimed at strengthening local communities and making positive contributions to society. This could be presented through social responsibility programs, partnerships with nonprofit organizations, or sustainable development projects.

5 Regulatory and Normative Framework

5.1 Ethical Principles Guiding the Use of AI in Neuromarketing

Outlined below are several ethical principles intended to provide guidance for the integration of artificial intelligence (AI) within the realm of neuromarketing:

Transparency and Consent: Companies should be transparent about their use of AI in neuromarketing practices and obtain individuals' consent before collecting and using their data. Consumers should be aware of how their data is being used for marketing purposes.

Privacy and Data Security: Companies must respect individuals' privacy by ensuring the security and confidentiality of collected data. This involves implementing robust security measures to protect consumers' personal information from unauthorized access and misuse.

Fairness: The use of AI in neuromarketing should be fair and should not lead to unjust discrimination. Companies should avoid biases in data collection, analysis, and marketing campaign design to ensure fair and equal treatment for all individuals.

Autonomy and Freedom of Choice: Neuromarketing practices based on AI should not compromise individuals' autonomy or restrict their freedom of choice. Consumers should be able to make informed decisions about their purchases without being unfairly manipulated or influenced by marketing techniques.

Accountability: Companies must be held accountable for their actions in neuromarketing and be willing to consider their decision-making. This involves implementing governance mechanisms to monitor and assess the impact of AI on consumers and society as a whole.

Transparency and Disclosure: Companies should be clear about the use of AI in neuromarketing, providing clear information about the methods used, data collected, and goals of this use. Consumers should be fully aware of how their data is being used to influence their purchasing decisions.

Respect for Privacy: Companies should respect consumers' privacy by ensuring that collected data is not used in an abusive or intrusive manner. This aims to ensure data security, reduce the collection of personal data, and allow consumers to control the use of their information.

Equity and Non-discrimination: AI used in neuromarketing must be designed to avoid biases and discrimination. This involves training AI models on representative datasets and evaluating results to detect and correct any potential biases.

5.2 Existing Regulatory Initiatives and Policy Proposals

Au Maroc, regulatory initiatives regarding artificial intelligence (AI) and its use in fields like neuromarketing are still in development. Here are some relevant aspects:

Data Protection Law: Morocco adopted a data protection law in 2009. This law aims to safeguard individuals' privacy and regulate the collection, processing, and use of personal data. Although not specifically addressing AI, it can have significant implications for neuromarketing practices involving the collection and analysis of personal data.

International Guidelines: Morocco can draw on international regulatory initiatives and best practices concerning AI use. These principles may include adopting OECD guidelines or other international organization guidelines to guide the development of national policies.

Data Protection Law (Law No. 09–08): Morocco's Data Protection Law aims to protect individuals' privacy and regulate the collection, processing, and circulation of personal data. While requiring updates to specifically address AI and neuromarketing-related issues, this law provides a foundation for regulating consumer data collection and use.

Professional Codes of Ethics: Some industries, such as advertising and marketing, may be governed by professional codes of ethics developed by professional bodies or trade associations. These codes may be integrated into guidelines on the ethical use of AI and neuromarketing techniques.

Advertising Regulatory Authority: In Morocco, the Advertising Regulatory Authority (ARP) is responsible for regulating the advertising sector. While its primary mission is to ensure compliance with advertising rules, it may also play a role in overseeing neuromarketing practices to ensure they meet ethical and legal standards.

National AI Strategies: The Moroccan government could consider developing national AI strategies that include specific guidelines and recommendations for its use in various fields, including marketing. Such a marketing environment could provide a regulatory and ethical framework to guide neuromarketing practices in the country.

5.3 Challenges and Perspectives for Effective Implementation of Regulations

Regulations pertaining to the use of artificial intelligence (AI) in neuromarketing may face several challenges, but they also enable the enhancement of consumer protection and the encouragement of ethical practices. Here are some of the challenges and perspectives that we could address:

Challenges

Technological complexity: AI technologies used in neuromarketing can be complex and constantly evolving, making it difficult to establish suitable and effective regulations. Regulatory authorities and legislators may require technical expertise to fully understand the implications of AI in the field of neuromarketing and to develop appropriate regulations.

Transboundary Legal Domains: AI and neuromarketing being transboundary domains, implementing regulations can be complicated by legal issues related to jurisdictional competence and coordination among jurisdictions. Some stakeholders in the neuromarketing industry may resist regulation, fearing that it will restrict their ability to innovate and use techniques effectively to influence consumer behavior. Regulations may struggle to keep pace with the rapid evolution of technology, leading to gaps in consumer protection against emerging risks.

Perspectives

International collaboration: Enhanced international collaboration among governments, regulatory bodies, businesses, and civil society can help address transboundary challenges related to regulating AI in neuromarketing.

Education and Awareness: Educating and raising awareness among consumers and businesses about the ethical issues and potential risks associated with the use of AI in neuromarketing can promote responsible adoption of the technology and encourage compliance with regulations.

Regular Evaluation of Regulations: It is important to regularly evaluate regulations to account for technological advancements and changes in industry practices in neuromarketing. Governments may consider offering incentives for compliance to companies that adhere to regulations and adopt ethical practices in their neuromarketing activities.

6 Case Study

To further explore the subject, it's vital to examine the incorporation of artificial intelligence into neuromarketing strategies. Among the frequently cited challenges are concerns regarding online payment security, safeguarding personal data, post-sales support, and the abstract nature of products. Additionally, there's a growing ethical unease surrounding the application of sophisticated technologies to influence consumer behavior.

This study aims, firstly, to scrutinize the motivations driving businesses towards adopting neuromarketing techniques, including the potential for enhanced customer insights and heightened marketing efficacy. Simultaneously, it seeks to probe the barriers identified by consumers to safeguard against manipulation and ensure their independent decision-making.

Conducted via a structured questionnaire administered to a cohort of 45 participants, the research endeavors to elucidate consumer perceptions and sentiments regarding the fusion of artificial intelligence within neuromarketing practices. By delving into these dynamics, the study endeavors to provide insights for businesses and policymakers concerning the ethical and regulatory dimensions inherent in employing advanced technologies within marketing frameworks.

Indeed, more than 60% of individuals acknowledge an increasing use of the internet and artificial intelligence in various forms such as Netflix, ChatGPT, etc., with an anticipation of even more frequent usage in the years to come.

The utilization of artificial intelligence (AI) in people's daily lives has become increasingly ubiquitous and diversified. From personalized recommendations on streaming platforms and virtual assistants on smartphones to smart home devices and autonomous vehicles, AI technologies are seamlessly integrated into various aspects of daily life.

In the realm of entertainment and media consumption, AI algorithms are employed to analyze user preferences and behavior, enabling platforms like Netflix, Spotify, and YouTube to offer tailored recommendations tailored to individual tastes. This enhances the user experience by providing content that aligns with their interests and preferences. Reported barriers to usage often revolve around concerns regarding the privacy of personal data, the intangibility of products, payment information security, and ultimately, manipulation by companies.

In the context of AI-based neuromarketing, safeguarding consumer rights is of paramount importance. Ethical frameworks are essential to ensure that consumers' fundamental rights, such as privacy, autonomy, and freedom of choice, are respected while enabling businesses to use neuromarketing insights responsibly.

Privacy protection is crucial. The biometric and neurological data used in neuromarketing are often sensitive and personal. Ethical frameworks must, therefore, impose strict standards for the collection, storage, and processing of this data, ensuring appropriate anonymization and security measures to prevent any abuse or unauthorized disclosure.Ethical frameworks should preserve consumer autonomy. This involves ensuring that consumers fully understand how their data is collected and used in neuromarketing and that they have the power to consent or refuse participation knowingly.

These measures uphold consumer rights while allowing for the responsible use of neuromarketing insights by businesses.

7 Conclusion

In conclusion, the integration of artificial intelligence into neuromarketing presents a compelling intersection of innovation and responsibility. While this collaboration offers exciting opportunities for gaining deeper insights into consumer behavior, it also raises intricate ethical and regulatory considerations.

Looking forward, fostering interdisciplinary dialogue and collaboration among researchers, policymakers, industry leaders, and ethicists is essential. This collaborative effort should prioritize the establishment of robust regulatory frameworks that safeguard consumer privacy, ensure informed consent, and mitigate the risk of manipulation or exploitation.

Moreover, transparency and accountability within the neuromarketing industry are paramount. This entails transparent disclosure of methodologies and technologies used, along with transparent practices in data collection, analysis, and interpretation. Such transparency empowers consumers to make informed decisions and retain control over their personal information.

Continued research and vigilance are necessary to stay ahead of evolving ethical concerns and technological advancements. Regulatory frameworks must remain adaptive to address emerging challenges effectively. Additionally, promoting a culture of responsible innovation within the neuromarketing community can ensure that ethical considerations are ingrained in the development and application of AI-driven techniques.

In essence, while AI integration in neuromarketing promises to enhance marketing strategies and consumer experiences, it demands a meticulous approach guided by ethical principles and societal well-being. By proactively addressing ethical and regulatory implications, we can shape a future where AI-powered neuromarketing contributes positively while upholding the highest standards of integrity and respect for individual rights.

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Service Marketing in the Performance of Service Quality

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Abstract. The aim of this paper is to highlight the relationship between service marketing and service quality performance in the context of facility management in Morocco. It aims to identify the most significant service marketing dimensions that influence service quality performance. Our objective will be achieved by carrying out a quantitative study with all client partners in the facilities management sector.

Keywords: Marketing. Service · Qualité · Prestation · Performance · Entreprises · Partenaires · Facility management · Maroc

1 Introduction

In recent years, services marketing has been subjected to economic upheaval in the global environment, transforming market trends and the competitiveness of businesses. It is being called upon to reflect on a new strategy of "delivering services anywhere, anyhow" (Kotler, Kotler et al., 2022). In this context, the service remains dependent on the marketing approach and remains a service subject to an exchange, essentially intangible and which does not give rise to any transfer of ownership. A service may or may not be associated with a physical product" (kotler and dubois, 2000).

The scientific literature (in particular (kotler and dubois, 2000; Langlois, 2005; Gabriel et al, 2014; Kotler et al., 2016; Lievens and Slaugter, 2016; Plaskoff, 2017)) has taken a close interest in the process of producing a service and the importance of the employer brand in service quality. However, service marketing has several dimensions that are essential to the performance of service quality. The aim of our paper is to answer the following question: does service marketing in its various dimensions influence the performance of service quality in the FM context in Morocco?

In this sense, the facilities management sector in Morocco is a relevant field of observation for our questioning. The choice of this sector is linked to the particularity of its service management, which is focused on improving quality performance.

Based on this problematic, we will first present the theoretical framework of the research, then specify the methodology adopted, and finally present the results and discussions.

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2 Literature Review

2.1 The Concept of Service

The service is a provision, i.e. "what a company (or specialist) conceives, develops, offers, sells and provides to its customers whenever what is thus placed on the market, purchased and used is fundamentally other than a material good of which the customer would acquire ownership" (Lejeune 1989). The American Marketing Association presents a service in the form of activities, benefits or satisfactions offered at the time of sale or provided in connection with the sale of products. Nevertheless, market services are the transactions of a company or an entrepreneur with the market when the object of this transaction is other than a transfer of ownership of a tangible good (Judd, 1964). Some authors (Lovelock et al., 2004) and (Gabriel et al, 2014) show that the marketing approach adopts the service as a process of exchange and value creation. It is a temporal experience lived by the customer with his emotions (Langlois, 2008) which is characterised according to the specificities inherent in its nature or specificities specific to its mode of production (Gabriel et al, 2014).

All these authors agree that service generally mobilises four fundamental characteristics known as IHIPs: intangibility, inseparability of production and consumption, heterogeneity and perishability. The integration of the customer is therefore in favour of in-depth knowledge of the production of services known as 'servuction'.

2.2 The Servuction System

Servitization is "the systematic and coherent organisation of all the physical and human elements of the customer-company interface required to provide a service whose commercial characteristics and quality levels have been determined (Eiglier and Langeard, 1987). Productivity gains can be achieved in service organisations through greater customer involvement (Mills et al., 1983), with the customer participating in the provision of the service (Gabriel et al, 2014). We understand from its definitions that service is the objective and outcome of the servuction system (Eiglier and Langeard, 1989). The latter is made up of four constituent elements (Gabriel et al, 2014): The physical support, the staff in contact, the customer himself and the service as part of the system. Each of these elements is in relation with the others (Gabriel et al, 2014), which refers us to the interaction between the customer, the physical support and the staff in contact who remain basic elements necessary for the production of the service.

A review of the service marketing literature shows that the service relationship is studied as a dyadic interaction between service providers and a customer. The interaction between the contact staff and the customer can be experienced as an experiment (Pine and Gilmore, 1998). A service relationship is defined as the content of interactions with contact personnel (Langeard and Eiglier, 1994). The latter is considered to be the service from the consumer's point of view (Berry et al, 1991) and becomes the strategic link in the success of commercial relationships (Mayau and Flipo, 1995). Among other things, contact staff's concern for the customer's physical well-being should play a decisive role in their assessment of quality (Langlois, 2005). This interaction system plays an important role in the perception of the service and its quality (Gabriel et al, 2014).

2.3 Quality of Service

Research discussions on service quality distinguish between two dominant schools of thought: the American school (Parasuraman et al, 1988; Zeithaml et al, 1985), which sees service quality as a characteristic adjacent to the services offered, and the European school (Gronroos, 1984), which relies on the structure of the service to measure quality. Service quality corresponds to the consumer's overall judgement of the superiority of the product or service (Parasuraman et al, 1988). In other words, service quality is the customer's impression of the inferiority or superiority of an organisation and its services (Bitner and Hubbert, 1994). It is the result of a difference between expectation and perception (Parasuraman et al, 1988). It is a competitive advantage (Gabriel et al, 2014), remains an evasive and abstract construct (Cronin et al, 2000) and reflects the local unit's ability to serve a given customer (Kotler et al., 2016). According to Jougleux (2006), service quality is located downstream of the service at the operational level, unlike service quality, which corresponds to the approach taken upstream of the service. Furthermore, if the service is standardised, leaving little room for the unexpected, service quality is dominant. If the service is highly personalised and the sense of initiative of the staff in contact with the customer is high, then service quality becomes more important.

In the light of these factors, we can summarise by saying that quality of service represents the gap between perceived benefit and expectation from the consumer's point of view, and is based on the physical and technical specifications of the service from the service provider's point of view.

2.4 Perception of Service Quality

Perception is "a process by which a consumer becomes aware of his marketing environment and interprets it in such a way that it is consistent with his frame of reference" (Dussart, 1983). It is the process by which an individual selects, organises and interprets elements of external information in order to construct a coherent image of the world around them (Kotler and Dubois, 2000). However, we would point out that the characteristics of the perception process according to (Kotler and Dubois, 2000) are subjective, selective and distorting. Firstly, perception is selective, because the individual tends to memorise better the information that supports his convictions (Kotler and Dubois, 2000). Secondly, the selectivity of perception is suited to the search for relevance in relation to needs. Finally, perception is distorted in proportion to mental and cognitive structures, which are the result of each individual's learning and experiences (Kotler and Dubois, 2000). The interactional aspect of service provision and the relational environment of a service are major determinants in the evaluation of service perception (Langlois et toque, 1992). Partners can evaluate the perception of their service experiences through perceived quality.

2.5 Perceived Quality

Perceived quality is the difference between consumer expectations and perceptions (Parasuraman et al, 1985). It is the difference between the consumer's expectations of service performance and their perceptions of the service received (Asubentong et al., 1996). It is an overall evaluative judgement about a product or service, about the relative superiority of that product or service (Seck, 2009) and also a result of a comparison between the customer's expectations and their actual experiences of the service (Grönroos, 1984). In addition, a good quality service is one that satisfies the customer in a given situation (Eiglier and Langeard, 1987) or exceeds the consumer's expectations (Lewis and Booms, 1993). Perceived quality is one of the primary drivers of customer satisfaction (Martensen et al., 2000).

2.6 Service and Human Resources

The service marketing literature emphasises the crucial role of contact staff in the success of service delivery (Berry, 1981; Grönroos, 1984; Igalens, 1992; Collins and Payne, 1991; Seignour, 1998; Lievens and Slaugter, 2016; Plaskoff, 2017). Services are resources that need to be transformed in order to make a particular use of them. This use will require prior mobilisation of knowledge and skills on the part of the user and the provider in order to make the choice (Gabriel et al, 2014). A good service marketing policy must consider contact staff as a source of information and feedback (Lendrevie, lévy and Lindon, 2006). Contact staff are considered to be the service from the consumer's point of view (Berry et al, 1991). The relationship between the customer and the staff in contact is a source of loyalty. The interactions of personal exchanges in customer contact are long term and reinforce the concepts of trust and commitment of the partners. The theoretical underpinnings of service marketing have been extended to all employees with the development of social marketing (Igalens, 1992) or internal marketing (Collins and Payne, 1991; Seignour, 1998) and recently we are talking about employer branding (Lievens and Slaugter, 2016; Plaskoff, 2017). It is in these theories that the interest in developing internal marketing and the employer brand emerges for the study of the functioning of relations between departments and human resources.

2.7 Internal Marketing in the Service Relationship

Originating in the literature on service marketing, internal marketing is part of the relational paradigm (Seignour and Dubois, 1999). It is a philosophy for managing staff and a systematic way of developing and reinforcing a service culture (Gronroos, 1990). Internal marketing is a marketing approach within the company that enables it to develop and promote ideas, projects or values that are useful to the company, to communicate through dialogue with employees so that they can express themselves and choose freely, and finally to encourage their involvement in the company (Michon, 1988). It is an essential prerequisite for effective external marketing (Gronroos, 1990), as customers base their impressions on the performance of the staff in contact with them (Parasuraman et al, 1985) and human resources are therefore perceived as a major competitive advantage (Seignour, 1998). Performance therefore has a dual content, a social content that stems from a customer focus involving both the staff in contact with the customer and the players in the decision-making process, and a technical content of the service (provision of execution equipment).

Having defined internal marketing in the service relationship, it is now appropriate, without being exhaustive, to clarify the concept of employer branding.

2.8 The Employer Brand

The notion of employer brand is a transposition of brand marketing principles to the field of human resources (Ambler and Barrow, 1996), studied from a recruitment perspective (Lievens and Slaughter, 2016). It is the set of functional, economic and psychological advantages inherent in employment, thanks to which an employer company is identified (Ambler and Barrow, 1996). Thus, the external form of the employer brand is consistent with an organisation's employer image and the internal employer brand corresponds to an organisation's identity (Lievens and Slaughter, 2016). In the context of our research, the focus of employer branding internally will therefore be on the employee experience or service experience, in other words, the perception of the employer brand image is made through the prism of the work experience (Pezet et al., 2013) with the aim of continuously improving service quality. It should be noted that the consumer experience is "an often emotionally charged personal experience, based on interaction with stimuli that are the products or services made available by the consumer system" (Caru and Cova, 2002). It is an interaction between an individual and an object that defines the practical effects of that object (Dewey, 2010) and can be broken down into five independent experiential activities (Camelis, 2009): sensory, emotional, behavioural, cognitive and social.

Ultimately, we conclude that the employer brand can be mapped onto the employer's brand image and that from a service marketing perspective, the interactive approach allows us to strengthen the quality of service in a vision that assimilates both the social content and the economic content of the exchange. If identity is the concept of issuing what the brand is, image is the concept of reception by a target audience of what the brand is (Viot and Benraiss, 2014).

3 Research Proposals

3.1 Trust

The concept of trust has been the subject of a great deal of theoretical and empirical research in various disciplines: psychology (Deutsch 1958, 1059), sociology (Lewis and Weigert, 1985; Luhmann, 1988), relationship marketing (Morgan and Hunt, 1994; Ganeson, 1994; Ring and Van de Ven,1994; Anderson and Narus,1990), service marketing (Moorman et al., 1993; Berry 1995; Zaltman and Moorman, 1988) and industrial management (Doney and Cannon, 1997). Trust refers to the extent to which relationship partners perceive each other as credible, honest and caring (Nyaga et al., 2010).

– "Credibility" is seen as the ability of the other party to honour its commitments reliably and effectively. It gives importance to reputation as an "implicit contract of trust" which implies that individuals respect it (Mangematin, 1998). This reputation provides a strong incentive for loyal behaviour, the aim of which is to generate trust (Baudry, 1998). Credibility is also based on the repetition of previous or expected interactions between partners (Mangematin, 1998).
– "Benevolence" refers to the belief that the trustworthy party takes into account the interests and the good of the other party granting the trust (Doney and Cannon, 1997). It also corresponds to the belief that the partner intervenes positively beyond opportunistic behaviour (Klein, 2007) and refers to the attention that one party may show to the interests and well-being of the other (Ganesan, 1994).

– "Integrity" measures the degree to which the partner conforms to a set of principles that the company agrees are acceptable (Klein, 2007). It refers to the belief that the other party will honour these promises with honesty and sincerity over and above opportunistic behaviour.

These factors lead us to formulate the following proposal:

(P1): Trust has a strong influence on the marketing of services in the FM context

3.2 Commitment

Commitment is an implicit or explicit promise relating to the continuity of exchange between partners (Dwyer et al., 1987). It represents an active relationship, an involvement or a psychological attachment with the organisation, so that individuals want to give something to contribute to the organisation's well-being (Shepsle, 1991). Commitment can be perceived in various ways:

– "Affective commitment" is an identification, involvement and emotional attachment to the organisation (Doumali, 2011) which refers to a state of mind of desire (Herrbach, 2005). It develops over time and creates an identification with the values, goals and future of the organisation (Sheln, 1971).
– "Reasoned commitment" is a mindset of perceived cost (Meyer and Herscovitch, 2001), which implies the cost of a person's investment in an organisation (benefits, training provided, skills acquired, etc.). As a result, the individual commits because he or she believes that the costs associated with leaving are too high (Meyer and Allen, 1984).
– "Normative commitment" is a state of mind of obligation (Meyer and Herscovitch, 2001), a feeling of loyalty resulting from a perceived obligation to the employer (Doumali, 2011) and unspoken, reciprocal expectations between the two parties. This reciprocity obliges the employee not to change organisation (Henri 2000; Guest, 2004; Bouachouch, 2015).

These developments lead us to adopt the following proposition:

(P2): Commitment has a strong influence on the marketing of services in the FM context.

3.3 Communication

Communication is the basis for sharing information and is usually combined with the two previous variables, trust and commitment, in the study of the FM sector. Communication is a philosophy towards which the organisation's objectives converge, enabling synergistic action and representing a strategic vector that brings together values and facilitates interactive processes by means of social relations within the organisation (Kunsch, 2003). It contributes to better co-ordination of the partners' actions (Anderson and Narus, 1990) and helps to rectify the opportunistic behaviour of the members of the co-operation by reducing asymmetry and/or the absence of information (Williamson, 1983). The concept of communication, through its dimensions of information sharing and relationship management, contributes to the development of service marketing within FM.

These various statements lead us to propose:

(P3): Communication strongly influences services marketing in the FM context.

Taking into account the conceptual framework allows us to develop our research model (Fig. 1).

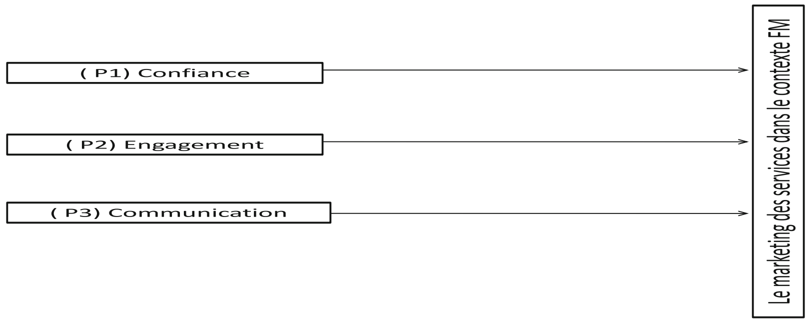

Fig. 1. Research model (source: own work)

4 Research Methodology

In order to answer our question: "Does service marketing in its various dimensions influence the performance of service quality in the FM context in Morocco", we opted for a deductive method based on a quantitative study. We used a questionnaire distributed to 70 partner-customers of companies in the FM sector in Morocco. It was organised in the traditional way, with an introduction, questions relating to each variable and a descriptive sheet. We developed our questionnaire using the Google forms platform, as it offers the option of saving the data in the form of an Excel file. All the variables were subject to a multi-item measurement assessed by a 5-point scale (completely agree…completely disagree). We went through three main phases: the first phase concerned the design of the questionnaire, the second phase concerned the distribution of the questionnaire and the collection of data, and the third phase concerned the analysis of the results. In view of the rules suggested by researchers (Bentler and Chou, 1987; Loehlin, 1992; Stevens, 2002; Honag, 2009) and the size of our sample (70 stakeholders), we were unable to carry out confirmatory factor analysis, which is not ruled out in the literature. Principal component analysis (PCA) is a technique that requires only at least 5 observations per indicator (Chandon, 2006), in order to test the unidimensionality of the scales. Prior to PCA, we developed a check of the examination of the correlation matrix by Bartlett's sphericity test, the KMO index and the anti-image matrix for carrying out factorial analyses.

– The correlation matrix indicates the correlation between items and enables factor analysis by including two or more correlations with a coefficient greater than or equal to 0.3.

- Bartlett's test of sphericity tests the hypothesis or research proposal. If the values are less than 0.05, this means that the factorial value is useful in this case. We must try to reject the null proposition to consider the test significant.
- The KMO (Kaiser-Meyer-Olkin) index is a statistical measure of the overall adequacy of the sample. If it is greater than 0.5, the adequacy of the sample is acceptable.
- The anti-image matrix represents the negative partial correlations of all pairs of items. If it is greater than or equal to 0.5, the equivalence of the sample is acceptable.

After checking that the data could be factorised, we performed a principal component factor analysis to test the unidimensionality of the scales. The tools used were Kaiser, total variance explained, Cattell's scree test and loadings.

- Kaiser: conservation of components which reflect the weight of the factors and which are greater than or equal to 1.
- Total variance explained: is reached when the percentage of variance explained by the first factorial axis in a PCA without rotation is greater than 50% and the remaining axes represent a small percentage of the total variance (Chandon, 2006).
- Scree Cattell test: observe a marked bend at the level of the second factorial axis when the eigenvalues from the latter are weak and aligned (Chandon, 2006).
- Loading (factorial contribution): the results of the loading test must show that only the correlations with the first factor are greater than 0.5 (Chandon, 2006).

The Cronbach Alpha indicator varies between 0 and 1 and calculated from the variance of the responses. Based on empirical studies carried out in psychometrics, the authors associate the level of acceptability of the alpha coefficient with the nature of the research (Evrard et al., 2003). In exploratory research, alpha is acceptable between 0.60 and 0.80, on the other hand in confirmatory research, it is acceptable at 0.80 and above. Due to the nature of our research, alpha values greater than 0.50 will be accepted.

5 Results and Discussions

5.1 Results

The verification of our research proposals on the 70 actors was carried out using the multiple regression method which requires a minimum of five observations per explanatory variable in the model, which is appropriate for our study.The analysis of the regression method demonstrates that our research model is of satisfactory quality with 97.5% of the variance restored by the three variables retained, namely: trust (CONF1), commitment (ENG1), communication (DEP1). The Durbin-Watson index indicates 1.721 and the student test confirms the significance of these retained variables. It should be said that the three variables retained have a positive impact on the explained variable (marketing of services), with a presentation of the standardized multiple regression coefficient (Beta) of:

- Trust 1 "credibility" strongly impacts the marketing of services in the FM context at 62%
- Commitment 1 "Involvement in the relationship" strongly impacts the marketing of services in the FM context with 30%

– Communication 1 “desire to exchange information” strongly impacts the marketing of services in the FM context at 8%

5.2 Discussions

Trust: The validation of our P1 proposition proves that trust is an essential variable in the marketing of services within the FM. This result is consistent with the studies of Ellram (1995), Bozzo (2000) and Morgan and Hunt (1994) which show the importance of trust in an exchange relationship between actors. Trust promotes interactions between actors and is based on rules and common interests, which result in mutual satisfaction in the achievement of common objectives as well as benefit from the commitments of the relationship. This consequence converges with the studies of Ganesan (1994), Mohr and Spekman (1994) and Brulhart et al. (2002). Trust is based on credibility, honesty, knowledge, experience and efficiency which are preliminaries of a service exchange relationship. Given the results of our quantitative study, we can argue that trust is a key element within services marketing in the FM context.

Commitment: The results of the confirmatory survey show that commitment, especially involvement in the relationship, strongly impacts the marketing of services in the FM context. The strong involvement of the actors in the relationship leads to interdependence, a high degree of investment and a long-term orientation of a service relationship. In this regard, the exchange leads to interactions of sharing behaviors, practices and common objectives for the satisfactory realization of the services undertaken and the success of the partnership commitment. Our results are in agreement with the studies of Mohr and Spekman (1994) which validate the impact of commitment on the success of partnership relationships.

Communication: The results of the quantitative survey validated a significant influence of communication on the marketing of services in the FM context. It makes it possible to build solid exchange relationships and facilitates the traceability of information in real time (Kunsch, 2003; Marc et al., 2015).

All the results lead to presenting the research model again (Fig. 2).

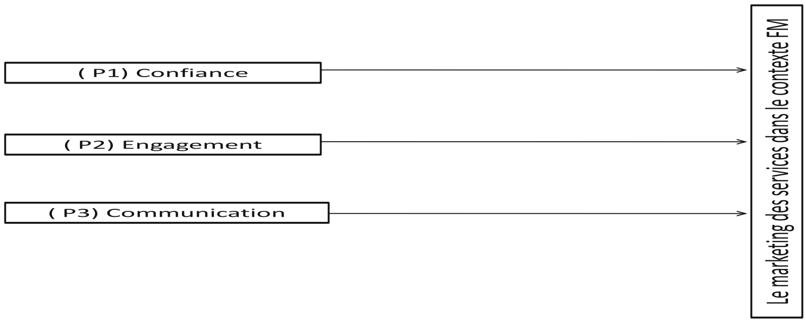

Fig. 2. Research model corrected (source: own work)

6 Conclusion

We can affirm that today service marketing is an essential lever for the performance of service quality. Through our study we wanted to highlight and expose the influence of the determinants of service marketing on the performance of the quality of services in the FM context in Morocco. The contributions of this research are of two orders: theoretical and managerial. On a theoretical level, if the marketing of services has been widely studied in the literature, the relationship between service and quality in the FM context remains a little explored theme to date in Morocco. From a managerial point of view, the research makes it possible to offer managers and FM service actors a reference framework, allowing them to work in accordance with a system of continuous improvement of the performance of the quality of services in order to achieve the common objective: production of quality service delivery and customer satisfaction.

However, our work has certain limitations. There may be other dimensions of service marketing within the Moroccan FM sector that we have not studied and which could have an influence on service quality performance. Also, the use of the questionnaire for data collection cannot ensure that the responses correspond to the practices of the respondents.

Despite these limitations, this research opens a relatively new field of investigation which addresses the importance of services marketing in the performance of service quality within the FM sector in Morocco.

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Big Data and Artificial Intelligence at the Heart of Management Control: Towards an Era of Renewed Strategic Steering

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Abstract. The advent of Big Data and Artificial Intelligence (AI) represents a revolution in the field of management control, profoundly changing the traditional methods of processing and analysing data within companies. This digital transformation is not just technical; it represents a genuine strategic, operational and cultural shift. In the information age, where the ability to collect, analyse and interpret vast sets of data is becoming a crucial competitive advantage, the role of the management controller is changing significantly. By leveraging Big Data and AI, these professionals can now access deeper and more predictive insights, facilitating informed decision-making, more refined risk management, and product and service innovation. At the same time, this technological evolution is placing new demands on skills, redefining training and recruitment profiles in the financial sector. The question then arises: how is the integration of Big Data and AI transforming the role and practices of management control in concrete terms, and what implications does this transformation have for today's businesses? This global question invites us to explore the multiple dimensions of the influence of data technologies on management control, revealing the challenges and opportunities of this digital era.

Keywords: Big Data · AI · Management Control · Renewed Strategic Steering

1 Introduction

In today's business and technology landscape, the transformative influence of Big Data and Artificial Intelligence (AI) is marking a watershed in various sectors, including management control. Prior to the advent of these technologies, companies relied primarily on traditional data processing methods, characterised by manual analysis and linear decision-making processes. These methods, although functional at the time, limited companies' ability to manage growing volumes of data and extract insights in real time.

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This article aims to explore the profound impact of Big Data and AI on the management control profession, beginning with an introduction to key concepts to establish a solid foundation for in-depth analysis. Recognising Big Data as a major driver of transformation and AI as an amplifier of revolutionary analytical capabilities, we explore their combined effects on management control practices.

We propose a global exploration of how these technologies are redefining the profession, highlighting the imperative for controllers to adapt to these developments. Using a conceptual research framework and rigorous methodology, we examine the influence of Big Data and AI across different sectors.

The results and discussion section highlights the sectoral changes brought about by Big Data and business intelligence, highlighting the benefits for companies, such as improved decision-making processes and greater operational efficiency. The article also looks at the changing role of the management controller in this new context, identifying the challenges and skills that need to be developed.

By offering an overview of the transformations brought about by Big Data and AI, this article enriches the debate on the modernisation of management control and its implications for professionals in the field.

2 The Transformative Influence of Big Data and AI

2.1 Definition of Big Data and AI

At the crossroads of this digital era, Artificial Intelligence (AI) is emerging as a key catalyst for transformation. AI, in essence, refers to systems or machines that simulate human intelligence to perform tasks and can improve themselves based on the information they gather. This definition encompasses a range of technologies, from machine learning, where machines learn from large data sets (Big Data), to strong artificial intelligence, capable of performing cognitive tasks comparable to those of humans. AI is transforming the way we analyse and process information, making it possible to manage and interpret previously unimaginable volumes of data.

The interaction between AI and Big Data is intrinsically complementary. While Big Data provides the raw material - massive volumes of information - AI offers the advanced analytical tools needed to extract valuable insights from this data. This synergy not only enables informed, data-driven decision-making in business and scientific research, but also opens the door to ground-breaking innovations in every sector, from healthcare to finance, education and beyond. In short, AI is not just an independent driver of innovation; it is also essential to unlocking the full potential of Big Data, acting as a key that opens up new ways to understand and reshape our world.

2.2 Big Data: A Major Lever

The adoption of Big Data in management control practices represents a major advance, profoundly transforming the use of data for the strategic and operational management of companies. According to Badr Boutgayout and M'Barka El Ghazali (2020), this development brings significant benefits to the role of the management controller. Firstly, it enables the efficient and rapid management of large volumes of data, including the analysis of thousands of accounting entries, thanks to the exploitation of data science. This capability is essential in today's environment, where financial data is characterised by its sheer volume and complexity. Secondly, Big Data enables innovative cross-fertilisation between internal data, such as that from ERP systems, and external data, facilitating the creation of accurate forecasts to optimise business management.

In addition, the introduction of 'smart reporting' systems based on automatic data analysis has resulted in significant time savings. These systems enable anomalies and significant deviations from forecasts to be identified quickly, alerting the management controller who can take corrective action proactively. Real-time analysis capability enhances effectiveness and efficiency, enabling rapid adjustment to market fluctuations. Predictive simulations, meanwhile, reduce the time spent drawing up budgets and increase the reliability of financial forecasts.

Access to a wide variety of information sources enriches analysis, improving understanding of the dynamics both internal and external to the business. Big Data also improves data storage capacity and processing speed, enabling more agile management. Finally, thanks to the integration of Business Intelligence tools, Big Data supports decision-making by providing contextual and precise insights that are crucial to the formulation of effective business strategies. In this way, Big Data is proving to be an indispensable asset for the management controller, providing the means for precise and responsive management in a constantly changing business environment.

2.3 The Transformative Influence of Big Data and AI on the Management Control Profession

The integration of Big Data and AI is radically transforming management control, not only by improving predictive analysis capabilities but also by redefining organisational structures and internal processes to better exploit these technologies. This transformation is taking place at several levels. At the level of improved decision-making, AI tools increase the accuracy of financial forecasts through the analysis of structured and unstructured data, enabling strategic decision-making based on richer and more diverse data. For example, a manufacturing company has integrated AI to analyse sales trends, customer feedback and operational data, enabling accurate forecasting of production and logistics requirements, reducing costs and improving customer satisfaction. Furthermore, in terms of process optimisation, the use of AI to model and simulate revenues and costs enables companies to identify key performance levers and adjust their strategies accordingly. In the retail sector, the adoption of advanced BI systems has enabled product profitability analyses to be carried out, resulting in adjustments to the product mix that have significantly increased profit margins.

And also in terms of structural transformation. To adapt effectively to Big Data and AI, companies are revising their organisational structures, integrating data science skills into the heart of their management control teams. One international financial group, for example, has formed a dedicated data analysis team made up of data scientists and management controllers, working together to identify opportunities for improving financial and operational performance. And finally, in terms of skills development, it is crucial that management controllers develop their skills in advanced analytics. One insurance company has launched a data science training programme for its controllers, enabling them to use AI algorithms to assess risks and optimise product portfolios.

3 Conceptual Research Model

The integration of Big Data and Artificial Intelligence (AI) into management control practices represents a major evolution with profound implications for decision-making, risk management, innovation and professional skills. These technologies offer unprecedented opportunities to refine analysis, predict trends and optimise decision-making processes within companies. Here is a theoretical basis for these hypotheses.

How is the integration of Big Data and AI into management control transforming decision-making processes and organisational culture within companies? This question aims to understand how these technologies influence strategic and operational decision-making, highlighting the shift to a data-driven decision-making culture.

How does the advanced use of Big Data and AI contribute to the reduction of operational and financial risks within organisations? This question seeks to identify the mechanisms by which predictive and prescriptive analyses improve companies' ability to anticipate and manage risk.

How does the adoption of Big Data and AI by controllers drive product and service innovation, and how does this influence the creation of business value? This question explores the potential of data technologies to reveal unexplored insights, thereby stimulating innovation and competitiveness.

What implications does the emergence of Big Data and AI have for the skills required of management controllers, and how is this transforming their role within companies? This question looks at how professional profiles, training paths and recruitment strategies are changing in response to the growing technological demands.

- **Data-Driven Decision Culture**

  The literature in management science and information systems suggests that the adoption of Big Data and AI fosters the development of a data-driven decision-making culture. According to Davenport (2014), this culture enables companies to become more responsive, accurate and efficient in their decision-making. Controllers, as the intermediaries between data and decision-makers, play a crucial role in interpreting and communicating the insights generated by these technologies, thereby transforming business strategy and operations.
- **Reducing Operational and Financial Risks**

  The ability of Big Data and AI to process and analyse vast volumes of data in real time leads to better risk identification and management. According to the work of Varian (2014), predictive and prescriptive analytics enable businesses to detect potential financial and operational problems before they materialise, significantly reducing the associated risks.
- **Innovation in Products and Services**

  Leveraging massive data and AI algorithms can reveal valuable insights into consumer preferences and behaviours, as well as emerging market trends. Bughin et al (2017) have shown that these technologies facilitate product and service innovation by enabling companies to anticipate customer needs and respond more quickly to market changes.

– **Big Data and AI Skills**

  The rapid evolution of information technologies is transforming the skills required of management control professionals. As highlighted by McAfee and Brynjolfsson (2016), mastery of Big Data and AI is becoming essential for controllers wishing to remain competitive in their field. This trend is changing educational pathways and recruitment criteria, highlighting the need for advanced analytical skills and a deep understanding of digital technologies.

These hypotheses are based on a vision in which Big Data and AI are not just technological tools, but strategic levers transforming the role and value of management control within modern businesses. The convergence of these technologies with management control functions paves the way for organisations that are more agile, innovative and resilient in the face of today's market challenges.

In this context, four main hypotheses can be formulated concerning the influence of technological developments, and in particular AI and Big Data, on management control **H1:** The integration of Big Data and AI into management control fosters a data-based decision-making culture, transforming management controllers into key players in corporate strategy.

H2: The advanced use of Big Data and AI in management control significantly reduces operational and financial risks thanks to more accurate predictive and prescriptive analyses.

H3: The adoption of Big Data and AI by controllers contributes to product and service innovation by revealing unexplored insights into consumer behaviour and market trends.

H4: Big Data and AI skills will become a fundamental requirement for financial controllers, changing training paths and recruitment profiles in the financial field.

4 Methodology

Our research approach began with an in-depth literature search, followed by a qualitative and deductive approach to better understand the implications of Big Data and AI in the management controller's job, working with a diverse sample of organisations. To carry out this study aimed at identifying new functionalities and emerging tools in the field of management control, we undertook the following actions:

- **Documentary Research**: Our process began with exhaustive research on the subject. The aim was to gather as many relevant articles on the subject as possible. In the course of this research, we noted the existence of several prospective scenarios concerning the future of the management control profession.
- **Qualitative Research Method**: To answer our main research question, we opted for a qualitative approach. This method is particularly suitable for small samples and when the results are not measurable or quantifiable. It offers the flexibility to conduct research without imposing strict limits on the scope of the study and the nature of participants' responses. This approach was appropriate because the existing literature on Big Data and artificial intelligence focuses mainly on theorising and expectations, but leaves little room for empirical data.

- **Deductive Approach**: Our study is based on a deductive approach, starting from one or more working hypotheses to explain these hypotheses. This approach has enabled us to understand the specific elements linked to Big Data and AI in management control, starting from the general to arrive at the specific.
- **Selection of Organisations**: Our study is based on a sample of 10 organisations selected using a purposive sampling method, a form of non-probability sampling. The choice was made to include organisations recognised for their expertise in management control and information technology, aiming for deliberate diversity in order to capture a rich and nuanced overview of the impact of technological innovations. This strategy highlights both the particularities and the dynamics common to different sectors, enriching our understanding of the interactions between technology and management (Table 1).

Table 1. List of Interviewed Individuals in the 10 Organizations

N°	*Type of business*	*Position held*	*Years of experience*	*Length of interview*
1	Bank	Management controller	15	45 min
2	Industrial manufacturing	Management controller	4	52 min
3	Textiles	Administrative Manager	4	38 min
4	Real estate	Administrative and financial manager	2	1h 10 min
5	Microfinance	Branch Manager	6	55 min
6	Insurance	Data scientist	2	50 min
7	Engineering and IT	IT engineer	4	48 min
8	Teaching	Research teacher	5	52 min
9	Teaching	Deputy Director	6	57 min
10	Food industry	Product Marketing Manager	7	1 h 10 min

Source: Authors

5 Results and Discussion

As part of our research, a manual analysis of the content of the interviews was rigorously carried out, following an approach based on the objectives of the study. In accordance with the methodological precepts set out by Roussel and Wacheux (2005), we segmented the data collected into distinct categories and sub-categories. This analytical structuring made it possible to identify recurring patterns and significant trends, thus facilitating the identification of points of convergence within the corpus of data. This qualitative analysis strategy is part of a systematic effort to interpret the discourse, with the aim of extracting relevant insights and building an in-depth understanding of the phenomena studied.

5.1 Sector Analysis of the Influence of Big Data and Business Intelligence on Management Control

An analysis of the relationship between the sector of activity and the influence of Artificial Intelligence (AI) and Big Data on management control reveals a diversity in the application and effects of these technologies depending on the field. This variability can be attributed to a number of factors, such as the intrinsic nature of the data generated, strategic objectives, and sector-specific challenges. We provide our main assessments based on our interviews.

- **Banking**: In this sector, AI and Big Data play a crucial role in managing risk, detecting fraud, and optimising financial operations. The Controller, with 15 years' experience, is likely to face complex challenges in regulatory compliance and financial reporting, where AI can offer accurate predictive analytics and automated processes for rapid decision-making.
- **Industrial manufacturing**: With 4 years' experience, the management controller in this sector benefits from AI and Big Data mainly in supply chain optimisation, inventory management, and production efficiency. These technologies enable more strategic planning and a reduction in operational costs.
- **Textiles and Real Estate**: These sectors, represented respectively by an administrative manager and an administrative and financial manager, show how AI and Big Data can influence cost management, dynamic pricing and demand forecasting. Managing customer data and market trends is becoming essential to staying competitive.
- **Microfinance and Insurance**: These areas exploit AI to accurately assess customer risk, personalise financial products and improve the customer experience. In microfinance, this can improve access to credit, while in insurance, it can optimise pricing and claims management.
- **Engineering and IT, Education**: Here, the influence of AI and Big Data can be seen in the improvement of operational processes and the personalisation of educational provision. For engineering and IT, this translates into innovations in products and services, while in education, it can improve adaptive learning and administrative management.
- **Food industry**: The use of AI and Big Data by a marketing product manager can revolutionise the analysis of consumer trends, food supply chain management, and marketing strategies. This helps to meet consumer demands more effectively and optimise operations.

In summary, the influence of big data and AI on the controlling profession varies considerably from one sector to another, influencing both operational and decision-making strategies. While some sectors benefit from improved processes and reduced costs, others benefit from personalised services and product innovation. This diversity underlines the importance of a sector-based approach to the implementation of AI and Big Data to maximise their potential in management control.

5.2 The Benefits of Big Data and AI for Businesses

Leveraging vast sets of real-time data from the marketplace enables businesses to act more wisely, improving customer engagement, increasing revenues and minimising costs. This technological era, marked by the advent of AI, is seen as one of the most significant transitions in our societies, impacting everyday life through chatbots and voice assistants in smartphones, with businesses positioning themselves as key beneficiaries of this evolution.

In the context of digital evolution, many businesses around the world are leveraging Big Data and AI to transform their operations, improve the customer experience, and secure a significant competitive advantage. Industry giants such as Netflix, Amazon, and Starbucks are prime examples of this trend. Netflix, for example, uses AI to refine its content recommendations, relying on detailed analysis of viewing preferences and behaviour to maximise user engagement. Amazon, meanwhile, is using Big Data and AI to refine its logistics and stock management, ensuring fast and efficient delivery, while personalising the shopping experience with targeted product recommendations. Starbucks is also using AI to analyse location data and customer preferences, optimising the location of its new shops and adapting its promotional offers to boost sales and enrich the customer experience.

Beyond these examples, other sectors are showing how the integration of Big Data and AI can lead to significant innovations. General Electric (GE) in industry is using these technologies to anticipate equipment breakdowns through predictive maintenance, while Santander in the banking sector is improving fraud detection by analysing transactions in real time. In agriculture, John Deere is developing intelligent machines that optimise crop yields by analysing soil data and weather conditions.

These examples demonstrate the profound impact of Big Data and AI on various industries, enabling not only innovation and cost reduction but also the creation of sustainable competitive advantages. The successful integration of these technologies has become a central pillar for companies wishing to remain at the forefront of innovation in an increasingly competitive global market.

These trends were supported by the comments of our interviewees. A quote from a data scientist illustrates the revolutionary influence of Big Data compared to traditional analytical methods, highlighting the ability to monitor in real time not only the actions of competitors but also their current strategies, thus offering a significant competitive advantage. The relevance of Big Data in monitoring markets and analysing competitive activity is thus highlighted.

In addition, a lecturer and computer science researcher highlights the value of the information extracted by Big Data, which can be translated into key business strategies and decisions for innovation. This highlights the central role of data in the business innovation and decision-making process.

A Big Data consultant adds that the integration of a dedicated Big Data department is essential for companies to understand and analyse problems in depth, leading to enhanced and relevant decisions. This perspective suggests that Big Data can transform strategies into productive actions, improving overall strategic management.

AI, for its part, is presented by a Business Intelligence and Data consultant as a catalyst for automating repetitive and time-consuming tasks, boosting productivity, reliability, availability and performance, while reducing operating costs and offering a substantial return on investment. AI's ability to process data on a scale unattainable by humans is described as revolutionary, promising in-depth analysis, intelligent forecasting and accurate modelling of the future.

We note that one agency director highlighted the crucial role of Artificial Intelligence (AI) and Big Data in the management control revolution, primarily through their ability to mitigate operational and financial risks. Thanks to predictive and prescriptive analyses, these technologies make it possible to anticipate and shape the future with unprecedented precision, offering companies the chance to prevent risks before they materialise. In particular, AI excels at identifying hidden trends and anomalies within vast volumes of data, facilitating the early detection of fraud or accounting errors. What's more, the automation and process improvements brought about by these technologies minimise human error and optimise operational efficiency. In short, the advanced integration of AI and Big Data into management strategies not only reduces risk, but also transforms business management into a more agile, responsive and informed process.

Similarly, a management controller in industry reiterates the importance of AI and Big Data in establishing reliable forecasts, generating robust indicators for better stock management and informed budget allocation. These technologies are emerging as essential pillars of efficiency and growth for companies, regardless of their field of activity, positioning Big Data and AI as competitive levers for the future**.**

However, almost all the interviewees maintain that it is crucial to note that the success of the application of big data and business intelligence depends on the quality of the data, the sophistication of the algorithms used and the integration of these technologies into existing management practices.

5.3 The Influence of Big Data and AI on the Role of the Management Controller

The widespread adoption of Enterprise Resource Planning (ERP) systems has initiated a centralisation of information, improving the traceability of data and providing reliable and rapid decision-making tools. This centralisation is transforming the practice of management control, as noted by Dechow and Mouritsen (2005).

The changing role of controllers in the era of Big Data and AI is marked by a transition from traditional tasks to advanced analytical and strategic functions. They need to master data, possess advanced analytical skills, and be able to interpret predictive information to support informed decision-making. This involves familiarity with Big Data tools, competence in predictive and prescriptive analysis, and the ability to translate complex insights into business strategies. Ongoing training and adaptation to new technologies are therefore essential if you are to thrive in this changing environment.

To illustrate the changing roles of management controllers with concrete examples, we can turn to case studies of leading companies in their sectors that have integrated Big Data and AI to transform their management control practices. Companies such as

Amazon, Google, and IBM have been at the forefront of this transformation, using predictive analytics tools to optimise decision-making and improve operational efficiency. For example, Amazon uses predictive analytics to optimise its inventory management and logistics, while IBM employs AI to improve financial accuracy and strategic planning. To further illustrate the changing roles of controllers, consider Volvo Cars and Unilever. Volvo has adopted advanced analytics to improve its financial forecasting and strategic planning, focusing on a better understanding of market trends and consumer behaviours. Unilever, meanwhile, is using data analytics to optimise its supply chain and stock management, reducing costs and improving market responsiveness. These cases demonstrate how mastery of data, advanced analytical skills, and the ability to interpret predictive information are essential for modern controllers to make a significant contribution to business strategy and operational efficiency.

One expert management controller describes this transformation as a move towards collective decision-making enhanced by access to relevant data, reflecting an entrepreneurial perspective and highlighting the crucial importance of data in decision-making.

A company's initiative to create a team dedicated to Big Data, and the integration of Data Scientists, illustrates a strategic shift towards a data-driven orientation. The aim is to collect, analyse and exploit data to improve forecasts and achieve the objectives set.

However, one management controller warns that these technologies require significant investment. Despite this, real-time analytics promises to revolutionise management control, suggesting that the integration of Big Data and AI, alongside ERP, will optimise existing management tools rather than replace them.

Another management control expert predicts that the influence of Big Data and AI is inevitable, leading to fundamental changes in vision, strategy and, consequently, in the budgeting process and key performance indicators (KPIs). This implies that the management control function will undergo a significant transformation in its operational execution.

The profession is also facing an imperative to evolve; as one experienced management controller points out, the ability to discuss and break down the business is essential. Those who fail to adapt to this new reality and limit themselves to operational tasks risk seeing their role and importance misunderstood within companies.

In short, although these technologies present challenges, they are also seen as an opportunity for management controllers to focus on higher value-added tasks, enhancing their role and recognition within the company.

5.4 Organisational Adaptation in the Era of Big Data and AI: Challenges and Opportunities

The advent of Big Data and AI is disrupting business and organisational models, creating a crucial need for companies to adapt in order to exploit their full potential (Manyika et al., 2013). This adaptation is not limited to improving existing processes, but involves a profound transformation of culture, structures and ways of working (Brynjolfsson and McAfee, 2014).

The importance of organisational adaptation lies in several key aspects (Davenport and Patil, 2012, 2012b):

- **Data culture:** The organisation needs to adopt a data-driven culture, where decision-making is based on objective analysis rather than individual intuition (LaValle et al., 2011).
- **Skills and talent:** New data science, AI and analytics skills are needed to exploit the technologies (Bughin et al., 2017).
- **Structures and processes:** organisational structures need to be adapted to facilitate collaboration between business teams, data scientists and AI experts (Caldwell et al., 2018).
- **Data governance:** Clear policies and processes must be in place to ensure the security, confidentiality and ethical use of data (Mittelstadt et al., 2016).

To facilitate data-driven decision-making and innovation, companies are restructuring their organisations in a number of ways:

- **Creation of dedicated teams:** Teams of data scientists and analysts are responsible for collecting, analysing and transforming data into actionable insights (Russom, 2013).
- **Adoption of decision-making tools:** Business Intelligence and AI platforms enable data to be visualised and analysed in real time for more agile decision-making (Gartner, 2019).
- **Development of data-driven decision-making processes:** Business processes integrate data analysis for greater efficiency and performance (Davenport, 2014).
- **Encouraging data-driven innovation:** Fostering a culture of experimentation and learning to explore new applications of Big Data and AI (Bostrom, 2014).

Organisational adaptation to the digital age presents many challenges and opportunities (Manyika et al., 2013):

Challenges:

- **Resistance to change:** Fear of the unknown and distrust of new technologies can hold back the adoption of Big Data and AI (Kotter, 1996).
- **Skills shortage:** A shortage of specialist data science and AI talent can limit business capabilities (Hunt et al., 2018).
- **Cost and investment: Implementing** Big Data and AI solutions can represent a significant investment (McAfee et al., 2016).
- **Ethical and Security Issues:** Responsible use of data and protection of privacy are major challenges (Mittelstadt et al., 2016).

Opportunities:

- **Better decision-making:** Faster, more accurate and fact-based decisions for better performance (Davenport, 2014).
- **Innovation and value creation:** Identifying new business opportunities and developing new products and services (Brynjolfsson and McAfee, 2014).
- **Improving operational efficiency:** optimising processes and reducing costs (Manyika et al., 2013).
- **Increased competitiveness:** Stand out from the competition by taking advantage of cutting-edge technologies (Brynjolfsson and McAfee, 2014).

In conclusion, organisational adaptation is a crucial process for exploiting the potential of Big Data and AI. Although adaptation presents challenges, the businesses that are able to overcome them and seize the opportunities offered by these technologies will be best placed to thrive in tomorrow's digital economy.

6 Conclusion

The advent of Big Data and AI is revolutionising management control, propelling the function into an era of unprecedented transformation. This revolution manifests itself in an increased reliance on data to inform decision-making, strengthening predictive and prescriptive analysis capabilities and offering insights in real time. This evolution paves the way for more strategic risk management, innovation driven by a deeper understanding of customers and the market, and requires controllers to develop new skills in data analysis.

For businesses, the benefits include increased operational efficiency and a clear competitive edge. However, this transformation requires ongoing investment in technology and training to stay at the cutting edge.

The upheaval in skills is affecting the financial sector in particular, prompting organisations to recruit talent specialising in Big Data and AI and to invest in the ongoing training of their employees. Diversified strategies are being put in place to develop these skills, including in-house training programmes, educational partnerships and access to e-learning platforms. Lifelong learning is becoming crucial to maintaining competitiveness in an ever-changing financial landscape.

The digital age presents both challenges and opportunities. On the one hand, data confidentiality and security issues are a major concern. On the other, the potential for growth and innovation offered by these technologies is fundamentally reshaping the way businesses operate and how they compete.

In conclusion, integrating Big Data and AI into management control is a driving force for organisational transformation. Seizing the opportunities and meeting the challenges of the digital age will enable businesses to thrive in an ever-changing economic landscape.

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Smart Street Lighting: Return on Investment for Cities of the Future

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Abstract. Smart lighting is a gateway to the smart cities of the future. Smart lighting and IoT are the keys to the city of the future. By using these technologies, cities can improve safety, reduce costs, and increase energy efficiency.

However, smart cities require a lot of work. New technologies are expensive, local governments are constrained, and politics is geared toward short election cycles, making it difficult to establish a highly operational and financially efficient centralized technology deployment model that is reused in areas urban areas on a global or national scale.

In Morocco, we note an awareness regarding the installation of intelligent street lighting in different areas of the kingdom and the development of smart cities. However, there are questions about the return on investment of these smart lighting solutions.

This work seeks to evaluate, through a qualitative study, the ROI of the implementation of intelligent public lighting in certain areas of the kingdom to identify the advantages and challenges encountered.

The main results claim that smart lighting allows real-time energy monitoring, automatic adjustment of brightness according to weather conditions and human activity, and the specific need at the location of the light point.

Keywords: Smart street lighting · Smart cities · Remote management system

1 Introduction

New technologies have transformed our lifestyles. New solutions are proposed to improve the quality of life of users. This orientation also affects the city management system by integrating cutting-edge technologies to offer a high-level living environment and optimal management of the resources of these cities: Machine learning, Artificial Intelligence, security surveillance systems, etc.; Among all of these solutions, in this article, we are mainly interested in smart street lighting.

Public lighting services have associated costs. Aside from the potential to contribute to light pollution and the negative environmental effects of power use, the amount of electricity used for urban lighting frequently accounts for a significant portion of municipal budgets. Leccese and Tuoni (2003), Kostic and Djokic (2009), Radulovic and Kirincic (2011), Mockey Coureaux and Manzano (2013). In order to place the issue in perspective, it is important to remember that public illumination, primarily street lighting, accounts

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for 3% of global electricity usage (Lobao et al., 2015). It is crucial for preventing crime, protecting property and goods, orienting oneself at night, and avoiding obstacles (Peña García, A. Hurtado, M.C. Aguilar-Luzón, 2004).

An intelligent street light management system recommends installing a wireless system to remotely monitor and control the energy consumption of the street lights and take appropriate action to reduce it through power conditioning and control (Khandelwal et al., 2015).

Costs associated with street lighting usage can be cut by 50% to 70% with an intelligent street lighting system (Parkash and Rajendra, 2016). Furthermore, compared to conventional lighting systems, smart lighting systems can reduce energy usage by 60 to 80 percent, according to a study done by Lawrence Berkeley National Laboratory.

Thus, it is critical to take into account this technical solution to increase security, decrease light pollution, and improve energy efficiency.

2 Intelligent Street Light and IOT

Nowadays, energy consumption is a major concern on a global scale. It is therefore a shared responsibility to see how to effectively save energy with the deployment of new technologies.

2.1 Intelligent Street Light in Cities

The acceleration of the population living in cities simultaneously generates an increase in citizen needs and forces stakeholders to face multiple challenges.

One of the most important challenges to face is related to the high level of energy needed and its cost.

Due to population growth and economic expansion, the world's energy consumption is rising at the quickest rate ever, and the supply of energy sources is still severely limited (Mohd. Saifuzzanman, and Nazmun Nessa Moon, 2017).

In order to lower the amount of energy that cities use, stakeholders are looking for creative and practical solutions. The goal is to increase lighting efficiency in streetlights by a factor of five by substituting light-emitting diode (LED) technologies, which have a lower power consumption, with high-pressure sodium (HPS) bulbs (Escolar et al. 2014).

Additionally, by using an intelligent on/off mechanism, targeted progressive dimming, and an organized approach to power consumption, energy expenses can be rapidly lowered to 35%. The total cost of consumption can be lowered by up to 42% by using proper maintenance (Mary et al., 2018).

2.2 IoT for Smart Street Lighting

IOT is considered an essential solution for data absorption but also its analysis. Any device or object having sensors that can share information over a network (the Internet) without the need for human involvement is considered to be part of the Internet of Things (IoT) (Atzori et al., 2010; Feki et al. 2013; Gubbi et al. 2013; Javed et al. 2018). The Internet of Things (IoT) is utilized in many different applications, such as industrial management, smart homes, sensors in the chemical industry, healthcare, military applications, and surveillance systems that investigate anomalies in security. (Arjun et al., 2019).

We are particularly interested in the use of IoT for smart lighting. The IoT solution helps to better manage the street light. The Internet of Things, or IoT, allows us to monitor and control the state of street lights in real time from any location. (Gunasundari and Science, 2017).

IoT is a physical object that is connected to the internet and is equipped with sensors, software, and electronics to gather and share data from its surroundings Saifuzzaman et.al (2017), Giusto et al. (2010), and Li Da Zu et al. (2014).

The use of new technologies for the light sources (such as LED technology) (Costa et al., 2009; Wu et al., 2010) and the creation of various remote-control systems based on intelligent light posts that communicate data to a central control system to streamline maintenance and management tasks (Caponetto et al. 2008; Niu and Qin, 2012). Additionally, there are several clever energy management solutions for streetlights that allow widely dispersed lighting to be remotely controlled and managed from a central management system. These commercial and research solutions allow streetlights to be remotely scheduled to dim or switch off when energy conservation is needed.

They also offer maintenance and repair orders, information on energy consumption, alarms for anomalous bulb functioning or outages, and many other things. (Elejoste et al. 2013).

3 Advantages and Challenges of Smart Street Lighting

Energy savings, lower maintenance costs, burn hour optimization, high uptime, immediate fault location, load balancing, load shedding, and a user-friendly interface that makes it simple for users to locate the information they need are just a few of the benefits of smart lighting. Other benefits include a visual graphical environment for tracking failures, monitoring system health, and gathering, organizing, and storing data. An alert is delivered right away to the web platform if a defect is found. If required, the alert can be sent by SMS or email to the appropriate parties. Lastly, automatic statistics production for historical data analysis is made possible by smart lighting. (Barve, 2017).

We cite as an example of smart lighting advantages, the city of Barcelona has implemented a smart lighting system that can adjust the brightness of lights based on traffic, weather, and special events.

The city of Los Angeles replaced its 215,000 street lights with smart LED lights, which can be controlled remotely and save 63% on energy costs.

The city of Rotterdam in the Netherlands has some of its fleets equipped with smart motion sensors that automatically turn lights on when a pedestrian or cyclist approaches and turn them off when they move away.

New technologies are expensive, local governments are constrained, and politics is geared toward short election cycles, making it difficult to establish a highly operational and financially efficient centralized technology deployment model that is reused in areas on a global or national scale.

The streetlights must adapt their behavior to the surrounding environment for them to operate autonomously. As a result, they must be able to detect some pertinent aspects of the surroundings, like ambient lighting, the presence of cars or people, or their behavior (i.e., system diagnosis). Thus, sensors of some kind must be installed in streetlights. Furthermore, streetlights must be able to respond based on information gathered from their surroundings. In this instance, action translates into the ability to regulate lighting intensity and operate at a lower level when not required (Elejoste et al., 2013).

4 Methodology

As part of this study, we focus on the case study method. Yin (1994) presents the case study method as an empirical investigation that seeks to study a phenomenon in its context. Stake (2005) states that the case study method is one of the most widely used methods for conducting qualitative studies. Indeed, several authors testify to its relevance (Eisenhardt 1989; Yin 1994; Yin 2003; Guba and Lincoln 1994). We remind that our objective is to evaluate, through a qualitative study, the ROI of the implementation of intelligent public lighting in certain areas of the kingdom to identify the advantages and challenges encountered. Return on investment (ROI) is the financial gain from investing funds in creating, modifying, or overseeing a system or product. According to Chang et al. (2015), return on investment (ROI) is a popular economic metric used to assess an investment's effectiveness or compare the effectiveness of several distinct investments.

Morocco is betting on the transformation of six cities into smart cities by 2026 (Ministry of Industry, 2013). The project targets Casablanca, Marrakech, Rabat, Tangier, Ifrane, and Fez. Morocco wishes to create a new model of urban management at lower cost, improve the efficiency of urban planning, and achieve sustainable social development meeting the needs of citizens in terms of transport, energy, green economy, security, and housing.

Among the cities mentioned, we are interested in the city of Ifrane with the project to implement intelligent public lighting (Fig. 1).

The figure shows the installation area of intelligent street lighting in the city of Ifrane which hosts 84 luminaires with a remote management system.

The analysis of the case is made based on a documentary study communicated by the NABILUM group, which specializes in the design and implementation of street lighting and urban furniture projects.

The simulation results were obtained on 13 February 2024 and were communicated by engineers from the NABILUM group, specialists in smart lighting, who provided information on the savings made using the EXEDRA remote management solution developed by SCHRÉDER.

To evaluate the ROI, we analyzed on the first level the street lighting without the use of smart solutions by evaluating the general performance in terms of power, power demand, unit price, the cost per hour, and we analyzed the estimated cost for 84 public lighting luminaires without the use of smart solutions.

In the second level of the study, we analyzed the street lighting with the use of smart remote management solutions and we established a comparison between the cost of

Fig. 1. Mass view of the intelligent LED street lighting implementation project of the city of Ifrane with the remote management system. (Source: NABILUM Group)

the intelligent street lighting solution and the traditional lighting for a quantity of 84 luminaires of 110 W.

The data was provided by the company NABILUM Group, and we conducted a descriptive analysis.

5 Results and Discussion

Before the implementation of the smart street lighting solution, a study was carried out to study the state of consumption of traditional street lighting in the area concerned.

The study initially identified the 84 lighting fixtures which will be replaced by the intelligent solution with a remote management system. The table below shows the collected results by the company NABILUM (Table 1).

We note that the traditional street lighting solution does not provide the possibility of adjusting the brightness according to weather conditions and human activity because the solution is not equipped with the remote management solution which allows optimal management street lighting network (Table 2).

This table presents the financial cost of 84 traditional street lighting fixtures which amounts to 58.810,75 Dhs (Table 3).

The smart street lighting solution using a remote management system makes it possible to make automatic adjustments across the entire lighting network with the possibility of managing each light point separately, according to a well-studied need. The remote management solution is used in smart cities to save money and reduce the high costs of street lighting. Considering that cities may spend as much as 40% of their allotted funds

Table 1. Street lighting without the use of smart solutions (Source: NABILUM Group)

Hours	Luminaire power in W	Quantity of project lighting fixtures	Active power in %	Power demand in W	Unit price including tax - ONEE in Dhs	Cost/hour
18h00	110	84	100%	9.240	1,36	12,57
19h00	110	84	100%	9.240	1,36	12,57
20h00	110	84	100%	9.240	1,36	12,57
21h00	110	84	100%	9.240	1,36	12,57
22h00	110	84	100%	9.240	1,36	12,57
23h00	110	84	100%	9.240	1,36	12,57
00h00	110	84	100%	9.240	1,36	12,57
01h00	110	84	100%	9.240	1,36	12,57
02h00	110	84	100%	9.240	1,36	12,57
03h00	110	84	100%	9.240	1,36	12,57
04h00	110	84	100%	9.240	1,36	12,57
05h00	110	84	100%	9.240	1,36	12,57
06h00	110	84	100%	9.240	1,36	12,57

Table 2. Estimated cost for 84 street lighting luminaires without the use of smart solutions (Source: NABILUM group)

Désignation	Numbers
Total power demand in w	120.120,00
Total cost per night in Dhs	163,36
Cost per month in Dhs	4.900,90
Cost per year in Dhs	58.810,75

on expenses (Parise et al., 2023), it is advantageous for cities to emphasize that smart street lights may reduce costs (Table 4).

The comparison between the two street lighting solutions (smart and traditional) gives a clear image of the importance of the savings achievable in terms of power in general and in terms of cost in particular. The difference between the two solutions is around 50% in terms of power demand and cost. In this regard, energy consumption reduction is significantly supported by smart lighting control systems. The ability to design modern lighting systems with smart technologies that effectively address the energy savings issue has been made possible by advancements in wired and wireless networks, control technologies, and embedded systems (Gagliardi et al., 2020) (Fig. 2).

Table 3. Street lighting with use of smart remote management solutions (Source: NABILUM group)

Hours	Luminaire power in W	Quantity of project lighting fixtures	Active power in %	Power demand in W	Unit price including tax - ONEE in Dhs	Cost/hour
18h00	110	84	90%	8.316	1,36	11,31
19h00	110	84	90%	8.316	1,36	11,31
20h00	110	84	90%	8.316	1,36	11,31
21h00	110	84	70%	6.468	1,36	8,80
22h00	110	84	60%	5.544	1,36	7,54
23h00	110	84	50%	4.620	1,36	6,28
00h00	110	84	50%	4.620	1,36	6,28
01h00	110	84	40%	3.696	1,36	5,03
02h00	110	84	30%	2.772	1,36	3,77
03h00	110	84	30%	2.772	1,36	3,77
04h00	110	84	30%	2.772	1,36	3,77
05h00	110	84	30%	2.772	1,36	3,77
06h00	110	84	60%	5.544	1,36	7,54

Table 4. Comparison between the intelligent street lighting solution and traditional lighting for a quantity of 84 110 W luminaires. (Source: NABILUM Group)

Désignation	Smart streetlight	Traditional lighting	Difference between the two solutions
Total power demand in w	69.300	120.120	50.820
Total cost per night in Dhs	94,25	163,36	69,11
Cost per month in Dhs	2.827,44	4.900,90	2.073,46
Cost per year in Dhs	33.929,28	58.810,75	24.881,47

The results of the implementation of the smart street lighting solution show the return on investment that the target area will be able to reap.

By analyzing the results, the table shows that the city can achieve a saving of 42% something which is confirmed by the literature which states that the total cost of consumption can be lowered by up to 42% by using proper maintenance (Mary et al., 2018).

Hours	Gradation
18h00	90%
19h00	90%
20h00	90%
21h00	70%
22h00	60%
23h00	50%
00h00	50%
01h00	40%
02h00	30%
03h00	30%
04h00	30%
05h00	60%
06h00	60%
Average	58%

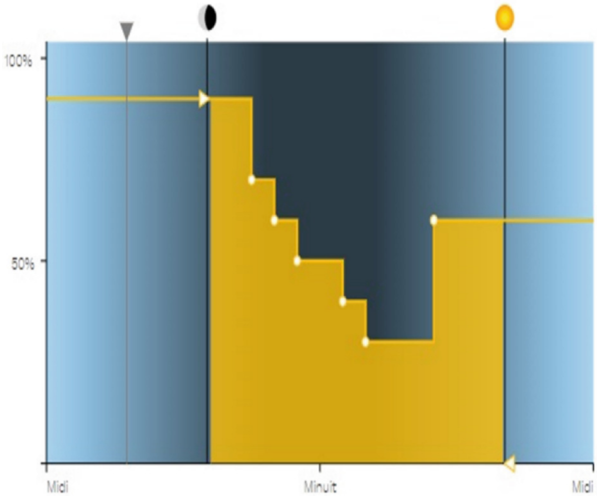

Fig. 2. Lighting profile programmed for the city of Ifrane (Source: NABILUM group).

6 Conclusion

Smart lighting is a gateway to smart cities. The luminaires create an ecosystem of sensors and devices allowing municipalities to streamline services to their citizens.

Optimizing energy consumption is in everyone's interest, particularly municipalities in city management and public establishments in general.

The introduction of intelligent street lighting makes it possible to optimize resources and reduce the budget and costs allocated to public lighting as demonstrated in the study, the solution makes it possible to reduce up to 42% of costs, and a better result can be achieved with better gradation.

We note that smart lighting allows several advantages like real-time energy monitoring, automatic adjustment of brightness according to weather conditions and human activity, and the specific need at the location of the light point.

The evaluation of the ROI in smart lighting projects allows us to shed light on the gain that the municipality could gain in terms of cost savings thanks to the optimization of lighting management.

Local governments and stakeholders must be aware of the expected gain through the optimization of the implementation and management of smart lighting solutions in Morocco for environmental impacts of electricity use and for cost savings.

For future research, we suggest exploring the long-term sustainability and scalability of smart lighting initiatives, evaluating citizen perceptions and acceptance of smart city technologies, and assessing the broader societal impacts of smart city development in Morocco.

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Transforming Morocco's Public Sector: The Synergy of Artificial Intelligence, Big Data, and Data Science

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Abstract. This perspective article examines the transformative impact of artificial intelligence (AI) on Morocco's public sector, highlighting the integration of AI as a catalyst for enhancing efficiency, decision-making, and citizen-centric services. Amidst the digital transformation era, the strategic incorporation of Big Data and Data Science emerges as crucial for advancing governance, public service delivery, and policymaking. Morocco's journey towards leveraging these technologies showcases significant initiatives, challenges, and potential future directions. The analysis emphasizes the necessity of a robust data governance framework and a solid digital infrastructure to foster a dynamic digital economy. Trust in innovative data collection and utilization processes is deemed essential for success. This article aims to illuminate the pathways towards achieving a responsive, transparent, and effective governance model through the synergy between AI technologies and public sector initiatives, proposing solutions to overcome institutional complexities and fragmentation that hinder effective data governance, thus contributing to the broader discourse on governance and technology in emerging economies.

Keywords: Artificial intelligence · Data governance · Digital transformation · Public sector efficiency

1 Introduction

Artificial Intelligence, once a mere figment of science fiction, has now become a pivotal force in driving innovation and operational excellence. In the public sector, the application of AI technologies offers promising avenues to overcome traditional barriers, streamline processes, and address complex societal challenges. As governments worldwide strive to meet the evolving needs of their citizens, the adoption of AI stands as a beacon of progress, promising enhanced public service delivery and informed policymaking. The advent of Big Data and Data Science represents a paradigm shift in how data is harnessed to inform decision-making and innovate public services.

Against this backdrop, an overview of the current state of the public sector in Morocco and the challenges it faces in terms of artificial intelligence, big data, and data science

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is provided. As it embarks on a significant journey to integrate these technologies into its public sector, Morocco aims to foster transparency, efficiency, and citizen-centric governance. This article provides an overview of Morocco's initiatives in this domain, exploring the synergy between Big Data and the public sectors.

In addressing the transformative impact of Artificial Intelligence (AI), Big Data, and Data Science on Morocco's public sector, this study is motivated by the urgent need to enhance governance, decision-making processes, and service delivery within a rapidly evolving digital landscape. The integration of these advanced technologies offers a paradigm shift towards more efficient, transparent, and citizen-centric public services. Specifically, the motivation stems from the unique challenges faced by Morocco's public sector, including bureaucratic inefficiencies, a lack of transparency, and a growing demand for more responsive and accountable governance. By leveraging AI's predictive analytics, Big Data's comprehensive insights, and Data Science's problem-solving methodologies, this research aims to propose a strategic framework that not only addresses these challenges but also sets a precedent for digital transformation in emerging economies. This endeavor aligns with Morocco's national digital strategy, which seeks to harness the power of digital technologies to foster economic growth, enhance public sector performance, and meet the evolving needs of its citizens. Therefore, the motivation for this study is deeply rooted in the potential of AI, Big Data, and Data Science to revolutionize public sector operations, thereby contributing to the broader goals of sustainable development and improved quality of life for Moroccan citizens.

1.1 Purposes

This paper endeavors to scrutinize the transformative capabilities of Artificial Intelligence (AI), Big Data, and Data Science within Morocco's public sector, against the backdrop of a rapidly evolving digital landscape. These avant-garde technologies present unparalleled opportunities to refine governance efficiency, enhance decision-making processes, and more aptly align public services with citizen demands. The core objectives of this discourse are multifaceted:

i. The paper delves into Morocco's strategic initiatives to exploit AI, Big Data, and Data Science, offering an overview of current projects. It seeks to comprehend the manner in which these technologies are being amalgamated into the public sector, with the intent of spurring innovation and augmenting service delivery;
ii. Through an investigation of the interplay between AI technologies and public sector endeavors, this perspective article underscores the revolutionary potential these technologies hold for governance models. Concurrently, it recognizes the inherent challenges and complexities of embedding such groundbreaking technologies within the public sector framework, such as institutional fragmentation, data governance hurdles, and the imperative for substantial digital infrastructure;
iii. In addition, this paper aims to illuminate the trajectory towards a governance model that is more responsive, transparent, and efficacious in Morocco. It contemplates the future course of Morocco's digital transformation journey, pondering on how current and prospective initiatives could surmount extant challenges and harness opportunities for enhanced public service innovation.

By evaluating Morocco's strides in this domain, the paper enriches the global dialogue on the employment of AI, Big Data, and Data Science within the public sector. It proffers insights and learnings that may prove beneficial for other nascent economies grappling with analogous challenges and prospects in their digital metamorphosis endeavors.

1.2 Research Methodology

Our perspective article employs a multi-faceted methodology to delve into the strategic incorporation of AI, Big Data, and Data Science within Morocco's public sector. Through an extensive literature review, we examine the theoretical underpinnings and global trends of digital transformation. This review sets the stage for a nuanced understanding of the digital landscape within Morocco and beyond. To complement the theoretical insights, the paper delves into a series of case studies highlighting Morocco's digital initiatives. These cases provide a practical lens through which the strategic deployment and challenges of AI and related technologies in governance and public service delivery are analyzed. To broaden our perspective, we conducted a comparative analysis against international benchmarks, such as the Government AI Readiness Index, assessing Morocco's digital maturity relative to other nations. This comparison shed light on best practices and lessons that could inform future strategies. Synthesizing these insights, we proposed a comprehensive framework aimed at guiding the ethical and effective use of digital technologies in the Moroccan public administration. Our approach emphasizes the need for an adaptive and holistic strategy to tackle the nuances of digital transformation in developing economies. Thus, our article offers a structured exploration of the potential and challenges of leveraging digital technologies for public sector enhancement in Morocco, contributing to the discourse on governance and technology.

2 Analytical Review

2.1 Expounded Definitions of Artificial Intelligence (AI)

To grasp the essence of Artificial Intelligence (AI), one must first dissect the terms *"artificial"* and *"intelligence"*. The term *"intelligence"* encompasses mental processes such as the ability to learn, reason, and comprehend [19]. Conversely, *"artificial"* denotes anything crafted by human hands as opposed to naturally occurring phenomena [23]. When these concepts are merged, AI emerges as the process of endowing machines with the capability to mimic intelligent behavior [37]. Also, [21] posited that the essence of AI research is predicated on the hypothesis that every facet of learning or any other indication of intelligence can, in theory, be so precisely defined that it becomes possible to create a machine that mimics this capability, and similarly, [14] described AI as the scientific inquiry into the creation of computer systems capable of performing tasks that, if performed by humans, would be considered a demonstration of intelligence, such as problem-solving and learning. Furthermore, [29] expanded on this by viewing Artificial Intelligence as a spectrum that encompasses four distinct categories: systems that emulate human behavior, systems that think along the lines of human reasoning, systems that think logically, and systems that behave logically. Moreover, [1] highlighted that AI encompasses systems with the capability to learn, replicate behaviors, and potentially surpass the cognitive and intellectual performance typically associated with human beings. Consequently, [28] defined AI as referring to programs with the capacity for learning, adapting to new circumstances, exhibiting creativity, and solving problems in a manner that would be considered intelligent if observed in humans. Lastly, [32] elaborated on the term AI to describe the phenomenon where a machine displays intelligence that is comparable to or exceeds that of humans, particularly in performing complex tasks, noting that this broad concept is often divided into subcategories such as 'weak' and 'strong' AI, reflecting the varying levels of machine intelligence.

2.2 Difficulties Associated with Implementing AI in the Public Sector

The implementation of Artificial Intelligence (AI) within Morocco's public sector faces significant challenges due to complex institutional arrangements and necessary governance reforms. The sector's division and complexity have resulted in numerous isolated strategies and programs, hindered by inconsistent coordination and fragmented dissemination practices. This environment undermines effective data sharing and the potential benefits of technical and legal advancements aimed at facilitating data and system interoperability. Additionally, a culture of inter-agency competition and confidentiality, prevalent in the current political and organizational climate, encourages ad-hoc collaborations rather than comprehensive reforms for a unified approach to data governance and digital transformation [41]. Acknowledging the complexities involved in integrating AI technology into the public sector is crucial. The literature reveals challenges in AI's social and ethical ramifications [7, 17, 22, 27], its incorporation into operational frameworks [4, 30, 32, 42, 43], and the surrounding legal landscape [8, 26, 30]. These discussions pinpoint four primary areas of challenge: practical deployment, legal and regulatory compliance, ethical considerations, and societal impacts. Addressing these areas is foundational to overcoming obstacles in implementing AI tools in public services. Technical prerequisites, such as advanced computing resources, data storage capabilities, and network infrastructure, are critical for AI deployment [4]. Public sector organizations must navigate these challenges, often with limited resources or budgetary constraints. Furthermore, interoperability and standardization are essential for integrating AI systems with existing technological frameworks [30]. Ensuring compatibility with legacy systems and diverse platforms is crucial for operational continuity and the utility of AI solutions. Organizational readiness is another pivotal aspect of AI implementation. Significant changes, including developing new skill sets among employees, establishing clear governance structures, and creating policies for ethical AI use, are necessary [32]. These changes require careful planning and management to ensure effective leveraging of AI technologies. Lastly, ethical and legal considerations, such as data privacy, algorithmic transparency, and accountability, are integral to AI deployment in the public sector. Strict adherence to data protection regulations and the development of ethical guidelines are essential to ensure AI applications respect citizens' rights and promote fairness and transparency [8, 26].

2.3 Maximizing AI Benefits in the Public Sector

[18] highlight the importance of public organizations being prepared for the adoption of advanced technologies such as AI. They identify uncertainties and obstacles, including a lack of specialized skills and challenges related to managing big data. This preparedness is crucial for fully leveraging the potential of AI while minimizing associated risks. Furthermore, the balance between transparency and data privacy is another area of concern emphasized by [16]. The use of open and linked data by AI in the public sector can enhance government transparency but also poses significant risks to citizens' data privacy. Developing robust ethical and legal frameworks to manage these tensions is essential. Additionally, [39] discuss various applications of AI in the public sector and the specific challenges faced, such as technological integration, ethical questions, and the need for effective governance. They stress that overcoming these challenges requires a holistic approach, considering both the benefits and potential implications of AI. Also, the perception of public sector employees towards the integration of AI and other advanced technologies is explored by [9]. Their study reveals concerns about the impact on employment and underscores the importance of developing strategies to support employees' adaptation to these changes, including training and professional development. Implementing AI in the public sector offers considerable opportunities but also presents complex challenges. Successfully navigating this landscape necessitates considering technical infrastructure, staff skills, ethical and legal considerations, and the impact on employees and society at large. By addressing these challenges in an integrated and thoughtful manner, the public sector can maximize the benefits of AI while mitigating its risks.

2.4 Ethical Foundations and Moral Considerations in AI Deployment

The ethical and moral underpinnings are paramount in the deployment of Artificial Intelligence (AI) technologies, as they hold the power to blur traditional boundaries between human intelligence and machine operations. The implementation of AI must adhere to ethical standards to prevent and mitigate inherent biases, ensuring that AI systems' decisions and processes align with universally recognized principles of fairness and justice [2, 6, 12]. AI ethics encompasses a set of values, principles, and methodologies aimed at guiding the creation and application of AI technologies in a manner that respects ethical norms and values [3]. Key issues such as ensuring transparency, minimizing bias, and preventing discrimination are at the forefront of ethical AI development [6]. The reliance of AI on large datasets introduces the risk of reproducing or even amplifying existing biases if the underlying data is unbalanced or inherently biased. This challenge calls for rigorous scrutiny and balanced data curation to avoid perpetuating creators' biases. High-profile incidents involving companies like Apple and Amazon highlight the real-world consequences of failing to address these ethical concerns adequately [15].

In response to the complexities of AI ethics, various organizations have initiated efforts to codify fundamental principles guiding AI's ethical use [15]. The European Commission has outlined seven key elements for ethical AI deployment, encompassing bias, transparency, accountability, safety and security, societal and environmental well-being, inclusivity in design, and the imperative of maintaining human control and oversight. These principles aim to reduce organizational risks and foster AI applications that exhibit ethically superior behavior compared to human actions, promoting a balance between the efficiency of opaque AI systems and the transparency required for trust and accountability [12, 20, 38]. Emphasizing these ethical considerations is essential for organizations to navigate the dichotomy between the precision of *"black-box"* AI systems and the clarity offered by *"white-box"* applications, ensuring that AI technologies not only advance operational capabilities but also adhere to the highest ethical standards.

2.5 Assessing Morocco's Position in the Government AI Readiness Index 2023

Morocco's journey through the digital age is marked by a series of ambitious initiatives aimed at positioning the country as a key player in the global and regional Information and Communication Technology (ICT) sector. Beginning in 1995, Morocco embarked on its digital journey with the introduction of the Internet, laying the foundation stone of its digital era. The following year, in 1996, the *"Morocco Competitive"* initiative was launched, signaling the country's desire to enhance its competitiveness in the ICT sector. In 1997, a specialized ICT working group was established within the Ministry of Trade and Industry, followed by a national seminar on the development of telecommunications services [24]. Significant regulatory and structural advances were made in 1998, notably the establishment of the State Secretariat for Post and Telecommunications and Information Technologies, and the creation of an independent regulatory authority. In 1999, ICT was incorporated into the Five-Year Plan 1999–2003, demonstrating Morocco's commitment to making ICT a national priority and a strategic vector for development. At the turn of the millennium, in 2000, Morocco took a significant step by setting up inter-ministerial committees dedicated to electronics, indicating increased coordination among various government sectors for the promotion of ICT. This momentum was further bolstered by the awarding of a license for a second GSM network, marking the expansion and liberalization of the telecommunications market in Morocco. The year 2001 was marked by two major events: the opening of 35% of the capital of the historical operator on the Casablanca stock exchange, and the establishment of a National Strategic Committee to reflect on Morocco's integration into the global information and knowledge society. The creation of a national committee for the development of electronic administration (e-Gov) in 2003 signaled a desire to modernize public administration through ICT [24]. The ICT regulation reform in 2004 and the launch of the audiovisual liberalization process continue to testify to Morocco's commitment to modernizing its ICT sector and adopting a new telecommunications law. The launch of the national Cyber-Strategy e-Maroc 2010 in 2005 laid the foundations for a more integrated information and communication society. In 2013, Morocco launched the ambitious Maroc Numeric 2013 program, aiming to establish the country as an active emerging nation in the ICT sector. However, after the mixed results of the *"Maroc Numeric 2013"* plan, Morocco launched *"Maroc Digital 2020"* to extend and amplify these efforts, with the aim of strengthening Morocco's position as a regional digital hub and overcoming systemic obstacles [10]. Looking towards 2030, the *"Maroc Digital 2030"* strategy aims to accelerate Morocco's digital development, focusing on the digital transformation of public services to improve access and quality of services for citizens and businesses, and stimulating the digital economy, including support for startups and development of the outsourcing sector [5]. This includes investments in cloud computing, increased data center capacity, and improved connectivity through the deployment of fiber optics and 4G, while highlighting the need for improved governance and collaboration among existing agencies for effective implementation of the strategy [31]. In light of this timeline of digital evolution in Morocco, it is evident that the country has demonstrated a consistent and progressive commitment to integrating and developing information and communication technologies within its economy and society. The focus on regulation, infrastructure, and long-term strategies reveals a comprehensive and foresighted approach to the adoption of digital technologies. This indicates an awareness of the stakes associated with the information society and a desire to create an environment conducive to ICT development to support economic growth and social progress.

The Government AI Readiness Index 2023 presents an interesting perspective on the state of AI readiness across different countries, with a particular focus on the public sector's preparedness to implement and support AI technologies. Looking at the data provided with a focus on Morocco (see Table 1), we can derive several insights and comparative analyses. Morocco's total score in the AI Readiness Index is 43.34, placing it in the middle tier of the countries listed. This score indicates that while Morocco has made some progress in AI readiness, there is still considerable room for improvement, especially when compared to the top-ranked countries in the dataset. The breakdown of Morocco's score into the three pillars—Government, Technology Sector, and Data & Infrastructure—provides a nuanced understanding of its position:

- Government pillar (37.54): Morocco's score in the Government Pillar is moderate. It suggests that the government has made some strides in creating a vision for AI implementation and has perhaps started to put some of the necessary regulations and ethical frameworks in place. However, Morocco's score is lower than that of Egypt (68.19) and Rwanda (67.82), indicating that these countries have a more robust strategy and framework for AI in their public sectors.
- Technology sector pillar (35.69): In terms of the Technology Sector Pillar, Morocco's score is again moderate. This score could reflect a developing but not yet fully mature AI technology sector, with a limited number of AI enterprises (unicorns) and perhaps moderate levels of investment and trade in the ICT sector. Compared to South Africa (40.22) and Tunisia (38.47), Morocco has some catching up to do in fostering a vibrant AI technology sector.
- Data & Infrastructure pillar (56.79): Morocco's highest score is in the Data & Infrastructure Pillar. This relatively high score indicates that Morocco has a reasonably strong infrastructure in place, potentially including telecommunications, supercomputers, and broadband quality. This infrastructure is critical for supporting AI technologies and suggests that Morocco may have better data availability and infrastructure than several other African countries, such as Rwanda (40.48) and Senegal (40.43).

In the context of exploring the transformative impact of digital technologies on public sector efficiency, the case of the Moroccan Directorate General of Taxes (DGI) serves as a compelling illustration of strategic innovation and technological adoption [13]. Morocco's DGI has strategically incorporated artificial intelligence (AI) and Big Data analytics to revolutionize its fiscal oversight and tax collection processes. This

Table 1. Comparative government AI readiness in African Nations: 2023 Index Rankings

Global Ranking Government AI Readiness Index 2023	Country	Total score	Government Pillar	Technology Sector Pillar	Data & Infrastructure Pillar
62	Egypt	52.69	68.19	40.11	49.77
77	South Africa	47.28	37.82	40.22	63.79
81	Tunisia	46.07	48.31	38.47	51.44
84	Rwanda	45.39	67.82	27.87	40.48
88	**Morocco**	**43.34**	**37.54**	**35.69**	**56.79**
91	Senegal	42.58	59.65	27.67	40.43
97	Benin	41.37	61.38	24.46	38.27
101	Kenya	40.19	40.03	28.95	51.58
103	Nigeria	39.88	44.94	24.49	50.21
110	Botswana	38.84	34.82	29.20	52.50
119	Cabo Verde	36.30	36.68	27.24	44.98
120	Algeria	35.99	30.10	30.56	47.30
125	Namibia	35.37	32.02	28.30	45.80

Source: created by the authors using data from Oxford insights 2023 [25]

initiative represents a forward-thinking approach to leveraging technology for enhanced governance and operational efficiency within the public sector. By integrating AI and Big Data, the DGI has significantly improved its capacity to process and analyze extensive tax-related data, enabling the identification of inconsistencies, potential fraud, and inaccuracies in tax declarations with unprecedented efficiency. The automation of routine tasks through AI has reduced the resources and time traditionally required for tax audits, marking a substantial improvement in the administrative efficiency of tax collection. The deployment of Big Data analytics allows for the aggregation and cross-referencing of information from various sources, providing a holistic view of taxpayers' fiscal behaviors and uncovering suspicious activities with greater accuracy. This sophisticated approach to tax administration enhances fiscal transparency and compliance, simplifying the tax filing and payment process for taxpayers and fostering a more positive relationship between them and the fiscal authorities. Moreover, the DGI's proactive initiative to commission a study for the development of a "Big Data" analytical environment and the implementation of a Data Cross-Referencing and Analysis System (SRAD) underscores a significant commitment to advancing Morocco's tax administration system. This initiative aims at building a robust analytical framework to further streamline tax collection and oversight processes, reflecting Morocco's dedication to adopting cutting-edge technologies to modernize its public services. The DGI's experience exemplifies the potential of AI and Big Data to enhance the efficiency and effectiveness of public sector operations, offering valuable insights for other nations considering similar technological advancements in their fiscal administration strategies. Overall, Morocco's position suggests that while there is a solid foundation in terms of data and infrastructure, more focus may be needed on enhancing government vision and policies related to AI, as well as fostering the technology sector to support innovation. This holistic development is crucial for Morocco to climb higher on the AI readiness index and compete more effectively with the leading nations in this space.

2.6 Big Data and Data Science in Enhancing Morocco's Public Sector Efficiency

Morocco is enhancing its data governance framework to capitalize on the opportunities for economic diversification offered by the digital era [10]. As data becomes increasingly central to the modern economy, the frameworks for managing this data are not yet as effective as necessary. To thrive in the upcoming stages of worldwide digital evolution, it is crucial for both governments and businesses to manage data in ways that benefit both the economy and society at large. Morocco, recognizing this, has been proactive in embracing digital technology advancements, leading to new data management strategies at the governmental level, along with the introduction of relevant regulations and policies [11, 36, 41]. This presents Morocco with a chance to streamline and enhance ongoing efforts, ensuring that its economy powered by data thrives. This involves ensuring that stakeholders in the private sector and civil society have the capacity to gather, share, and utilize data from both public and private sources reliably.

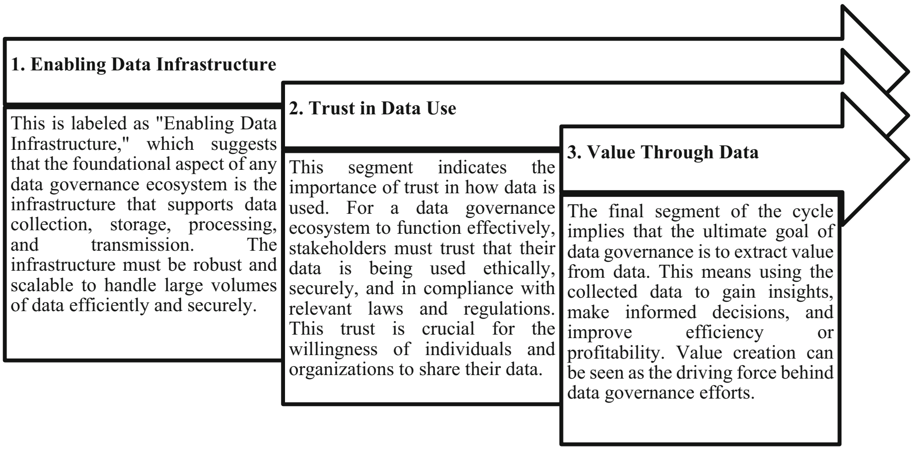

Fig. 1. The triadic cycle of data governance: infrastructure, trust, and value creation (authors)

The Fig. 1 depicts a data governance ecosystem as a cyclical flow with three interlinked components, illustrating a dynamic interplay among them, as evidenced in Fig. 1. The cycle suggests that these three components reinforce each other: a robust infrastructure enables the secure and efficient use of data, which builds trust among data subjects and stakeholders. Trust, in turn, encourages the sharing and use of data, which can then be leveraged to create value. Finally, the value realized from data use can justify further investment in infrastructure, thus continuing the cycle. The overlapping areas between each pair of components suggest that they are not isolated; for example, the infrastructure must be designed with trust in mind, and the creation of value is dependent on both the infrastructure and the trust in data use.

3 Discussion

In Morocco's journey towards digital transformation, the importance of developing a culture based on data utilization is increasingly apparent. The adoption of Artificial Intelligence (AI) and Big Data in the public sector offers a chance to transform governance and service delivery. Nonetheless, this shift also brings forth challenges that necessitate a collaborative approach to address. Promoting data exchange between agencies and fostering partnerships with the private sector are essential steps to boost Morocco's capabilities in Big Data and Data Science. Additionally, utilizing AI and machine learning for predictive analytics in services and urban management heralds innovative prospects. While the integration of AI and Big Data holds significant potential for the public sector, it faces obstacles such as institutional complexities and a fragmented landscape. The need for cohesive data governance and a comprehensive strategy for digital transformation is evident. The current environment, marked by competitive and secretive practices among agencies, poses barriers to effectively leveraging AI technologies. Hence, a shift towards collaborative efforts and adopting a government-wide strategy for data governance is crucial. Beyond technical hurdles, embracing AI in the public sector involves cultural and organizational changes, moving from conventional bureaucratic methods to more dynamic and innovative management and service delivery. This transformation is dependent on establishing trust among stakeholders in the novel use of data, essential for the fruitful deployment of AI technologies.

3.1 Recommendations

Based on our detailed analyses of reports from [10, 11, 33–36, 40, 41], we recommend a series of strategic enhancements and reforms to further strengthen Morocco's public sector through the strategic use of AI, big data, and data science. Key recommendations include:

- Establish a holistic national AI strategy that promotes the integration of AI, big data, and data science within the public sector. This strategy should outline clear objectives, implementation plans, and mechanisms for collaboration across different government agencies and with the private sector;
- Strengthen Morocco's digital infrastructure to support AI and data science initiatives. This includes investing in high-speed internet, data centers, and cloud services. Simultaneously, develop robust data governance frameworks to ensure data privacy, security, and ethical use of AI technologies;
- Encourage collaborations between government agencies and the private sector, particularly with startups and tech companies specializing in AI and data science. These partnerships can bring innovative solutions to public sector challenges and facilitate knowledge transfer;

- Implement comprehensive training programs for public sector employees to develop their skills in AI, big data analysis, and data science. Promote a culture of continuous learning and adaptation to new technologies;
- Expand and promote open data initiatives to increase transparency, foster innovation, and enable the development of AI applications that can benefit the public sector and society at large;
- Launch pilot projects in key areas such as healthcare, education, and transportation to test and refine AI applications. Use the insights gained from these projects to scale successful initiatives across the public sector;
- Develop and enforce ethical guidelines for the use of AI in the public sector. These guidelines should address issues such as bias, transparency, and accountability in AI systems to build public trust in government-led AI initiatives;
- Set up a dedicated center for AI and data science innovation within the public sector. This hub can serve as a focal point for research, development, and collaboration on AI projects, providing resources and support to government agencies.

4 Conclusion

Morocco's strategic initiatives in Big Data, Data Science, and Artificial Intelligence signify a transformative approach to governance and public service delivery. The country's journey towards leveraging these technologies, while fraught with challenges, also offers valuable lessons for other emerging economies aiming to harness the power of data for public sector innovation. Morocco's efforts to enhance public sector efficiency, transparency, and responsiveness to citizen needs through digital transformation are commendable. However, success in this endeavor requires addressing existing challenges, including the need for robust data governance frameworks, digital infrastructure, and a culture of trust in data use. The path forward for Morocco involves continued investment in digital infrastructure, data governance frameworks, and skills development to navigate the complexities of digital transformation effectively. By embracing a holistic approach that includes fostering a data-driven culture, enhancing inter-agency collaboration, and leveraging AI technologies, Morocco can realize the full potential of its public sector. The lessons learned from Morocco's experience offer insights into the broader implications for governance and public administration in the context of emerging economies, highlighting the pivotal role of AI in driving public sector innovation and transformation. As Morocco continues to advance its digital transformation agenda, the integration of AI, Big Data, and Data Science into the public sector will undoubtedly play a critical role in shaping the future of governance and public service delivery in the country and beyond.

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Strategic Intelligence as a Pillar of Economic Intelligence in the Era of Governance 2.0

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Abstract. The shift from traditional governance to Governance 2.0 is characterized by the advent of innovative technologies and increased interconnectivity, reshaping conventional methods of governance towards a more open and collaborative framework. Nevertheless, this emerging but little-explored new concept is accompanied by several flaws, highlighting the crucial need to combine Economic Intelligence and strategic intelligence efforts. Governance 2.0 is characterized by greater openness, but also by increased risks in terms of data security and confidentiality. In this context, strategic intelligence becomes an essential pillar of Economic Intelligence, enabling organizations to remain competitive by anticipating trends, risks and opportunities in a constantly changing environment. By integrating Economic Intelligence into their overall strategy, organizations can better respond to the challenges posed by governance 2.0 and fully exploit the advantages it offers.

Keywords: Economic Intelligence · Strategic intelligence · Information processing · Risks and opportunities · Governance 2.0 · Decision-making

1 Introduction

In an ever-changing economic context, marked by increased competition and rapid technological advances, effective information management is becoming a major strategic challenge for companies. At the heart of this dynamic lies the practice of strategic intelligence, which involves collecting, analyzing and interpreting relevant data to anticipate market trends and make informed decisions. At the same time, Economic Intelligence is emerging as an essential tool for transforming this information into competitive strategies.

In this changing landscape, governance 2.0 is emerging as a new management model, characterized by a more participative and collaborative approach. Decision-making is decentralized, and knowledge sharing is encouraged at all levels of the organization. This evolution calls into question traditional information management practices, and raises new challenges for the integration of Economic Intelligence into Economic intelligence.

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In this context, the problem we will be addressing is as follows: How can the integration of strategic intelligence into Economic Intelligence strengthen the conceptualization of governance 2.0 and improve organizational decision-making?

From this problematic, two central hypotheses emerge:

Hypothesis 1: Integrating the "Economic Intelligence/strategic intelligence" duo into the 2.0 governance process promotes informed, proactive decision-making, and contributes to better risk management and crisis prevention.
Hypothesis 2: The Implementation of Strategic Intelligence Based on Economic Intelligence Strengthens the Competitiveness, Transparency and Resilience of Governmental and Economic Players.

This article will thus be crowned by the following plan: Firstly, we will try to highlight the theoretical basis of the three concepts in question, namely their definitions, objectives and characteristics. Secondly, we will look at how they can be coherently articulated to support the strategic objectives of organizations in a constantly evolving environment. And finally, we will analyze the potential synergies of the said concepts, to then discuss the challenges and obstacles to be overcome for a successful integration in a Governance 2.0 context.

2 Governance 2.0, Economic Intelligence, Strategic Intelligence: Definition, Importance and Characteristics

2.1 Governance 2.0

The notion of "Governance 2.0" has been discussed and defined by various researchers, who have helped to determine its content for all types of organization (public or private), and to measure its consequences. According to Don Tapscott and Anthony D. Williams, governance 2.0 is a concept that takes advantage of information and communication technologies to foster cooperation, transparency and commitment among the players involved, using online platforms as privileged media. Whereas for Beth Simone Noveck, governance 2.0 is based on the fundamental values of openness, participation and collaboration, helping to improve public governance and increase citizen engagement through the use of digital resources and data accessible to all. The evolution of governance practices has led to some striking disparities between traditional governance and that of the 2.0 era:

- **Centralization vs. decentralization:** In traditional governance, decision-making power is often centralized at the top of the organizational hierarchy. Decisions are made by a small group of executives or managers. In contrast, governance 2.0 often favors a more decentralized approach, where power is distributed throughout the organization. Decisions can be made collaboratively, involving wider participation by the organization's members.
- **Communication and transparency:** In traditional governance, communication is often top-down. Information can be filtered, and transparency can be limited. Governance 2.0, on the other hand, favors more horizontal and transparent communication. Information is shared openly via online platforms, and decisions can be more visible to all members of the organization.

- **Participation and collaboration:** Employee or stakeholder participation is often limited in traditional governance. Decisions are taken by a small group of decision-makers. In contrast, governance 2.0 encourages the participation and collaboration of the organization's members in decision-making processes. Online platforms enable individuals to contribute to discussions, share their ideas and participate in decision-making.
- **Agility and responsiveness:** Traditional governance can sometimes be rigid and slow to adapt to changes in the market or environment. Decisions can require a long and complex process. Governance 2.0, on the other hand, is often more agile and reactive. Decision-making processes can be more flexible and adaptive, enabling the organization to respond more quickly to challenges and opportunities.

For all its considerations, governance 2.0 embodies a substantial transformation of traditional governance models, propelled by technological advances and evolving stakeholder expectations. It is characterized by its dynamic, interactive and collaborative approach, featuring intensive use of information and communication technologies. This approach has a number of distinctive features:

- **Intensive use of digital technologies**: Governance 2.0 takes full advantage of digital tools such as online collaborative platforms, corporate social networks and cloud computing technologies.
- **Increased participation and collaboration:** Unlike traditional models, where decision-making was often centralized, Governance 2.0 encourages the participation and collaboration of all stakeholders.
- **Transparency and access to information:** Transparency is a fundamental pillar of Governance 2.0. Organizations put in place mechanisms to share relevant information in an open and accessible way.
- **Adaptability to rapid change:** Governance 2.0 is characterized by its ability to adjust rapidly to market developments, new technologies and changing stakeholder expectations.
- **Collaborative knowledge management**: Organizations adopting Governance 2.0 recognize the strategic value of collaborative knowledge management.

Several organizations have mastered the concept of Governance 2.0, for example:

- **International Business Machines Corporation (IBM):** IBM adopted Governance 2.0 by launching "IBM Jam", an online collaboration platform enabling thousands of employees, customers and partners to contribute to discussions on strategic topics. This approach has facilitated the co-creation of innovative solutions and strengthened stakeholder engagement.
- **Wikipedia online encyclopedia:** Wikipedia is an emblematic example of Governance 2.0 in the online collaborative domain. Thousands of contributors from all over the world participate in content creation and management, demonstrating the power of distributed collaboration and participative knowledge management.

Governance 2.0 represents a response to the demands of an ever-changing digital world. Organizations that embrace these characteristics benefit from the diversity of ideas, innovation and speed of adaptation, while addressing the following challenges:

- **Security and privacy**: Open data and processes can raise security and privacy concerns, requiring proactive risk management.
- **Conflict management:** The diversity of stakeholders and opinions can sometimes lead to conflict. Effective conflict management becomes crucial to maintaining positive collaboration.
- **Cultural transition:** Moving from a traditional governance approach to Governance 2.0 often requires a significant cultural change within the organization, which can meet with resistance.

2.2 Economic Intelligence

Economic intelligence (EI) can be characterized as a systematic process aimed at gathering, analyzing and ethically exploiting strategic data to inform decision-making and improve an organization's economic competitiveness. This approach demands originality in the collection and interpretation of information, while scrupulously respecting intellectual property rights, in order to maintain ethical and responsible conduct. It encompasses intelligence, but goes beyond this to include aspects such as the protection of the organization's economic interests.

The main aim of Economic Intelligence is to improve strategic decision-making, reduce risks, seize opportunities and increase an organization's competitiveness in a constantly changing economic environment.

This concept can be synthesized into a triptych comprising the collection of relevant strategic information, the preservation of the data obtained and lobbying through the injection of information into the organization's environment with the aim of favorably influencing decisions, thus completing the overall Economic intelligence process. The skillful integration of business intelligence tools is therefore essential to anticipate market fluctuations, identify emerging opportunities and consolidate the competitive position of organizations. These tools include:

- **Business intelligence systems:** they automatically collect and filter relevant data from a variety of sources.
- **Data analysis tools:** process large quantities of information to identify significant trends and correlations.
- **CRM platforms:** essential for managing interactions with stakeholders and understanding market dynamics.
- **Business Intelligence (BI) software:** offers advanced features for visualizing data and performing in-depth analysis.
- **Economic modeling tools:** used to simulate scenarios and assess the impact of economic decisions.
- **Cybersecurity tools:** indispensable for protecting data and ensuring information security.
- **Social networks and associated analysis tools:** used to monitor online conversations, understand public opinion and detect emerging trends.

2.3 Strategic Intelligence

Strategic intelligence represents a continuous process in which a deliberately committed group tracks down and exploits anticipatory information linked to possible changes in an organization's external environment. The main aim of this approach is to create business opportunities while minimizing risk and uncertainty.

The information sought includes early warning signals, which will be detailed later. In essence, Economic Intelligence aims to facilitate rapid and timely action. The English terms "Environmental Scanning" and "Competitive Intelligence" are often used to describe similar concepts. It should be noted that, according to Herbert Simon's decision-making model, strategic intelligence is integrated into the phase known as "intelligence of the corporate environment".

According to Caucal's classifications, strategic intelligence information can be categorized according to its degree of confidentiality and accessibility:

- **White:** This is legal information, coming from formal sources and accessible to all via the press, Internet, etc.
- **Grey:** This information is not protected by law, is not directly published and is obtained informally from company networks.
- **Black:** This information is protected by law, with access limited to authorized persons. Obtaining it through espionage is illegal.

3 Meeting Horizons: Towards Convergence

3.1 Economic Intelligence and Strategic Intelligence

Strategic intelligence and Economic Intelligence are two closely related concepts, aimed at collecting, analyzing and exploiting information to inform economic decision-making.

- **Common objectives:** These two concepts share the overall objective of assisting organizations in making informed decisions by improving their understanding of the environment, with the intention of minimizing uncertainties, identifying opportunities and anticipating risks.
- **Integrated processes:** Often considered an integral part of the Economic Intelligence process, strategic intelligence contributes to the latter by gathering information crucial to understanding the economic and competitive context.
- **Focus on economic security:** Economic Intelligence frequently focuses on the protection of economic interests, encompassing defense against espionage, counterfeiting and the like. Although strategic intelligence can also incorporate these aspects, EI goes beyond this by securing economic activities more deeply.
- **Use of information:** Both concepts strive to transform information into usable knowledge, which can then be used to guide strategy, encourage innovation and manage risk.

3.2 Strategic Intelligence and Governance 2.0

Strategic intelligence and good governance are closely linked, both helping to improve decision-making, transparency and organizational performance. Here are a few points illustrating the link between strategic intelligence and good governance:

- **Information for decision-making:** Business intelligence focuses on gathering relevant information on the external environment, essential for informed decision-making. Good governance also requires reliable information for ethical and responsible decision-making.
- **Anticipating risks and opportunities:** Strategic intelligence enables us to anticipate developments, opportunities and threats. Good governance implies the ability to anticipate risks and seize opportunities, requiring in-depth knowledge of the external environment.
- **Transparency:** Good governance is based on transparency. By providing objective information, strategic intelligence reinforces the organization's transparency, crucial for accountability to stakeholders.
- **Strategic alignment:** Strategic intelligence helps to align strategy with market trends. Effective governance requires strategic alignment to ensure that the organization's objectives are in line with market reality.
- **Reactivity and adaptation:** Proactive strategic intelligence enables the organization to be reactive to market changes. Effective governance must be able to adapt to new information and take appropriate measures for long-term success.
- **Risk management:** Strategic intelligence contributes to risk management by identifying threats. Good governance establishes risk management mechanisms to ensure sustainability and organizational stability.

3.3 Economic Intelligence and Governance 2.0

The convergence between Economic Intelligence and governance 2.0 represents a dynamic synergy in the context of modern business. Here are a few key elements that highlight this convergence:

- **Use of Information Technology:** Governance 2.0 focuses on information technology, in other words collaboration and information sharing via interactive digital platforms, facilitating the rapid circulation of information within the organization. These tools can also be integrated into Economic Intelligence processes to improve the collection, analysis and dissemination of strategic information.
- **Active stakeholder participation:** Governance 2.0 encourages the active participation of stakeholders through interactive communication tools. This participation can be exploited in the context of Economic Intelligence to gather diverse perspectives, feedback and crucial information from different stakeholders.
- **Responsiveness and agility:** Governance 2.0 promotes organizational responsiveness and agility, aligned with the objectives of Economic Intelligence, which seeks to rapidly anticipate market changes and proactively adapt to opportunities and risks.
- **Transparency and Accountability:** Governance 2.0 promotes transparency and accountability through open communication and traceability of actions. These principles are also essential in the context of Economic Intelligence, where trust and transparency reinforce the quality of the information gathered.

To make this convergence a reality, it should be noted that economic intelligence tools are applicable to governance 2.0 through the following steps:

1. identifying needs → 2. Tool selection → 3. Data collection → 4. Data analysis → 5. Interpretation of results → 6. Informed decision-making → 7. Ongoing monitoring

Successfully incorporating economic intelligence (EI) into an organization's overall strategy to meet the challenges of governance 2.0 requires a thoughtful, structured approach. To navigate the complexities of governance 2.0, organizations can adopt the following recommendations:

- **Identifying specific needs:** Before integrating EI, organizations need to define their specific strategic information needs.
- **Alignment with strategic objectives:** EI integration must be consistent with the organization's strategic objectives.
- **Management commitment:** To ensure the success of EI integration, the active involvement of management is crucial. Management must recognize the strategic value of EI.
- **Staff training:** Teams need to be trained in business intelligence concepts and tools.
- **Investment in technology:** Organizations must invest in technological tools adapted to EI, such as data analysis software, online intelligence platforms and information management systems.
- **Legal and ethical compliance:** EI integration must respect legal and ethical standards. S assure la collecte et l'utilisation de l'information sont conformes aux lois et réglementations en vigueur, et mettre en place des politiques éthiques robustes.

4 Research Methodology

In the context of our study, we will focus on presenting the research methodology we have chosen for this article. Our research is therefore based on a qualitative hypothetico-deductive approach, implementing an in-depth documentary analysis. This methodology enables us to explore in depth the interactions between strategic intelligence, Economic Intelligence and 2.0 governance, while testing specific hypotheses formulated within the framework of the study. In this study, we formulated two central hypotheses on the integration of the binomial "strategic intelligence and Economic Intelligence" in 2.0 governance. This hypothetico-deductive approach guides the design of the study, guiding the choice of data collection and analysis methods. This means that an in-depth literature review is carried out, covering company reports, books and relevant academic articles to enrich understanding of the concepts studied and provide complementary perspectives, so as to be able to confirm or refute the chosen hypotheses. Thus, it should be noted that the ultimate aim of our research is in line with an interpretivist epistemological vision aimed at understanding and interpreting social phenomena, taking into account the evolution of the construct of concepts, the perspectives of actors and the tools involved in strategic intelligence. Thus, it should be noted that the ultimate aim of our research is in line with an interpretivist epistemological vision aimed at understanding and interpreting social phenomena, taking into account the evolution of the construct of concepts, the perspectives of actors and the tools involved in strategic intelligence, Economic Intelligence and 2.0 governance. Recognizing that reality in this field is socially constructed, this approach, which we deem relevant, will enable us to explore how these concepts are perceived and interpreted differently according to the governance 2.0 context marked by a phase of mutation where the emphasis is on the active participation of stakeholders and citizens (who constitute the pillars of private and state organizations respectively), increased transparency, the use of digital technologies and the adoption of agile and inclusive approaches to meet challenges. We recognize that in this field, reality is subjective and multiple, and that understanding is influenced by individual interpretations and the meanings attributed by the actors involved. By adopting this paradigm, we are committed to exploring the diversity of interactions and synergies between the concepts in question, in order to better understand the complex dynamics underlying the practice of strategic intelligence and Economic Intelligence in the age of governance 2.0.

5 Analysis of Results

The rapidly changing economic and technological context has prompted organizations to revisit their approaches to governance. The rapidly changing economic and technological context has prompted organizations to revisit their approaches to governance. However, the dynamic and interactive characteristics of Governance 2.0 bring with them significant vulnerabilities, namely:

- **Data security:** Governance 2.0, with its intensive use of digital platforms and social networks, exposes organizations to major risks such as phishing, malicious intrusions and data leaks.
- **Data confidentiality**: Frequent interactions on social media as part of Governance 2.0 can compromise data confidentiality, exposing sensitive information to unauthorized third parties.
- **Information manipulation:** In the context of Governance 2.0, misinformation, manipulation campaigns and the propagation of fake news can jeopardize the credibility of available information, leading to erroneous decisions.

To mitigate the vulnerabilities and risks associated with Governance 2.0, several strategies can be adopted:

- **Strengthening Security Measures:** Implement robust security protocols, including two-factor authentication, real-time monitoring of suspicious activity and regular system audits.
- **Education and Awareness:** Train staff and end-users on security best practices, including recognizing phishing attacks and protecting sensitive information.
- **Clear Privacy Policies:** Develop and implement transparent privacy policies, informing users of how their data will be used and ensuring their informed consent.
- **Media Intelligence:** Implement media intelligence systems to monitor online discussions and react quickly to misinformation to limit its spread.
- **Regulatory Compliance:** Ensure that governance practices comply with data protection regulations, implementing compliance standards such as the RGPD.
- **Collaboration with Stakeholders:** Work in collaboration with digital platform providers, cybersecurity experts and other stakeholders to strengthen collective security and share best practices.

By adopting these strategies, organizations can mitigate the vulnerabilities and risks associated with Governance 2.0, strengthening data security and confidentiality in this dynamic, interconnected environment. This is why Economic Intelligence (EI) and Strategic Intelligence are emerging as fundamental pillars guiding corporate decisions and actions towards a more adaptable and efficient model. The incorporation of this tandem, formed by economic intelligence and strategic intelligence, is becoming an essential element of governance 2.0, representing a significant evolution in organizational governance.

Within this dynamic framework, Economic Intelligence (EI) and strategic intelligence are emerging as fundamental pillars guiding corporate decisions and actions towards a more adaptable and effective model. The incorporation of this tandem, formed by Economic Intelligence and strategic intelligence, is becoming an essential element of governance 2.0, representing a significant evolution in organizational governance.

Governance 2.0 is characterized by its innovative aspect, influenced by technological advances and the need to anticipate constant market changes. With this in mind, Economic Intelligence, defined as the ability to gather, analyze and exploit strategic information, is naturally combined with strategic intelligence, which aims to anticipate market trends and identify opportunities and threats.

This combination offers a comprehensive approach to guiding the decisions of managers and stakeholders. It goes beyond traditional governance models by placing strategic information at the heart of the decision-making process. The aim of this synergy is to give companies a competitive edge, by fostering an in-depth understanding of their competitive environment, a capacity for rapid adaptation, and informed decision-making. Integrating the duo of economic intelligence and strategic intelligence in the development of the Governance 2.0 concept is of crucial importance, for a variety of reasons. This integration can be achieved in a number of ways.

Integrating Economic Intelligence and strategic intelligence into 2.0 governance is a fundamental approach for companies seeking to thrive in an ever-changing environment. This integration provides the tools needed to successfully navigate a complex and competitive environment, fostering agility, innovation and organizational sustainability. This translates into the ability to anticipate change, react swiftly to opportunities and threats, optimize decision-making, adapt to a changing competitive context, ensure strategic alignment, and strengthen organizational resilience.

The integration of Economic Intelligence and strategic intelligence within Governance 2.0 marks a significant turning point in the way companies approach decision-making and strategic management. Initially, this collaboration is based on the in-depth collection and analysis of strategic information, going beyond traditional data to encompass predictive elements and emerging trends. These insights are then fed directly into the decision-making process, providing executives with a more in-depth view of the economic and competitive landscape.

Furthermore, the integration of Economic Intelligence and strategic intelligence into 2.0 governance stimulates greater organizational agility. By anticipating market developments, companies can react swiftly, adjusting their strategies in real time and adopting more flexible approaches in the face of uncertainty. This leads to more effective adaptation to changing conditions, and strengthens organizational resilience in the face of future challenges.

Finally, this synergy ensures close strategic alignment between Economic Intelligence initiatives, strategic intelligence and the company's overall objectives. It helps build a solid knowledge base, encourages innovation and keeps the company at the forefront of its sector. In short, the integration of Economic Intelligence and strategic intelligence into Governance 2.0 provides a comprehensive strategic framework, conducive to informed decision-making, increased agility and organizational sustainability. This integration is therefore conducive to decision-making (which confirms the choice of H1), and this choice is supported by the following advantages:

Incorporating the duo of Economic Intelligence and strategic intelligence into 2.0 governance offers a number of essential benefits for companies operating in a constantly changing environment. This strategic collaboration not only anticipates market trends, but also optimizes responsiveness to emerging opportunities and threats. By placing strategic information at the heart of the decision-making process, it encourages faster, more informed decision-making. In addition, this integration enhances the company's adaptability to its competitive environment, ensures effective strategic alignment, and contributes to organizational resilience. In short, it represents a comprehensive approach to guiding companies towards more agile, innovative and sustainable governance, thus conferring an undeniable competitive advantage.

The introduction of a strategic intelligence based on Economic Intelligence gives organizations considerable advantages, promoting proactive, enlightened management. Firstly, it enables real-time anticipation of market trends, by gathering information on economic developments, competitor behavior and emerging opportunities. This ability to anticipate change gives companies a competitive edge, enabling them to make informed decisions and adjust quickly to a constantly changing environment.

In addition, Economic Intelligence strengthens the decision-making process by providing in-depth, relevant information. Analysis of the data collected enables managers to formulate more precise strategies, aligned with organizational objectives. This improvement in the quality of decisions contributes to operational efficiency and the achievement of the company's strategic objectives.

Finally, proactive risk management represents an additional crucial advantage. Strategic Intelligence facilitates the identification and assessment of potential risks, whether related to competition, regulatory change or economic instability. By anticipating these risks, organizations can develop appropriate mitigation plans, thereby consolidating their resilience, and ability to cope with unforeseen situations.

In short, the implementation of Strategic Intelligence-based on economic intelligence offers a proactive approach, raises the quality of decisions and strengthens the resilience of organizations, thus providing an undeniable strategic advantage in the dynamic business context.

The H2 hypothesis stipulating that the implementation of strategic Intelligence-based on Economic intelligence enhances the competitiveness, transparency and resilience of governmental and economic players finds solid support through various arguments.

Firstly, the use of Strategic Intelligence-powered by Economic intelligence enables in-depth analysis of the competitive context and market trends. This in-depth understanding gives government and economic players a competitive edge, enabling them to anticipate developments, identify opportunities and make informed decisions. As a result, their competitiveness is strengthened, positioning them favorably to meet the challenges of the future.

In terms of transparency, the implementation of strategic Intelligence based on economic intelligence facilitates the collection and dissemination of relevant, up-to-date information.

This helps to establish a climate of trust by providing stakeholders, whether in economical or governmental sector, with a clear and transparent view of the issues, risks and opportunities at stake. This newly acquired transparency strengthens the credibility of stakeholders and encourages more open relations with the public and partners. Finally, the resilience of government and economic players is enhanced by proactive strategic intelligence. By quickly identifying potential threats, players can implement mitigation strategies and adapt effectively to change. This ability to anticipate and react quickly consolidates resilience, enabling governmental and economic entities to better cope with external disruptions and shocks.

In short, the integration of strategic intelligence based on Economic Intelligence emerges as an essential lever for enhancing the competitiveness, transparency and resilience of governmental and economic players, conferring a significant advantage in a complex and constantly changing environment.

6 Conclusion

In the era of governance 2.0, the future prospects for the integration of strategic Intelligence into economic intelligence are promising, offering new opportunities and challenges for organizations. Governance 2.0, characterized by a more participative, collaborative and transparent approach, calls for proactive information management to meet the demands of an ever-changing business environment.

Indeed, better mastery of the "Strategic Intelligence and Economic Intelligence" duo offers organizations a privileged path to strengthening 2.0 governance through several essential aspects. Firstly, by enabling proactive gathering and in-depth analysis of relevant information, Strategic Intelligence provides decision-makers with a clearer, more precise vision of the economic and competitive environment in which the organization operates. This enhanced understanding of market dynamics and emerging trends enables decision-makers to make informed and strategic decisions, contributing to more informed and responsive governance. What's more, by encouraging the sharing and dissemination of information at all levels of the organization, Economic Intelligence promotes a culture of transparency and collaboration that is one of the hallmarks of governance 2.0.

By encouraging the participation and commitment of internal and external stakeholders, strategic intelligence also strengthens accountability mechanisms, thus promoting more democratic and participative governance.

Thus, to promote the effective integration of Strategic Intelligence into Economic Intelligence, policymakers and practitioners can consider several recommendations.

Firstly, it is crucial to invest in innovative technologies and tools for the collection, analysis and dissemination of strategic information. In addition, it is important to encourage collaboration and knowledge sharing at all levels of the organization, fostering an organizational culture focused on learning and innovation. Finally, it is essential to establish effective governance mechanisms to oversee and coordinate Economic Intelligence activities, ensuring that they are aligned with the objectives of Governance 2.0.

By following these recommendations, organizations can strengthen their ability to anticipate market changes, seize emerging opportunities and maintain their competitiveness in a dynamic Economic environment. Ultimately, the successful integration of strategic intelligence into Economic Intelligence will help to support strategic decision-making, and to promote organizational performance in the age of governance 2.0.

As a result, EI faces a number of important challenges: monitoring economic trends, analyzing the impact of government policies, engaging stakeholders, detecting risks early and optimizing resources.

Thus, EI as a whole faces several important challenges, namely: monitoring economic trends, analyzing the impact of government policies, engaging stakeholders, early detection of risks and optimizing resources.

In terms of potential research areas, it would therefore be pertinent to explore the ongoing evolution of information and communication technologies and their impact on EI practices. In addition, a deeper understanding of real-time collaboration mechanisms within organizations and with external partners could be a promising avenue of research. In terms of practical implications, organizations are strongly encouraged to implement these recommendations in a way that is adapted to their specific context. Ongoing awareness of the importance of EI, staff skills enhancement and judicious investment in relevant technologies are key elements for successful integration.

For all these considerations, the following question will enable a deeper and more creative exploration of the subject under study, encourage researchers to consider different perspectives, challenge established assumptions and push back the frontiers of knowledge by exploring new research horizons. **Should we therefore invest more in training human capital and raising decision-makers' awareness of Economic Intelligence and strategic intelligence practices, in order to generalize effective and responsible governance 2.0?**

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The Contributions of Digital Transformation to Local Finance Management: The Example of the Electronic Visa Procedure for Territorial Collectivities Budgets

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Abstract. The Ministry of the Interior, through the Directorate General for Local Collectivities (DGLC), and in collaboration with its partners in local finance, has placed the digitization and dematerialization of procedures at the top of its agenda.

Digitizing the management of local public finances has now become a priority for the competent authorities in Morocco, with the aim of simplifying procedures and improving services to citizens.

This paper aims to show the impact of the digitization of certain local finance procedures on local collectivities. We have taken the example of the dematerialization of the budget programming process. Within this framework, a case study will be carried out using a qualitative approach, with executive and semi-executive interviews with stakeholders in the AL HAOUZ Province (Municipalities, publics accountants and the supervisory authority).

The results of the study will enable us to explore the achievements of this digital transformation of territorial collectivities financial management procedures, identify the obstacles and challenges faced, and present the prospects for this digitalization strategy.

Keywords: Digitization · e-government · budget programming · local finance management information systems

1 Introduction

Like all ministerial departments, the Ministry of the Interior has launched digitalization programs in a number of areas, with the aim of aligning itself with the government's E-GOV strategy, and ensuring the digital transformation of all public services, whether provided to citizens, businesses or inter-administrations.

The digitalization of services provided to citizens and businesses was ensured by the WATIQA, CHIKAYA and ROKHAS platforms, not forgetting the Civil Status modernization program and the digital registry office. As for the management of local authority finances, several projects were launched with the Ministry's partners, especially the Kingdom's General Treasury (TGR), which is the main player in local public finance in

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Morocco. The two partners have set up integrated information systems for the benefit of local collectivities, to ensure efficiency, transparency and quality in their work. These include the Integrated Expenditure Management system (GID), the Integrated Revenue Management system (GIR), and the WADEF@UJOUR-INDIMAJ platform dedicated to career management and payroll processing for municipal staff.

The digitization of local public finance management, a concrete example of effective interoperability between administrations, has been launched by the French Ministry of the Interior via the Directorate General for Local Collectivities (DGLC), benefiting from TGR's expertise in information systems. The main aims of this dematerialization strategy are to simplify procedures, reduce costs, save time by minimizing processing times, and improve service to users.

The GID-CT system, is one of the first examples of this successful partnership between the two administrations, it is part of a modernization project with the prospect of contributing to establishing good budgetary, financial and accounting governance within local collectivities [1].

The GID-CT information system is considered to be a coherent, integrated and dynamic system, insofar as it has been designed in such a way as to enable it to easily integrate future regulatory changes, reengineer budget and expenditure procedures, dematerialize acts, integrate new business areas and open up to other actors. The dematerialization of budgetary acts and the approval of local authority budgets by the supervisory authority via GID-CT are examples of the new perspectives opened up by this system, and demonstrate its dynamism and agility.

While the GID-CT system has shown good results in terms of good governance, reduced costs and timeframes, and simplified procedures, the evaluation of new functionalities integrated into this system requires further assessment. It is in this context that we have attempted in this work to explore the various contributions of digitization on the budgetary programming of municipalities, by providing elements of an answer to the following question: What impact does the digitization of local financial management have on the budget programming process of local collectivities, in terms of simplifying procedures?

The aim of this research work is not to study the relationship between variables, or to develop a cause-and-effect model, but above all to explore the contributions of the strategy of digitizing local finance management and its added value to the CT budget programming process. We will therefore attempt to assess the importance of the dematerialization of the approval procedure for local authority budgets by the supervisory authority, to obtain the opinions of stakeholders, and to identify the benefits it brings in terms of simplifying procedures, reducing costs and processing times for acts, and improving services, and to specify the challenges faced by local collectivities when implementing this procedure.

To address this topic, we carried out a case study using a qualitative and quantitative approach, with executive and semi-executive interviews with stakeholders in the AL HAOUZ Province, namely the 40 municipalities within the province, the supervisory authority represented by the Local Collectivities Department (LCD) and the public accountants concerned, in particular the Collector of AMIZMIZ.

The first part of this article will be devoted to a literature review on the key words of our problem. In the second part, we will look at the impact of the digitization of local financial management on the budget programming process of local collectivities, and we will use the procedure of electronic submission of the budgets of the municipalities of the Province of AL HAOUZ to the supervisory authority for approval, as an illustration and case study.

2 Conceptual and Theoretical Framework

2.1 Digital Transformation and Public Administration: A Literature Review

Several authors and organizations have tried to define digital transformation (TD), often referred to as digitalization. However, the literature review revealed that these concepts are linked to a number of other terminologies, namely technology, digital and new information and communication technologies. As a result, digital transformation differs from one organization to another, depending on the objectives to be achieved, the fields of application and the tools used. All this makes it difficult to find a universal definition for this concept.

The literature review we carried out enabled us to identify the main aspects related to this concept, as illustrated in the following Table 1:

Through these definitions, we can define digital transformation as a change in operational processes and procedures, using new technologies, with the aim of boosting an organization's efficiency and competitiveness, and improving services to users.

The role of digital transformation can vary depending on the company or organization [6]. Generally speaking, and whatever the type of entity (private company, public administration or other), TD aims to improve operational efficiency by speeding up processing times and minimizing the margin for human error. It also enhances the user experience, enabling these organizations to better identify and understand their expectations and provide them with quality service.

Public administration is one of these organizational entities that finds itself in the imperative of adopting digital transformation in its procedures and services, hence the birth of new concepts such as e-government, e-administration, digital government and digital government.

In 2003, the OECD defined e-government as "the use of information and communication technologies (ICT), and in particular the Internet, to improve the management of public affairs" [7].

El ATTAR A & MAZOUZ Y [8] presented a simple and clear definition of e-government as "the use of information and communication technologies (ICT) to improve government processes".

The aim is to take advantage of ICT to modernize the administration, simplify procedures and improve services for all stakeholders. Today, digital technology is a fundamental tool for facilitating exchanges between the public administration and its partners (citizens, businesses, civil society and the rest of the world).

Table 1. Literature review on the concept of digital transformation

Authors	Definition	Keywords in the definition
Patrick Varenne and Cécile Godé [2]	Digital transformation refers to the combination of three phenomena - automation, dematerialization and the reorganization of intermediation schemes - which affects all business processes, from the business model to stakeholder relations	Automation, dematerialization
Vial [3]	Digital Transformation is a process that aims to improve an entity by triggering significant changes in its properties through combinations of information technology, computing, communication and connectivity	Information and communication technologies
OECD [4]	Digitisation, which is the conversion of analogue data and processes into a machine-readable format, represents a first outcome of digital technology. "Digitalisation", represents a second structural step and results from the interconnection of digital technologies, which results in new activities or in profound modifications of existing ones	the conversion of analogue data
Océane Mignot [5]	Integrating digital technology at all levels of the company to change the way it operates and deliver value to its customers	Digital technology

Source: Realized by the authors

2.2 Digitizing Local Financial Management in Morocco

In the age of digitalization, all Moroccan public administrations have embarked on processes to modernize and simplify procedures, using new information technologies. The Ministry of the Interior, like all these administrations, has made a range of information systems and platforms available to local collectivities, to enable them to keep pace with technological progress and align themselves with the government's digitalization strategy.

"With a view to improving the services provided to citizens, the General Directorate of Local collectivities, in partnership with several actors, has set up a range of programs and worked to interconnect local collectivities to several platforms offering a multitude of services in different fields", confirmed the Minister of the Interior during his speech to the Chamber of Councillors in November 2023 [9].

These programs mainly concern the economic and town-planning sectors, with the ROKHASS platform for managing economic and town-planning authorizations. Another platform, "watiqa.ma", enables local collectivities to receive requests from citizens for administrative documents such as extracts and full copies of birth certificates, not forgetting the "MAJALISS" platform for managing the activities of local authority councils.

In the field of local authority financial management, several information systems have been implemented, mainly in partnership with the Kingdom's General Treasury, a key player in local public finance in Morocco.

- **Local finance management information systems**

Beyond their technical dimension, the integrated information systems developed and deployed by the TGR for local collectivities are of strategic importance in the process of administrative modernization [10]. These systems provide local collectivities with management, monitoring, steering and decision-making tools in various areas: public procurement and expenditure execution, revenue collection, administrative accounting and personnel management.

The main local authority financial management information systems designed by TGR for the Ministry of the Interior and local collectivities are shown in Table 2 below:

- **Digitization of the territorial collectivities budget programming process**

The GID-CT information system enables local collectivities to carry out all operations relating to the management of budget appropriations and the execution of public expenditure. The system has been designed in such a way as to enable continuous improvement in functionality, broadening of its scope, introduction of new authorizations, addition of new actors, reinforcement of security measures and adaptation to new regulations concerning public procurement.

In this context, following the roll-out of the GID-CT system to all local collectivities in 2014, new functionalities have been introduced, mainly concerning the dematerialization of certain budgetary acts, in this case special and program authorizations (commitment and mandating by the DCLC, acceptance by local collectivities, authorization monitoring, etc.), as well as the dematerialization of the budget approval process by the supervisory authority.

Prior to the introduction of these new functions, the process of drawing up, adopting and approving the budget by the Wali or Governor, and of having the accountant take charge of the TC budget, was largely manual. Once the TC president has drawn up the draft budget, the Budget, Financial Affairs and Programming Committee examines it at least 10 days before the opening of the session at which the budget is to be approved by the Council. Once the session is over, the authorizing officer sends the Governor or

Table 2. TC information systems and areas of intervention

Information system	Area of intervention	Contents
GID-CT (Integrated management of local authority expenditure)	Managing local authority expenditure	• Budget credit management; • Public spending commitments; • Payment of expenses; • Year-end closing operations; • Editing financial statements; • Supplier database management • Traceability of operations • Availability of accounting and financial information
GIR-CT CT (Integrated management of local authority expenditure)	Local authority revenue management	• Taxpayer database management; • Tax settlement; • Issuing revenue orders; • Revenue collection; • Payment of receipts to the public accountant; • Editing taxpayer situations; • Collection follow-up;
WADEF@UJOUR and INDIM@J	Payroll management	• Budget item management; • Processing of personnel administrative acts; • Personnel career management

Source: Realized by the authors

Wali the adopted or unadopted budget, together with the minutes of the deliberations and supporting documents.

After approval by the supervisory authority, the approved budget or, failing that, the governor's decree - authorizing the authorizing officer to collect revenue, and to commit, liquidate and authorize operating expenditure within the limits of the appropriations entered in the last approved operating budget - is notified to the assigning accountants for charging.

The digitization of this procedure, as illustrated in Fig. 1, consists of introducing the GID-CT system into the budget approval process. Once the draft budget has been drawn up by the President, it is entered into the system, and the initial version undergoes modifications after examination by the Economic Affairs Committee and adoption by the CT Council. The final version of the budget is sent via the system to the Governor or Wali, as the case may be, together with the minutes and other supporting documents, duly scanned and uploaded to the system. Once the budget has been approved, it is immediately forwarded to the authorizing officer, who sends it directly to the accountant for payment.

As shown in figure N° 1, a number of operations in the budget process have been dematerialized (in orange). However, it should be noted that the budget preparation,

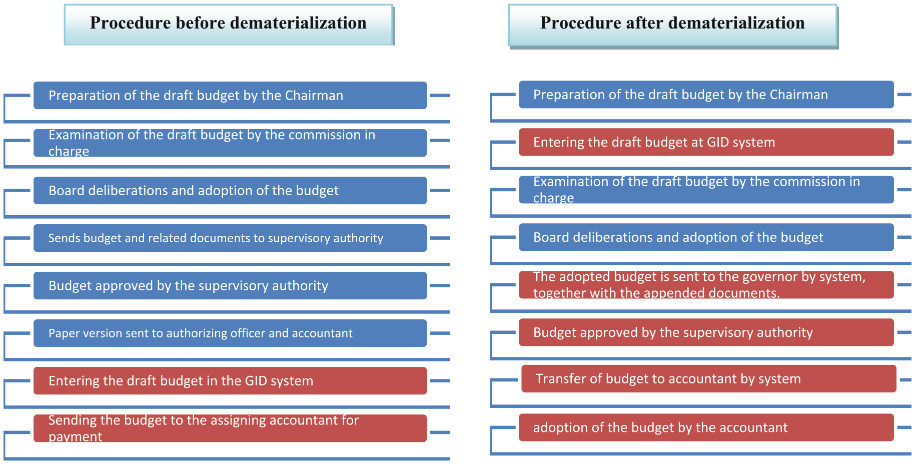

Fig. 1. Local authority budget programming process. Source: Realized by the authors

adoption and approval procedure is carried out within the regulatory timeframes laid down in the organic laws governing local collectivities. Thus, the commitment of public expenditure is conditional on the budget being taken over by the assigning accountant in the GID-CT system.

3 Digitization of Local Finance Management and Electronic Budget Approval Procedures: The Case of Municipalities in the Province of AL HAOUZ

3.1 Reminder of the Problem and the Methodology Adopted

- **Reminder of the problem and presentation of the field of study**

The implementation of the GID-CT system at local authority level for the processing of acts relating to the execution of public expenditure (commitment and authorization) has shown good results in terms of reducing processing times for these acts, improving service rendered, exploiting accounting and financial information and simplifying procedures. Of course, an evaluation is required for the new functionalities introduced into this system as part of the digitization of all TC financial management procedures and as part of the continuous improvement of this system. The central question of this research work is as follows: What impact does the digitization of local financial management have on the budget programming process of local collectivities?

The aim is not to measure this impact or to study the relationship between variables, or even to develop such a conceptual model, but rather to highlight the contributions of these new functionalities, which mainly concern the budget programming process.

To deal with this subject, we have chosen to study the case of municipalities in the Province of AL HAOUZ. This province has 40 municipalities, spread over 3 public accountants who control their expenditure and revenue operations.

- **Methodology and scope of study**

To address our subject, we adopted a combination of qualitative and quantitative methods, in addition to direct observation and data collection directly from the municipalities concerned, insofar as one of the authors of this work belongs to a structure that is interested in operationalizing the elements of the subject, namely the TGR, which is a key player in local public finance.

In fact, we conducted personalized interviews with various actors in local public finance. Firstly, an interview with the head of the advice department of the Al Houz Province's local authority department, with a view to obtaining his opinion on the digitization of local authority financial management in general and on the dematerialization of the procedure for approving adopted budgets and certain budgetary acts in particular. Secondly, we were asked to clarify any difficulties encountered in implementing and applying this procedure.

Another interview was conducted with the representative of the Perception of AMIZMIZ, a public accountant in charge of controlling the revenue and expenditure operations of 10 municipalities in the province. The aim was to present the public accountants' point of view on the digitization of local public finance management in the area of budget approvals, and to shed light on the various challenges associated with this project, as well as its prospects.

The other interviews were conducted with the managers of 3 municipalities, namely the Director of Services of the ANOUGAL commune, the budget and expenditure officer of the TIZGUINE commune, and that of the AMAGHRAS commune, not forgetting the telephone interviews conducted with all the representatives of the other municipalities of the Province.

For the quantitative method, we sent out a questionnaire to all local collectivities, via Google Form, the results of which were collected electronically and processed on the same platform. The aim of this questionnaire was firstly to assess the general progress made in digitizing local financial management, and in particular the dematerialization of the electronic budget approval procedure, and secondly to confirm certain assertions.

It should be noted that the choice of municipalities in the province of AL HAOUZ was motivated by the ease of access to data and the availability of the various actors expressed to the authors, and their willingness to contribute to the completion of this research work. Thus, this Province is characterized by its geographical diversity, with communities divided between urban centers and rural municipalities, which can be considered as a representative image of the Moroccan space. This observation gives an added advantage to our study and makes its results generalizable to other Moroccan regions.

3.2 Presentation and Analysis of Results

In this part of the article, we present the results of the interviews we conducted with local public finance actors, as well as a summary of the results of the questionnaire we sent out to the 40 municipalities of AL HAOUZ Province.

- **Interview with local public finance actors**

Interviews with various actors involved in local finance procedures showed that they are aware of the importance of digital transformation in modernizing administration and simplifying procedures within municipalities. For the TGR representative, the dematerialization of the procedure for submitting commune budgets to the supervisory authority for approval, which is a stage in the budget programming process at local authority level, "is highly commendable", insofar as it enables: a single input of data (all that's needed is 1ère input at the level of the initiator, i.e. the commune, for the budget to follow its approval circuit), an acceleration of the approval process as a result of the time saved by this dematerialization, and finally the traceability of the information or data (everything is saved and time-stamped with the designation of the participants or actors).

For his part, the supervisory authority, in the person of the Head of the Councils Department within the AL HAOUZ province, stressed the importance of this digitization project. The dematerialization of acts linked to budget programming will bring a degree of transparency to this process, simplify and standardize procedures, and reduce processing times for operations," he explained.

Answering the question of the main challenges faced by local collectivities in the digital transformation of local finances, the deputy collector of AMIZMIZ explained that the main challenges are the availability of qualified human resources to carry out this transformation, and the presence of high-performance IT platform management services (Hardware and HR) that are friendly and responsive to platform users, to ensure the success of this major digitization project.

As for the obstacles encountered during the implementation of this digitization project, the representative of the supervisory authority emphasized the reluctance of a category of staff to change, and the inadequacy of the necessary technical resources, especially the low speed of the connection in certain remote municipalities.

- **Questionnaire for municipalities**

The results obtained after processing the questionnaire are summarized in the following table (Table 3):

Table 3. Results of municipal survey

Appreciated component	Questions	Results
Assessment of the project to digitize the management of TC finances	How do you assess the project to digitize the management of local authority finances?	95% of municipalities have a positive assessment of the digitization of TC financial management and consider it to be of great importance, while only 5% think that it is rather unimportant

(*continued*)

Table 3. (*continued*)

Appreciated component	Questions	Results
The impact of digitalization on local collectivities	Reduce visa processing times by the Governor	77.5% of municipalities in the province of AL HAOUZ agree that the dematerialization of the procedure for submitting commune budgets to the supervisory authority for approval has reduced the time taken to approve these budgets, while only 15% disagree with this statement
	Respect regulatory deadlines for drawing up and adopting budgets	The majority of municipalities (i.e. 95%) agree that the dematerialization of the procedure for submitting commune budgets to the supervisory authority for approval has enabled stakeholders to meet the statutory deadlines for drawing up and adopting budgets, including approval by the supervisory authority
	Ensure dual control at GID-CT level (first by the supervisory authority and second by the assigning accountant)	87.5 of municipalities agree that the dematerialization of the procedure for submitting commune budgets to the supervisory authority for approval has made it possible to ensure a dual control of budgets in the GID-CT information system: the first is an administrative control carried out by the supervisory authority itself when approving the budget, and the second is carried out by the accountant responsible for approving the budget

(*continued*)

Table 3. (*continued*)

Appreciated component	Questions	Results
	Avoid budget entry errors in GID-CT	The majority of municipalities (i.e. over 92%) agree that the dematerialization of the procedure for submitting commune budgets to the supervisory authority for approval has made it possible to avoid budget entry errors in the GID-CT information system, and consequently possible rejections by public accountants when the budget in question is taken over by the system
	Start the expenditure commitment procedure at the beginning of the year	The majority of municipalities (i.e. over 72%) agree that the dematerialization of the procedure for submitting commune budgets to the supervisory authority for approval has made it possible to start the CT expenditure commitment procedure at the beginning of the financial year, which will have a positive impact on the expenditure execution operation
	Keep track of budget-related documents in GID-CT (minutes of board meetings, performance reports, etc.)	The majority of municipalities (i.e. over 87%) agree that the dematerialization of the procedure for submitting commune budgets to the supervisory authority for approval has made it possible to trace budget-related documents in the GID-CT system. These include minutes of council deliberations, performance reports and other documents required by current regulations

(*continued*)

Table 3. (*continued*)

Appreciated component	Questions	Results
	Cost reduction: printing costs, travel expenses for depositing or withdrawing the targeted/rejected budget…	70% of municipalities agree that the dematerialization of the procedure for submitting commune budgets to the supervisory authority for approval has helped to reduce costs related to the budget programming process, such as printing costs and travel expenses for submitting and withdrawing paper budget documents, especially in the event of rejection and suspension of approval by the supervisory authority. Whereas 20% disagree with this statement
	Expedite issuance of the Governor's decree authorizing the commune to collect revenue and incur expenditure, in the event of failure to adopt the budget within the regulatory timeframe (budget deficit, budget not adopted by the council, etc.)	87.5% of municipalities agree that the dematerialization of the procedure for submitting municipalities' budgets to the supervisory authority for approval has enabled the supervisory authority to speed up the decree suspending approval, authorizing the authorizing officer to collect revenue, and to commit, liquidate and authorize operating expenditure within the limits of the appropriations entered in the last approved operating budget

(*continued*)

Table 3. (*continued*)

Appreciated component	Questions	Results
Difficulties and obstacles during implementation	What difficulties have you encountered in setting up this dematerialization procedure?	In answering this question, the people representing the municipalities questioned cited the difficulties they had encountered when implementing this dematerialization procedure. The difficulties cited in order of number of repetitions are: • Insufficient technical and logistical resources (computers, internet, etc.); • Lack of procedural training; • Lack of assistance from accountants; • Lack of assistance from the guardianship authority; • Accountants still require duplicate paper copies
Digitalization outlook	In your opinion, are there any procedures relating to the management of local authority finances that still need to be digitized?	Demonstrating the importance of digitizing local financial management, our interviewees specified the procedures that need to be digitized: • The order desk • Inventory management • Management of casual staff and dematerialization of credit carryovers; • Salaries paid by expense accounts; • Legal Affairs and City Council Affairs Departments • Financial statements, surplus programming • Fleet management

3.3 Discussion of Results

The interviews we conducted with representatives of various local public finance stakeholders (public accountants, supervisory authorities and local collectivities) enabled us to identify the benefits of digitizing certain local finance management procedures for local collectivities, in this case, the electronic submission of budgets to the supervisory authority for approval, and to show the main challenges faced by these local collectivities in unpacking this transformation project, and finally to explore the prospects for modernizing local public administration.

- **The benefits of digitizing the electronic budget approval procedure**

As noted in the theoretical section, simplifying procedures, reducing costs and improving services to users are the main objectives of a digital transformation strategy.

To confirm this observation, we took the example of the digitization of local authority financial management, as a strategy implemented by the Ministry of the Interior as part of the government's E-GOV program, these include expenditure execution, revenue management and collection, personnel management and accounting. In this research project, we have focused on the digitization of the budget programming process, and more specifically on the electronic submission of the local authority budget to the supervisory authority for approval. From a legal point of view, this step is essential before starting the expenditure execution and revenue collection phase.

According to the study we carried out among the municipalities of the AL HAOUZ Province, and the local finance actors we interviewed, the digitization strategy is having a positive and remarkable impact on the budget programming process within local collectivities. This impact, which concerns the various stakeholders, mainly concerns the effectiveness and efficiency of this digitized procedure, insofar as it becomes more simplified, achievable within the regulatory timeframe at lower cost, with reduced lead times, and with greater control and a lower risk of error.

The benefits of digitizing the electronic approval procedure for local authority budgets are as follows:

- ***Respecting and reducing processing times***

The budget programming procedure for local collectivities must be initiated within the regulatory deadlines laid down by current legislation. A local authority's budget, whether or not it has been adopted by the council, must be submitted to the supervisory authority by December 10 of the year at the latest, for approval before December 31 of the same year. The Governor's approval results either in a budget that has been adopted and approved, or in a Governor's decree authorizing the collection of revenue and the commitment and authorization of operating expenditure within the limits of the appropriations entered in the last approved budget.

Prior to the digitization of this procedure, it was noted in some of the municipalities surveyed that these deadlines are not always respected, especially in the case of deficit budgets or budgets not adopted by the councils, as the aforementioned governor's decree is not issued before the start of the financial year. This has a subsequent impact on the expenditure execution process, which is conditional on the public accountant taking charge of the budget appropriations.

On the other hand, prior entry of the budget in the GID-CT information system facilitates the control exercised by the assigning accountant beforehand, and eliminates the need to re-enter it in another computer application, as was the case before GID-CT was set up, thus reducing the time taken to process and process budget appropriations.

At the level of the supervisory authority, the decision to approve or reject the budget support can be taken within a very short timeframe, as soon as the documents and supporting documents (budget, minutes of council deliberations, annexed reports, etc.) have been transferred via the system, without having to wait for the local authority's staff to submit the paper version of these documents. After approval, the budget is notified directly to the public accountant, still via the system, which means a remarkable reduction in lead times.

- ***In-depth control of budget support***

The dematerialization of the procedure for submitting the budget to the supervisory authority for approval has made it possible to carry out in-depth checks on the electronic budget support. The first control is carried out by the authorizing department itself (the commune), in the phase which consists of entering the draft budget into the GID-CT system, before submitting it for examination by the committee responsible for budget, financial affairs and programming, and subsequently for a vote by the council. The second check is carried out by the supervisory authority, which verifies that the budget is balanced, that its components have been included, that compulsory expenditure has been entered, and that supporting documents and reports exist and are in conformity. The GID-CT system enables these control points to be verified. The final check is carried out by the assigning accountant before taking charge of the budget in question.

All these checks help to minimize the margin of error, and avoid any rejections by either the supervisory authority or the public accountant.

- ***Marking traceability in the system***

Once the budget has been adopted by the TC board, the department concerned integrates the accompanying documents (minutes of deliberations, performance reports, etc.) into the GID-CT system, and then sends the electronic budget file to the supervisory authority for approval. This formality ensures traceability of the budget programming process, and enables the corresponding documents to be consulted at any time.

- ***Reducing costs***

The costs incurred in the budget programming process for local collectivities include the cost of printing budget documents and appendices, as well as the cost of travelling to the province to submit the budget to the supervisory authority, especially for remote local collectivities. The dematerialization of the budget submission procedure will eliminate or at least reduce these costs.

- **Implementation challenges:**

The obstacles and challenges faced by local collectivities when digitizing local finance procedures are generally linked to insufficient human and material resources and the absence or inadequacy of assistance from other actors. For example, some local collectivities still have problems accessing the Internet, which is an essential element for initiating digitized procedures, while others do not yet have the necessary technical and IT equipment (scanners, for example).

To overcome these challenges, the agents involved in these digitized procedures in the municipalities work together in a collaborative manner, ensuring a mutual exchange of data and knowledge, and taking the initiative to unblock the situation of insufficient technical means, not hesitating to travel to connected areas to solve the problem of internet access.

The success of a digital transformation project requires qualified human resources who are aware of the importance of this project and are not resistant to change. It is also important to raise staff awareness of the benefits and added value of such a digitalization strategy, and to provide ongoing training and the necessary assistance, especially from the supervisory authority and the public accountant.

If e-government is about integrating new information and communication technologies into administrative processes, TCs need to equip themselves with the necessary resources to meet the challenges and succeed in this digital transformation project.

- **Prospects for the digitization of local financial management**

The interviews carried out as part of this project showed that there are still other aspects and procedures relating to the management of TC finances that can be digitized. While the INDIM@J and WADEF@UJOUR systems have enabled better management of acts relating to the management of permanent communal staff, the management of casual staff has not yet been computerized in an integrated way, which will enable actors (Authorizing Officers and Public Accountants) to process all acts relating to this category on a single platform (from recruitment to payment of their salaries).

Another aspect of digitalization concerns inventory management within local collectivities. It will be highly beneficial and very transparent for them to integrate inventory tracking into an IT platform associated with the GID-CT information system, which handles the expenditure process that gives rise to inventories.

On the other hand, a number of accounting and/or budgetary situations are still required by certain TST partners (supervisory authorities, Court of Auditors, other inspection and audit bodies). We need to work towards digitizing the production of these statistics or situations, their validation and exchange with those who request or use them (As the deputy tax collector of AMIZMIZ points out).

There are also other departments involved in managing local authority finances, and digitizing their procedures will help to modernize local public administration. These include the departments in charge of legal affairs, and those responsible for managing the car park.

4 Conclusion

Through this work, we have been able to show that the digitization of a simple procedure has a number of positive effects on local authority management. It's a procedure that integrates three actors in local finance, namely the TCs concerned, the supervisory authority and the public accountants. A procedure that makes dematerialization and electronic signature essential elements of this digitization strategy.

Indeed, the electronic approval of budgets has enabled local collectivities to reduce the costs associated with the budget programming procedure, meet regulatory deadlines, ensure traceability within the information system, guarantee thorough control and minimize errors. Of course, the success of any strategy requires the implementation of the necessary technical resources, and above all qualified human resources who are aware of the importance of digital in new public management.

Government authorities in Morocco have made a number of efforts to modernize public administration, simplify procedures, rationalize costs and improve services to users. Several strategies and programs have been launched in this context.

The digitization of local financial management is an example of such a successful strategy. It enables local collectivities to equip themselves with integrated information systems, which cover various aspects: GID-CT for expenditure execution, GIR-CT for revenue collection, INDIM@J and WADEF@UJOUR for processing of municipal personnel acts, not to mention other platforms for the various departments of these local collectivities.

Furthermore, it is important for the scientific community to evaluate this strategy of digitizing the management of local finances in its entirety, and to study its impact on investment and on the national economy. It will also be beneficial to focus on the new tools used to operationalize these digitization strategies, such as dematerialization and electronic signatures.

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Shareholder Relationship Management's Impact on Value Creation in the Casablanca Stock Exchange

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Abstract. Shareholders marketing practices have proved their usefulness in numerous studies. It is demonstrated by the diminution of costs, the increase of liquidity, and the decrease of information asymmetry. These improvements are generally accompanied by a large increase in investors' assurance, by encouraging long-term investment. Practically speaking, stocks that implement shareholders marketing expertise into their financial communication distinguish themselves from companies that merely comply with the legal requirement in regards to financial disclosure. As a result, this perception can influence stocks' market value, as rational investors appreciate whether a stock is overvalued or undervalued based on subjective judgments regarding these practices in the financial domain, particularly within the Casablanca stock exchange (CSE). The strategies of shareholder marketing encompass two key dimensions: finance and communication. The financial aspect centers on dividends and monetary benefits, while the communicative aspect is geared towards the exchange of information and open dialogue. This study underscores the importance of effectively managing shareholder relationships in boosting the market value of 51 companies listed on the CSE between the year 2018 and 2020, by employing both financial and communicative elements of marketing. The empirical method is based on two sets of statistical analyses: bivariate and multivariate.

Keywords: Marketing · Market value · Shareholders · Stock exchange

1 Introduction

The financial sphere has noted an increase in the necessity of transactional marketing to mitigate speculation risks and bolster the liquidity of securities in the stock market. However, this type of marketing presents a degree of limitations, as its practices primarily aim to induce buying behavior rather than fostering an investment logic based on long-term strategies [1]. A new marketing logic grounded in the relational aspect can be introduced as stock market investors are primarily individuals pursing objectives related to profit realization and alignment with values shared by the issuing company.

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In a ground breaking exploration of the interplay between market-based assets and shareholder value, marketing is heavily involved in the development and management of stock market-base assets [2]. However, the company can only engage with individuals within the confines of this market through financial communication. Therefore, there is a necessity to institute a discipline focused on overseeing, enhancing, and positioning the company with these economic agents.

The relationship between shareholders and publicly listed companies has undergone a significant shift following the adoption of several practices originating from shareholder marketing in terms of financial communication and financial benefits. The transition from a purely legal obligation to voluntary disclosure of both financial and non-financial information [3], coupled with the advent of the digital Internet platform, represents some of the changes undertaken in the context of shareholder marketing practices.

An examination has further underscored the need to establish a new role, that of an Investor Relations Manager, instead of the Financial Communication Officer, who was previously limited to the publication of financial statements [4]. This role, successful in France, requires a dual expertise in both marketing and financial concepts. Additionally, we can also highlight the impact of the introduction of the ESG aspect on financial communication, reflected in the publication of related reports [5].

This approach mirrors the principles of services marketing, where, for instance, a bank maintains direct relations with customers, leading to the implementation of customer relationship management (CRM) to foster a favorable business environment and attract new deposits. These strategies can be extrapolated to the stock market, giving rise to shareholder marketing. This new form seeks to establish relationships with investors, leading to the creation of a dedicated role for managing investor relations. Additionally, it aims to sustain these relationships, particularly by fostering loyalty.

Moreover, the financial instruments being marketed are likened to products or services, making the adaptation of this offering a crucial element as it shapes the company's image in the stock market. In light of this, shareholder marketing introduces tools to achieve these objectives, incorporating practices grounded in a relational approach. Two pivotal aspects of this approach include financial considerations related to dividend policies and loyalty incentives, as well as information aspects related to communication, dialogue, and the overall management of relationships with investors [6].

For an effective financial communication based on shareholder relationship management, marketing practices provide a range of channels designed for engaging with shareholders. These channels complement traditional mediums like the annual report, shareholders' meetings, and press releases. Diverse and versatile, these practices facilitate the explicit exchange of information interactively, establishing a connection between the listed company and its stakeholders [7].

In an effort to promote long-term engagement, certain companies are integrating existing financial tools with marketing practices to establish interactive platforms for engaging shareholders. This strategy aligns with the objective of fostering individual shareholder loyalty, emphasizing value creation. Common applications within listed companies include the shareholders' club, roadshows, and websites. Additionally, some companies opt to establish exclusive mechanisms reserved for their most devoted shareholders, such as preferential subscriptions. The primary aim of these subscriptions is to enhance the connection with shareholders. The prioritization of loyal shareholders in these subscriptions allows them the opportunity to subscribe first to financial operations conducted by the listed company. This method serves to fortify the relationship with shareholders and cultivate their loyalty by incentivizing long-term ownership and the acquisition of new shares.

2 Conceptual Framework and Hypothesis Development

Establishing the link between shareholder marketing practices and stock market value creation relies on an initial exploration of research context. The chosen context for this paper is the Moroccan stock market. Examination of various practices employed by listed companies in the CSE revealed the recurrence of two main vectors:

1. Monetary benefit: pertaining to dividend payments;
2. Communication: related to the dissemination of financial information.

The impact of shareholder marketing practices on stock value creation examines dividend policy on one hand [8] and financial communication on the other [9]. The results obtained at the CSE level are often comparable to those achieved elsewhere [10, 11]. For instance, in India, the dividend distribution policy serves as a source of liquidity for the stock market [12]. Similarly, in the Tunisian case, stock value creation is tied to both dividend distribution and financial communication [13]. Furthermore, the implementation of web marketing has yielded significant outcomes concerning financial performance within the framework of the CSE [14].

Based on these two vectors, a more in-depth exploratory phase is initiated to identify all practices associated. This second phase highlighted that listed companies in the CSE are much more present in the digital realm. This aligns reasonably and coherently with the evolution of international stock markets, marked by a strong presence in the virtual world.

According to these observations, the formulation of hypotheses revolves around four major axes characterizing, to some extent, shareholder marketing practices.

2.1 Dividend Policy

In order to understand the impact of dividends on the stock price of a share, one must move beyond the legal, accounting, and financial aspects of its distribution policy. While dividends are indeed a shareholder's right attributed to an internal decision made by the management, the Moroccan legislation allows companies to decide on the distribution of special dividends under certain conditions. However, due to the lack of awareness regarding the importance of this remuneration, some leaders choose not to distribute special dividends.

Based on this information, an idea emerges about the future cash flows generated by the company's operations, perceived as strong and successful due to its dividend distribution [8, 12]. Similarly, the distribution of a special dividend is seen as a very strong signal, usually indicating exceptional performance compared to competitors. Additionally, leaders may choose to pay special dividends to compensate for years without profit distribution or to retain and incentivize shareholders. This practice is often viewed as a loyalty premium [15].

Therefore, the initial hypothesis formulated is as follows: **H1 - Dividend policy enhances value creation in the CSE.**

2.2 Flow of Information and Open Dialogue

Investors, as well as other stakeholders, gather information about an organization from various sources: media, stock market, financial statements, or directly from the management. In other words, financial communication is not limited to the disclosure of annual reports. Although these reports serve as a reference point in the process due to the particularly relevant and important information disseminated on this occasion.

Effective communication and open dialogue builds trust with the public, while a lack of transparency in terms of financial results leads to distrust, placing the entity in a shadow of doubt. At this point, new approaches focus on the relational aspect, establishing a lasting relationship with shareholders through interactive tools enabling direct dialogue, particularly in the stock market. Opening a dialogue with shareholders allows a better understanding of their needs, and consequently, satisfaction.

This procedure enables the leaders of listed companies to clarify their position, strengthen their image with shareholders by supporting future prospects, or gather the opinions of investors. Furthermore, dialogue reinforces the relationship by integrating shareholders into the company's value chain, which is a good opportunity to benefit from their expertise, leading to sustainable long-term performance.

Derived from these considerations, we can formulate the following hypotheses:

H2 - The presence of a shareholders' space enhances value creation in the CSE.
H3 - Engaging dialogue with shareholders contributes to value creation in the CSE.
H4 - The existence of a newsfeed plays a role in value creation in the CSE.

2.3 Conceptual Framework

To enhance the reliability of the research model and considering that other variables are deemed crucial to the ability of listed companies to create stock market value, we have opted to introduce control variables:

1. Financial profitability: This parameter exhibits a significant and positive relation with stock prices [16]. It is measured by the return on equity and demonstrated a significant impact on value creation;
2. Growth rate: The listed company's growth rate has illustrated a great impact on stock prices, indicating that the increase in the earnings per share has a positive effect on the created stock market value [17];
3. Company size: The size of listed companies is an important vector in their ability to created market value, demonstrating a positive and significant impact on shareholders' investment behavior [18].

The culmination of these ideas leads to the conceptual framework illustrated in Fig. 1. Within the context of the current investigation, value creation serves as the dependent variable, whereas shareholders' marketing practices (Dividend, shareholders' space, open dialogue, and news feeds) are considered as the independent variables.

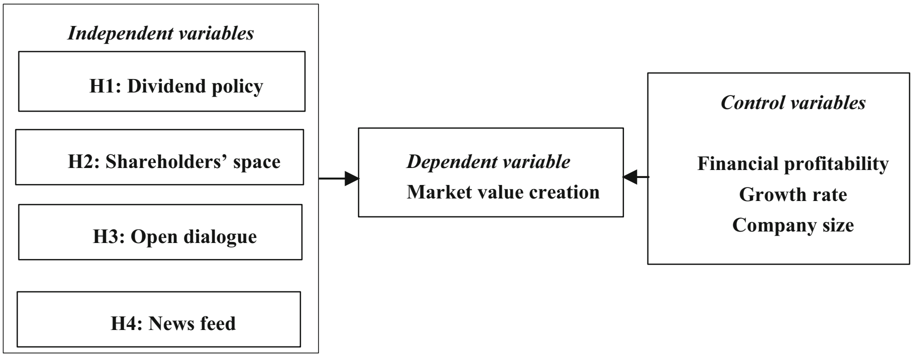

Fig. 1. Conceptual framework: shareholders' marketing versus market value creation.

3 Methodology

The empirical phase of this paper, which involves investigating potential connections between shareholder marketing and market value creation, aligns with the positivist approach. To ensure this application to the field and obtain relevant results, a deductive mode of reasoning is logically more appropriate. Moreover the dual impact of the quantifiable nature of stock market value creation and the primary objective focused on measuring the effect of shareholder marketing has led to the adoption of a quantitative approach. It aims to assign an appropriate mathematical parameter to each variable, facilitating the scientific measurement of the influence of shareholder marketing practices on stock market value creation.

In addition to the deductive reasoning and the quantitative approach, we selected the CSE, housing a total population of 76 companies listed in the equity market. The listed companies underwent two specific sampling stages based on primary and secondary selection criteria. Primary criteria centered on the sector-specificity of certain companies, subject to specific standards in the financial sector, such as banks, insurance companies, and finance companies. Secondary criteria involved eliminating companies with statuses that did not allow for a relevant study, such as those with temporarily suspended listings or newly introduced companies to the CSE.

Following these two selection stages, the final sample comprises 51 companies, representing 93% of non-financial companies and 67% of the initial population. Regarding the data collection for the studied companies, we relied on their websites as well as those of the CSE and the Moroccan Capital Market Authority (MCMA).

3.1 Variable Configuration

In the scope of our investigation, the **Marris ratio** proves to be an optimal metric, precisely reflecting the central research query by assessing a listed company's capacity to generate stock market value (MAR) [19]. This ratio, derived from the reconciliation between book value of equity and market capitalization, offers a clear and precise depiction of a stock's performance over a specified time frame.

To calculate market capitalization, data can be sourced from the CSE or MCMA websites, while equity data is available on these platforms, annual reports, or the listed company's website. We have chosen a three-year analysis window ranging from the year 2018 to the year 2020 due to data availability constraints, ensuring consistency across companies.

To refine our analysis, we compute an average Marris' [20], and extend our investigation to incorporate the **Dividend Yield** (DIY), a percentage ratio reflecting a company's dividend distribution policy. It is generally used to gauge stock market dynamics and dividend policy impact on stock price volatility [21].

Moreover, website structures vary, leading to the categorization of companies based on their approach to shareholder interaction. We translate these parameters into binary variables (SPA, DIA, and FLO) indicating the **presence** (1) or **absence** (0) of these elements on the company's website: **shareholders' spaces**, **dialogue options**, or **news feed management**.

In order to enhance the research model's robustness, control variables are introduced:

1. Financial profitability which is calculated by the return on equity (ROE);
2. Growth rate which is related to the earnings per share ratio (EPS);
3. Firm size which is the log of total net assets (LOG).

3.2 Statistical Analysis

The approach to detect relations between the key variables is divided into two essential steps: bivariate and multivariate analyses. The first step explores the bilateral relationship between two variables separately from the rest of the parameters. As for the second analysis, it focuses on detecting simultaneous interactions among all variables through modeling, allowing the measurement of variation biases.

From this reflection, it is evident that the first phase of our empirical study aims to isolate the unique effect of each independent variable on the creation of stock market value. This isolation is achieved through **Pearson correlation** by calculating the coefficient measuring the impact of an explanatory variable on the dependent variable and the direction of the relation, considering that the correlation can be positive or negative.

However bivariate analysis does not capture all the interactions among the variables; thus, a multivariate analysis is necessary. As a result, the multivariate analysis revolves around a **multiple linear regression** considering the explanatory variables collectively to extract the simultaneous impact of dividends and informational aspects on the creation of stock market value.

4 Results and Discussion

Derived from the results obtained, it is evident that companies with a robust dividend policy generate increased value within the CSE. Likewise, listed companies that prioritize information dissemination and engage in meaningful dialogues with their shareholders contribute more value within the CSE.

In line with our assumptions, the dividend policy emerges as a variable that positively influences a company's capacity to generate stock market value. This is evidenced by the positive and significant correlation, at the 5% threshold, between the DIY variable and the Marris ratio as shown in Table 1. The act of distributing dividends is perceived as a robust signal in the stock market, signifying the company's sound financial health.

Similar observations hold for the SPA variable, indicating the presence of a dedicated section for managing investor relations. We observe a positive and significant impact, at the 1% threshold, of the existence of this section on the creation of stock market value by CSE listed companies, as demonstrated in Table 1. This finding aligns with the argument that effective management of investor relations has become a crucial variable in projecting a positive image in the stock market. Companies prioritizing investor relations tend to position themselves favorably among market players, earning recognition as entities that create value.

This observation extends to variables associated with open dialogue and flow of information disseminated by listed companies. Both DIA and FLO variables exhibit positive and significant correlations, at the 1% threshold, with the Marris ratio, highlighting the listed company's adeptness at generating stock market value.

Table 1. Bivariate analysis of key variables

Variable	Pearson's correlation with Market value creation	Threshold
Dividend policy	,348*	5%
Shareholders' space	,589**	1%
Open dialogue	,631**	1%
News feed	,476**	1%
Growth rate	,472**	1%
Financial profitability	,099	-
Firm size	,428**	1%

The standard model resulting from the multivariate analysis of all research variables exhibits noteworthy characteristics, boasting a Fisher's F value of 11.594 and significance at the 1% level, as shown in Table 2. This model distinctly illustrates the substantial correlation between informative, financial and control variables regarding the creation of stock market value.

The substantial $\mathbf{R^2}$ of 65% implies that the generation of stock market value is comprehensively elucidated by the independent variables, encompassing the dividend distribution policy, investor relations, the utilization of dialogue tools, and the implementation of newsletters.

Additionally, the estimated betas of the explanatory variables demonstrate significant associations, notably concerning informative aspects of shareholders' marketing on one hand, and the growth rate on the other, as demonstrated in Table 2.

With the outcomes of both bivariate and multivariate analyses shown in Table 1 and Table 2, we can affirm the validity of all our hypotheses. Consequently, companies listed with more advanced shareholders' marketing practices contribute increased value in the context of the CSE.

Table 2. Multivariate analysis of key variables

Variable	Excepted sign	Beta	Sig.	Threshold
Dividend policy	+	,095	,375	-
Shareholders' space	+	,317	,004***	1%
Open dialogue	+	,269	,034**	5%
News feed	+	,210	,043**	5%
Growth rate	+	,192	,070*	10%
Financial profitability	+	,014	,889	-
Firm size	+	,168	,105	-

5 Conclusion

The conclusion of this paper has produced several noteworthy contributions that hold significant implications for the Moroccan stock market. Originating from the central inquiry guiding this investigation, we have successfully elucidated tangible links between marketing and finance within the stock market context.

Theoretical Contribution: Existing studies on the Moroccan context, particularly the CSE have not directly delved into the connection between shareholder marketing and the creation of stock market value. This paper stands as the first to directly address this link, providing a unique perspective on the relationship.

Methodological Contribution: Our research not only identifies gaps in existing knowledge but also lays the groundwork for future studies by establishing a methodological framework that can guide research endeavors on the same theme. The proposed variables and methodological approach can serve as a foundation for more in-depth investigations.

Despite its contributions, this paper acknowledges certain constraints that influenced the scope of the study.

Temporal Limitations: The research utilized data from the period 2018–2020 due to the unavailability of essential information for empirical study during subsequent years.

The State of Shareholder Marketing in Morocco: The adaptation of shareholder offerings in the Moroccan stock market is in its early stages, limiting the broader applicability of the findings. The absence of certain value-creating aspects observed in other financial avenues slightly narrows the study's scope.

This paper suggests future avenues for research and provides actionable insights for stakeholders in the stock market. A follow-up survey could provide a more nuanced analysis of the effect of identified variables on company stock performance and stock market dynamism. Recommendations and suggestions derived from the research aim to invigorate the CSE, directing attention to areas that can improve the quality of Moroccan shareholder offerings.

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Customer Experience as a Lever for Loyalty: An Investigation into Orange Morocco

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Abstract. The concept of customer experience has significantly emerged in the business realm as an alternative to the conventional marketing practices, which are widely considered outdated in the era of rapidly evolving technological perspectives. This research endeavors to deeply explore the factors that contribute to the success of the customer experience and its potential impact on customer loyalty. Following a theoretical framework, we aim to investigate this causal relationship between customer experience and loyalty on the field, with a focus on the Orange company. To this end, a questionnaire was administered to a sample of 384 individuals. The resulting data were analyzed using the quantitative data analysis software "SPSS" through univariate and bivariate analyses of the questionnaire responses., unequivocally demonstrating the direct influence of a successful customer experience on loyalty. This study yields two significant contributions: firstly, it enhances the understanding of the interplay between customer experience and loyalty, and secondly, it furnishes researchers with a high-quality resource capable of stimulating novel research avenues.

Keywords: customer experience · loyalty · experiential marketing · holistic approach

1 Introduction

Digitalization has induced a fundamental evolution in consumer behavior, transforming the consumer from a passive role to that of an active participant and co-creator. This shift challenges the effectiveness of traditional marketing models, which are based on consumer rationality and the functional attributes of products. In the face of a consumer who is now better informed and interconnected, experiential marketing, which focuses on personalized experiences aligned with individual values, emerges as an effective strategy to enhance customer engagement, stand out in a competitive environment, and ensure business sustainability.

In this context, this article aims to examine the impact of customer experience on customer loyalty at Orange Morocco, posing the research question: "To what extent

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does customer experience influence loyalty at Orange Morocco?" This inquiry highlights the crucial need to unravel the effects of customer experience on loyalty in the highly competitive telecommunications sector.

The goal is therefore to assess how the quality of service and the ethical commitment of Orange Morocco contribute to shaping the customer experience and, consequently, to what extent this experience affects customer loyalty. By offering new perspectives, this study seeks to enrich the academic research body while providing strategic insights for decision-makers at Orange Morocco.

Relying on a hypothetico-deductive approach and a quantitative methodology, the study aims to clarify the concept of customer experience and demonstrate its critical role as a lever for loyalty.

2 Literature Review

This section addresses the emergence of experiential currents in consumption and their role in enhancing customer loyalty, based on an in-depth literature review.

2.1 The Rise of Experiential Currents in Consumption

Academic interest in lived experience, a concept rooted in philosophical sciences and denoted by the Latin term "experientia", has seen a significant surge in the consumer behavior domain following 1982. This year marked a turning point with the seminal publication by Holbrook and Hirschman, "The Experiential Aspects of Consumption: Consumer Fantasies, Feelings, and Fun", laying the groundwork for the experiential current in consumption research (Roederer 2015). This movement then branched into two main directions: the Consumer Culture Theory (CCT) and experiential marketing.

The CCT, proposed by Arnould and Thompson in 2005, presents a holistic perspective on consumer behavior, incorporating cultural, experiential, ideological, and social aspects. It challenges the traditional, rational, and utilitarian approach that prevailed up to the 1980s, revealing the significance of values, culture, emotions, and motivations in purchase decisions. The CCT emphasizes that consumption goes beyond the transaction to become a rich and complex experience.

In parallel, experiential marketing focuses on enriching the customer experience to differentiate and increase perceived value. This strategy moves away from traditional methods focused on the functional attributes of products or services, in favor of enhancing the overall customer experience. Experiential marketing aims to establish an emotional connection and create lasting memories through sensory stimuli, recognizing the consumer as an emotional and sometimes irrational actor.

The shift towards a Customer-Centric Logic (CCL) since the 1990s reflects a change from the Good Dominant Logic (GDL), which valued tangible product features since the 1950s (Wided 2017). The CCL emphasizes the needs and desires of the modern consumer, promoting meaningful experiences over passive product acquisition. This perspective views the consumer as an active co-creator of value, highlighting the importance of experience beyond mere product or service quality.

It is crucial to note that this transition to a customer orientation does not overshadow the quality of the product or service, which remains vital in the experiential offering. The fundamental difference between the GDL and the CCL lies in their objectives: the former seeks to maximize functional utility, while the latter aims to enrich the consumer's overall experience, considering functional, emotional, symbolic, and relational dimensions.

2.2 Enhancing Customer Loyalty Through Experiential Marketing Strategies

The literature on customer experience and its impact on loyalty reveals a significant evolution in the understanding and application of marketing strategies. Holbrook and Hirschman (1982) laid the foundation for this shift by highlighting the importance of experiential aspects of consumption, where emotions and the constitutive value of the experience play a central role, marking a departure from traditional models focused on information processing (Holbrook and Hirschman 1982). Pine and Gilmore (1999) further elaborated on this concept with the introduction of the experience economy, stating that experiences now surpass traditional product and service offerings as a value driver for consumers that engage them (Pine and Gilmore 1999). Schmitt (1999) expanded this perspective by introducing first-generation experiential marketing, which focuses on creating holistic experiences for consumers by recognizing their rational and emotional duality and employing eclectic research methods to engage customers and satisfy them (Schmitt, 1999). Other researchers have also contributed to this discussion, such as Tallec (2015), who acknowledges that experience leads to even greater loyalty. Chabry (2021) confirms that customer loyalty is a long-term journey built over time and founded on trust and attachment, stemming from experiences that elicit positive emotions and opinions from customers, enabling them to renew their purchases.

These collective works underline a transition towards an economy and marketing where customer experience is paramount, suggesting that the creation of rich and engaging customer experiences is crucial for loyalty. By integrating experiential approaches, brands can not only meet consumer expectations but also exceed them, thus establishing a solid foundation for customer loyalty. The richness and depth of the experiences provided have therefore become key indicators of the value perceived by consumers, directly influencing their loyalty to a brand.

3 Theoretical Framework

In this section, we explore the theoretical foundations of customer experience and loyalty to clarify the understanding of these concepts and their role in contemporary marketing strategies.

3.1 Customer Experience

The advent of customer experience marks a significant evolution in the field of marketing, emphasizing an approach that goes beyond mere commercial transactions to value a deep human connection, characterized by the emotions and perceptions of the consumer. This concept, becoming a key vector of differentiation and competitive advantage, has captured the attention of both the academic and professional spheres, leading to enriching definitions.

Hélène Douville (2017) presents the customer experience as a coherent set of actions aimed at providing customers with a distinct and valorizing perception of the offer, from the beginning to the end of their journey. Batat (2018), on the other hand, sees the customer experience as the consumer's complete journey, from information search to post-purchase interaction, highlighting the overall perception of the value of the shopping experience. Roederer (2015) emphasizes the differentiation dimension of the customer experience, defining it as a means for companies to distinguish themselves by adding affective and emotional dimensions to their value proposition.

Indeed, the customer experience unfolds through various phases, from the formation of initial expectations to post-purchase interaction, each stage playing a crucial role in establishing a lasting and meaningful relationship between the consumer and the brand. This holistic approach encompasses discovery, purchase, use, and after-sales service, considering the customer journey in its entirety as an opportunity to enrich the relationship.

This holistic conception recognizes the customer experience as a fundamental element of corporate strategy, involving a complete and personalized immersion of the customer across all touchpoints and phases of the buying lifecycle. It is based on three pillars: satisfying fundamental needs, loyalty to service commitments, and the crucial importance of pleasure and emotions as drivers of loyalty and the perpetuation of the relationship.

To materialize this vision, Pine and Gilmore (1999) cited by Roederer (2015), the founding fathers of experiential marketing, suggest five key factors for developing a successful experiential offer: thematization to create a unique universe, alignment with positive impressions, elimination of negative aspects, offering an assortment of memories, and engaging the customer's multisensory involvement. These elements highlight the importance of an immersive strategy that touches the consumer on an emotional and sensory level, thus offering a distinct and memorable experience.

3.2 Loyalty

In customer relationship management, the concept of loyalty is pivotal but varies in interpretation. Oliver (1999) defines loyalty as a profound commitment to rebuy a favored product or service consistently, despite situational hurdles and aggressive marketing efforts. Dragon (2018) considers loyalty as a result of deliberate marketing strategies. It plays a key role in reducing costs, fostering growth by minimizing customer turnover, and boosting the brand image through recommendations from satisfied customers as mentioned by Barbaray (2016). In today's market, where consumers are more knowledgeable and demanding, it's essential for companies to devise a loyalty strategy that deeply understands the customers' rational and emotional needs. This approach aims to spur repeat business and sustain a long-term relationship.

4 Technology and Consumption Trends: The Impact on Customer Experience

This section examines the impact of technology and consumer trends on customer experience. It highlights the characteristics of the new consumer as defined in the CHEPS model, as well as the role of recent technologies in enhancing customer experience.

4.1 Characteristics of the Current Consumer

In the context of digital transformation, the consumer has evolved into a key and active player, embodied by the term "prosumer," a notion that emphasizes a more collaborative, emotional, and committed participation in consumption. Wided Batat (2018) conceptualizes this evolution through the CHEPS star model, which encompasses Collaboration, Hedonism, Engagement, Postmodernism, and Symbolism, inducing companies to adapt their relational strategies to meet these diversified expectations.

Collaboration, illustrated by the role of "PROSUMER," reflects an era where consumers actively contribute to value creation, encouraged by digital development and social networks. This dynamic offers companies the opportunity to engage their customers in a creative process, thereby fostering loyalty and innovation.

Hedonism and Engagement reveal a facet of the modern consumer that goes beyond the simple search for utility in goods or services to embrace consumption experiences enriched with pleasure, ethics, and a social dimension. This orientation towards responsible consumption and charged with emotions demands from brands an offer that aligns not only with functional expectations but also with the personal and societal values of consumers.

Postmodernism and Symbolism emphasize a consumption seeking meaning, where cultural and symbolic dimensions prevail, requiring companies to have a profound experiential approach.

In summary, responding to the characteristics of the new consumer, as defined by the CHEPS model, and satisfying their intrinsic needs becomes essential for companies aiming for success. The customer experience, focused on emotion, collaboration, and engagement, is fundamental to retain a clientele in search of meaningful and memorable experiences.

4.2 Customer Experience in the Age of Technology and Its Impact on Loyalty

In the era of globalization and digitalization, customer experience becomes an essential pillar for loyalty. Adopting a holistic view that integrates functional, service, hedonic, and symbolic aspects is crucial to meet the diversified expectations of today's consumers. Functional aspects satisfy essential needs, service quality emphasizes customer respect, while hedonic and symbolic dimensions enrich the experience, forging an emotional link that fosters lasting loyalty.

Technological advancement offers valuable tools for refining this experience, making the collection and analysis of customer data more efficient than ever. A careful interpretation of these data is necessary to gain a strategic advantage. Loyalty, key to the growth and sustainability of businesses, requires strategies that effectively merge customer experience and loyalty. This approach enables a solid competitive advantage and deepens customer relationships. A deep understanding of customer expectations, supported by big data analysis and a multi-channel strategy, is indispensable to successfully navigate today's complex purchasing journey.

5 Methodology

This section outlines the methodology employed to examine the impact of customer experience on loyalty at Orange Morocco, utilizing a quantitative approach to test our hypotheses.

5.1 Quantitative Research Methodology

In the context of our research exploring the impact of customer experience on loyalty at Orange Morocco, we adopted a methodological approach grounded in the hypothetico-deductive model. This approach began with a review of existing literature to establish a solid theoretical framework surrounding customer experience and its impact on consumer loyalty.

The empirical phase was based on the distribution of a quantitative questionnaire to 384 participants. This sample size was calculated using the following formula: n = Z^2 $\times$ P (1-P) / e^2 with Z: 1,96 for a 95% confidence level, P: 0,05 representing the estimated proportion of the population, e: 5% corresponding to the margin of error.

This process ensures the representativeness and significance of the data collected. Subsequently, we proceeded to filter the data to retain only responses from Orange customers, thus ensuring the relevance and specificity of the insights collected for our analysis.

The questionnaire was designed to capture the various aspects of customer experience through different question formats (dichotomous, multiple choice, and Likert scales), allowing for a nuanced analysis of the perceptions and attitudes of Orange customers. The choice of these formats aims to maximize the quality of the data collected, fostering a deep understanding of the dimensions of customer experience.

The reliability of the questionnaire was assured by a Cronbach's Alpha coefficient of 0.682, indicating acceptable internal consistency of the items. Moreover, a KMO score of 0.734 confirms the adequacy of our sample for factor analysis, validating the questionnaire structure and the relevance of the data for our study.

Our analyses center around three main hypotheses:

H1: Service quality is fundamental to a successful customer experience.
H2: The ethical values adopted by the company play a crucial role in the customer experience.
H3: A positive customer experience is a precursor to customer loyalty.

To examine these hypotheses, we employed cross-analyses of the collected data, enabling direct exploration of the relationships between variables. The use of Chi-Square tests and Cramer's V, conducted via SPSS-V26, allowed us to accurately assess the associations and strength of relationships between categorical variables. This analytical approach sheds light on the dynamic interactions between customer experience, service quality, ethical values, and customer loyalty.

In summary, our methodology combines careful questionnaire design with a rigorous statistical analysis strategy. This combination ensures that our study effectively and meaningfully addresses the question of the impact of customer experience on loyalty at Orange Morocco, laying a solid foundation for a deep understanding of the levers influencing the enduring relationship between the brand and its customers.

5.2 Overview of the Company Orange

Founded in 1999 and previously known as Méditel, Orange Maroc is a major player in the telecommunications sector in Morocco. With a customer base exceeding 17.4 million, the company offers a wide range of services, including mobile and fixed telephony, cybersecurity, and mobile financial services. The transition from Méditel to Orange Maroc, completed in December 2016, marks a significant evolution of the brand.

6 Analysis and Discussion of Results

This section provides an analysis and discussion of the results from our survey, focusing on the customer experience at Orange Morocco and its impact on loyalty.

6.1 Analysis of Results

The survey was conducted among 384 participants. After filtering, it turns out that 59.6% of them, which equates to 229 individuals, are Orange customers. The composition of this sample reveals a predominance of females, accounting for 62.5%, while males constitute 37.5%. Furthermore, the sample is predominantly young, with 83.6% of respondents aged between 18 and 36 years.

Orange's experience customer is based on several key pillars: the ease with which consumers can become customers, the efficiency and speed in processing requests and complaints, constant innovation in service offerings, as well as the responsiveness and interactivity of their website, not to mention the feeling of value experienced by users. The collected data indicates that Orange has received particularly positive evaluations, with a large number of respondents expressing their agreement with positive statements regarding these aspects.

These results allow us to assert that Orange provides an overall satisfying customer experience.

To validate our fundamental hypotheses, we performed a cross-tabulation analysis and tested the causal links with the Chi-Square tests and Cramer's V.

H1: Service quality is the foundation of a successful customer experience.

To validate this hypothesis, we crossreferenced the following two questions (Fig. 1):

- How do you perceive the quality of Orange's services?
- In your opinion, does Orange manage to deliver a good customer experience?

		In your opinion, does Orange manage to deliver a good customer experience? Non	Oui	Total
How do you perceive the quality of Orangeís services?	1	7	0	7
	2	11	9	20
	3	26	34	60
	4	6	111	117
	5	2	23	25
Total		52	177	229

Fig. 1. Cross-Tabulation of Customer Service Quality Perception and Delivery of Good Customer Experience at Orange Moroco. Source: SPSS Output

Referring to the cross-tabulation analysis:

- customers assigned the lowest rating (1), and all consider that Orange does not deliver a good customer experience.
- 117 customers gave a rating of 4, indicating high satisfaction, and 95% of this group (111 individuals) confirm receiving a good customer experience.

To measure the strength of the association between the two cross-tabulated variables, we used the Phi and V-Cramer coefficients.

Both Phi and Cramer's V provide insights into the strength and direction of association between categorical variables. They are valuable tools for understanding the relationships uncovered through cross-tabulation analyses (Fig. 2).

		Value	Approximate Significance
Nominal by Nominal	Phi	,568	,000
	Cramer's V	,568	,000
N of Valid Cases		229	

Fig. 2. The Measure of the Strength of the Association Between the Perception of Service Quality and the Customer Experience. Source: SPSS Output

Both measures indicated a value of 0.568, with an approximate significance of 0.000. These measures suggest a medium to strong association between the variables.

H2: The ethical values adopted by the company play a crucial role in the customer experience.

To validate this hypothesis, we cross-referenced the following two questions (Fig. 3):

- As an Orange customer, do you feel that you share the same values as this brand?
- In your opinion, does Orange succeed in delivering a good customer experience?

		In your opinion, does Orange succeed in delivering a good customer experience? Non	Oui	Total
As an Orange customer, do you feel that you share the same values as this brand?	Non	33	35	68
	Oui	19	142	161
Total		52	177	229

Fig. 3. Cross-Tabulation Between The Value Alignement Perceived by Orange Clients and Customer Experience. Source: SPSS Output

- 48.5% of the 68 customers who do not feel aligned with Orange's values consider that they do not receive a good customer experience, whereas 51.5% believe otherwise.
- 88% of the 161 customers who feel aligned with Orange's values attest to receiving a good customer experience, with only 12% not sharing this opinion.

For the symmetrical measurements (Phi and Cramer's V) performed, they show a value of 0.401 indicating an average strength relationship between the two measured variables as shown in the table below (Fig. 4):

		Value	Approximate Significance
Nominal by Nominal	Phi	,401	,000
	Cramer's V	,401	,000
N of Valid Cases		229	

Fig. 4. The Measure of the Strength of the Association Between the Value Alignment Perceived by the Customers of Orange and The Customer Experience. Source: SPSS Output

H3: A successful customer experience leads to customer loyalty.

To validate this hypothesis, we cross-referenced the following two questions (Fig. 5):

- As an Orange customer, do you feel that you share the same values as this brand?
- In your opinion, does Orange succeed in delivering a good customer experience?

The analysis of the cross-tabulation between customer experience satisfaction with Orange and the intention to remain a customer reveals that among the 229 respondents:

- 49 customers do not plan to stay with Orange in the next five years. Within this group, a majority of 36 customers are not satisfied with the current customer experience.

		In your opinion, does Orange succeed in delivering a good customer experience? Non	Oui	Total
Do you plan to remain a customer of Orange for the next five years?	Non	36	13	49
	Oui	16	164	180
Total		52	177	229

Fig. 5. Cross-Tabulation Between the Perception of Customer Experience and The Intention of Loyalty at Orange Morocco. Source: SPSS Output

- Conversely, 180 customers intend to remain loyal to Orange for the next five years. Among these, a large majority of 164 customers are satisfied with their customer experience.

For symmetrical measures, the Phi and Cramer's V show a value of 0.632, indicating a medium to strong relationship between customer experience and loyalty intention (Fig. 6).

		Value	Approximate Significance
Nominal by Nominal	Phi	,632	,000
	Cramer's V	,632	,000
N of Valid Cases		229	

Fig. 6. The Measure of the Strength of the Association Between the Perception of Customer Experience and the Intention of Loyalty at Orange Morocco. Source: SPSS Output

6.2 Analysis of Results

The analysis of data from the cross-tabulations and the Phi and Cramer's V test highlights a close relationship between service quality, ethical orientation, and the customer experience at Orange, which in turn influences customer loyalty.

The results support Hypothesis 1, stating that service quality is a key element of customer satisfaction. A significant majority of respondents who positively evaluated the quality of Orange's services also reported a satisfying customer experience. These findings align with existing literature that identifies service quality as the foundation of a successful customer experience.

Hypothesis H2 is partially validated, revealing a complex relationship between alignment with the company's values and the customer experience. While the majority of customers aligned with Orange's values report a good experience, a considerable proportion of those who do not feel aligned remain satisfied. This suggests that other factors, beyond ethical alignment, contribute to the customer experience.

Thus, the analysis strongly supports Hypothesis H3, showing a positive correlation between a good customer experience and the intention to remain loyal to Orange. This finding is particularly relevant for loyalty strategies, underscoring the importance of investing in the continuous improvement of customer experience for retention.

In summary, after exploring the concept of customer experience in the field study of Orange, we find a close connection with the theoretical framework and that our three hypotheses have been well verified.

However, this study is subject to certain limitations. One of the main constraints lies in the inability to access a comprehensive list of Orange's customers to form a representative sample.

This limitation compelled us to distribute the questionnaire to a broad audience, then filter the responses to target the population of interest. This approach has partially limited the representativeness of the sample.

7 Conclusion

This research delves deeply into the role of customer experience in client loyalty within Orange Morocco, employing a hypothetico-deductive methodological approach. Through documentary analysis and a quantitative survey conducted with 384 participants, this study highlighted the paramount importance of service quality, the significant influence of the company's ethical values, and the pivotal role of a positive customer experience in enhancing client loyalty.

Theoretically, our investigation enriches the field of customer experience by providing a comprehensive literature review, drawing on domain experts and incorporating recent technological advancements as well as the complexities of modern consumer behavior. This approach offers readers a robust and nuanced theoretical framework for understanding customer experience from various perspectives.

From a managerial standpoint, this study delivers valuable insights to Orange Morocco on key parameters affecting its experiential offering. It specifically identifies improvement opportunities, notably in building emotional and affective connections with customers, underscoring the importance of diversifying and enriching all aspects of the consumer experience.

Furthermore, our conclusions pave the way for future research avenues, particularly on the transformative impact of new technologies, such as artificial intelligence, augmented reality, and big data. These technologies hold substantial potential for delivering innovative and memorable customer experiences, thus establishing unique and lasting bonds between businesses and their clientele.

In summary, despite the methodological challenges encountered, our study makes a significant contribution to understanding customer experience and its capacity to generate loyalty at Orange Morocco. It also sketches a promising horizon for leveraging emerging technologies to revolutionize this experience, marking an important step in the evolution of customer engagement strategies.

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Sustainability and Technology-Driven Marketing Practices in a Post-Pandemic Scenario: The Challenges and Opportunities for the Fashion Industry

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Abstract. The COVID-19 pandemic has impacted the fashion industry in the same way it has affected every other industry in the world. The unprecedented challenges brought by the COVID-19 pandemic to the fashion industry in the form of economic shutdowns and a high-level reduction in the sales volumes have thoroughly transformed the ways of thinking around successful marketing (D'Adamo and Lupi 2021). This drop in sales can be attributed to the rapid shutdowns of retail stores. However, the continued challenges of declined sales **volumes** are the result of the changing purchasing patterns of the consumers. It should be noted that the sudden arrival of the pandemic and the lack of preparedness of the industry caused it to suffer these challenges since the business models adopted by most of the industry players were inadequate in responding to the changed consumer behaviors.

Keywords: COVID-19 · technology · sustainability · digital marketing · fashion industry · green marketing · digitalization

1 Introduction

Fashion industry is one of the most important retail industries in the world today, which involves various operations, ranging from raw materials, production, supply chain aspects, distribution, and marketing. Like many other industries, it has been severely impacted by the pandemic. While the big industry players had adequate technology setups in place to respond to the uncertain situation in an effective manner and revamp the lost in-store sales with e-commerce, not every company was able to perform at the same level (D'Adamo and Lupi 2021). This digital divide led some companies to perform better than others based on their digital and analytical capabilities, even before the pandemic (Gonzalo et al. 2020). Hence, the pandemic brought with it two of the most critical issues, i.e. the economic concerns of the customers and the issue of the technological divide in marketing practices. These issues have put a huge emphasis on the adoption of marketing that is based on an immense focus on sustainability as well as

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digitalization. This chapter highlights these impacts, thereby forming the basis for this research. In addition, the chapter also outlines the aims and objectives of the research, research questions, and hypotheses, along with the significance of this study.

2 Aims and Objectives

The proposed article aims to establish a sustainable and technology-based framework for the fashion industry, based on the insights from the market players. To fulfill this aim, the following objectives have been devised:

1. To understand the issue of a digital divide in the fashion industry in terms of marketing
2. To understand the issues with the current business models
3. To understand the extent to which the marketing practices of fashion industry players are built on sustainability
4. To provide key recommendations regarding sustainability and a technology-driven marketing framework for dealing with any future uncertainties.

3 Legitimacy Theory

Todeschini et al. (2017) has regarded sustainable business models in fashion industry as a way of bringing balance between the goal of achieving a competitive advantage and caring about the social and environmental concerns. Todeschini et al. (2017) has also asserted that consumer awareness and increase trend of sustainability brings sustainable marketing and business into the loop of gaining competitive advantage. This aspect can be seen in terms of legitimacy theory. This theory establishes that CSR practices can be regarded as an action for gaining legitimacy by the organizations. In order to successfully survive in the long-term, corporations need to have a positive overall image in the public. Hence, only if the corporations corroborate with the relevant market trends, they can maintain a positive public image. Since customers are one of the key determinants of success, gaining a positive public image is an effective way of achieving a competitive advantage. When this kind of image is created through an uptake of CSR and sustainability efforts, the balance between competitive advantage and CSR objectives can be achieved. According to Crossley et al. (2021), legitimacy theory relates to the actions of organizations that are in accordance with the socially constructed values, norms, and beliefs of the consumers. The researchers have also established that since environmental practices have become largely desirable, proper, and appropriate in an organizational setting, since more people are becoming aware of the issues of climate change, the organizations are more likely to engage in voluntary practices directed at environmental and social protection (Crossley et al. 2021). The study by Crossley et al. (2021) has particularly focused on the fashion market, deeming it highly competitive and asserting that a pragmatic legitimacy is essential to sustain in the fashion industry. This includes the level of commitment to the environmental and social agendas and the ethical dynamics of the companies across their value chains. Here, it is also important to look at the aspect of "trend". Since sustainable has become trendy and "cool" in the current fashion environment, which associates closely with the social and environmental goals, the companies in the fashion industry have excessively been engaging in relevant practices of CSR. This trend increases the chance for these companies to benefit from the sustainable products. This aspect has also been depicted in light of green marketing and green produces, where researchers have asserted that not only do these organizations gain legitimacy through the quality of the sustainable products, but it also pushes them to more efficient production and manufacturing, where resources become highly affordable for the fashion organizations. Hence, two factors that are relevant in the discussion of legitimacy theory is the heightened awareness of the consumers in relation to environmental degradation and the growing trend of sustainable products being considered as fashionable in the fashion industry.

4 Role of Technology in Sustainable Marketing

A huge digital divide exists in the industry, where advanced technology and technological knowledge are available to only a few market players (Gonzalo et al. 2020). This research assertion provides a rationale for integrating technology into the marketing practices of the fashion industry. The research study by Rao et al. (2021) has explained that a considerable change in the consumption pattern of customers in a post-pandemic setting calls for the need for a better assessment of customer information. This can only be done when the internal systems of an organization are integrated with advanced technology, including data analytics, big data, the internet of things, and other tools and technologies for predictive data analysis (Rao et al. 2021).These technologies, which can enable real-time collection of information on customers, can provide rapid insights into any changes in the preferences and needs of the customers, thereby allowing the businesses to act accordingly (Rao et al. 2021). However, this study does not comment on the digital divide that exists within the fashion industry, which would make the implementation of such technologies a challenge for certain market players.

5 Research Framework

The proposed research is based on the following framework of digitization provided by Rao et al. (2021) (Fig. 1).

5.1 Research Approach

The proposed research is based on a qualitative research approach, which entails an in-depth investigation and exploration of the research information at hand that has been gathered from participants or via observations made in a natural setting. The rationale for using this approach for the proposed study is based on the requirement of the proposed study to dive deep into the issues and requirements of the fashion industry in terms of sustainability and technology. It will also be based on a constructive/interpretivist philosophy that contends that knowledge is subjective, which ultimately means that a researcher's pre-conceptions and pre-assumptions can have a huge impact on the construction of reality. Hence, for every phenomenon that a researcher observes, the resulting interpretation is based on his/her personal experience and already-existing beliefs (Goldkuhl 2012).

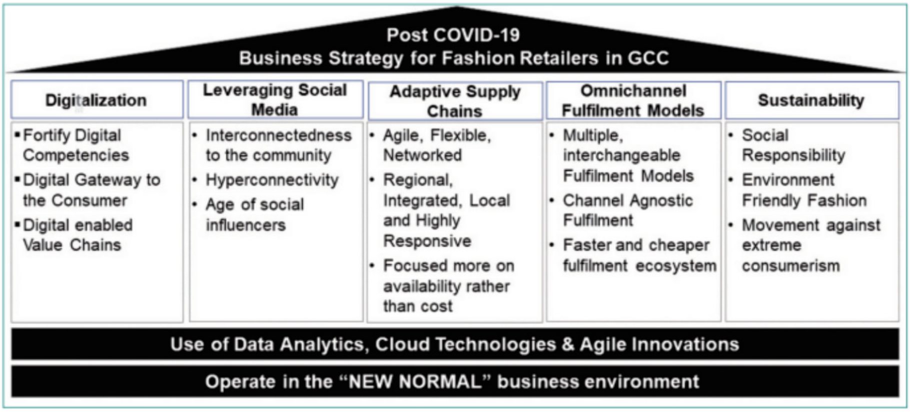

Fig. 1. Framework governing the proposed research

5.2 Research Method and Tools for Data Collection

The research method that has been used for this study includes an interview-based approach, which will be based on a semi-structured interview method. A semi-structured method is based on the construction of a loosely defined set of questions that introduce a little bit of direction in the interview. During the interview, the researcher can ask various probing questions, which are the questions that emerge in response to specific answers given by the respondent. Hence, a set of 7–8 basic questions were devised, which are mentioned below:

1. Has COVID-19 impacted the fashion industry in some way? What is it?
2. What technological systems did you use for your company before the pandemic?
3. Were you using digital or social media marketing? If yes, to what extent?
4. Do you market and sell your products online? Which platforms do you use?
5. How the pandemic changed your approach towards doing business?
6. How did you cope with the low demand of fashion products?
7. What systems or technology solutions do you think are needed for a sustainable business in the fashion industry?

6 Results and Discussion

6.1 Demand Change

Demand changes, especially in wake of the COVID-19 pandemic, were found to be highly significant. The interview respondents highlighted that during the pandemic, the demand for their clothing products significantly declined. One of the respondents reported that this plunge in the demand was most likely due to the fact that the consumer spending was diverted to the essential items and medicine. As people were spending more on food, daily items, and medicines due to the fear of them running out in the market. In addition, the economic conditions also declined for many people, with industries closing due to the lockdown restrictions and many people going out of jobs. As a result, their financial capacity for investing in leisure items, especially fashion apparel decreased. It should, however, be noted that the respondents reported a higher level of purchase for on-sale items, especially warm clothes during January and February. One of the respondents reported,

"As soon as the pandemic hit, the company saw a sharp decline in sales. It was anticipated though. We also slowed down our production because we knew that the demand will fall even more the next year in January and February."

It is interesting to note that while some fashion companies interviewed for this study were able to cope with the sharp change in demand, others were not. This was mostly because of the fact that some companies were not able to assess the future demand via business analytics, a theme that has been explored in ahead as well. One of the respondents highlighted the drastic impact on the pandemic on their company's financial health,

"*COVID-19 was a disaster for our business. We were booming before. But in February 2019, our inventories were overloaded with no significant orders placed by the customers. It was a really difficult time for our business and we spent a whole year recovering from this damage.*"

It is evident from this response that the fashion companies going through a loss failed to estimate the expected demand of their products in the future, which resulted in inventory overflow. On the other hand, the companies that made production decisions in light of the insights from consumer and market data, were able to scale down their production accordingly. This assertion has been made based on the finding that only 2 of the 10 respondents having business intelligence were capable of scaling down their production.

6.2 Preference and Behavior Change

Change in the preferences of the customers after the pandemic was another major theme that was highlighted in the study. It was found that consumers now prefer low cost options for fashion, especially after the pandemic. It is important to note that the companies interviewed were either small businesses or SMEs, which means that cost is a major factor at play for such fashion brands. These brands are inherently placed on a low-cost medium-quality or low-cost high-quality spectrum, when compared to luxury brands. This is why such small and medium-sized fashion outlets are a go-to for customers looking for affordable fashion. This is the reason why it was found that after an early decline in the demand of the fashion products, the companies were able to recapture the market towards the end of the year. Online retail was also found to be a driving factor for this recapturing. For instance, one of the respondents reported,

"Customers were beginning to rely on online retail for everything, from groceries, medicines, and take-outs to household items and apparel. Many businesses were going digital and changing their strategy to become relevant in this new digital

market. Luckily we already had a digital presence and we had the knowledge of these online channels. It was easy for us to recover."

However, due to supply chain disruptions, especially from China, which is one of the exporters of textile products, the supply and demand balance was difficult to balance for the companies as well. Some respondents highlighted that with demand going back to its initial levels, the supply of the goods saw a decline due to the supply chain disruptions. This was true for 6 out of the 10 respondents, who were directly shipping raw materials or clothing items from China.

Another important finding under the theme of demand preferences is related to the aspect of the change in the tastes of the consumers. It was highlighted that the customers' preferences changed to more durable or sustainable fabrics. The respondents were also asked the reason behind this shift and how they are responding to this changed demand through marketing. One of the respondents highlighted,

"Well, I think the change is due to the economy. People have become more careful with what they're spending on. They don't go with items that they will dispose in a year or so just for the sake of fashion. Our customers now demand more durable and useful. For example we have stopped using acrylic as a fabric for our winter or fall collection. Regenerative wool and linen are in more demand. So we use these materials more often than before because this is what our customers want."

1 out of the 10 respondents also said that there is a growing trend towards organic and green products as well, which is an important response, considering how it corroborates with the literature on slow-fashion. The response is highlighted below,

"It's not a new trend if you ask me. People were already all about sustainability and organic products even before the pandemic so much so that green and organic had become buzz words in many industries. For this particular reason we already were planning to include sustainability and green products in our apparel. If you see our content on our socials, you'll see how our marketing is based on the organic and locally sourced cotton and how we make sure that our products and packaging is biodegradable."

The above-mentioned responds holds an immense significance, as it is the only response that tends to establish a link between post-pandemic consumption and sustainable marketing on digital platforms.

It is also pertinent to note that the responses also highlighted that the preferences and buying behavior of the consumers has shifted to more comfort and self-care, which led to an increase in basic, sleepwear, and active wear clothing among other categories. However, it does not mean that the customers have ignored the social dimension of sustainability. For instance, when asked about the CSR efforts as a result of a probing question, one of the respondent contended,

"We invest in social responsibility and philanthropy because we know it matters to the customers. Ethics is important. Without it, you cannot survive in this competitive environment. We also mobilize efforts and collect funds from the customers

for such causes. We also did it for the pandemic, when we collected funds for the marginalized communities for vaccine and providing shelter and clothes to the homeless."

Interestingly, CSR has been found among all the respondents, with 9 out of the 10 respondents directly engaged with charities and NGOs, while one of them focuses on marketing campaigns for the poor and needy during the times of need. The reason for establishing this finding under the theme of changed behaviors of the customers is that CSR efforts are becoming highly desirable for the customers in the recent times.

"Our target market cares more about people now. Maybe it's the pandemic or maybe it's the social media that connects the communities on such a level that we all are aware of each other's miseries. Anyhow, the thing is that CSR matters and businesses need to strategize their CSR activities to be successful."

6.3 Secondary Data for Validating Interview Responses

Secondary data confirms the changing patterns, allowing for validating the responses that were received in the interviews. However, it is also important to note that such consumer responses remain non-uniform across different regions. For instance, a study by Vladimirova et al. (2022) revealed an increase in online shaping behavior across most countries with a few exceptions, as evident from the data in Fig. 2.

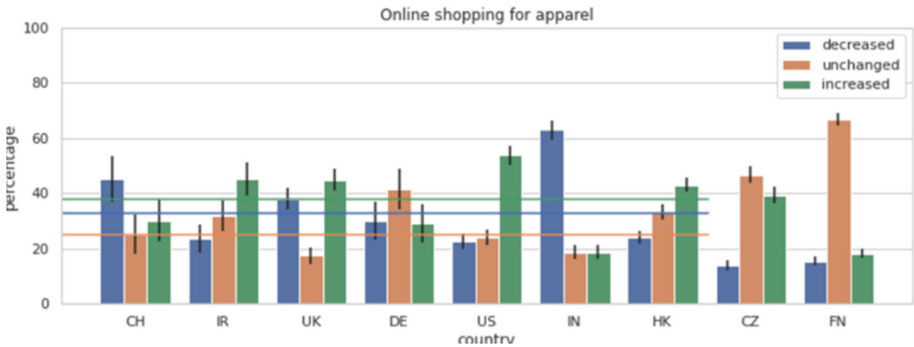

Fig. 2. Online shopping behavior for apparel (Vladimirova et al. 2022)

Similarly, frequency for buying apparel decreased, which can be attributed to the economic factors discussed by the respondents in the interviews, as well as a focus towards more sustainable clothing. This is evident from Fig. 3.

This ultimately meant a lower amount of spending on fashion apparel across these regions, further validating the significance of the economic factor, as evident from Fig. 4.

Secondary data from McKinsey & Company also reveals that behavior within the industry changed, with customers becoming more focused on comfort and self-care, spending more on basics and sleepwear. This can be seen evident in Fig. 5, where the data shows a −27% decline across the comfort category, compared to the hefty declines

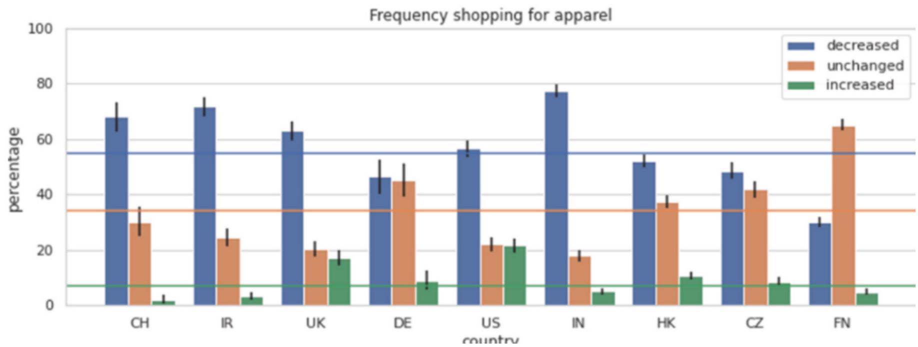

Fig. 3. Frequency shopping for apparel (Vladimirova et al., 2022)

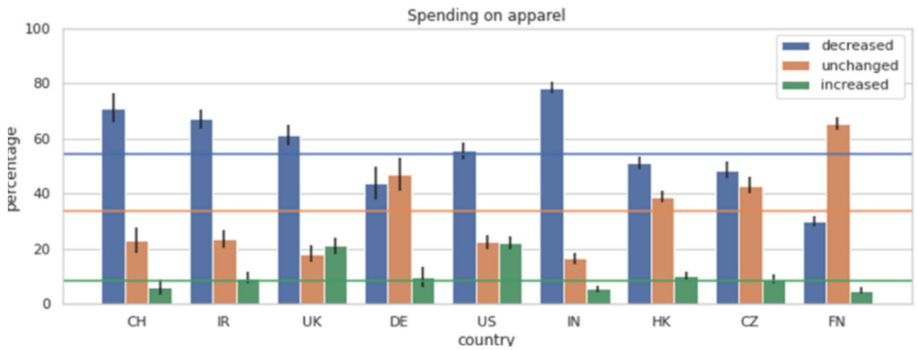

Fig. 4. Spending on apparel (Vladimirova et al. 2022)

across active wear and other categories that include dresses, suits, swim wear, and bridal wear categories that faced the most decline (Baum et al. 2020).

7 Recommendations

- Given the shift in consumer preferences towards sustainable and durable fashion, companies should prioritize sustainable marketing efforts. Highlight the use of eco-friendly materials, ethical practices, and transparency in the supply chain. Leverage this shift towards sustainability as a competitive advantage.
- Recognize the importance of predictive analysis in anticipating changes in demand and preferences. Companies should invest in technology-based solutions, such as business intelligence and predictive analytics, to forecast market trends accurately. This will help in avoiding issues like inventory overflow and enable agile responses to market fluctuations.
- Strengthen digital marketing efforts, especially on platforms like Instagram that resonate well with fashion consumers. Continue using social media for both marketing and e-commerce purposes. Explore influencer marketing strategies to reach a wider

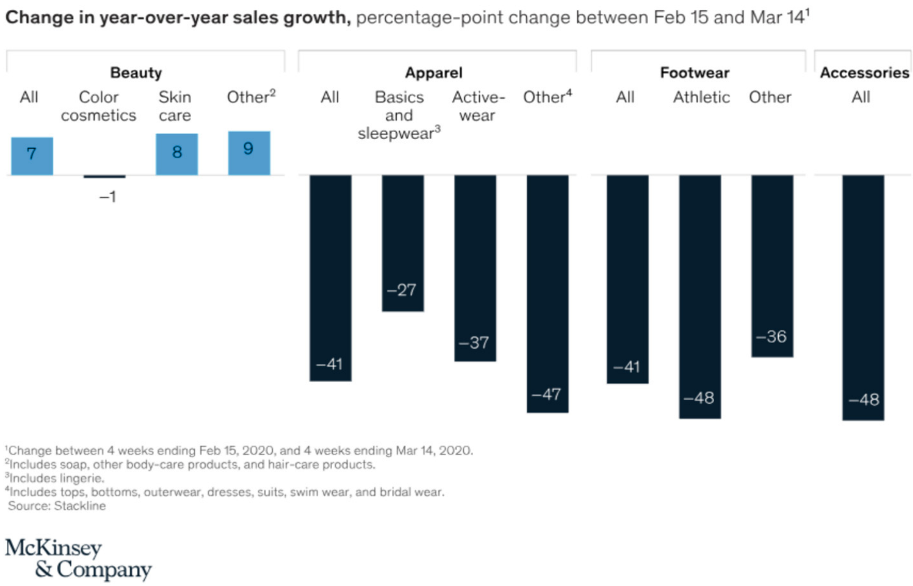

Fig. 5. Sales data from Amazon for Apparel shopping (Baum et al. 2020)

audience. Consider investing in virtual and augmented reality solutions to enhance the online shopping experience.

- Recognize the growing consumer demand for transparency in the fashion industry. Implement systems to track and share information about the entire supply chain, from procurement to production. Consumers are increasingly concerned about the origin and ethical aspects of the products they purchase.
- While awareness of circular fashion is present, consider innovative strategies to implement circular fashion practices. Explore options for recycling, reusing, and repairing products. Encourage customers to sell back or recycle their old clothes, creating a closed-loop system.
- Strengthen Corporate Social Responsibility (CSR) initiatives, aligning them with the changing values of consumers. Engage with charities, NGOs, and social causes that resonate with the target market. Leverage CSR efforts not only as a responsibility but also as a strategic approach to building brand loyalty.
- Recognize the importance of advanced data analytics tools, including Business Intelligence (BI), for gaining actionable insights. Utilize these tools to collect and analyze data on customer behavior, sales, returns, and overall demand patterns. This will enable more informed decision-making and strategic planning.
- Consider emerging technologies such as virtual and augmented reality to enhance the online shopping experience. Explore innovative technological solutions to address challenges brought about by the pandemic, keeping in mind the growing trend of online shopping and the need for a seamless digital experience.

- Given the challenges posed by supply chain disruptions, especially from key exporters like China, stay informed about global supply chains. Diversify suppliers where possible and implement contingency plans to address potential disruptions in the future.

8 Conclusion

To sum up, this research is based on the identification of the ways in which sustainable marketing approaches and the technological system can complement each other in a way that the resulting marketing efforts allow the fashion industry to cope with market fluctuations. All is set in the post-pandemic, i.e. the current situation, where a closer look at the fashion retailers and their marketing practices has become imperative, owing to the rapid changes that have been brought by the pandemic in terms of a change in customer behavior and consumption patterns. As the lockdown restrictions increased, it was seen that people have not only become more concerned about the economic situation but also about the environmental change and the impact of business and human activity on the planet. As a result, a considerable percentage of the target audience of the fashion industry has moved its preferences from fast fashion to a more sustainable slow fashion. In addition, customers also look for affordable options with better quality and higher usability, as contended in the introduction section of the proposal. However, these are not the only ways in which consumers have changed their shopping patterns. To better dive into this issue, and to understand the interplay among sustainability, technology, and marketing, this research adopted a qualitative research approach based on a semi-structured interview methodology, which will be carried out on participant firms that provide international shipping services.

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Multi-agent Simulation of Traffic Flow and Collision Detection Using GAMA

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Abstract. This research paper presents a comprehensive study on simulating traffic flow and collision detection in a multi-agent framework using the GAMA platform. The aim of the study is to check out the effectiveness of different approaches for modeling traffic behavior and assessing collision risks in a simulated road network. The simulation consists of three main parts: a multi-agent design of traffic flow, random movement of vehicles with increased collision rates, and the application of the Intelligent Driver Model (IDM) for vehicle movement. The results demonstrate the capability of the multi-agent simulation in capturing realistic traffic patterns and evaluating collision risks. The findings contribute to the understanding of traffic dynamics and provide insights for the development of efficient traffic management strategies.

Keywords: Traffic simulation · IDM · Collision Detection · GAMA

1 Introduction

The efficient management of traffic flow and the prevention of collisions are critical aspects of transportation systems worldwide. To address these challenges, traffic simulation models have emerged as powerful tools for evaluating the behavior of vehicles and predicting potential collision risks. In this paper, a multi-agent traffic simulation system is presented and implemented in GAMA plateforme. The urban traffic components in this system, such as the vehicles, road segments, and intersections, are abstracted to agent models. The objective of this study is to investigate the effectiveness of different approaches in

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modeling traffic behavior and assessing collision risks within a simulated road network. The simulation consists of three main parts: a multi-agent design of traffic flow, random movement of vehicles, and the application of the Intelligent Driver Model (IDM) for vehicle movement. In the first part, we design a multi-agent framework to simulate traffic flow. Each vehicle agent is endowed with autonomous decision-making capabilities, allowing them to adapt their speed and direction based on local traffic conditions [1]. We evaluate the ability of this approach to capture realistic traffic patterns and observe the emergence of collective phenomena such as traffic congestion. The second part features adding randomized vehicle movement in the simulated road network to cause more collisions. We test the effect of varying vehicle density and distribution on collision rates to study the impact of traffic congestion. Our aim is to understand how traffic flow affects the risk of collisions, which can help inform traffic management strategies and safety precautions. Lastly, we incorporate the Intelligent Driver Model (IDM) into our simulation framework. The IDM is a well-known car-following model that simulates the behavior of individual drivers, considering factors such as desired speed, reaction time, and safe headway distance. By implementing the IDM, we aim to enhance the realism of vehicle movement and further assess collision risks under different traffic scenarios. Through our comprehensive simulation study, we expect to gain a deeper understanding of traffic dynamics, evaluate collision risks, and provide valuable insights for traffic management strategies. The findings of this research can inform the development of effective measures to enhance traffic safety and optimize traffic flow in real-world road networks.

2 Agent-Based Simulation and GAMA Platform

Agent-Based Simulation (ABS) is a simulation technique that focuses on modeling the behavior and interactions of autonomous agents to understand the emergent properties of a system. It involves representing individual agents as autonomous entities with their own behaviors, decision-making processes, and interactions with other agents and the environment. Object-oriented functionality allows an agent to act towards its own goals, which can be programmed or dynamically changed during runtime based on system tasks. Creating a full agent model necessitates four important components: a sensor for environmental data collection, a knowledge base for learning and expressing strategies, a processor for handling system events, and a communicator for collaborating and interacting with other agents. The model functions by recognizing environmental changes using the sensor and utilizing its knowledge and learning strategies in the processor to address the new situation. This enables the agent to attain its intended goal with self-sufficient decision-making. Additionally, when operating within a complicated system, the communicator is employed to exchange information with other pertinent agents, allowing for the completion of common tasks. In this paper, we use agent-based simulation to model the traffic main components and develop the multi-agent traffic system in GAMA platform [2]. The

GAMA Software is a proper multi-agent programmable environment for modeling complex phenomena including social, medical, etc., which runs dynamically over time. GAMA is purely written in JAVA language and can run any operation platform that supports JAVA.

3 Multi-agent Design of Traffic Flow

In this section, we describe the multi-agent design of traffic flow within the simulation. The objective is to create a realistic representation of vehicle behavior and interactions in a dynamic traffic environment.

3.1 Vehicle Agent

In the context of the traffic simulation, a vehicle agent represents an individual vehicle within the simulated road network. The vehicle agent is responsible for capturing the behavior and interactions of a specific vehicle throughout the simulation. It possesses various attributes (id, length, width, position, speed...) and behaviors that enable it to navigate the road network and interact with other vehicles.

3.2 RoadAxis Agent

In the traffic system RoadAxis agent represents a segment or portion of the road network within the simulation. It is responsible for defining the layout, properties, and behavior of the road segment. The RoadAxis agent plays a crucial

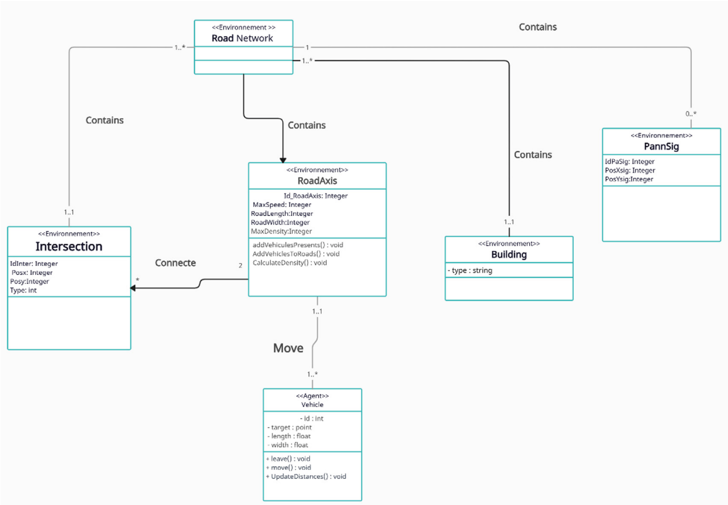

Fig. 1. UML diagram representing model classes

role in defining the characteristics and behavior of the road network within the traffic simulation. It determines factors such as road length, number of lanes, speed limits, and traffic density, which directly influence the movement and behavior of the vehicles within the simulation. The general structure in UML format (Unified Modeling Language,) is shown in Fig. 1:

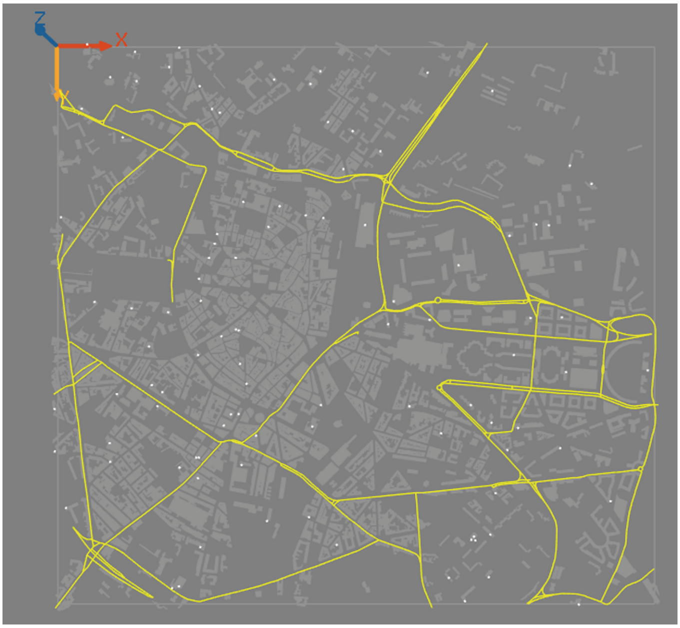

Fig. 2. The multi-agent traffic simulation system in GAMA

4 Experimental Setup

The experimental setup involved importing a road network comprising routes and buildings into the GAMA simulation platform. This integration was achieved through the inclusion of the road network data in the simulation's resources. Each road segment within the imported road network was configured with a single lane, indicating a one-way traffic flow. This constraint facilitated the modeling of realistic traffic scenarios, where vehicles traveled in a specified direction on each road segment. To emulate real-world traffic conditions, the placement and generation of vehicles were randomized within the building areas of the simulated environment. This randomness ensured the distribution of vehicles throughout the road network and reflected the dynamic nature of traffic patterns in urban areas. By incorporating the imported road network and generating vehicles randomly within the building areas, the experimental setup created a realistic and dynamic simulation environment. This environment enabled the evaluation of traffic flow characteristics, collision risks, and the effectiveness of traffic management strategies within the context of the simulated road network. The implemented multi-agent traffic simulation system is shown in Fig. 2 The simulation involved generating 1000 vehicles that traversed the road network in a randomized manner. The choice of this number of vehicles is based on the need for a high density to conduct a relevant study of collisions. Each vehicle was assigned a random initial position and a random velocity within the range of 20 km/h to 60 km/h to match typical urban speed limits. The vehicles followed the road network, adhering to traffic rules such as lane assignment and right-of-way. During the simulation run, the vehicles interacted dynamically, adjusting their speeds, changing lanes, and responding to the surrounding traffic conditions. The simulation captured the movement and behavior of the vehicles, simulating a realistic traffic flow scenario within the road network. After the simulation concluded, a dataset was generated that contained information about the vehicles involved in collisions. The collision detection was performed by comparing the coordinates of the vehicle's corners to identify overlapping or intersecting regions [3]. The dataset provided valuable insights into the collisions that occurred during the simulation. Table 1 displays a subset extracted from the dataset:

Table 1. Extract from dataset.

Cycle	24	242	25	253	26	27	...	31
Id_Vehicle	12	13	12	13	12	13	...	12
X	−0.448611365	−0.435984692	−0.458436897	−0.425860918	−0.468256135	−0.415915614	...	−0.514237619
Y	0.509855098	−1.006892223	−1.006522309	−1.006998124	0.51496287	0.509512931	...	−1.008051922
Heading	0.354450371	2.065593231	−1.027077016	2.011103265	0.4424653	0.034499459	...	0.765162111
Current_edge	311	257	311	328	278	328	...	317
X_av	−1.183064118	0.653877658	−1.183064118	0.653877658	−1.183064118	0.653877658	...	−1.183064118
X_ar	−1.190193724	0.667929772	−1.190193724	0.667929772	−1.190193724	0.667929772	...	−1.190193724
Y_ar_d	−1.146395815	0.415006196	−1.146395815	0.415006196	−1.146395815	0.415006196	...	−1.146395815
Y_ar_g	−1.160684765	0.460041554	−1.160684765	0.460041554	−1.160684765	0.460041554	...	−1.160684765
Speed (Km/h)	20	30	20	30	20	30	...	20
Density	0	1	0	1	0	1	...	0
Hascolide	1	1	1	1	1	1	...	1

4.1 Intelligent Driver Model (IDM)

By integrating the IDM, which is a well-known car-following model, into the simulation, the vehicles' behavior was influenced by factors such as desired speed, reaction time, and safe headway distance. The IDM provided a more realistic representation of how drivers adjust their speeds and maintain safe distances from preceding vehicles [5]. Following the introduction of the IDM, the simulation was re-run, and the results showed a notable decrease in the number of collisions. This finding highlights the effectiveness of the IDM model in mitigating collision risks and enhancing traffic safety within the simulated environment

[6]. The reduction in collisions observed after implementing the IDM suggests that the model contributed to better vehicle coordination, smoother traffic flow, and improved adherence to safe driving practices [4]. The IDM's ability to regulate vehicle acceleration, deceleration, and following distance likely played a crucial role in minimizing the occurrence of collisions. This outcome is particularly significant as it demonstrates the potential of the IDM model as a valuable tool for developing strategies to prevent collisions and improve overall traffic safety [7]. By further analyzing the effects of IDM on various traffic scenarios, researchers and traffic management professionals can gain insights into how IDM-based strategies can be employed to minimize collision risks and enhance the efficiency of traffic flow. The integration of the IDM into the simulation provides a valuable contribution to understanding the benefits of incorporating intelligent driver models into traffic management systems. It emphasizes the importance of utilizing advanced modeling techniques and intelligent algorithms to optimize traffic dynamics and reduce collision risks in real-world scenarios [8]. Furthermore, the successful reduction in collisions with the implementation of the IDM model in this single-lane road scenario highlights its potential for broader applications in the simulation. As future work, expanding the simulation to include intersections, traffic signals, and multiple lanes becomes an exciting prospect. By incorporating additional road features and complexities, such as traffic lights, yield signs, and multiple lanes with varying speed limits, the IDM model can be further tested and evaluated for its effectiveness in collision prevention under more intricate traffic scenarios [9].

5 Conclusion

In this study, we conducted a comprehensive simulation of traffic flow and collision detection using the GAMA platform. By incorporating a multi-agent framework, random vehicle movements, and the Intelligent Driver Model (IDM), we gained valuable insights into traffic dynamics and collision prevention. Our findings demonstrate that unregulated random vehicle movements led to a high number of collisions. However, the integration of the IDM model significantly reduced collision rates by considering factors such as desired speed and safe following distance. Our findings demonstrate that unregulated random vehicle movements led to a high number of collisions. However, the integration of the IDM model significantly reduced collision rates by considering factors such as desired speed and safe following distance.

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Comparative Study on Machine Learning Based Decision-Making for Microgrid Component Operation

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Abstract. Proposed energy management strategy for micro-grid (MG) with renewable energy storage (hydrogen tank) reduces emissions. Comparing k-Nearest Neighbors (k-NN) and Random Forest machine learning methods, RF is more suitable for decision making on storage system components (battery, supercapacitor, fuel cell). Ensures continuous load supply, reduces non-renewable energy consumption, and maintains storage component health. The finding results indicate that the RF method outperforms k-NN in terms of accuracy with a high accuracy of around 90%, while the k-NN method had a maximum accuracy of 61% across the four control cases.

Keywords: Machine learning · Microgrid · Decision making · Energy management system

1 Introduction

Increased energy demand and fossil fuel production harm the environment. Energy storage in microgrids is crucial for the energy transition. Microgrids improve power system performance using AI techniques. AI enhances power system stability, efficiency, and protection [1]. Machine learning methods optimize hybrid micro-grid management, reduce emissions, and integrate fuel cells [2]. Hydrogen is a vital energy vector obtained from renewable and non-renewable sources [3]. Comparative study evaluates RF, DT, Gaussian NB, and KNN algorithms [4]. Focuses on predicting sources for load demand. FLC controls power exchange using microgrid energy and battery SOC. Offline optimization determines FLC parameters for quick response and battery SOC maintenance. Experimental validation confirms feasibility in a real microgrid. The article compares supervised machine learning techniques for microgrid energy management, it can be

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concluded that the RF method outperforms k-NN in terms of accuracy. The remaining sections of this work are organized as follows: Sect. 2 discusses the machine learning strategies employed. Section 3 outlines the operation states of the system components. Section 4 presents the results and discussions of the comparative study. Section 5 concludes the paper with a summary and highlights future prospects.

2 Machine Learning Strategies Used

In the digital world, technology dominates by combining artificial and human intelligence [5]. AI predicts future values based on past learning. ML uses mathematics and statistics to build intelligent systems and predict the future values [6]. ML applications include object classification [7]. ML methods can be classified into unsupervised, supervised, semi-supervised, and reinforcement learning. This study focuses specifically on supervised learning.

2.1 Supervised Learning (SL)

SL uses labeled datasets to train algorithms for accurate classification and prediction. It includes classification and regression problems [8]. Decision trees, classifiers, k-nearest neighbors, support vector machines, and neural networks are common supervised learning algorithms. They are used to train and make predictions based on labeled data in various tasks [9].

2.1.1 k-NN and RF Methods

The k-Nearest Neighbors (k-NN) method is simple and effective but has drawbacks such as low accuracy and dependence on choosing a suitable k value [10]. In a specific reference, k-NN is used to identify the type of vehicle driver. On the other hand, the Random Forest (RF) classifier, a supervised method, consists of multiple decision trees and performs well with large datasets. However, it requires more resources and is more complex and time-consuming to construct compared to a single decision tree [11].

3 System Components Operation States Meaning

The operating states of the system components are as follows: T_{-1} represents the correct prediction of class −1, T_0 represents the correct prediction of class 0, and T_1 represents the correct prediction of class 1. F_0 and F_1 represent the conditions when the predicted class is different from the target class. The accuracy parameter measures the ratio of correctly predicted observations to the total number of observations. Equation (1) represents the mathematical model for the fuel cell, while Eq. (2) corresponds to the mathematical model for the other system elements [12].

$$\text{Accuracy} = \frac{T_0+T_1}{T_0+F_0+T_1+F_1} \tag{1}$$

$$\text{Accuracy} = \frac{T_{-1}+T_0+T_1}{T_{-1}+T_0+T_1+F_{-1}+F_0+F_1} \tag{2}$$

This study compares Random Forest and k-Nearest Neighbors in managing electrical energy in a microgrid. Inputs like SOC, SOC*, hydrogen tank level, photovoltaic production, and load consumption determine system element states. Accuracy measurement determines element operation or malfunction. Relay states of system elements are represented in Fig. 1.

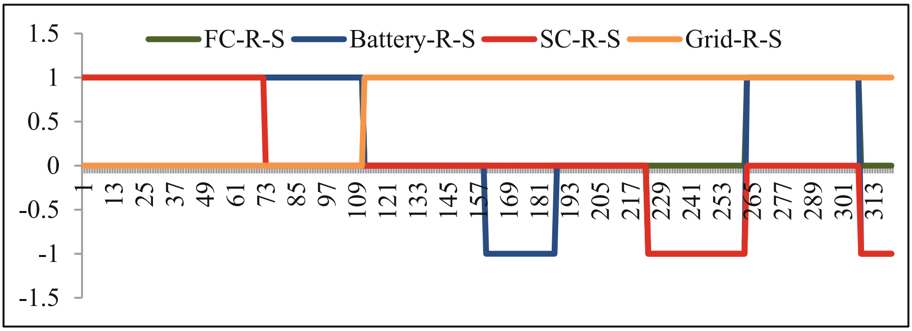

Fig. 1. System compenets relays states

4 Results and Discussions

The algorithm acquires decision-making capabilities by considering the system's current state and available actions. A comparative study can assess the performance of various machine learning algorithms in making decisions for micro-grid components under diverse conditions. Evaluation metric, including accuracy can be used to assess the effectiveness of different decision-making methods.

4.1 Fuel Cell Relay Accuracy

For the decision making of the operating state of the fuel cell relay, the k-NN method achieved an accuracy of 52%, the RF method an accuracy of 90% as shown in Fig. 2.

4.2 Battery Relay Accuracy

For the decision making of the operating state of the battery relay, the k-NN method achieved an accuracy of 27%, the RF method an accuracy of 86% as shown in Fig. 3.

4.3 Super Capacitor Relay Accuracy

The operating state of the super capacitor relay was determined using two different methods and their corresponding accuracies were compared. According to the results presented in Fig. 4, the k-NN method achieved an accuracy of 21%, while the RF method achieved a higher accuracy of 88%.

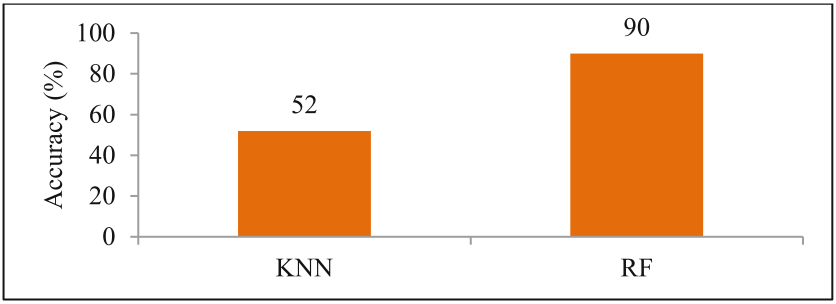

Fig. 2. Both methods achieved high accuracy scores, especially for the FC relay

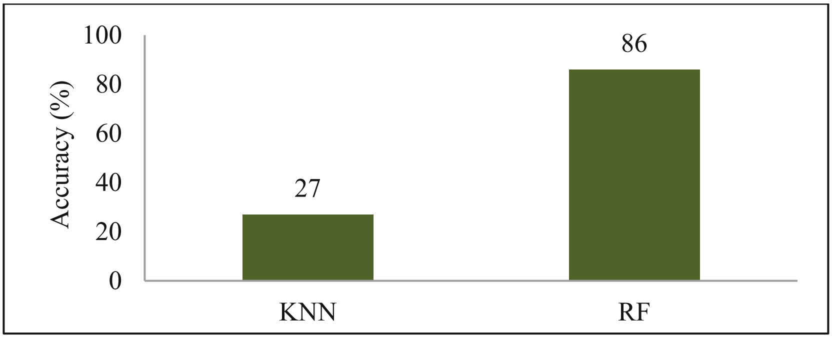

Fig. 3. Both methods achieved high accuracy scores, especially for the battery relay

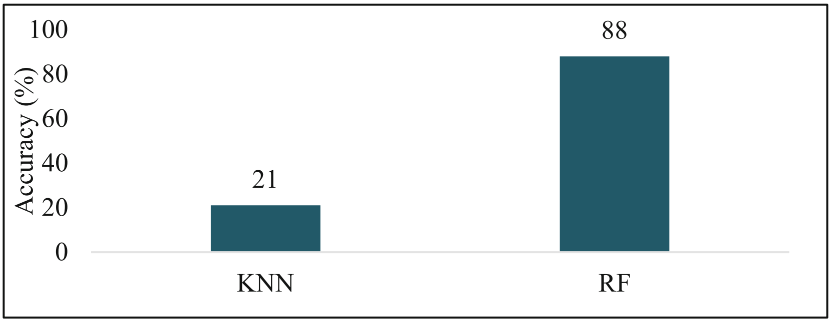

Fig. 4. Both methods achieved high accuracy scores, particularly for the SC relay

4.4 Grid Relay Accuracy

The operating state of the grid relay was determined using two different methods, and their corresponding accuracies were compared. As shown in Fig. 5, the k-NN method achieved an accuracy of 61%, while the RF method achieved a higher accuracy of 86%.

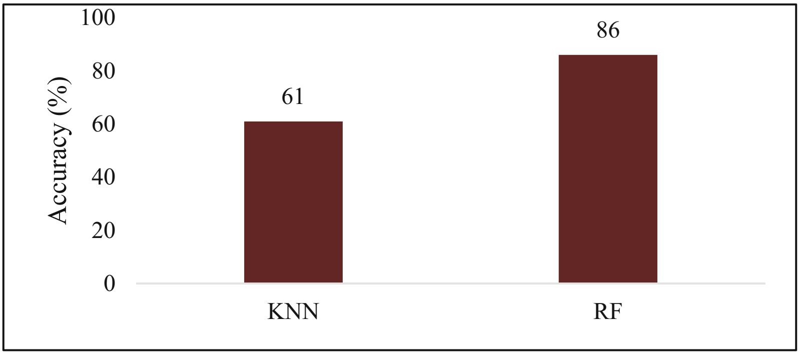

Fig. 5. Both methods achieved high accuracy scores, especially for the grid relay

The comparison of the two methods for decision-making in determining the functional states of micro-grid system elements shows that the random forest method consistently outperforms k-NN in all four cases. It is evident that the random forest method achieves a higher accuracy compared to k-NN, as shown in the simulations results.

5 Conclusion

According to the findings, the RF method achieved an accuracy level of approximately 90%, while the KNN method reached a maximum accuracy of 61% across the four control cases. In summary, the results suggest that the RF method performs better than the k-NN in term of accuracy, in accurately predicting the operating state of the FC, Battery, Super capacitor and the grid, and hence it may be a more suitable algorithm for this specific application.

Future work aims to investigate the utilization of machine learning and deep learning techniques for efficient management of hydrogen storage systems in vehicles and microgrids.

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A Comparative Analysis of VGG16 and VGG19 for Automated Defect Detection in Solar Panels

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Abstract. The growing demand for solar energy necessitates reliable and efficient solar panel systems. However, various defects like cracks, surface imperfections, dust buildup, and hot spots can significantly impact their performance and longevity. Early detection of these faults is crucial for optimal solar panel operation. This study explores the application of deep learning for automated surface defect detection in solar panels. We employ pre-trained VGG models, specifically VGG16 and VGG19, to analyze images of solar panels captured under various conditions. These images encompass both normal panels and those exhibiting defects. The analysis revealed VGG19's superior performance in defect identification compared to VGG16. VGG19 achieved an impressive 80% precision and an F1 score of 89%, indicating its effectiveness in accurately classifying defective panels. While VGG16 also demonstrated strong results with a precision of 79% and an F1 score of 85%, VGG19's deeper architecture likely contributed to its slight edge in accuracy. These findings highlight the capability of the VGG19 model for visual detection of surface defects in solar panels.

Keywords: Intelligent defect detection · faults detection · photovoltaic (PV) system · Pre-trained VGG model

1 Introduction

Solar energy is increasingly playing a vital role in the worldwide shift towards renew-able energy sources [1]. Solar panels function as photovoltaic (PV) devices, utilizing the photoelectric effect to convert incident solar radiation into direct current (DC) electricity [2]. These panels comprise the fundamental building blocks of solar energy conversion systems. Nevertheless, various surface defects such as shading, dirt accu-mulation, cracks, hotspots, and dust can undermine the dependable performance and longevity of solar panels [3, 4]. If these issues remain unaddressed, they can result in energy wastage,

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decreased efficiency, and potentially, total system breakdown [5]. Consequently, it's crucial to devise efficient techniques for identifying and diagnosing surface flaws in solar panels. Conventional methods for detecting and inspecting defects in solar panels typically involve manual visual examination, which is slow, laborious, and prone to human mistakes [6]. The growing need for automated defect detection has spurred significant interest in utilizing artificial intelligence (AI) and computer vision techniques [7]. Advanced machine learning techniques, particularly Artificial Intelligence (AI) and Deep Learning (DL) models, are being explored alongside traditional methods for the automated detection and classification of surface defects on solar panels. One study achieved an average accuracy of 86% in classifying 12 different anomalies using such models [8]. This is not the only promising approach. Research by K. Liao et al. [9] investigates Unmanned Aerial Vehicles (UAVs) as a viable method for solar panel inspection. UAVs offer advantages in cost-effectiveness, speed, and the capability to detect hidden defects that might be missed from the ground. Furthermore, another study explores an automated framework for defect detection using Electroluminescence (EL) imaging, achieving high accuracy in defect detection [10]. This approach utilizes the fact that solar cells emit light under certain conditions, highlighting potential defects. By combining AI and Deep Learning with these other technologies, researchers are creating a comprehensive approach to solar panel inspection that can ensure optimal performance and energy production. Through a comprehensive review of the literature, the inherent complexity and variability of solar panel anomalies themselves necessitate the development of advanced algorithms. Defects can manifest in diverse forms, and their characteristics may subtly change over time. Robust AI models capable of not only identifying these anomalies but also monitoring their evolution are crucial for effective preventative maintenance and performance optimization. This study evaluates the effectiveness of a deep learning system for solar panel defect detection, utilizing both VGG16 and VGG19 models. We compare the performance of these models in accurately classifying faulty panels. The results demonstrate that VGG19 outperforms VGG16, exhibiting superior proficiency in defect identification and categorization. These findings lead to significant implications for improving solar panel maintenance strategies and optimizing overall system efficiency. The structure of this article proceeds as follows: Sect. 2 delineates the proposed methodology. Section 4 presents and discusses the results of the experimental analysis. Finally, the concluding section summarizes the study's key findings.

2 Proposed Method

2.1 Solar Panel Image Dataset Preparation

A diverse dataset of labeled images is crucial for training the proposed fault detection model for solar panel surfaces. This dataset was constructed by capturing images of two solar panels under various conditions using a visual camera. The focus was on capturing faults such as shadows, bird droppings, and soiling. The collected dataset is then categorized into two primary classes: normal panels and panels exhibiting faults, as illustrated in Fig. 1.

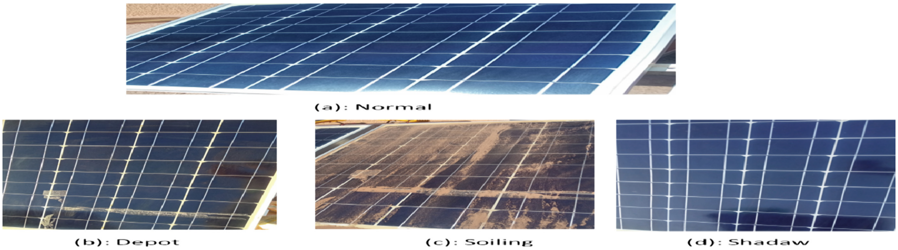

Fig. 1. The dataset incorporates images of both healthy solar panels and panels exhibiting diverse faults, including those illustrated in Figures (b), (c), and (d).

2.2 Deep Convolutional Neural Network (DCNN) Design for Surface Defect Detection

The VGG16 and VGG19 models, developed by the VGG group, are DCNN architectures widely used in computer vision tasks like image classification, object detection, and image segmentation. VGG19, as illustrated in Fig. 2, utilizes a series of 16 convolutional layers with ReLU activation for non-linearity. Max pooling layers are incorporated for downsampling the feature maps. This is followed by three fully-connected layers with ReLU activation, leading to a final output layer employing softmax activation to generate class probabilities [11]. VGG19's ability to learn intricate image features makes it a valuable tool for various computer vision applications [12].

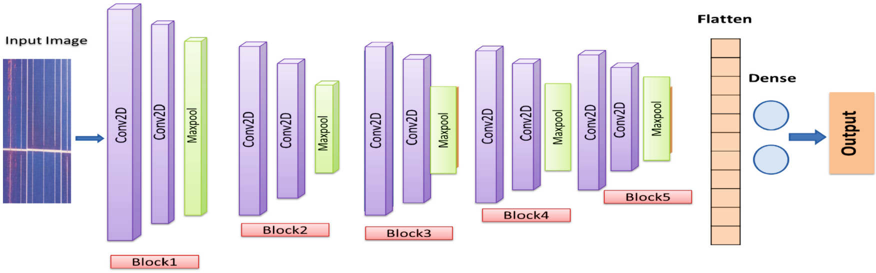

Fig. 2. Design framework of the vgg19 model.

The performance of each model is evaluated using various metrics, including accuracy, precision, recall, and F1-score [13].

3 Results and Discussions

In this study, a deep neural network model was trained within the TensorFlow 2.2 framework to achieve this goal [14, 16–18]. To prevent overfitting, an early stopping mechanism halted training if validation loss failed to improve for 10 consecutive epochs, although a maximum of 30 epochs was allowed. The training environment leveraged a PC with a powerful CPU, RAM, and a Google Colab-accessed Tesla T4 GPU [15], with each epoch taking approximately 2 s. To optimize the model's performance, we conducted experiments adjusting various hyperparameters like activation functions, network layer numbers, and optimization algorithms.

3.1 VGG16 Detection Performance

The VGG16 model achieved a 92% success rate in identifying normal solar panels, as shown in Fig. 3(b). However, its performance in detecting faulty panels was lower, with a 75% detection rate. The model exhibited some misclassification issues, highlighting the need for further improvement in accuracy. As illustrated in Fig. 3(a), the training process resulted in a significant reduction in the model's loss value, dropping from 0.89 to 0.05. This suggests improved training performance, potentially leading to enhanced predictive accuracy in future iterations.

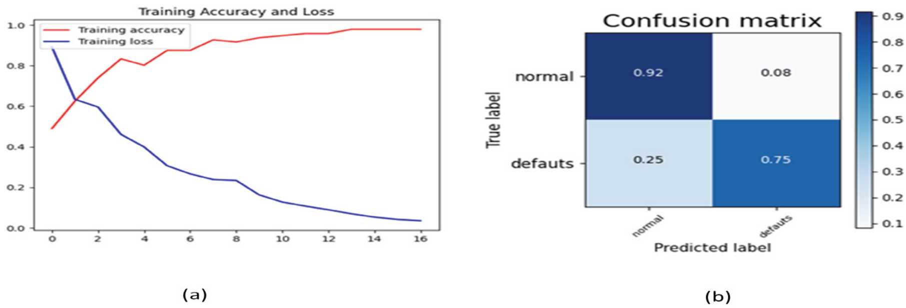

Fig. 3. VGG16 Results: (a) Training Performance Accuracy and Loss Curves. (b) The confusion matrix.

3.2 VGG19 Detection Performance

As illustrated in Fig. 4(a) and Fig. 4(b), the VGG19 model surpassed VGG16 in several aspects. VGG19 achieved higher training accuracy (99% compared to 97%) and lower training loss (0.03 compared to 0.04). Additionally, VGG19 reached higher accuracy earlier, surpassing VGG16's performance from epoch 7 onwards, while VGG16 maintained a lead until epoch 14. This suggests VGG19's superior predictive capabilities.

The deeper architecture and increased complexity of VGG19 likely contribute to its superior performance. The deeper and more complex architecture of VGG19 likely enhances its capacity to learn data features and relationships, potentially leading to higher accuracy and reduced loss during training.

Analysis of recall and F1-score in Table 1 revealed VGG19's superior performance in faulty solar panel detection. VGG19 achieved a perfect recall of 1, indicating it identified all faulty panels correctly. Its F1-score of 0.89 further supported this notion. Although VGG16 exhibited promising results with a recall of 0.92 and F1-score of 0.85, VGG19 achieved superior performance. Notably, VGG19 attained a perfect precision score of 1 for identifying normal solar panels, outperforming VGG16's precision of 0.9.

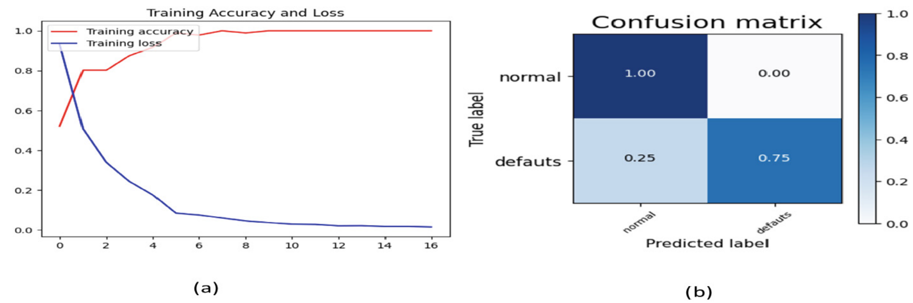

Fig. 4. VGG19 Results: (a) Training Performance Accuracy and Loss Curves. (b) The confusion matrix.

Table 1. Performance assessment of the VGG16 and VGG19 models for normal and faulty solar panels detection.

	Normal class			Faulty class		
	Precision	Recall	F1 score	Precision	Recall	F1 score
VGG16	0,9	0,75	0,82	0,79	0,92	0,85
VGG19	1	0,75	0,86	0,8	1	0,89

4 Conclusion

This paper proposes the use of VGG models to improve the detection of surface faults in solar PV panels. The results demonstrate significant capability, when comparing F1 scores, recall, and precision. VGG19 achieved an F1 score of 0.89, recall of 1, and precision of 0.80, suggesting a good balance between precision and recall, indicating superior ability in identifying faulty solar panels. While VGG16 also performed well with a precision of 0.79 and F1 score of 0.85, it fell short compared to VGG19, particularly in terms of recall (0.92). This means VGG16 might have missed a slightly higher number of true faulty panels compared to VGG19. Looking forward, two primary areas can be further investigated to enhance the intelligent detection of surface defects in solar panels using AI. Firstly, expanding the dataset to include a wider variety of defect types can enhance model generalizability and robustness. Secondly developing real-time detection capabilities enables continuous monitoring, facilitating prompt identification and repair of emerging defects, thereby bolstering preventative maintenance and system performance.

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CNN-LSTM Approach for Forecasting Daily Maximum and Minimum Temperatures: A Case Study of Southeast Morocco

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Abstract. Accurate prediction of maximum and minimum temperatures is crucial in many domains, such as energy planning, agriculture, and water resource management. In this work, applying Deep Learning (DL) techniques for predicting these climate variables has been investigated. Thus, an approach based on Long-Short-Term-Memory (LSTM) networks and Convolutional Neural Networks (CNNs) was proposed. CNNs are used to extract spatial features from meteorological data, while LSTMs capture temporal dependencies in the corresponding time series. The combination of CNNs and LSTM makes it possible to fully exploit the information contained in weather data. Historical data including variables such as Maximum Daily Temperature (MaxDT) and Minimum Daily Temperature (MinDT), Maximum and Minimum Daily Relative Humidity (MaxDRH) and (MinDRH), Mean Daily Wind Speed (MeanDWS) and Maximum Daily Wind Speed (MaxDWS), Mean Daily Wind Direction (MeanDWD), and Daytime Insolation Duration (DINSOL) are used to train the implemented model. To measure the performance of the hybrid model, we used evaluation criteria such as the Root Mean Square Error (RMSE), the Mean Absolute Error (MAE), and the coefficient of determination (R). The results indicate that our DL methodology excels at providing accurate forecasts for the maximum and minimum temperatures of the day. Indeed, the hybrid model test provided an R-value of up to 96.9% for extreme daytime temperatures in Errachidia City, situated in Southeast Morocco.

Keywords: Maximum temperature · Minimum temperature · Deep learning · Prediction

1 Introduction

Due to the substantial impact of the climate on various aspects of human activity, weather forecasts are extremely important [1]. Accurate prediction of the day's maximum and minimum temperatures is of crucial importance in many areas, such as agriculture, energy

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management, urban planning, and decision-making in weather operations [2–4]. These predictions are essential for optimizing resources, minimizing the risks associated with extreme weather conditions, and improving the planning of day-to-day activities. Over the years, many approaches have been developed for predicting temperatures. Traditionally, models based on statistical methods, such as time series or regression models [5, 6], have been used. However, these methods can be limited in their ability to capture the non-linear dependencies and complexity between meteorological variables. Recently, Deep Learning (DL) techniques emerged as a promising approach to temperature prediction, in particular maximum and minimum temperature prediction. Deep neural networks can automatically learn complex patterns and relationships from large, heterogeneous data sets. They can also take account of temporal and spatial variations in the data, making them a powerful tool for predicting weather temperatures. Several recent studies have demonstrated the effectiveness of DL techniques in predicting maximum and minimum temperatures. Fahimi et al. [7] used Artificial Neural Networks (ANNs) to predict seasonal maximum temperature more accurately than traditional models. In another study, Han et al. [8] used Convolutional Neural Networks (CNNs) to simulate subsurface temperatures in the Pacific Ocean from a series of satellite remote sensing measurements. The study carried out in [9] investigates the ability of ANNs to directly predict daily temperature extremes at 2 m using a vertical profile measurement. However, even with these improvements, there are still challenges to be resolved in the deployment of DL techniques for predicting extreme temperatures. Some of these challenges include the management of missing data, taking account of seasonal variations, and the robustness of models in the face of extreme climatic conditions.

This paper introduces a DL-based approach for predicting maximum and minimum daytime temperatures. Custom neural network architecture and hybrid learning strategies are explored to enhance prediction performance. By combining the advantages of CNN-LSTM techniques with available meteorological data, our aim is to provide advanced tools for predicting maximum and minimum temperatures, thereby contributing to better resource management and informed decision-making.

2 Dataset

The historical data used in this study include several key climatic variables collected in Errachidia City. These variables include maximum and minimum air temperature, which allow the thermal extremes recorded over time to be quantified. Minimum and maximum relative humidity are also taken into account, allowing us to understand variations in the water content of the ambient air. In addition, average and maximum wind speeds are considered, as they play a crucial role in influencing weather conditions. The data also includes the duration of sunshine during the day. This measurement is essential for assessing the amount of sunlight received over a period. Sunshine duration is a key factor in understanding solar radiation patterns and the distribution of solar energy over a day. Finally, mean wind direction is also studied to understand atmospheric circulation patterns in the studied region. Analysis of these historical data provides valuable information for evaluating climate prediction models and improving our understanding of local weather conditions. Figure 1 illustrates the variations in maximum and minimum air temperatures over a five-year period, providing essential information on climatic variations, and present an overview of the range of thermal extremes in this specific geographical area.

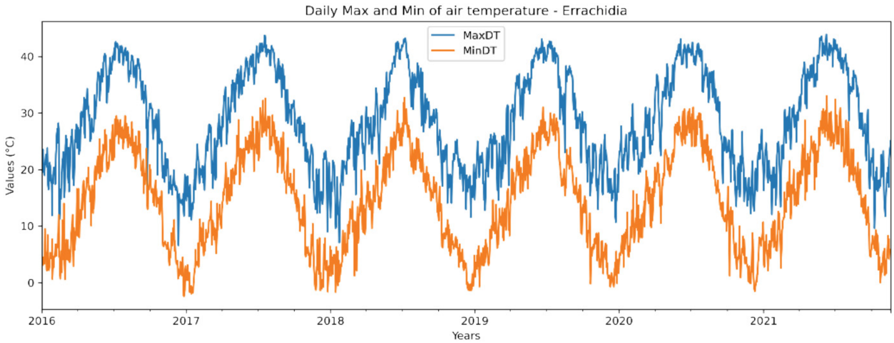

Fig. 1. Daily maximum and minimum air temperatures under Errachidia between 2016 and 2021.

3 Methodology

The CNN-LSTM fusion method is a highly effective approach for prediction tasks that combine recurrent neural networks and convolutional neural networks. This approach exploits the advantages of each unit to capture spatio-temporal patterns in the historical data. CNNs are well suited to extracting features from structured data such as images [10], while LSTMs are effective at modeling temporal dependencies from sequences [11]. The combination of CNN-LSTM allows for the learning of intricate spatial and temporal features, making it a robust approach for forecasting. Feature selection based on correlation can be valuable in prediction and analysis, as it identifies variables that are highly likely to directly or indirectly influence the target variable. Using this approach, we can reduce data complexity by retaining only the most relevant features, which facilitates model interpretation and can improves prediction algorithms' performance. The degree of correlation between the input variables and the target variables is shown in Fig. 2. While the architecture of the proposed CNN-LSTM model is mapped out in Fig. 3. Overall, we used a 7-day (window_size = 7) past history to predict the maximum DTmax and minimum DTmin temperatures on the 8th day. A key advantage of our approach is the automatic feature extraction from multivariate historical data, made achievable through the use of CNN layers. Our CNN model consists of two 1D convolution layers with a kernel of size (2x2). While the LSTM model captures temporal dependencies with 250 neurons and a 'relu' activation function [12]. Finally, with the Dense layer, we obtain accurate predictions for the target variables Maximum Daily Temperature (MaxDT) and Minimum Daily Temperature (MinDT).

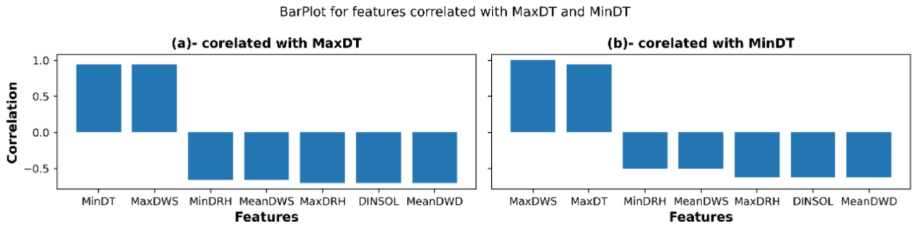

Fig. 2. Bar chart of features correlated with MaxDT (a) and with MinDT (b).

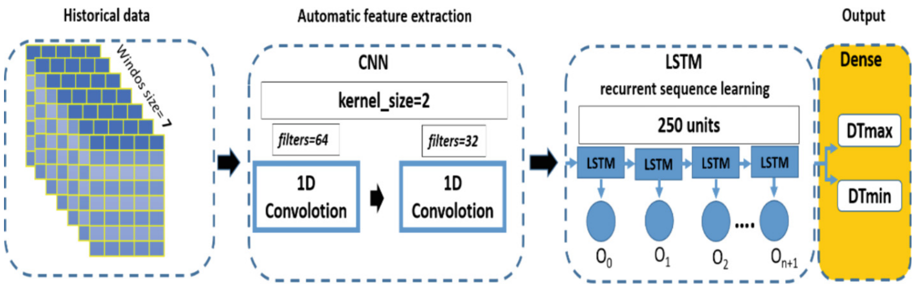

Fig. 3. Architecture of the proposed CNN-LSTM.

4 Results and Discussion

Table 1 presents an early comparison of the results obtained by the model in different learning phases: training (4000 days), validation (300 days), and testing (884 days). Using the RMSE, the MAE, and the R coefficient as evaluation criteria [13], the results indicate that the CNN-LSTM combination performs stably and significantly in all the phases considered for both target variables. In the test phase, model performance metrics were calculated to assess the predictive accuracy of the maximum MaxDT and minimum MinDT temperatures. In this case study, the RMSE obtained for MaxDT is 2.48 °C. For MinDT, the RMSE is 2.08 °C. In contrast, the MAE is 1.90 °C for MaxDT and 4.39 °C for MinDT. Despite the notable difference in the MAE between MaxDT and MinDT, the coefficient of determination R is almost identical for the two variables. The coefficient of determination evaluates the proportion of variance explained by the model in relation to the total variance of the data. In this case, R exceeds 96%, which suggests that the model is able to explain close to 96% of the variance in the data for the maximum and minimum temperatures. However, the values of the metrics are not sufficient to make a decision on the quality of the predictions. Figure 4 shows the predicted values compared with the actual values, accompanied by the linear regression established in the test phase for each variable.

These results show that the proposed CNN-LSTM model has a significant predictive capability for both variables, despite potentially different MAE for MaxDT and MinDT. The high value of R also indicates a satisfactory fit of the model to the actual data, which is demonstrated by the graphical presentation of the predicted and actual values in Fig. 4(a) and (b) and by the fitted linear regression in Fig. 4(c) and (d).

Table 1. Performance measures calculated in three learning phases.

Phase	Training			Validation			Testing		
Metrics	MAE	RMSE	R	MAE	RMSE	R	MAE	RMSE	R
MaxDT	1.37	1.86	97.63	1.63	2.10	95.57	1.90	2.48	95.99
MinDT	2.34	1.53	98.43	4.02	2.00	96.02	4.39	2.08	96.93

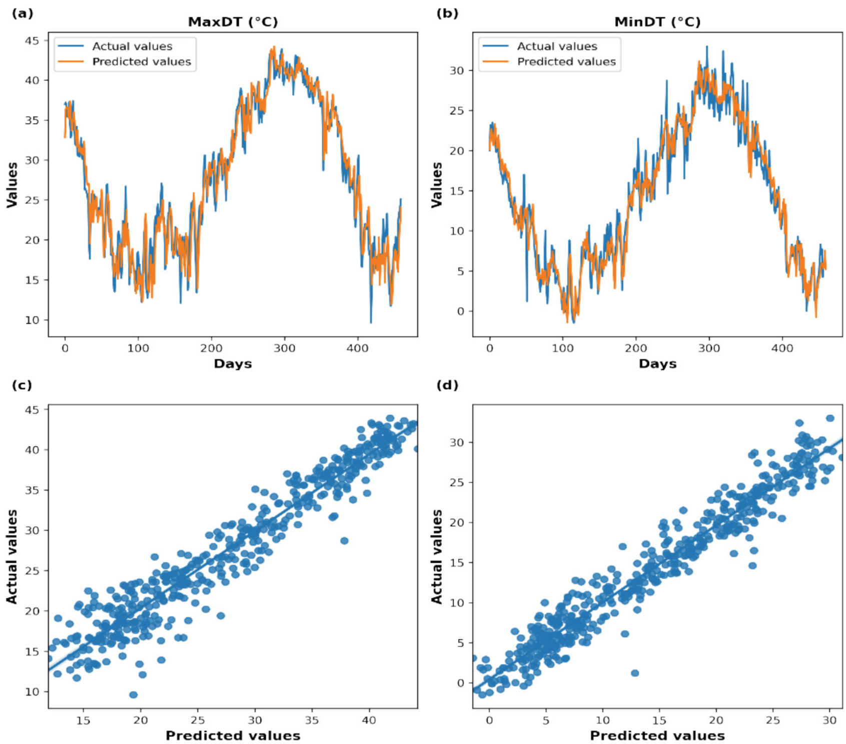

Fig. 4. Stacked values of predicted and actual MaxDT(a) predicted and actual MinDT (b), linear regression of predicted and actual values (c) for MaxDT (d) for MinDT.

5 Conclusion

The use of DL techniques to predict maximum and minimum temperatures during the daytime offers new perspectives and significant improvements over traditional approaches. Deep neural networks can capture the complex, non-linear relationships between meteorological variables and are capable of taking into account both temporal and spatial variations in the data. In this work, we constructed a hybrid CNN-LSTM model to predict daily extreme temperatures in the Errachidia region. Hence, it is possible to obtain more accurate and reliable forecasts of maximum and minimum temperatures with an RMSE of 1.96 °C and 1.96 °C for MaxDT and MinDT and an R coefficient of around 96.9% for the two important climatic variables.

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A Novel Approach for Arabic Character Recognition Using Hybrid SIFT-SVM

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Abstract. For more than three decades, recognizing handwriting has been a desirable goal for people looking to enter data into computer systems. The emergence of handwriting recognition technology is keenly anticipated across various fields. For several years, OCR systems have allowed computers to view characters as images and retrieve information about their distinct characteristics. Indeed, according to Arabic writing, which has benefited from a few researches. The main stage of identifying individual characters involves the use of machines to analyze hand-written documents. The identification of isolated Arabic characters is the primary focus of this research. The recognition of Arabic characters holds significant importance in the domain of computer vision, as it is crucial to accurately identify and categorize manuscript Arabic letters and characters. The objective of this paper is to propose a fresh methodology, which involves the utilization of Scale Invariant Feature Transform (SIFT) features of Arabic characters, Moreover, the Bag of Visual Words (BoVW) approach is used to classify the characteristics. Then those characteristics are grouped using K-means clustering in order to create a dictionary. The following stage involves using the Support Vector Machine (SVM) technique to categorize the word images in the codebook that was produced from these visual representations.

Keywords: Optical Character Recognition (OCR) · Feature Extraction · SIFT · K-means

1 Introduction

The calligraphy of Arabic is highly researched because of its complex cursive style and the morphological changes that characters display as a result of their placement inside words. Due to the usage of the Arabic language, which has over 422 million speakers worldwide, this issue has made some progress, but is still only partially resolved [1], The cursiveness and variety of letter patterns found inside words in Arabic handwriting make it difficult to read. Despite the offer of various strategies, successful outcomes remain elusive for this objective. Several of these techniques, which were first developed for Latin and Chinese characters, are not suitable for Arabic script and require extensive adaptations. In Arabic character recognition, it is crucial to extract distinctive features or primitives. By producing descriptive representations, often in the form of vectors,

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this procedure aims to characterize characters, words, or subwords. The main objective of these representations is to ensure that they are both original and reproducible, which allows for precise character recognition [2, 3].

The main purpose of this research is to enhance the accuracy and efficiency of identifying isolated Arabic handwriting. The aim of this study is to evaluate and examine the efficacy of the Scale Invariant Feature Transform (SIFT) technique [4], which is recognized for its resistance to various distortions. Recognition is achieved through the use of a Support Vector Machine (SVM) classifier and the Bag of Words (BOW) method. To ensure the proposed approach's practicality and effectiveness, the study takes into account the distinct features of Arabic script. This paper is organized as follows in the sections that follow: A complete review of pertinent literature in this field is given in Sect. 2, followed by an explanation of the method we propose in Sect. 3, a description of the experimental setup and outcome analysis in Sect. 4, and a detailed discussion of the experimental results. Section 5 provides an overview of the paper's main results and conclusions.

2 Related Work

In accordance to our suggested method, we have carried out a number of interesting recent research focusing on Arabic character analysis and feature extraction. This article [5] Performance and applicability of different window-based descriptors for Arabic handwritten letter recognition are thoroughly compared. Local Binary Patterns (LBP), GIST, SURF (Speeded Up Robust Features), and Scale Invariant Feature Transform (SIFT) are the descriptors that are being examined. In order to address the unique difficulties associated with Arabic handwritten letter identification, the study seeks to offer insightful information about how well these descriptors work. A comprehensive experimental evaluation is conducted to assess the performance of various descriptors in conjunction with multiple classifiers Examples of methods taken into account in the study are Support Vector Machine (SVM), Logistic Regression, and Artificial Neural Network (ANN). This study is hampered by its use of a small-scale dataset, which affects the ability to generalize results. we also find that these methods are used separately, the article [6, 13] presents a new recognition system using Scale Invariant Feature Transform (SIFT) descriptors for Arabic handwriting recognition The approach divides images into five vertical frames so that training and testing images may be compared segment by segment. To examine the similarity of matching segments and help determine how similar they are, the Euclidean distance metric is employed. The algorithm then classifies the testing image based on the closest training image's class and the derived similarity measure. In the same contexts, the research described in the paper [7] suggests employing texture characteristics in a comparative study to identify Arabic handwritten words. The methodology employed consists of five fundamental steps: pre-processing, representation, segmentation, feature extraction, and classification. In order to depict the image of the handwritten text, the researchers employed Local Binary Patterns, Gray Level Co-occurrence Matrix, and Multi Level Local Phase Quantization descriptors. Furthermore the paper [8] offers two efficient methods to improve the recognition rates of Arabic handwritten characters: Spatial Distribution of Pixels (SDP) and Local Binary Patterns (LBP). The Arabic portion of the Isolated Farsi Handwritten Character Database was used to evaluate these techniques. The process entails segmenting the image, generating local binary pattern histograms within each segment, then merging these histograms to form a feature vector. A neural network classifier uses this feature vector as input. Correspondingly, the study [9] investigates the same issue. The purpose of this article was to develop a method for recognizing isolated Arabic handwritten characters that takes into account their spatial and textural aspects. For the purpose of extracting features from character images, the authors presented a modified Bitmap Sampling approach in conjunction with Local Binary Patterns (LBP). They then compared the performance of these two methods and investigated their combination. The experimental results showed that their proposed method achieved high recognition accuracy on the Isolated Farsi/Arabic Handwritten Character Database (IFHCDB) dataset. Previous research addressed similar objectives using various methodologies of characteristic extraction,In the same field, the article [9] proposes a methodology for recognizing isolated Arabic handwritten characters using an Artificial Neural Network (ANN) as a classifier. To successfully capture the textural properties of the characters, this study's methodology combines binary matrices with histograms of Local Binary Patterns (LBP). The study allows for the same evaluation of both issues by combining the results of these two methodologies.

3 Materials and Methods

3.1 Dataset

We evaluated the effectiveness of our methods by analyzing the AHCD1 dataset that was obtained from Kaggle [10]. There are 16,800 Arabic characters in this collection, which are divided into 28 different classes. It is divided into two subsets: 3,360 characters (120 images per category) in the testing set and 13,440 characters (480 images in the training set).

3.2 Scale Invariant Features Transform (SIFT)

In 2004, David Lowe invented the Scale-invariant feature transform (SIFT) [4]. This approach generates invariant descriptors from images that can withstand frequent geometrical changes and images. Scale-invariant feature transform (SIFT) begins with key point detection and associated descriptor extraction.

Principle of the SIFT algorithm:
The algorithm main computation steps are:

- *Scale-space extrema detection:* The DoG function is applied across scales and picture locations first to find spots of interest that are scale- and orientation-invariant.:

$$\mathbf{D}(\mathbf{x}, \mathbf{y}, \boldsymbol{\sigma}) = \mathbf{L}(\mathbf{x}, \mathbf{y}, \mathbf{k}\boldsymbol{\sigma}) - \mathbf{L}(\mathbf{x}, \mathbf{y}, \boldsymbol{\sigma}) \tag{1}$$

$$\mathbf{L}(\mathbf{x}, \mathbf{y}, \boldsymbol{\sigma}) = \mathbf{G}(\mathbf{x}, \mathbf{y}, \boldsymbol{\sigma}) * \mathbf{I}(\mathbf{x}, \mathbf{y}) \tag{2}$$

The Gaussian functions are used to convolve the input image I(x, y) using the scales and k to create two images, L(x, y, σ) and L(x, y, k σ). I(x, y) is the input picture, and G(x, y, σ) Standard deviation-adjusted Gaussian function is written as

$$\boldsymbol{G}(\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{\sigma}) = \frac{1}{2\boldsymbol{\pi}\boldsymbol{\sigma}^2}\mathbf{exp}\left[\frac{\mathbf{x}^2 + \mathbf{y}^2}{\boldsymbol{\sigma}^2}\right] \tag{3}$$

- *Key point localization:* In the second algorithmic stage, the DoG image and 26-pixel neighborhoods are compared, with extreme locations chosen based on grayscale values and distortion resistance being examined.
- *Orientation assignment:* The third step of SIFT involves calculating key point orientations using gradient directions, ensuring they are transformation-invariant. Gaussian-smoothed picture data is used to construct gradient orientation histograms for important points based on nearby points.

Module of gradient:

$$\boldsymbol{m} = \sqrt{(\mathbf{L}(\mathbf{x}+1, \mathbf{y}) - \mathbf{L}(\mathbf{x}-1, \mathbf{y}))^2 + (\mathbf{L}(\mathbf{x}, \mathbf{y}+1) - \mathbf{L}(\mathbf{x}, \mathbf{y}-1))^2} \tag{4}$$

Gradient direction :

$$\boldsymbol{\theta}(\mathbf{x}, \mathbf{y}) = \mathbf{tan}^{-1}\left(\frac{\mathbf{L}(\mathbf{x}, \mathbf{y}+1) - \mathbf{L}(\mathbf{x}, \mathbf{y}-1)}{\mathbf{L}(\mathbf{x}+1, \mathbf{y}) - \mathbf{L}(\mathbf{x}-1, \mathbf{y})}\right) \forall(\mathrm{x},\ \mathrm{y}) \text{ in a neighborhood } (\mathrm{x0},\ \mathrm{y0}) \tag{5}$$

- *Key point descriptor:* 128-dimensional vector is used to generate a local characteristic descriptor close to critical spots to uniquely characterize their surroundings. By utilizing the local picture gradient and adjusting it dependent on the direction of the key point, this descriptor maintains orientation invariance.

3.3 Support Vector Machine (SVM)

The Support Vector Machine (SVM) algorithm [11] introduced by Vapnik [12], is a supervised learning technique designed to classify data correctly. Using a high-dimensional space and a hyperplane, SVM effectively divides the data into distinct classes.

3.4 Proposed Methodology

In this study, we have developed an innovative method for identifying Arabic characters by combining the Scale Invariant Feature Transform (SIFT) and Support Vector Machine (SVM) algorithms in our study. This method is based on the visual bag-of-words model, which consists of three main modules: feature extraction, Bag-of-Words (BoW) construction, and SVM classification. We aim to evaluate the performance of BoW paired with SIFT and k-means clustering in feature quantification. We use the SVM classifier to enhance accuracy by guaranteeing accurate feature extraction, effective representation, and dependable classification techniques. Figure 1 illustrates the overall system for Arabic handwritten character recognition. The process begins by extracting features using the SIFT method and then selects the most intriguing features for a visual word collection using a percentage parameter. The dimension can be reduced by using K-means clustering. These processed features are employed to train the SVM classifier that classifies histograms from test images during system deployment.

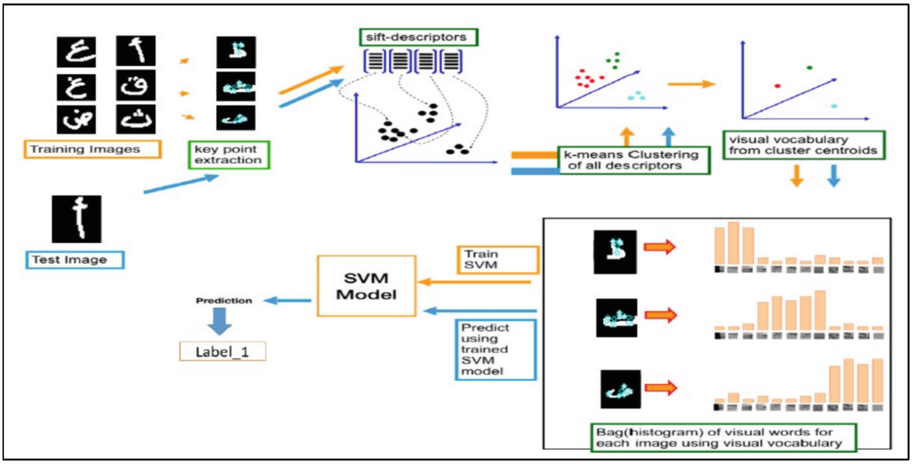

Fig. 1. A general description of the proposed method.

4 Results and Discussion

On a computer with an Intel processor and 8GB of RAM, algorithms are executed using Python's image processing features. Through tests on an Arabic character wheat picture dataset (AHCD1), evaluating classification performance with a multiclass SVM, the originality of the suggested technique is proven. For a comprehensive analysis, two separate experiments were carried out:

In the initial experiment, the dataset was used without any preprocessing. As indicated in Table 1, the test set was used to predict image classes, including those with geometric modifications such 90° and 180° rotations. The results of the subsequent experiment, which employed the identical parameters and a Gaussian filter of size (5.5), are shown in Table 2 and are summarized below.

Table 1. Sample class prediction for Experiment 1

Image test	True class	Predict class	Observation
 test 1	label_15	label_15	Test= ض result= ض “Positive”
 test 2	label_22	label_7	Test= ك result= د “Negative”
 test 3(rotation 90°)	label_1	label_1	Test= ا resultat= ا “Positive”
 test 4 (rotation 90°)	label_17	label_17	Test= ظ result= ظ “Positive”

Table 2. Sample class prediction for Experiment 2

Image test	True class	Predict class	Observation
 test 1	label_16	label_16	Test= ط result= ط “Positive”
 test2(rotation 180°)	label_28	label_28	Test= ي résultat= ي “Positive”
 test 3	label_26	label_22	Test= ه résultat= ك “Negative”
 test4	label_6	label_6	Test= ح résultat= ح “Positive”

The following table depicts an evaluation of the model’s accuracy (Table 3).

Table 3. Model’s comparison table.

model	Accuracy
Without data processing	53.28%
Application of a treatment	62.53%

The system originally identified handwritten Arabic letters at a rate of 53.42%, although recognition rates for other characters varied depending on their complexity and shape. After manipulating the database, the accuracy improved to 62.53%, demonstrating higher functionality even with rotated test photos. Significant improvements in performance were observed in the following experiment, which resulted in a recognition rate of 62.60%. To evaluate performance, the confusion matrix, which displays the average classification rates for categories, was utilized. The model’s accuracy in the first experiment was 53.28%, with training set accuracy of 76.96% and test set accuracy of 53.28%. In the second trial, accuracy rose to 62.53%, with a test set accuracy of 62.52% and a training set accuracy of 90.65%, all in a shorter runtime of 12 min (Fig. 2).

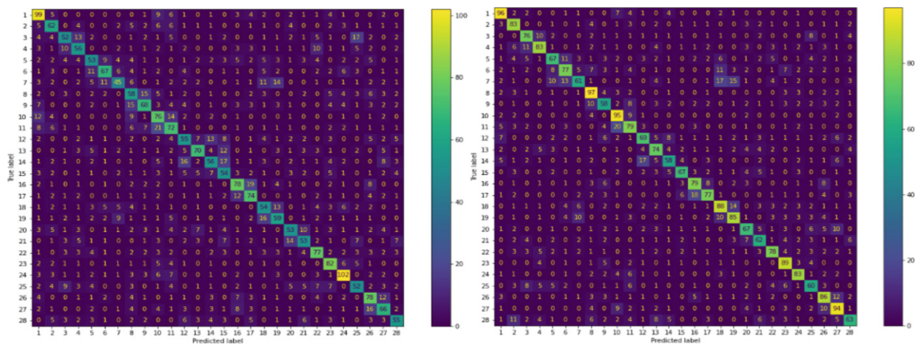

Fig. 2. Confusion matrix

5 Conclusion

The study utilizes the SIFT approach to extract feature points, which are then clustered with K-means and classified using Support Vector Machines (SVM). Despite the challenges of visual rotation and lighting changes, it is still durable. Future work will involve expanding to complete character classes, working with larger databases, and examining features that can improve accuracy, such as modifiers and better feature extraction.

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An Advanced Modified Freeman Chain Code Algorithm for Enhancing Arabic Character Recognition

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Abstract. An important challenge in the process of understanding and analyzing writing in Arabic is the recognition of Arabic characters. This article describes an enhanced algorithm aimed at creating Freeman code based on handwritten Arabic letters. This code takes into consideration all variations of handwritten Arabic characters and offers the shortest code length without losing any character information. To exploit the code produced by our improved algorithm, we evaluated this code using a collection of Arabic characters in different formats to recognize Arabic characters. Additionally, we compared our Freeman code with codes produced in other similar works. As a result, the code we received accurately depicts the Arabic character in all of its forms, including those that were not taken into account by the algorithms in previous articles. Therefore, our creative approach based on Freeman coding represents an important step in the recognition of Arabic characters. Additionally, our approach offers an efficient way of representing and classifying Arabic characters.

Keywords: Freeman Chain Code · handwritten Arabic characters

1 Introduction

The importance of writing recognition extends to various domains of our society, including tasks like preserving historical documents and facilitating automated translation processes. One of the many systems for recognizing handwritten characters that currently exist in the system for recognizing handwritten Arabic characters, which is a difficult problem because of the cursive form and variety of handwritten Arabic characters. However, despite its importance, Latin character recognition has gotten considerably more research and attention than Arabic character recognition [1].

In this paper, we present an enhanced Freeman encoding designed for Arabic character recognition. Our approach attempts to address the specific issues brought on by the complexity of Arabic letters as well as improve the accuracy of the existing recognition algorithms.

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The structure of the article is as follows: In the second part after the introduction, we review the features of Arabic writing and we explain the various phases of a handwritten character recognition system, concentrating on the feature extraction phase and related works. The third part discusses our proposed method. The tests and results are presented in the fourth part. We finish with a conclusion.

2 Recognition of Handwritten Arabic

2.1 Characteristics of Arabic Writing

Arabic writing differs from other writing systems in several characteristics [2, 3]. The following are some of the main features of Arabic writing:

- There are 28 distinct characters in the Arabic alphabet.
- Right to left is the standard direction for Arabic writing [4].
- The dots are a crucial feature that differentiates Arabic writing different from other writing systems [5].
- As shown in the letter "ط"several Arabic letters have looping forms.
- The Arabic language is classed as having a cursive script, which is distinguished by joined letters inside words.

2.2 System for Recognizing Handwriting

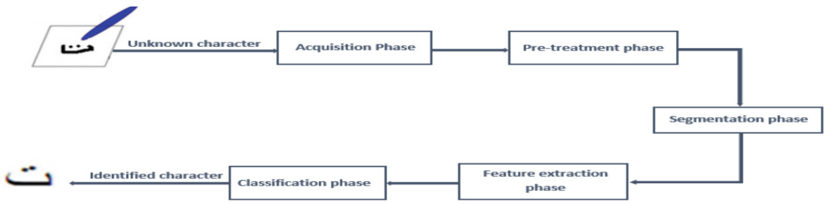

Fig. 1. A Standard Recognition of Handwriting System.

The process of identifying the Arabic letters or words displayed in a digital picture of handwritten text is known as handwritten Arabic recognition. The standard handwriting recognition system is structured as follows, as seen in Fig. 1:

- Acquisition Phase: The process of acquisition includes converting a paper document into a digital picture.
- Pre-treatment phase: decreases noise that is overlaid on the data, and improves writing, smoothing, normalizing, and skeletonization.
- Segmentation phase: text cut out in words or symbols.
- Feature extraction phase: The shapes obtained from the segmentation procedure are represented in coded form by the feature extraction.
- Classification phase: the process of labeling or categorizing handwritten letters or words according to their visual characteristics.

2.3 Models for Extracting Features

One of OCR's (Optical Character Recognition) most challenging and crucial processes is feature extraction. It is crucial since it would be challenging to carry out efficient recognition if it was improperly constructed. Four major categories of characteristics may be distinguished: structural features, statistical characteristics, global transformations, superposition of the models, and correlation [6]. The Freeman code is considered one of the special methods employed in this field which is employed in OCR techniques for the extraction of features.

We will review some research related to the Freeman coding method in the section that follows.

2.4 Related Work

In terms of the approach we provide, this study can be seen as a development and extension of other efforts that have applied this approach to the recognition of Arabic characters. The following are a few of these pieces: In 2017, research conducted by [7] developed a technique for recognizing Arabic characters written by hand using Freeman coding. The same goal was served by other previous work using Freeman coding, like [8] explains an OCR technique that uses template matching and the Freeman chain code to recognize handwritten, isolated Arabic characters. Also, [9] demonstrates a method for recognizing isolated Farsi/Arabic characters that combine a chain code algorithm with more characteristics like dots, auxiliary components, and holes. Moreover, [10] presents a method for determining similarity in written characters that combines structural information and the Freeman code. Hence, in the part that follows, we will provide our methodology.

3 Our Proposed Method

3.1 Extraction of Feature

The extraction of Arabic characters is one of the main areas of research in the field of automatic recognition of this complex language. This method involves analyzing the shape curves and characteristic points of the Arabic characters to represent them numerically and accurately. For this, we proposed adding a vector of four elements. We assign to element p1 a value that denotes the number of points of each character, and for element p2, we will register the position of the points, using the value 1 to indicate that point above the character. The value 2 indicates that the point is under character the value 0 indicates that there is no point. In the third element, p3, we will register the number of holes. Thus, the normalized code of the Arabic character is in the fourth element.

$$P = [P1,\ P2,\ P3,\ \text{normalized code}] \tag{1}$$

3.2 Freeman Chain Code

We present a new method dependent on the Freeman chain code for the recognition of isolated handwritten Arabic letters. The Freeman chain code, which is referred to as Freeman coding, is an approach to encoding the contours of objects in an image. Freeman chain code depends on the concept of encoding a contour as an ordered series of directions. It employs a collection of discrete directions, typically comprising various possible moves in an 8-neighbor grid. These directions are numbered from 0 to 7, with each number representing a different direction [11]. As seen in Fig. 2(a). To represent a contour using Freeman encoding, we start by selecting a starting point on the contour. Then we follow the contour by saving the directions taken during each step. The recorded direction sequence constitutes the Freeman chain, which represents the contour [12]. As seen in Fig. 2(b).

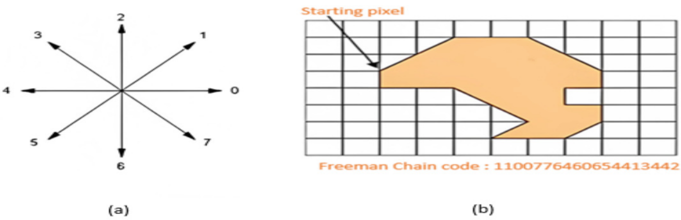

Fig. 2. (a) 8-connectivity of the Freeaman chain code. (b) An example of an "8-connectivity" Freeaman chain of code

3.3 Freeman Code Normalization

After extracting the Freeman code of the Arabic character, we necessary to normalize this code. As a result, our approach is based on limiting the length of the offered Freeman code. If the code is smaller than 10, zeros are added at the end of the code to obtain a length of 10. We calculate the frequency of occurrence of each direction in the code if the code is larger than 10. Then, the directions are arranged in descending order of frequency, and the 10 most frequent directions are chosen. The Freeman code is then modified to contain only the 10 chosen directions. Finally, The Freeman code has been completed with zeros at the end to make it a total length of 10. This normalization offers a standard Freeman code that effectively represents the most frequent directions.

4 Tests and Results

We performed tests to evaluate the performance of our Freeman coding method to recognize Arabic letters. Thanks to the vector that was used in the extraction of features, we obtained two results:

- First result: classify characters into nine classes using the first three vector characteristics. Table 1 shows the classification of Arabic characters.

Table 1. Arabic Characters Divided Into Nine Groups.

	P= (P1, P2, P3)	Character
1	P= (0, 0, 0)	ا ح ص ك ل م ه د ع ر و ط س
2	P= (1, 1, 0)	خ غ ز ذ ن
3	P= (1, 2, 0)	ج ب إ
4	P= (1, 1, 1)	ض ظ ف
5	P= (2, 2, 0)	ي
6	P= (2, 1, 0)	ت
7	P= (2, 1, 1)	ق ة
8	P= (3, 1, 0)	ش ث
9	P= (0, 0, 2)	هـ

- Second result: By counting the number of holes in each letter, we could solve the problem of confusion between the « هـ »character and the « مـ »character during the recognition phase, as the algorithm only offers the Freeman code for the perimeter of the Arabic character. Thus, we found two holes for the letter " هـ "and one for the letter "مـ ".

As we mentioned earlier, it is necessary to normalize the Freeman code. Then, the following Table 2 shows the freeman code normalized for some Arabic characters handwritten.

Table 2. Results Achieved by Using a Few Handwritten Arabic Characters

Arabic character	Image of Arabic character	Normalized Freeman code
أ		3407521600
ب		3726405100
د		3104527600
ر		3704261000
ص		3702465100

Table 3 presents the normalized Freeman code of three examples of the «ل»character written in various forms. The results show that our normalization method gives a similar code despite the differences in writing.

Table 3. Results of Application of the Recommended Method.

Image of Arabic character	Normalized Freeman code
	2615374000
	2613574000
	2651374000

5 Conclusion

Our research focuses on the precise extraction of Arabic handwriting characters. To achieve this, we developed a novel technique that combines normalized Freeman code with diacritical features. Our study makes a significant advancement in the normalization of the Freeman code, which reinforces the method we use. We were able to categorize letters into 9 different groups by using diacritical features. Also, we could solve the problem of the « ـهـ »character and the «ـمـ»character being confused during the recognition phase. Moreover, our normalization method gives encouraging results.

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Impact of Consumer Behavior Modeling on the Marketing Performance of Moroccan Companies

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Abstract. In an environment that is characterized by the digitalization of processes, data science, big data, the omnipresence of several consumer profiles, and the massive use of intelligent IT applications, modeling consumer behaviors has become a new approach that makes it possible: to identify the needs of these rational economic agents, as well as the factors that can influence their purchasing decisions; define the best strategy to capture their attention; and better understand the way in which these consumers targeted by companies perceive all the information circulating in such a competitive environment. By acting in this manner, the business can then exhibit marketing performance, which is exemplified by, among other things, effective and flexible marketing strategies, targeting the right consumers with effective advertising at the right time, planning and implementing a better marketing mix policy, consolidating successful business relationships that connect the company with a particular customer category, optimally allocating financial and human resources, and ensuring the satisfaction and loyalty of these consumers.

Keywords: Behavioral modeling · Intelligent IT applications · Marketing performance · Digitalization of processes · Big Data

1 Introduction

Several researchers and marketing specialists have been interested in highlighting the major contributions of investment in the modeling of consumer behavior, which will benefit companies that are always keen to seek the best avenues to follow and to demonstrate creativity and innovation in order to continue to exist as long as possible in a market that is constantly changing. Among these specialists, we find Kotler and Keller (2012) and Schiffman et al., 2012. Thus, according to (Kotler & Keller, 2012), modeling consumer behavior allows companies to identify the factors that influence the purchasing decisions

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made by the latter and to develop effective marketing and commercial strategies. (Schiffman et al., 2012) for their part emphasized the approaches to be used to model consumer behavior, in particular the theory of marginal utility, the theory of expected utility and the theory of prospective decision. According to these two specialists, these approaches rely on assumptions about consumer preferences and behaviors that can be used to predict future purchasing decisions and behaviors. In this same context, it emerges from the majority of research work relating to the modeling of consumer behavior that by using these models, companies can better target the best marketing and sales strategies to define and implement and which must be oriented towards the consumer segments most likely to purchase their products or services. These companies can also use these models to evaluate the effectiveness of their existing marketing and sales strategies and develop new ones. Furthermore, it is also clear that by being able to understand and anticipate consumer behavior and adapt accordingly, companies can differentiate themselves from their competitors, improve customer satisfaction and loyalty and increase their market share and profitability. From another angle, we can also deduce that despite the very limited number of studies carried out in Morocco relating to the modeling of consumer behavior and its impact on the marketing performance of companies, studies developed by authors such as (Georges & Badoc, 2010) & (Viot, 2016) suggest that this modeling can be seen as a useful tool for Moroccan companies wishing to improve their commercial and marketing performance. Based on this study, we can then conclude that consumer behavior modeling is considered a relevant practice capable of improving and strengthening the marketing performance of companies that constantly operate in an environment characterized by increased competition exerted by other competitors and which is also marked by a rapid evolution of consumer preferences. Indeed, based, for example, on information drawn from past consumer behavior, companies can create models to better understand the preferences, needs, and expectations of these rational economic agents and to study and analyze how these individuals make their purchasing decisions and choices? and finally, how do they interact with brands? Consumer behavior modeling also allows businesses to predict future consumer behavior, especially when it comes to the types of goods and services they might purchase in the future. Thus, companies are able to better define flexible and effective marketing strategies and, in the same sense, target and adapt effective advertising campaigns that are likely to promote a better return on investment, thanks to this modeling's ability to understand the purchasing behavior of such an autonomous agent and its decision-making process, as well as the possibility of predicting its choices and future decisions. This research, which is the subject of this article, is therefore descriptive and analytical in nature and aims to answer the following main question: **To what extent could modeling consumer behavior allow Moroccan companies to improve their marketing performance?**

2 Usefulness of Consumer Behavior Modeling for Businesses and Its Impact on Their Performance

Among the researchers who have focused on studying the relationship that exists between the modeling of consumer behavior and the marketing performance that companies that constantly operate in a market that is constantly changing seek to achieve at all costs, we find: Lilien et al. (1983), Dahlén & Nordfält (2004), and Gensch et al. (2005).

Thus, for researchers such as (Lilien et al., 1983), modeling consumer behavior allows marketers to better understand consumers' interest in different brands, and this is done by taking into consideration different factors such as age of the buyer, color preferences, desired brand, preferred engine, and seasons (if it is, for example, products like cars) and therefore predicting sales and market trends. These same researchers also explain to us that through this modeling, companies will be able to optimize their marketing mix and better understand how the different elements of the latter, such as price, product, communication, and distribution, influence the behavior of consumer purchasing, therefore allowing these entities to adjust their predefined marketing strategy.

For other specialists such as (Dahlén & Nordfält, 2004), consumer behavior modeling allows companies to identify the main purchase triggers for their consumers, to better understand who their target customers are and how to reach them effectively, and therefore to be able to easily target their advertising and marketing campaigns.

Finally, for authors such as (Gensch et al., 1990), the use of this modeling of consumer behavior allows companies to develop new products that meet the real needs and preferences of customers.

2.1 Definition of the Concept of Consumer Behavior Modeling

Several definitions have been given to this concept of consumer behavior modeling, the main ones being as follows:

Consumer behavior modeling is the study of how individuals, groups and organizations select, purchase, use, evaluate and exchange products, services, experiences, ideas and resources to satisfy their own needs and desires (Peter & Olson, 2010).

It is also the study of the consumption decisions of individuals and groups, and which also aims to predict and influence these decisions (Hawkins & Mothersbaugh, 2016).

In the same framework and referring to authors such as (Schiffman & Kanuk, 2007), (Solomon & Rabolt, 2004), we can also deduce that thanks to this modeling, companies seek to study how individuals, groups and Organizations choose, purchase, use products, services, brands and information sources to create, maintain and improve their well-being and satisfaction.

In addition and according to the Organization for Economic Co-operation and Development (OECD), we can also see that consumer behavior modeling consists of "describing and explaining consumer choices in terms of goods and services, taking into account their preferences and constraints.

For its part, the International Marketing Association (IMA) considers that consumer behavior modeling aims to "understand and predict purchasing decisions, consumption behaviors and responses to marketing stimuli".

Finally, according to the Journal of Consumer Research, consumer behavior modeling is "the study of how individuals, groups and organizations choose among alternative products, services and experiences available on the market. ".

2.2 Marketing Performance: A Major Challenge for Businesses in a Constantly Changing Competitive Environment

Based on the fact that marketing performance is linked to a set of marketing techniques that make it possible to measure the results of a campaign and attribute its performance to the different channels according to the results obtained, within the framework of this article we have therefore ensured to emphasize this results-oriented approach, which thus allowed us to extract the following main definitions of this concept:

According to (Scott, 2017), performance marketing is a marketing strategy focused on achieving measurable results and continually optimizing campaigns to achieve these goals.

In the same sense we can also say that marketing performance is a marketing strategy that aims to achieve specific objectives by using specific measurement methods to evaluate the effectiveness of marketing efforts" (Forbes Agency Council, 2017).

Neil Patel (2021) finally considers marketing performance as: a results-oriented approach that aims to maximize the returns on investment (ROI) of marketing efforts by measuring and optimizing campaigns according to their effectiveness.

2.3 The Main Determinants of Company Marketing Performance

Several marketing specialists have also been interested in defining and delimiting the main determinants of this concept of the marketing performance of companies, among which we cite (Sittisom et al., 2020), (Bendle, 2016), (Farida, 2016)).

Thus, based, for example, on Sittisom et al., (2020) and Bendle, (2016), we can see that among the main factors explaining this concept of marketing performance, we find the quality of market segmentation and the quality of the strategy positioning.

On the other hand, based on Farida, (2016), we can also deduce that there are several factors likely to positively influence the marketing performance of companies, among which we cite:

- The quality of the defined marketing strategy, which must be adapted to the needs and objectives of the company
- The quality of customer relationship management, which must be oriented towards customer satisfaction and loyalty
- Marketing innovation
- The quality and effectiveness of the marketing communication strategy
- The quality of human resources and working conditions.
- The management style adopted by the company
- The ability of a leader to take risks and take initiatives.
- Human resources and skills management.
- The size and structure of the company

3 Research Methodology

In order to answer our main question, the subject of this research work, which we asked at the beginning of this article, we then based ourselves on a mixed data collection method, and the data analysis was carried out by factorial correspondence analysis supplemented by dynamic cluster analysis in two classes. In addition, the processing of the collected and analyzed data was carried out via SPSS. It is also important to specify that, in order to answer this question, we established the following three hypotheses:

- Modeling consumer behavior using in-depth analysis of their purchases made in the past and also basing it on IT support and applications is seen as an excellent means for effective marketing positioning.
- Succeeding in developing an attractive personalized product and/or service offering adapted to the real needs of consumers is conditioned today by the ability of a company to understand the behavior of its consumers and to analyze and identify what influences their decision-making process.
- Modeling consumer behavior is a new strategic direction that must now be established in the minds of decision-makers in a Moroccan company in order to enable them to demonstrate a perfect understanding of the real needs of their main targets while also anticipating their expectations and therefore succeeding not only in satisfying them but also in retaining them.

It is also important to point out that once we collected the data from the respondents, we coded and entered it. Subsequently, in order to verify the accuracy and validity of each of our three pre-established hypotheses, we took care to define for each hypothesis two variables as well as the indicators associated with them and which are nothing other than subvariables. By acting in this way and then having recourse to the combined analysis applied to each of the two variables which delimit each hypothesis and by applying to them the Factorial Correspondence Analysis then the analysis in dynamic clusters in two classes we were therefore able to come out with deductions and results approving the validity of each of our three hypotheses and which will be detailed later as part of this modest work.

4 Analysis and Discussion of the Main Results

Our study consisted of highlighting the importance of investing in consumer behavior modeling and in intelligent IT applications, considered today as excellent tools for the marketing performance of Moroccan companies. Based on our analysis of data collected from marketing managers, sales managers, employees and managers working within a sample of companies located in the Darâa Tafilalet region, we were able to achieve the following main results:

- According to 64.25% of people surveyed, modeling consumer behavior has allowed the companies where they work to identify the different personal, psychological, sociological and cultural factors that influence the decision-making process of the latter once arrived and engaged in the market.
- According to 58.3% of respondents, thanks to this behavioral modeling, the companies where they work have been able to define flexible and effective marketing strategies and provide new products and/or services that are adapted to the real needs of customers and which are also in harmony with their expectations.

- 50.62% of those questioned affirmed that, thanks to the study, analysis and understanding of all the data relating to purchasing experiences concluded in the past by the consumer, this modeling allowed the marketing managers to target the best marketing mix policy to implement
- 57.34% of the people surveyed told us that this behavioral modeling allowed marketing managers to know the nature of the products that this autonomous decision-maker wishes to purchase, the timing chosen to make his purchase and his favorite companies with which he decides to buy. These same people add that marketers use this modeling to develop effective marketing plans that target the right consumers with the right advertising message and at the right time.
- According to 56.48% of respondents, consumer behavior modeling was perceived as an effective means and support that allowed marketing managers to design effective and flexible marketing strategies since they can be modified instantly in addition to the advertising message in such a way as to attract each specific group of customers with common characteristics, even if they are geographically dispersed. In other words, this behavioral modeling was considered as a favorable means to serve the segmentation of customers and markets on a behavioral level.
- 61.8% of those surveyed told us that modeling consumer behavior has promoted creativity and innovation to the extent that it has allowed marketing managers to offer consumers a personalized offer of products and/or services adapted to their needs and preferences and that also conforms to their expectations, allowing companies to better satisfy their customers, build their loyalty, and thus increase their sales.
- For 51.6% of the people surveyed, this behavioral modeling allowed marketing managers to extract relevant data relating to consumers' purchasing habits, which was used to set the sales prices of the products they marketed on the market and which have been adapted to the purchasing power of each segment of consumers, that is to say, the prices that these economic agents have been predisposed to pay.
- According to 66.4% of those questioned, the modeling of consumer behavior has made it possible to build consumer loyalty thanks to the development of brand strategies desired by them and which are consistent with their attitudes and perceptions as well as to the dissemination of credible and quality advertising messages.
- According to 39.78% of those questioned, the investment of the companies where they work in this modeling of consumer behavior has caused considerable losses for these entities since their products have not managed to capture the attention of consumers.
- 89.5% of those surveyed are convinced that modeling consumer behavior in a context which is marked by the evolution of the standard of living and the use of computer applications and software by companies has enabled these entities to achieve satisfactory financial results and turnover.
- According to 78.2% of those questioned, the modeling of consumer behavior and which was supported by the use of IT applications and the investment in the digitalization of processes promoted good communication of the company with the consumers, to consolidate the successful business relationships that bind it to them and to win the challenge of attracting a new category of customers.

- For 82.4% of people surveyed, modeling consumer behavior is considered a better way that has allowed the company to effectively analyze the sales trends it seeks to achieve in the medium and long term, therefore offering its rational economic agents attractive commercial discounts as well as high quality products and services.
- According to 90.5% of those questioned, the modeling of consumer behavior and the use of intelligent technologies have enabled the company to demonstrate great speed in its intervention and adaptation to changes in the environment, and it has also enabled it to better organize its human resources as well as the orders that it ensures and which are sent to suppliers on time.
- According to 85.42% of those surveyed, the strategic and operational orientation imposed by these technological advances, especially in a new era marked by artificial intelligence, has allowed companies to better target potential buyers in each market segment.
- According to 95.2% of those surveyed, behavioral modeling helped marketing managers make effective decisions regarding the marketing of new products
- For 79.5% of those questioned, modeling the behavior of such autonomous economic agents is based on the hypothesis that these individuals make rational decisions by evaluating and comparing the attributes or characteristics of different alternatives before making a choice.
- According to 68.6% of respondents, consumer behavior modeling has enabled companies to optimize their product features as well as their marketing strategies and advertising campaigns and effectively allocate the limited resources they have.
- According to 94.75% of those surveyed, modeling consumer behavior helped companies rationally choose the right strategic decisions to implement regarding their entry into new markets, the positioning of their products, and the sales prices to be set for the latter.

5 Conclusion

Moroccan businesses are convinced that in order to maintain their competitiveness for as long as possible, they must exhibit creativity and innovation, particularly when it comes to modeling the behavior of the consumers they are targeting. This is because the business and corporate world of today is characterized by the emergence of new consumer profiles that have different purchasing orientations and who are also influenced by new information and communication technologies. The attainment of this goal is clearly contingent upon not only the utilization of competent and experienced human capital but also computer programs, which are regarded as excellent tools for assisting these organizations in better comprehending the decision-making processes of their customers. In this context, it is therefore clear that in order to continue to face an uncertain competitive environment that is constantly changing, recourse, for example, to investment in artificial intelligence and intelligent technologies has become inevitable and an indisputable reality. Furthermore, by carefully monitoring and thoroughly analyzing the history of all the consumer's past purchases from the company, a marketing manager can now not only identify but also predict the product categories that the customer is accustomed to and regularly purchases, whether through in-person visits to the company's headquarters or online. This marketing manager can therefore predict the future possibilities of action of this rational economic agent by relying on intelligent monitoring assisted by specific software and applications that are oriented towards the habits previously expressed by this autonomous decision-maker, as well as the frequency of his previous purchases made, the dates and amounts of orders and deliveries executed, the preferred payment methods, and the desired quality of products and/or services. Finally, it's important to specify that, as a new results-based approach, behavioral modeling offers businesses a number of benefits that can be summed up as follows:

- Provide a better simulation of how decisions are made by a consumer and the likelihood that a particular consumer will make one choice over another.
- Succeed in a good consumer segmentation policy which makes it possible to classify and organize them according to groups of homogeneous people who share similar habits and purchasing motives.
- Better target a credible, coherent, and adequate advertising campaign that is likely to capture the attention of consumers and where there is a balance between the perceived value, the value expected by them, and the value desired by the company.
- Personalize the product and/or service offering and achieve good marketing positioning.
- The sustainability of the beneficial commercial relationship brings companies together with their main customers, thereby meeting the challenge of customer obsession, which can only be achieved by constantly offering them promotions and discounts to motivate them, satisfy them, and therefore earn their loyalty.

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Artificial Intelligence and Knowledge Management in Business Classification in Latin America

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Abstract. Small and medium-sized enterprises play a crucial role in the industrial sector, contributing significantly to regional economic development. Classification and cooperation among these companies are considered key aspects for the efficient management of value creation processes. In some countries of the region, business classifications show varying combinations, reflecting the diversity of geographical approaches, influenced by factors such as economic structure, government policies and local market characteristics. Diversity presents significant challenges to the consistency of business information and can lead to misdiagnosis and inaccuracies when classifying and comparing business levels across countries. However, the digitization of end-to-end processes, adopting data as the primary source of value, has rendered traditional classification models obsolete. This chapter proposes an alternative for classification and collaboration between competing companies, emerging as critical factors in the advancement of the industrial sector. Addressing this challenge effectively requires an adequate re-presentation based on solid structures based on the theory of resources and capabilities. These structures, enriched with relevant variables derived from data, information, and knowledge from various sources, are subjected to the application of variable engineering. This process, supported by knowledge management and artificial intelligence, culminates in the consolidation of relevant models. From these models, specific indexes and metrics are defined that allow an objective evaluation and a meaningful comparison between companies. This contribution provides substantial value to the scientific and business landscape, highlighting the importance of adapting to the digital era to improve efficiency in management and collaboration in the industrial sector.

Keywords: Cooperation · Classification · Competition · SMEs

1 Importance of Small and Medium Enterprises in the Current Context

Within the international economic landscape, small and medium-sized enterprises (hereinafter referred to as SMEs) are of considerable importance as they make a significant contribution to the business fabric (Espinoza-Gallardo et al., 2023). These companies

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not only con-form an essential component of the economic structure of each country, but also play a crucial role in the dynamics and vitality of society, bringing diversity and flexibility to the global business fabric (Arroio & Scerri, 2018; Gonzalez-Tamayo et al., 2023). Indeed, SMEs are not only limited to being drivers of economic growth in each country, but their participation is essential, as they play a key role in job creation, thus promoting an active and dynamic workforce (Dudauri, 2023). In addition, their active presence in the market contributes to fostering competition, which benefits the industrial sector and consumers by stimulating efficiency and innovation among companies (Moscow State Linguistic University, Moscow, Russian Federation et al., 2023).

SMEs acquire undeniable significance, making up, on average, more than 90% of all business entities in the region (Bekkers, 2019). This business segment has a considerable impact, contributing between 50% and 75% of the total workforce, and its importance lies in its ability to generate wealth, drive Gross Domestic Product (GDP) growth and propitiate job creation (Bekkers, 2019; Bernat et al., 2017; Tleubekova et al., 2021). Concordant with these findings, an additional report corroborates that 99% of duly incorporated companies are classified as micro, small or medium in size (Katarryniuk et al., 2021). These entities, in turn, play a prominent role by generating 61% of formal employment and contributing significantly with 25% of the gross domestic product (Katarryniuk et al., 2021; Viglioni et al., 2020).

Therefore, SMEs stand as crucial entities for the development of countries, especially in developing nations (Khoualed et al., 2023). In this sense, SMEs not only represent fundamental economic actors, but also play a strategic role in building solid foundations for the progress and prosperity of communities (Garcia-Martinez et al., 2023).

The impact of SMEs transcends economic boundaries, as they act as drivers of innovation development. Being agile and flexible, these companies have the ability to adapt quickly to market demands and propose innovative solutions that often trigger significant breakthroughs in various industries (Anning-Dorson, 2021; Khoualed et al., 2023).

SMEs also take an active role in solving social problems. Through corporate social responsibility initiatives and co-community involvement (Passaro et al., 2023), these companies address fundamental social issues, thus contributing to the construction of a more equitable and sustainable society (Moscow State Linguistic University, Moscow, Russian Federation et al., 2023). Indeed, SMEs are driving agents that not only strengthen the economy, but also trigger significant benefits for society as a whole (Alekseievska, 2023; Passaro et al., 2023).

1.1 Digitization of Small and Medium Enterprises in the Current Context

In the current context, characterized by digital transformation, identified as the fourth industrial revolution, entails significant transformations in business models and their performance. The need for SMEs towards digital transformation is supported by the characteristic that new technologies pose significant potential to stimulate in-novation and secure competitive advantage (Vitón-Castillo et al., 2022).

This process not only entails technological transformations, but also establishes a digital innovation ecosystem, conceptualized as interactions between organizations and stakeholders that employ digital technologies to make cooperation effective in competition in an industrial sector. This ecosystem raises the need to adequately characterize the company according to relevant indicators and to participate in a complex network of competitive companies (Khouibiri & Farhaoui, 2023).

Indeed, in this context of technological advancement and the lowering of trade barriers in a scenario of increasing globalization (Bekkers, 2019; Katarryniuk et al., 2021; Valenzuela-Hurtado et al., 2023; Viglioni et al., 2020), the competitive dynamics and, consequently, the interest in the export performance of SMEs has intensified (Malca et al., 2020). In an increasingly interconnected world, where economic boundaries are blurring, it is imperative to direct deeper attention to the characteristics and capacity of SMEs to participate, cooperate and thrive in international markets (Gonzalez-Tamayo et al., 2023; Marzi et al., 2023).

Digital transformation is revolutionizing activities, processes and business modes in general, taking advantage of continuous technological advances. In this context, entrepreneurs must stay abreast of the latest innovations in today's online era. Whether we prefer it or not, Small and Medium Enterprises (SMEs) must have the ability to adapt to this technology to ensure the continuity and success of their operations. Business owners and SMEs alike are faced with the imperative need to keep up to date with existing advances, undertaking a digital transformation to develop and efficiently manage their businesses.

This transition also implies a significant change in the way buying and selling transactions are carried out, product offerings are presented and business models are structured, moving from traditional methods to digital approaches (Bonilla-Jurado et al., 2023).

It is relevant to note that, although most research contributions have addressed Big Data Value Chain models in various areas, no contribution has been found that takes an end-to-end approach, thoroughly considering each step along the Big Data Value Chain (Miller & Mork, 2013).

One of the challenges is that there are substantial disparities between technology implementation and sustainability practices by large corporations and those adopted by small and medium-sized enterprises in the industrial sector. Limitations in access to capital, resources and expertise characterize SMEs. Most strategies for sustainable manufacturing rely on indicators and evaluation models designed mainly for large companies.

1.2 Classification of Firms in the Current Context

In examining the existing literature on firm classification, we observe that most classification practices are rudimentary, often based simply on the number of employees of each firm (Dafoe et al., 2020; Olaya et al., 2022), and that these classification practices are extremely reductionist, especially considering that the number of employees does not necessarily reflect the current state of a firm. Currently, there are examples of companies with a small number of employees that demonstrate high performance and great success in specific sectors, such as companies specializing in emerging technologies (Bettiol et al., 2023).

In different countries, there are divergent criteria in the parameters for classifying companies, which makes it difficult to establish policies in the region under a standard classification criterion (Angeles et al., 2022). Each nation has developed its own classification method, using variables such as number of workers, annual sales, total assets, investment, and combinations of these. In addition, in some countries two classifications coexist, each designed for specific purposes such as legal issues, financial support, statistics, exporting, among others (Altenburg & Meyer-Stamer, 1999).

Likewise, in certain countries of the region, business classifications pre-sent combinations of variables, thus evidencing the diversity of approaches used in different geographical areas (Yoo et al., 2022). This variability may be influenced by various factors, such as economic structure, government policies and specific local market characteristics (Angeles et al., 2022; Lobato et al., 2023; Paus & Robinson, 2024).

It is important to note that diversity presents significant challenges in terms of consistency of information when describing an enterprise; the variety of classification practices could lead to incorrect and inaccurate diagnoses when classifying and comparing enterprise levels across countries (Arturo-Delgado & Díaz-Piraquive, 2021).

The way in which each country establishes definitions and boundaries for classifying enterprises has a significant impact on the formulation and implementation of policies to support this business sector. This diversity of criteria can influence the identification of the specific needs of enterprises, as well as the allocation of resources and the implementation of effective support strategies ("The Entrepreneurial State", 2015).

The definitions and criteria used to classify enterprises are fundamental to understanding the composition and dynamics of a country's business fabric (Dvouletý et al., 2021). For example, the way in which SMEs are financed varies considerably from one country to another, which affects the application of support measures and fiscal and regulatory policies aimed at this sector (Audretsch & Thurik, 2000). This can limit the effectiveness of business support policies and hinder collaboration in areas such as innovation, internationalization and access to finance. (Shamim, Rejuwana, and Al, 2024; Khouibiri.N and All, 2024, Farhaoui, Y, 2024; Folorunso, S.O. and All,2024; Adeniyi, A.E. and All,2024; Awotunde, J.B. and All,2024; Triantafyllou, Serafeim A. and All,2024).

In this sense, it is crucial that policymakers understand the importance of establishing clear and consistent definitions for classifying firms, as well as the need to standardize these criteria internationally (Diaz, 2023; Fritsch & Storey, 2017).

This divergent approach can be attributed to the different economic dynamics and business structures present in diverse national contexts, which re-emphasizes the need to understand and consider these disparities when analyzing and comparing business support policies at the international level (Didi & Stumpo, 2018).

One of the commendable efforts aimed at homogenizing business classification criteria was carried out under the proposal of the Central American Integration System (SICA), which gave rise in 2001 to the Regional Center for the Promotion of Micro and Small Enterprises (CENPROMYPE) (Aguilar & Orantes, 2020). In an act of collaboration, SICA member countries agreed, in 2011, on a specific regional agenda for SMEs, with the objective of coordinating efforts and strengthening this crucial business segment (Leandro, 2011).

Despite some progress, the challenge remains of establishing a single business classification criterion that, without overlooking socioeconomic and sectoral variations, would make it possible to implement coherent public policies. This endeavor seeks to foster improved management and increased productivity of SMEs in the region (Altenburg & Meyer-Stamer, 1999; Peña-Vinces et al., 2017).

This call for standardization of enterprise classification criteria is based on the recognized importance of having a solid and uniform basis for the formulation of enterprise development policies and strategies (Ridderbusch & von Uexküll, 2021). The European Union, for example, has addressed this challenge by implementing common standards for the classification of enterprises, which has facilitated decision-making and the implementation of coherent policies at the enterprise level (Batura & Peeters, 2021). Likewise, successful experiences in the implementation of uniform business classification criteria have shown to improve the efficiency of public policies and promote a more equitable and competitive business environment (Gorrión, 2005; Horak et al., 2020).

Consequently, the search for a single business classification criterion in an industrial sector for the region not only addresses a theoretical and practical need, but should also be aligned with inter-national classification practices, in order to constitute a key factor for strengthening the business fabric and stimulating sustainable economic growth (Corvello et al., 2023).

1.3 Representation of Companies for Classification Purposes

The effective representation of a firm in a context of techno-logical development plays a crucial role in the dynamics of the industrial sector (Miller & Mork, 2013). We propose an alternative that employs data structures in order to address the challenges related to the representation and classification of competing firms. In this analysis, we will explore the application of the value chain, which has been recognized as a fundamental model to efficiently manage value creation processes within organizations (Ricciotti, 2020). This implies that value chain analysis involves breaking down the business into strategically relevant activities in order to understand their impact (Prajogo et al., 2008). However, the comprehensive digitization of processes, which has incorporated data as the main source of value, has rendered traditional value chain models obsolete. Research in this direction has reported new value chain models, termed the Big Data Value Chain, to realize data-driven organizations and as a consequence an adequate representation of the system (Miller & Mork, 2013; Ríos-Quispe, 2023).

For an adequate representation of the enterprise, it is necessary to elaborate a data structure by selecting the relevant variables of the enterprise stored in the Big Data. The comprehensive analysis of a company requires an accurate representation that encompasses crucial dimensions such as Management, Marketing, Operations, Finance, Human Resources, Infrastructure and Technology, also oriented to the application of the theory of resources and capabilities of the company (Hortovanyi et al., 2023).

This proposal comprises the application of structured, semi-structured and unstructured data, adjusting to the nature of each dimension. The process must be supported by variable engineering, which involves the extraction, selection, cleaning, standardization, normalization, and damification of categorical variables, to ensure consistency and homogeneity, thus facilitating accurate interpretation, for which pipeline-based platforms can be used to automate the analysis of large volumes of data (Fradj et al., 2024; Olson et al., 2016).

1.4 Knowledge Management for Enterprise Representation and Classification

Considering the theory of resources and capabilities, it is essential to highlight the importance of knowledge in the representation process. This element is not only a determining factor for success, but also a strategic resource of great importance. In fact, knowledge becomes the foundation of a solid competitive advantage for companies (Holsapple & Singh, 2003; Noa Guerra & González González, 2023; Taherdoost & Madanchian, 2023).

Knowledge management emerges as a fundamental method in the process of business representation with a view to its adequate classification and cooperation. This approach is oriented towards the location and organization of specialized knowledge in order to enable efficient retrieval and reuse (González-Ramos et al., 2023). In carrying out knowledge management both internally and externally, the underlying purpose is to bring value to companies (Singh et al., 2023).

Today, modern companies are committed to adopting effective knowledge management practices, as these not only foster continuous learning, but also promote growth, innovation and institutional success (Santhose & Lawrence, 2023). The ability of companies to effectively manage their knowledge base translates into significant competitive advantage (Saniuk et al., 2023).

Knowledge-based organizations that have successfully integrated knowledge management processes into their structure have proven to be more resilient and competitive in the marketplace (Abbas & Khan, 2023). This strategic approach not only boosts the adaptability of companies to unexpected changes, but also provides them with the ability to excel, cooperate in an increasingly challenging business landscape (Demir et al., 2023).

Representing the knowledge that generates value to the classification and cooperation process is very important, and should be part of the representation structure, for which, it can be represented by rules based on propositional logic, predicate logic, semantic networks or ontologies (Villegas-Ch & García-Ortiz, 2023; Yang et al., 2023).

1.5 Artificial Intelligence for Business Representation and Its Classification

Business Intelligence is a system and an application that processes data of a company or organization to convert it into knowledge. This application analyzes past data, analyzes it and then uses this knowledge to support decisions and organizational design. Business intelligence is an aspect that will help companies to determine marketing strategies based on market data and to exploit this data to obtain information for decision making. This process is carried out mathematically using specific methods and computer systems. Then, the data set will be processed using appropriate techniques, tools and software.

In this direction, Artificial Intelligence (AI) technologies deploy various methods, including heuristic search, machine learning, deep learning, etc. (Doumpos et al., 2023). Learning algorithms, which rely heavily on extensive amounts of labeled data, play a crucial role in classification and prediction. In this context, it is imperative to apply artificial intelligence methods to design classification and cooperation model of competing companies (Nguyen et al., 2023).

Apply algorithms integrating artificial intelligence concepts such as heuristic search to generate the ranking of the company. This approach offers an innovative perspective to optimize business representation and overcome the limitations associated with game theory in situations of uncertainty and competition (Fouad et al., 2020).

1.6 Conclusions

In conclusion, ranking and collaboration among competing companies emerge as critical factors in the advancement of the industrial sector. To address this challenge effectively, it is imperative to have an adequate representation that establishes solid structures based on the theory of resources and capabilities. These structures, enriched with relevant variables derived from data, information and knowledge gathered from various sources, are then subjected to the application of variable engineering. This process, supported by knowledge management and artificial intelligence, culminates in the consolidation of relevant models. From these models, specific indexes and metrics are defined that enable an objective evaluation and a meaningful comparison between companies, thus providing a valuable contribution to the scientific and business landscape.

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Artificial Intelligence Applied in Higher Education: A Bibliometric Analysis

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Abstract. Higher education centers focus on knowledge construction and for its management new technological tools are implemented, as is the case of artificial intelligence. The objective of the research is to analyze the scientific production related to the applications of artificial intelligence in higher education. The research paradigm is quantitative, based on a bibliometric study, using a descriptive and retrospective approach. Only review and research articles in open access related to the application of artificial intelligence in higher education in the areas of computer science, engineering and social sciences, without language restriction, during the period 2023 - 2024 in the SCOPUS database were taken into account. A total of 232 research papers were identified, 223 of which were published in 2023, with a predominance of research articles. There were 182 researches in the areas of social sciences as the most representative field with 53% of the total. The most cited journal was the Journal of Applied Learning and Teaching. The country with the highest number of research papers was China with 26 and the University of Monterrey was the most outstanding institution with 10. Seven lines of research associated with seven of the 13 clusters identified were identified.

Keywords: bibliometric analysis · artificial intelligence · Higher Education · bibliometric indicators · artificial intelligence

1 Introduction

Everyday life demands alternatives that guarantee quality of life and economic sustainability; therefore, educational centers should focus their curricular plans on the creation of entrepreneurial skills in students (Gonzalez-Argote & Castillo-González, 2024; Luna, 2023; Ricardo, 2022). In this sense, Higher Education (HE) centers focus on the construction of knowledge and its management in terms of the development of society as catalysts of local development or good living in the regions (Eslava et al., 2023; C. Gómez, 2022; O. Gómez, 2023).

The processes in HE institutions have three main lines according to comprehensive development: undergraduate education, postgraduate education or research, and university extension. Álvarez et al. argue that quality education must include formative

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research as a cross-cutting axis to the teaching-learning process, as well as assimilate and adapt to new technologies (Álvarez et al., 2023). These elements demand teaching staff dedicated to innovation and resilient to change (Bolaños, 2023).

In this context, learning systems have been modified, adopting curricula focused on virtual learning and centered on scientific, technological, and engineering textual study as a highly motivating strategy appropriate to the needs of future professionals (Laplagne & Urnicia, 2023). Thus, pedagogical guidance becomes a necessity for them to succeed in their professional lives, especially those who will work as teachers (Cano et al., 2023; Castillo-González et al., 2022; Delgado et al., 2023; Romero-Rodríguez et al., 2023).

With the emergence of COVID-19 and the growing demands of HE institutions to transform their processes and use new technologies as teaching support, but without depending entirely on it (Miranda & Sanabria, 2023), in this panorama, the use of information and communication technologies (ICT) has become an effective tool and alternative for the development of learning strategies (Pérez et al., 2023). In this context, the use of different artificial intelligence tools emerges as an opportunity, considered as an educational model scarcely used and known until now (Gutiérrez Páez et al., 2023).

Artificial Intelligence (AI), as a potential technological tool, though not new, expands across all professional and knowledge fields, affecting, impacting, and causing a true revolution in the field of education (Castillo-Gonzalez, 2022; Castillo-González, 2023; Flores Vivar & García Peñalvo, 2023). It can be defined as the ability of a computational system to simulate the behavior of the human brain, capable of receiving external data as information, learning through training, and based on this learning, achieving the objectives for which it was trained (Incio Flores et al., 2022). Based on the Beijing Consensus, the Forum shared policies and practices regarding the role of AI in education, with a specific focus on defining the competencies required in the AI era and strategies for preparing everyone to live and work with AI effectively. (Adeniyi, A.E. and All, 2024; Awotunde, J.B. and All, 2024. Triantafyllou, Serafeim A. and All, 2024.; Folorunso, S.O. and All,2024, farhaoui Y, 2024).

The applications of AI in the educational field are a complex process (Selwyn, 2020), an analysis conducted by Ocaña Fernández et al. on the implications of AI in HE synthesized: increasing student interactivity through the use of machine-supported learning, the need to develop digital competencies in teachers, the necessity to recapitulate aspects of form and substance in university education, and the utilization of chatbots and intelligent or virtual agents as forms of knowledge self-management.(Ocaña Fernández et al., 2019).

These tools demand a high level of training based on the acquisition of skills, knowledge, motivation, self-confidence, problem-solving abilities, as well as entrepreneurial inclinations (Guatemala & Martínez, 2023).

These tools are increasingly gaining ground in society and in HE institutions, thus analyzing and tracking research trends in this field will facilitate increasingly comprehensive education and learning systems (Saltos et al., 2023; Vanoy, 2023; Zapata et al., 2024). Consequently, the objective of the research is to analyze scientific production related to the applications of artificial intelligence in higher education.

2 Methods

The research paradigm is quantitative, based on a bibliometric study, using a descriptive and retrospective approach. The study was conducted in the SCOPUS database (https://www.scopus.com/) for the period 2023 – 2024. Only open-access review and research articles related to the application of artificial intelligence in higher education in the fields of computer science, engineering, and social sciences were considered, without language restriction.

The main thematic descriptors used were: Artificial intelligence and Higher Education, combined with the boolean descriptor AND. The search formula was:

• "TITLE-ABS-KEY ("Artificial intelligence" AND "higher education") AND PUBYEAR > 2022 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (OA, "all"))".

The search was conducted on January 22, 2024, and a total of 232 research articles were identified (N = 232). The search was conducted independently by two researchers on the same day and at the same time, following prior coordination by a third researcher with the same criteria to verify the results. The elements analyzed were: total number of publications and coincidence between the research outputs (the process was supported by a bibliographic manager).

Table 1 shows the analyzed indicators.

Table 1. Analyzed Indicators.

Indicator	Source of Information
Number of research articles per year	SCOPUS database (download ".XLSX" files (Excel format) from the analysis tab)
Number of research articles by type	
Number of research articles by field of knowledge	
Ranking of most cited journals, analyzing indicators such as number of citations (CC), impact factor (IF), H-index, quartile (Q), and country of publication	SCOPUS database (processed in the bibliographic manager EndNote X8) Scimagojr Journal Rank (https://www.scimagojr.com/)
Production by country (number of research articles per country)	SCOPUS database (download ".XLSX" files (Excel format) from the analysis tab)
Production by institutional affiliation of the first author	

Source: Own elaboration

An analysis of the quantity of publications per author and their interrelations was conducted through the construction of bibliometric maps. Additionally, density and network maps were constructed to analyze the main lines of research and the most significant contributions of artificial intelligence in Higher Education. The software

VOSviewer (https://www.vosviewer.com/download) was used for the construction of knowledge maps.

3 Results and Discussion

223 research studies (n = 223) were identified during the main objective of the study in 2023, and 9 research studies (n = 9) in 2024. According to the type of publication, there is a predominance of research articles with 208 (n = 208), representing 89.66% of the total, and 24 review articles (n = 24), representing 10.34%.

An analysis of knowledge areas was conducted, identifying studies in 17 fields based on the research objective and the constraints described in the materials and methods section. The areas of engineering, computer science, and social sciences were explored further. A total of 182 studies were conducted in the field of social sciences, representing 53% of the total research, followed by computer science and engineering with 122 and 41 studies, respectively.

Research studies were identified in 118 scientific journals, with the most cited article being: "ChatGPT: Bullshit spewer or the end of traditional assessments in higher education?" (Rudolph et al., 2023), with 185 citations (n = 185), published in the Journal of Applied Learning and Teaching by authors Rudolph, J; Tan, S. and Tan, S. The journals with the most publications were Computers and Education: Artificial Intelligence and Education Sciences with 17 and 12 articles respectively. The journal that received the highest number of citations was the Journal of Applied Learning and Teaching with 378 citations (n = 378).

An analysis of the top 10 most cited journals (Table 2) was conducted, with an impact factor (IF) of 2.12. The British Journal of Educational Technology had the highest value. The most cited journals are in quartiles 1 (Q1) and 2 (Q2), and the most representative country was the United Kingdom. The journal with the highest h-index was Sustainability (Switzerland) with 136 (H-index = 136).

The published research originates from 64 countries, and this diversity is due to the consideration of countries even with just one research study. Figure 1 shows an analysis of countries with more than seven publications. The country with the highest production was China with 26 articles (n = 26), followed by the United Kingdom, Australia, and Spain with 23 articles each (n = 23).

Institutions with scientific backgrounds, especially those in Higher Education, are significant sources of knowledge generation and scientific production. An analysis of institutional affiliation by first author was conducted (Fig. 2), identifying publications across 159 institutions. The most representative ones include Tecnológico de Monterrey with 10 publications (n = 10), followed by the University of Tasmania and CQUniversity Australia with six publications each (n = 6).

In Fig. 3, the author collaboration map is presented with a co-occurrence level equal to or greater than two ($n \geq 2$), and the frequency element is expanded in Fig. 5. The most representative authors were: Cowling, M., Crawford, J., Rudolph, J., and Tan, S., each with four research studies (n = 4) (Fig. 4).

Table 3 displays an analysis of keyword co-occurrence based on the previously defined search strategy. Thirteen clusters and 209 items were identified for a keyword

Table 2. Ranking of the top 10 most cited journals.

Journals	CC	IF	H-index	Q	Country
Journal of Applied Learning and Teaching	378	-	2	-	Singapore
Innovations in Education and Teaching International	274	0,71	58	Q1	United Kingdom
Journal of University Teaching and Learning Practice	172	0,49	15	Q2	Australia
International Journal of Educational Technology in Higher Education	82	2,05	49	Q1	Netherlands
Computers and Education: Artificial Intelligence	57	1,7	17	Q1	Netherlands
Sustainability (Switzerland)	29	0,66	136	Q1	Switzerland
Teaching in Higher Education	18	0,94	69	Q1	United Kingdom
British Journal of Educational Technology	18	2,12	110	Q1	United Kingdom
Applied Sciences (Switzerland)	16	0,49	101	Q2	Switzerland
Cogent Education	14	0,44	28	Q2	United Kingdom

Source: Own elaboration

co-occurrence level of two. The items with the highest weight and similarity index were described, and network and density maps were represented. In both cases, Artificial Intelligence was identified as the main item.

An analysis of the first seven clusters was conducted based on the weight per number of items, representing 53.85% of the total (13). The main research lines around these clusters were identified as follows:

- Cluster 1 (27 items): Focuses on applications of artificial intelligence in education (Wang et al., 2022), through the development and adoption of educational policies aimed at digital transformation, industry 4.0 (Al-Maskari et al., 2024; Chaka, 2023; Shenkoya & Kim, 2023), and emerging technologies enhancing collaborative learning (Ngo et al., 2024; Zheng et al., 2023).
- Cluster 2 (26 items): Focuses on bibliometric studies related to applications of artificial intelligence in improving educational processes (Maphosa & Maphosa, 2023).
- Cluster 3 (23 items): Focuses on educational innovation strategies through digitization, mobile learning, and chatbots, especially in scenarios like the COVID-19 pandemic (Pitso, 2023; Soliman et al., 2023).
- Cluster 4 (23 items): Focuses on artificial intelligence applications in higher education, including quality assessment (Grájeda et al., 2023), curriculum design, and ethics of teachers, with tools like chatbots and ChatGPT (Chang et al., 2023; Cowling et al., 2023; Crawford et al., 2023; Naidu & Sevnarayan, 2023; Nikolic et al., 2023; Rodrigues & Rodrigues, 2023; Romero-Rodríguez et al., 2023).

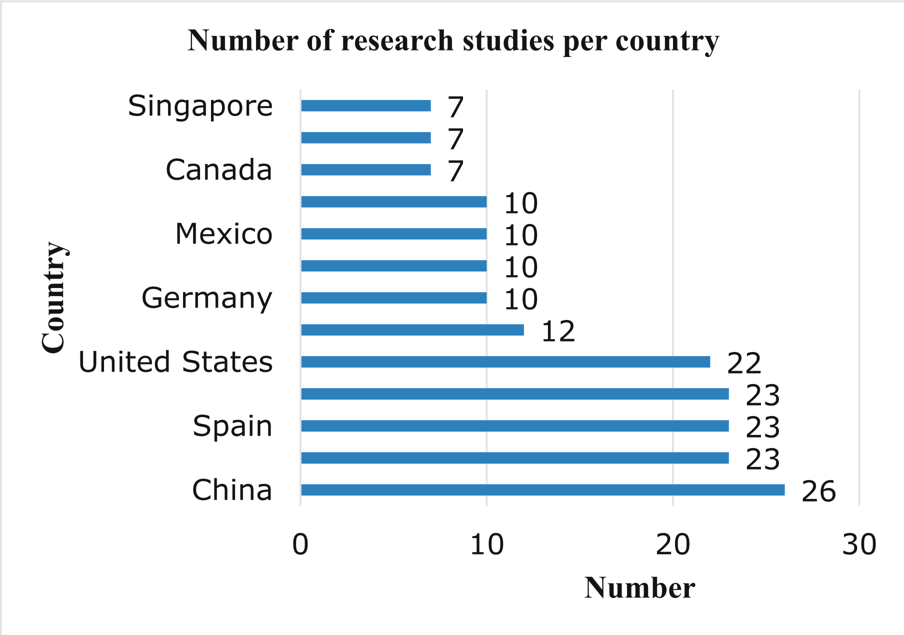


Fig. 1. Number of research studies per country.

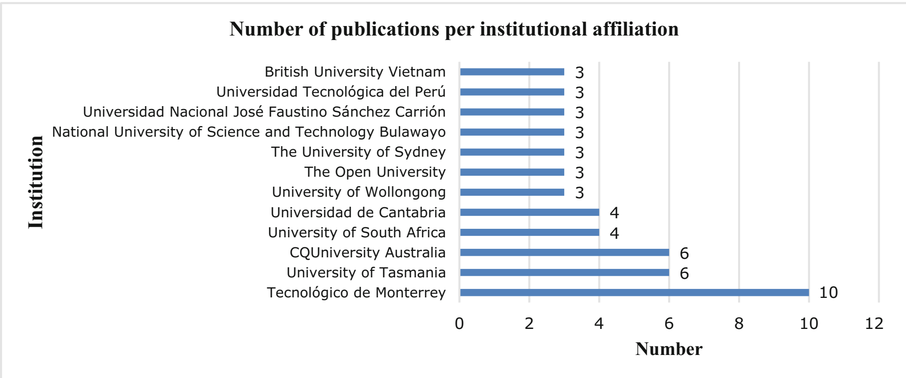


Fig. 2. Number of research studies per institutional affiliation.

- Cluster 5 (19 items): Focuses on educational innovation strategies analyzing concepts like Education 4.0 and their influence on the digitalization of educational processes and knowledge management (Domínguez-Ruiz et al., 2023; Sanabria-Z, Alfaro-Ponce, et al., 2023; Sanabria-Z, Castillo-Martínez, et al., 2023).
- Cluster 6 (17 items): Focuses on different models for managing educational processes (Segbenya et al., 2023; Villarreal-Torres et al., 2023), incorporating new technologies and artificial intelligence (Rahiman & Kodikal, 2024; Zhu, 2023).

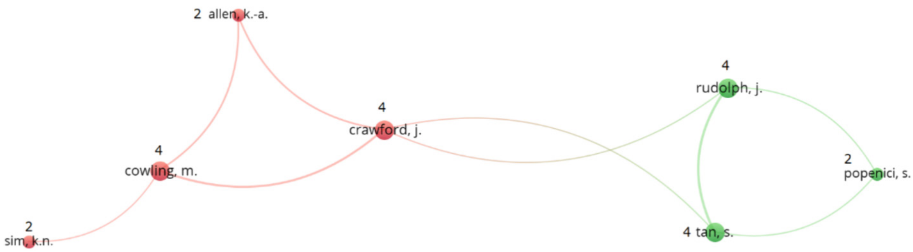


Fig. 3. Author collaboration map. Source: Own elaboration.

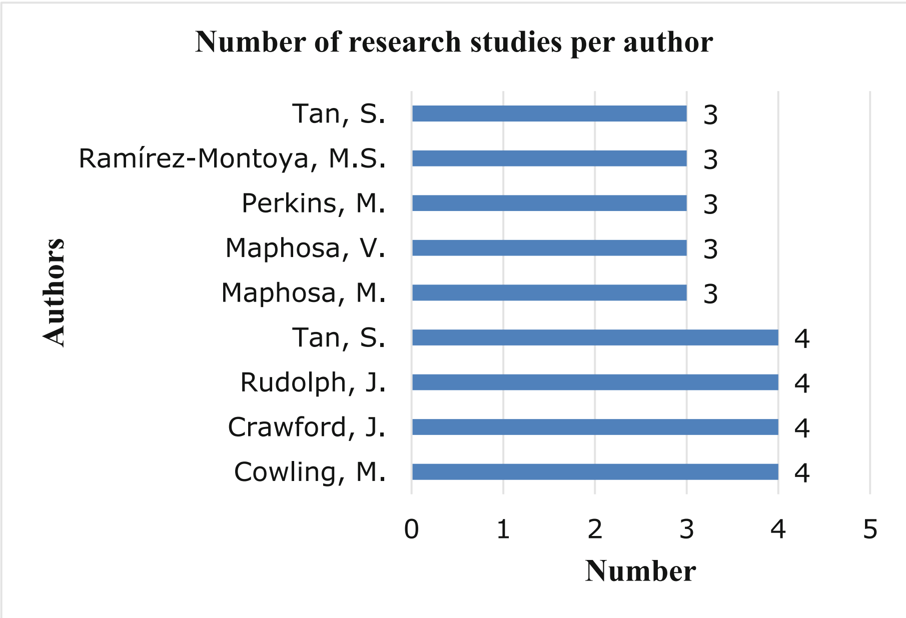


Fig. 4. Analysis of the number of research studies per author.

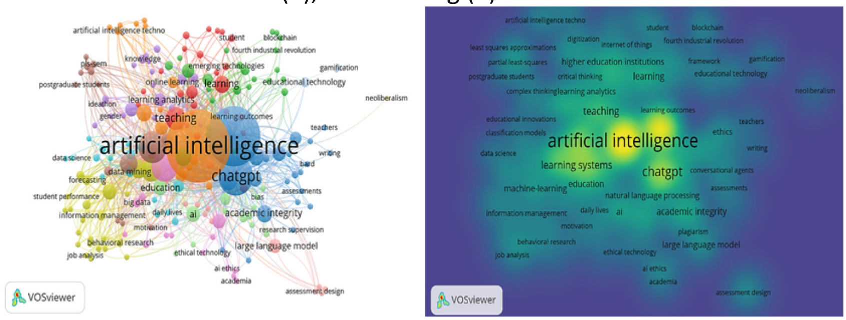
- Cluster 7 (15 items): Focuses on artificial intelligence techniques and tools influencing engineering students and the design of various curriculum strategies (Ibarra-Vazquez et al., 2024; Imhof et al., 2023).

Bibliometric studies allow for the analysis of scientific production across various knowledge areas (Guardiola Wanden Berghe & Sanz Lorente, 2022), guiding researchers on which journals to publish in (Valle Goñas, 2022), and identifying leading countries or institutions, as well as knowledge lines (Sarmentero Bon et al., 2022). Research is primarily found in the social sciences, which is consistent with findings by Díaz Ramos and Angüis Fúster (Díaz Ramos & Angüis Fúster, 2023).

Bernal-Corrales et al., in their study "Bibliometric Analysis of Global Scientific Production in Nursing on Childhood Obesity," identified that major research is published

Table 3. Keyword Co-occurrence Analysis.

Strategy	**Metrics**			
Artificial Intelligence and Higher Education (n≥2)	**Items**	**Clusters**	**Percentage of articles per year**	
			2023	2024
	209	13	223 (96,12 %)	9 (3,88 %)
	Attributes with the highest weight and similarity index			
	Artificial intelligence (144), higher education (103), chatgpt (50), students (34), learning systems (20), teaching (19), education computing (15), e-learning (13), Chatbots (12), curriculum (11), machine learning (10), education (10), engineering education (8), Data mining (5).			



Source: Own elaboration.

in Q1 and Q2 journals, which aligns with findings in this study (Bernal-Corrales et al., 2023).

Limitations of the research include its reliance on only the SCOPUS database, which may affect its generalizability to other impactful databases. Additionally, it only covers the last year (2023–2024), suggesting potential extensions to the last three, five, or ten years. Collaboration analyses between institutions, average citations per year, and the institutions funding the research should also be considered.

4 Conclusions

Higher education institutions, in their pursuit of constructing and disseminating knowledge with greater impact, increasingly implement alternatives to enhance the quality of the teaching-learning process, including the utilization of artificial intelligence models and tools.

The addressed topic has significant impact and development among researchers, with 209 investigations identified in just the year 2023 across three knowledge areas (engineering, computer science, and social sciences). Publications were predominantly in high-impact journals, mainly in quartiles 1 (Q1) and 2 (Q2), with the most cited article garnering 185 citations and published in the Journal of Applied Learning and Teaching. The journal with the highest number of publications was Computers and Education: Artificial Intelligence, with 17 research papers.

From the analysis of authorial collaboration, two research lines were identified linking the most prolific authors. Collaboration was observed among only seven of the 159 authors who published articles on the topic during the defined period, indicating the need for increased collaboration or joint project strategies among institutions and countries to develop more robust and generalizable strategies.

Seven research lines associated with the identified clusters were identified from the keyword co-occurrence analysis, resulting from network and density bibliometric maps. Among the main and most addressed lines are the implementation of artificial intelligence models and tools (especially chatbots and ChatGPT) to improve teaching-learning processes in higher education institutions.

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Applications of Artificial Intelligence in Marketing: An Approach from the Patent Record

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Abstract. Artificial intelligence emerges as a disruptive technology with a significant impact on the field of marketing. The research question is as follows: What are the trends in patenting AI applications in marketing based on Patentscope records between January and August 2023? The specific objectives of the research are as follows: (i) identify patents available on Patentscope that involve the application of artificial intelligence in the field of marketing; (ii) describe specific applications of artificial intelligence in marketing through the analysis of patent applications registered on Patentscope during the mentioned period; (iii) classify the application sectors of patents that include the use of AI in marketing, based on Cooperative Patent Classification (CPC) and International Patent Classification (IPC) codes. The methodology selected for this study is of a mixed nature, with an exploratory-descriptive approach. It will focus on analyzing current trends and advances in the implementation of artificial intelligence in marketing, using primary information extracted from the full text of patents. The results obtained revealed various trends in patenting artificial intelligence applications in marketing. These include personalized advertising, optimization of the customer experience, prediction of user behavior, and automation of processes in marketing.

Keywords: Artificial Intelligence · Patents · Industrial Property · Marketing · WIPO · Patentscope

1 Introduction

In the era of Industry 4.0, companies are immersed in an increasingly competitive and digitized environment (Restrepo & Lis-Gutiérrez, 2023; Soto & Leon, 2022). In this context, the ability to adapt to new technologies and utilize data analysis tools is fundamental for strategic decision-making in the field of marketing (Valdés Hernández et al., 2023). The utilization of artificial intelligence (AI) has become indispensable for achieving continual improvements, enhancing productivity in business processes, tailoring consumer experiences, and optimizing products and services (Carranza et al., 2024; Medina Minaya & Moreno Briceño, 2023).

Despite the potential advantages of AI in marketing, challenges and obstacles persist in its implementation and effective utilization. Some companies are not maximizing the

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potential of artificial intelligence, encountering issues with integrating data and business systems with available solutions, as well as managing intellectual property (Alonso & Forradellas, 2022; Duque et al., 2023).

In an environment oriented toward the implementation of this emerging and disruptive technology, the lack of adoption of AI-based solutions and strategies can lead to lagging behind and a loss of market share (Castillo & Cano, 2024; Torres et al., 2024). The implementation of AI holds the potential to transform decision-making processes and data analysis on a global scale, enabling companies to compete or cooperate successfully (Blázquez-Jiménez & Sanchis, 2023) in the era of Industry 4.0.

It is crucial to highlight that the use of AI in marketing has a profound impact on the future, as many brands employ it for basic customer interactions through conversational marketing in everyday life. This leads to hyper-personalization in the customer experience through individualized product and service recommendations (Gao & Liu, 2022), based on the analysis of vast amounts of data (López De La Cruz & Arévalo, 2022; Torres et al., 2022). Such personalization not only directly affects the consumer but also has the potential to foster greater brand loyalty. In summary, the implementation of AI in marketing not only enhances business competitiveness but also revolutionizes how customers interact with and consume products and services from brands.

Considering these global transformations in decision-making processes and data analysis resulting from the use of AI in companies worldwide (Cuervo Sánchez, 2021; Matos-Paucar et al., 2023; Rojas & Agudelo, 2024), conducting research to understand the scope and implications of this trend is essential for improving efficiency and effectiveness in business decision-making (Bag et al., 2021; Castellanos & Aldana, 2022; Mendivelso Rincón & Lis-Gutiérrez, 2020).

In this context, the guiding question is: What are the trends in the patenting of AI applications in marketing, based on Patentscope records between January and August 2023? This question focuses on analyzing patent data related to artificial intelligence and marketing to identify trends and patterns in the legal protection of AI applications. The specific objectives include: (i) identifying patents available in Patentscope that involve the application of artificial intelligence in the field of marketing; (ii) describing specific applications of artificial intelligence in marketing through the analysis of patent applications registered in Patentscope during the mentioned period; (iii) categorizing the application sectors of patents that include the use of AI in marketing, based on CPC (Cooperative Patent Classification) and IPC (International Patent Classification) codes.

The methodology involves a mixed research approach with an exploratory-descriptive focus, centered on analyzing trends and advancements in the implementation of AI in marketing. Primary information will be extracted from the full-text of patents to comprehend how companies protect their intellectual property in this field.

2 Literature Review

For the literature review, the Scopus database, Google Scholar, and information from the World Intellectual Property Organization (WIPO) were utilized, initially identifying 40 works. Following a refinement process, 21 of these were excluded due to lack of availability of full text and their lack of direct relevance to the topic of interest.

In the realm of intellectual property, a significant increase in demand for patent protection was observed during the year 2022, with China, the United States, Japan, South Korea, and Germany leading in PCT applications (Instituto Nacional da Propriedade Industrial, 2023). This evolution is part of the transition towards Web4.0, characterized by technological trends such as the Internet of Things, Big Data, Artificial Intelligence (AI), and new forms of communication (Pineda-Domínguez et al., 2021). Technological transformation, particularly the presence of AI, is redefining multiple sectors, with its notable role in marketing. The implementation of AI offers substantial improvements in decision-making efficiency and accuracy, customer experience personalization, and large-scale data analysis (Madriz, 2023). Moreover, it is used in the creation of premium digital content platforms and customer service tools incorporating voice and facial recognition (Bharati & Dahiya, 2023; Liunai & Zhixiang, 2023; Vikram, 2023). Its application in marketing stands out in personalization, logistical optimization, inventory management, and creation of customized content, transforming the industry despite existing challenges.

In the realm of marketing, AI has emerged as a disruptive element, altering product promotion strategies and empowering consumers in the process (Alvin Yau et al., 2021). This revolution is grounded in the understanding of individual preferences and customer interactions, enabling informed decisions and efficient customer experience personalization (Hamidi et al., 2022). AI, as a key enabler, enhances customer understanding and automates routine tasks, thereby increasing operational efficiency and customer engagement (Bulchand-Gidumal et al., 2021).

Beyond optimizing efficiency, AI incorporates diverse applications in marketing, ranging from automated drone deliveries to advanced ad personalization (Huang & Rust, 2018). These applications extend even into the realm of business, where AI technology is gaining popularity and effectiveness, especially in B2B marketing (Keegan et al., 2022).

AI also reshapes the approach to brand marketing, focusing on brand value and utilizing technology to accurately capture consumer demand and consumer group descriptions (Cui et al., 2022).

This expansion of AI raises critical ethical questions, especially as the technology becomes widespread and affects various aspects of marketing (Gonçalves et al., 2023). AI sparks debates on privacy, decision-making, and responsibility, demanding deep reflection on its ethical implications (Hermann, 2022). Ultimately, AI not only redefines strategies and relationships in marketing but also triggers vital discussions about its ethical impact in the field.

3 Method

3.1 Data

The literature review was conducted using available sources from Scopus and Google Scholar, employing keywords related to the use of AI in marketing published between 2021 and 2023. The search equations were as follows:

-Google Scholar search equation: allintitle: and marketing “artificial intelligence”.

-Scopus search equation: (TITLE (“artificial intelligence”) AND TITLE (“marketing”)) AND (EXCLUDE (DOCTYPE, “ed”) OR EXCLUDE (DOCTYPE, “er”) OR

EXCLUDE (DOCTYPE, "no")) AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2023)) AND (LIMIT-TO (OA, "all")).

Initially, a total of 40 relevant articles were identified up to the cutoff date of October 16, 2023. However, following a thorough analysis of the retrieved documents from the Scopus database, a decision was made to exclude a total of 21 articles. This exclusion was based on a lack of evidence of a direct relationship with the topic guiding the current research. It is worth noting that some of these documents were restricted to the general public, which posed challenges for conducting a comprehensive literature review.

The complete content of patent applications available in Patentscope between January and August 2023 was also reviewed. The search equation used was: FP: ("artificial intelligence" and marketing). A total of 29 patents were identified as of the August 2023 cutoff date, and after a thorough reading, 13 of these were excluded as they were not directly related to marketing strategies.

The inclusion criteria for patents were as follows:

a) Availability on the Patentscope platform.
b) Compliance with the search equation.

The exclusion criteria were:

a) Not directly related to marketing strategies.
b) Not published between January and August 2023.

3.2 Research Design, Type, and Scope

The research employs a mixed design with an exploratory-descriptive scope, focusing on analyzing current trends and advancements in the implementation of AI in the field of promotion and marketing. This approach combines both quantitative and qualitative elements.

In the initial phase, a qualitative analysis of relevant documents related to various AI applications in marketing is conducted. These documents are extracted from Scopus for a specific period (January to August 2023).

The subsequent phase involves a quantitative and descriptive analysis of the CPC and IPC codes of patents registered in Patentscope during the same period.

Lastly, a qualitative inspection of the selected patents is undertaken in the final phase. This involves using content analysis techniques to highlight the characteristics of AI applications in marketing.

3.3 Procedure

The procedure for reviewing academic literature and patents is summarized in Figs. 1 and 2.

The complete texts of the identified patents were analyzed, alongside the development of manual and automated coding using specialized software (Fig. 2).

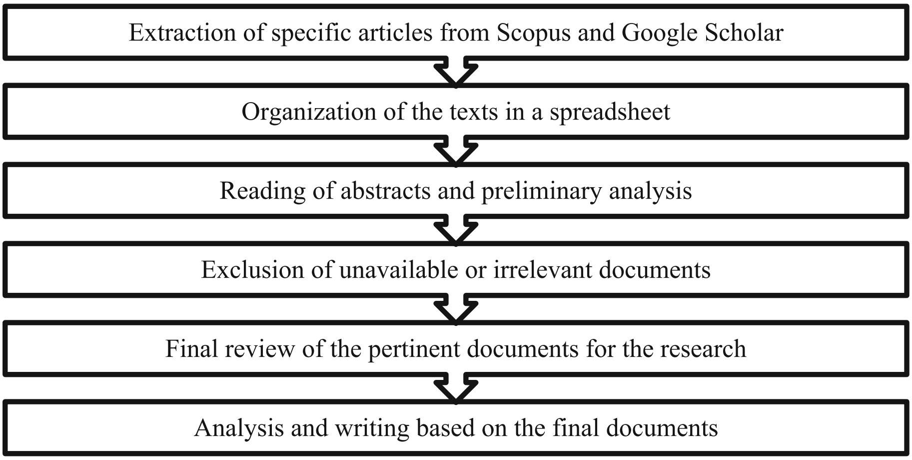

Fig. 1. Illustrates the steps taken for the analysis of academic literature. (Source: Authors' own elaboration).

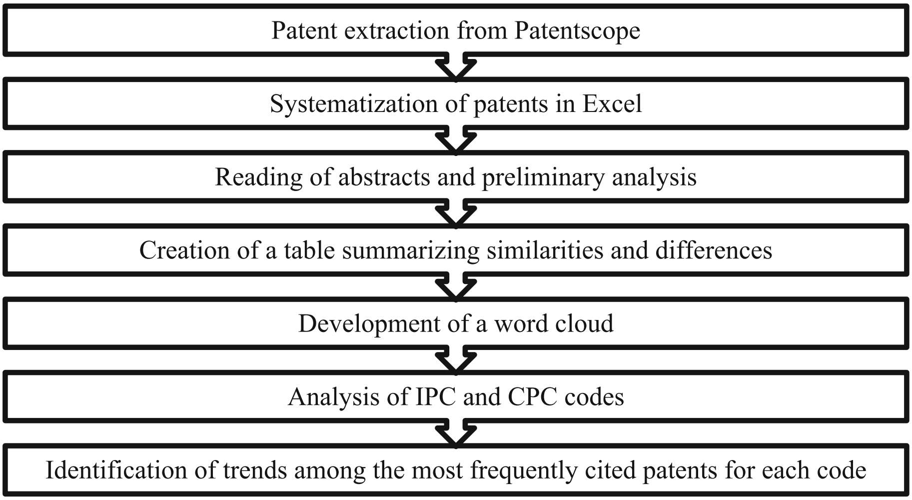

Fig. 2. Depicts the steps taken for the analysis of patents. (Source: Authors' own elaboration).

4 Results

4.1 Patents Available in Patentscope on AI in the Marketing Field

Table 1 aim to provide an overview of patents related to artificial intelligence (AI) and their diverse applications within the marketing field. Each section offers a concise description of specific patents, outlining their objectives and primary applications. These patents harness AI to enhance marketing strategies, ranging from leveraging influencers on social media to implementing automated management, AI-driven marketing tactics, blockchain integration, and their impact on consumer behavior. This table aims to showcase the breadth of approaches and applications, offering a comprehensive view of innovations in this domain (Adeniyi, A.E. and All, 2024; Awotunde, J.B. and All, 2024. Triantafyllou, Serafeim A. and All, 2024.; Folorunso, S.O. and All, 2024).

Table 1. General Analysis of Identified Patents.

Patent	Analysis
Yener, F., & Çimen, V. (2023). Artificial Intelligence-Based E-Commerce and Social Media Analytics Platform (Wo. 2023.113705) (Yener & Çimen, 2023)	The invention focuses on a platform that combines e-commerce with social media influencers to increase the revenues of e-commerce platforms, reduce spending on digital marketing, and facilitate automatic and long-term collaborations based on a revenue-sharing model. This enables influencers to generate sustainable income through a transparent and automated system, earning based on sales and establishing mutually beneficial business relationships in the new era of commerce
Bagheri, H. (2023). Ai-Based Marketing Management System (Wo. 2023.084287) (Bagheri, 2023)	HAMED MMD is an AI system that automates marketing management, offering companies worldwide the ability to monitor and optimize their marketing strategies, assess the effectiveness of marketing activities, identify inefficiencies and issues, and anticipate future needs. This tool aims to assist businesses of any type and individuals in remote areas or without access to marketing specialists, promoting efficiency and effectiveness in global marketing decision-making
Adheer, A. Goyal, N. (2023). AI and (IoT) Based Digital Marketing Strategies, Approaches and Result (India Patent Number 202121048709) (Adheer & Goyal, 2023)	The invention focuses on AI and Internet of Things (IoT) based digital marketing strategies to enhance visibility and reach a wider target audience. It provides companies with the opportunity to adopt customer-centric approaches and utilize IoT technology and traditional marketing methods to meet advanced marketing needs. This is relevant for individuals, businesses, and researchers seeking effective digital marketing strategies to reach their target market

(*continued*)

Table 1. (*continued*)

Patent	Analysis
Olden, M. R. (2023). Blockchain-Based Digital Advertising and Marketing System and Method (United States Patent Number 11636520 B1) (Olden, 2023)	It is a digital platform that uses blockchain to advertise and promote casinos, lotteries, and online games. It operates with advanced technology that creates dynamic content using AI and machine learning. It offers advertising rules, game promotions, coupons, and emails using virtual, as well as interactive, games. It connects with casino and lottery operators to provide these services
Sawant, A. P., et al. (2023). A Method And System For Leveraging Artificial Intelligence In Marketing, Consumer Research, and Psychology (India Patent Number 202321018340) (Sawant et al., 2023)	The invention utilizes AI in marketing, consumer understanding, and their psychological profiles. It employs AI, such as automated learning and natural language processing, to assess and understand large amounts of data and gain insights into consumer behavior. Its goal is to personalize marketing messages, enhance consumer research, and improve accuracy in psychological diagnostics. The system processes data from various sources, such as social networks, to automatically identify patterns, enhancing effectiveness in these areas through AI
Saravanan, P., et al. (2023). Artificial Intelligence and Machine Learning Based Approach to Predict the Preferences of Target Customers for Various Marketing Strategies (India Patent Number 202341010211) (Saravanan & Shenbagaraman, 2023)	It discusses the exploration of machine learning (ML) potential in marketing, highlighting its relevance and benefits, such as improving scientific discoveries. An overview of ML types and algorithms is presented, along with strategies for marketing researchers to learn ML. Additionally, applications of ML in marketing research are analyzed, and the discussion on potential future ML trends in marketing is raised, noting its significance in the industry
Shoamanesh, K., et al. (2023). System and Method for Product Placement and Embedded Marketing (United States Patent Number 20230078712) (Shoamanesh & H, 2023)	This method uses AI and machine learning to select publishers in advertising campaigns based on advertiser device data. It then collects and combines campaign results with past data to enhance future decision-making. In summary, it improves publisher selection and optimizes advertising outcomes

(*continued*)

Table 1. (*continued*)

Patent	Analysis
Chinthamu, N., et al. (2023). Machine Learning and Artificial Intelligence Based Digital Marketing Influences Consumer Behavior (India Patent Number 202341002611) (Chinthamu, 2023)	AI is key to enhancing customer experience in digital marketing. With a constantly changing market and a growing need for exceptional experiences on digital platforms, AI enables companies to gather real-time detailed data and personalize digital marketing experiences. Although many companies are yet to fully adopt AI, they recognize its value in creating exceptional customer experiences during the purchasing process. This review focuses on how AI-driven digital marketing influences consumer buying trends and enhances online experiences
Vishwanath, M., Anisuddin, S. (2023). An Overview of Exploring the Potential of Artificial Intelligence Approaches on Digital Marketing (India Patent Number 202241060785) (Yener & Çimen, 2023)	Artificial Intelligence is already influencing marketing and its impact will be even greater in the future. AI enables hyper-personalization through individual recommendations and intelligent customer service. However, the lack of trust in technology and ethical challenges are obstacles to its adoption. Business leaders must prepare to implement AI in marketing and train their employees for this cultural shift
Bharati, K. F., et al. (2023). Implementing Artificial Intelligence-Based Techniques for Social Media Marketing Analytics with Potential Uses Expectations (India Patent Number 202341008062) (Bharati & Dahiya, 2023)	Facilitating access to social monitoring and marketing tools through single sign-on credentials for employees. Identifying the context of keywords and relevant competitors through inspection of social media posts. Conducting semantic analysis to assess the importance of terms in internal social media messages. Allowing users to post and tag content, then categorizing it based on performance metrics and sending messages identifying the advertiser to mobile devices

(*continued*)

Table 1. (*continued*)

Patent	Analysis
Zhede, et al. (2023). Control Method and Control Device of Marketing System Based on Artificial Intelligence (China Patent Number 115641189) (Zhede et al., 2023)	The invention is an AI-based marketing system control device. It has a touch screen embedded in a box body, a scanning camera also embedded in the top of the box body, and modules for login, product selection, among others. This system enables consumers to efficiently find products in a mall through AI, improving both the shopping experience and the efficiency of sellers. Additionally, AI analyzes consumer preferences to optimize marketing
You, et al. (2023). Marketing Retail Putting System and Method Based on Big Data Screening (China Patent Number 115630989) (You, 2023)	The invention focuses on intelligent retail marketing and uses a system and method based on big data screening. It utilizes AI algorithms and deep learning to extract information from retail sales characteristics in different stores. It then optimizes the presentation of retail products based on these characteristics and spatial relationships between stores. This allows for precise product placement in retail stores by categorizing the purchasing demands of specific groups at each store location
Vikram, P., et al. (2023). Mobile Device Marketing and Advertising Platforms, Methods and Systems Using Artificial Intelligence (India Patent Number 202241075430) (Vikram, 2023)	This document presents platforms, methods, and systems for marketing and advertising on mobile devices using Artificial Intelligence. The method involves receiving premium digital content generated by AI in response to user promotional activities. Then, a digital display system is used to plan advertising promotions targeting mobile users, with locations where premium content can be accessed. Goals are set for the advertising promotions and performance reports are generated based on performance metrics and collected data

(*continued*)

Table 1. (*continued*)

Patent	Analysis
Haifang, H., et al. (2023). Blockchain-Based Activity Marketing Method and Device (China Patent Number 115587104) (Haifang et al., 2023)	This invention presents a marketing method and device based on blockchain in the field of AI. The method involves obtaining user salary information through a blockchain, including the salary date. If the current date matches the salary date, a specific activity marketing message is sent to the user's terminal. This allows for automatic marketing opportunities, time savings, and improvement in marketing performance
Kahn, S. H., & Williams, T. J. (2023). Approaches to Predicting the Impact of Marketing Campaigns with Artificial Intelligence and Computer Programs for Implementing the Same (United States Patent Number 20230267499) (Kahn & Williams, 2023)	An approach is proposed that uses machine learning to accurately and reliably measure the impact of advertising strategies on product sales. This is achieved by creating a machine learning algorithm trained with specific company data. This algorithm is implemented in a data analysis platform to assess the effectiveness of advertising, aiding in more precise allocation of resources in future advertising campaigns
Pamuru, S. K. (2023). Artificial Intelligence Machine Learning System for Classifying Images and Producing a Predetermined Visual Output (United States Patent Number 20230274318) (Pamuru, 2023)	A technology is presented that automates the modification, sequencing, and display of vehicle images for marketing purposes. A seller uploads vehicle images into the system, which uses AI and machine learning to enhance the images, identify objects, and add relevant information. The system then organizes the images and displays them to potential buyers, simplifying the marketing process for vehicles

Source: Authors' own compilation based on the analysis of patents extracted from Patentscope

Figure 3 visually represents the thematic focus discussed in the extracted patents pertaining to the research topic. The analyses predominantly highlight various applications and trends in AI tool patenting for marketing purposes.

4.2 Applications of AI in Marketing from the Registration of Patent Requests in Patentscope

Following a detailed review of information for each patent, the thematic areas were grouped according to their application (Table 2). It is noteworthy that all patents share a focus on the application of AI in the realms of advertising and marketing, aiming

Fig. 3. Word Cloud based on Table 1 (Authors' own creation using https://www.nubedepalabras.es/ based on Table 1).

to enhance efficiency, personalization, and effectiveness in marketing strategies. However, significant differences are visible in the specific fields of application, such as e-commerce, marketing management, digital advertising, influence on customer behavior, among others. Each patent addresses a particular niche within the broad field of marketing, showcasing the versatility of AI in this domain.

4.3 Classification of Applications

The CPC (Cooperative Patent Classification) and IPC (International Patent Classification) codes are classification systems used to organize patents, trademarks, and other forms of intellectual property. They facilitate tasks such as publication date tracking, patent searches, and patent analysis. The CPC, developed collaboratively by the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO), is designed for global patent searches based on technical features. Meanwhile, the IPC, established by the World Intellectual Property Organization (WIPO) in 1971, provides a hierarchical structure for patent classification.

The IPC divides patents into eight sections comprising 124 classes, 650 subclasses, 3,400 groups, and 15,000 subgroups within each section. These codes are instrumental in organizing and searching for specific patent information, elucidating the technological scope, functions, and distinct characteristics of patents (Trends in Technological Trends through Patent Analytics, 2023).

Table 2. Grouping of Patent Applications

Application of AI in Marketing	Description
Mobile Marketing and Advertising Platforms	Utilization of AI to receive premium digital content, plan advertising promotions, set objectives, and generate performance reports targeted at mobile device users
Supply Chain Management (SCM)	Use of artificial intelligence methods to enhance supply chain management, identify areas for improvement, and optimize efficiency in logistics, marketing, supply chain, and manufacturing
Insurance Renewal Prediction	Employment of an XGBoost model to predict insurance renewal behavior based on user profiles, preferences and interests data, associated marketing data, and current subscription data
Blockchain Analysis for Green Marketing	Application of blockchain technology in managing digital files and green marketing to gain financial benefits and improve company advertising
Consumer Sentiment Analysis	Use of AI to analyze consumer emotions and preferences by monitoring social networks, online reviews, and patient records to enhance marketing and consumer research
Advertising and Marketing Platforms for Casinos and iGaming	Development of a blockchain-based advertising and marketing platform for casino, lottery, and online gaming operators using artificial intelligence and machine learning
User Gameplay Analysis	Utilization of modules for collecting, processing, and analyzing game information to predict future gaming behaviors and personalize the user experience in games
E-commerce Process Automation	Implementation of big data technologies to enhance e-commerce infrastructure, from management and marketing to payments and supply chain, with a focus on data organization and automated decision-making
Digital Advertising for Vehicles	Application of AI and machine learning to receive, modify, sequence, and display vehicle images with the goal of effectively marketing them to potential buyers

(*continued*)

Table 2. (*continued*)

Application of AI in Marketing	Description
Customer Service Monitoring with AI	Use of cameras, facial recognition, and voice processing through AI to detect the mental state of customer service employees and improve service quality and operational efficiency
Location-Based Marketing Platforms	Implementation of marketing platforms utilizing AI to plan specific advertising promotions based on the location of mobile device users and accessibility to premium digital content

Source: Authors' own compilation based on the reading of the patents listed in Table 1

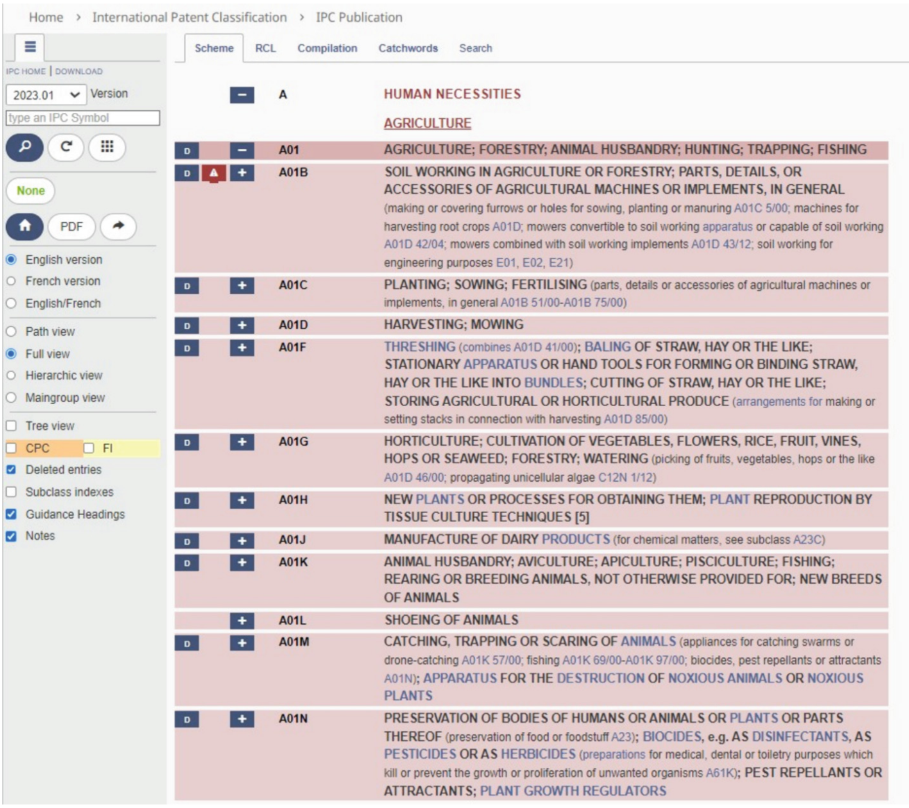

Fig. 4. IPC Code Classification Search Portal (Source: Instituto Nacional da Propriedade Industrial) (Instituto Nacional da Propriedade Industrial, 2023).

Figure 4 illustrates the interface of the portal used for searching and classifying IPC codes. The left section allows users to apply filters using specific codes and keywords related to patent searches. The platform's main body facilitates classification, offering a wide range of categories and subcategories (Fig. 4).

The CPC, introduced in 2006 by the EPO and USPTO, enhances the existing IPC structure by providing a more detailed categorization of patents. It consists of nine sections with 120 classes, 1,000 subclasses, 1,000 groups, and 1,000 subgroups. These codes are pivotal for classifying intellectual property, focusing on specific technologies, and enabling a detailed analysis of the state-of-the-art within specific fields.

Similar to the IPC portal, the platform for searching and classifying CPC codes features dropdown menus for users to conduct more specific searches based on categories, subcategories, classes, and subclasses (Fig. 5).

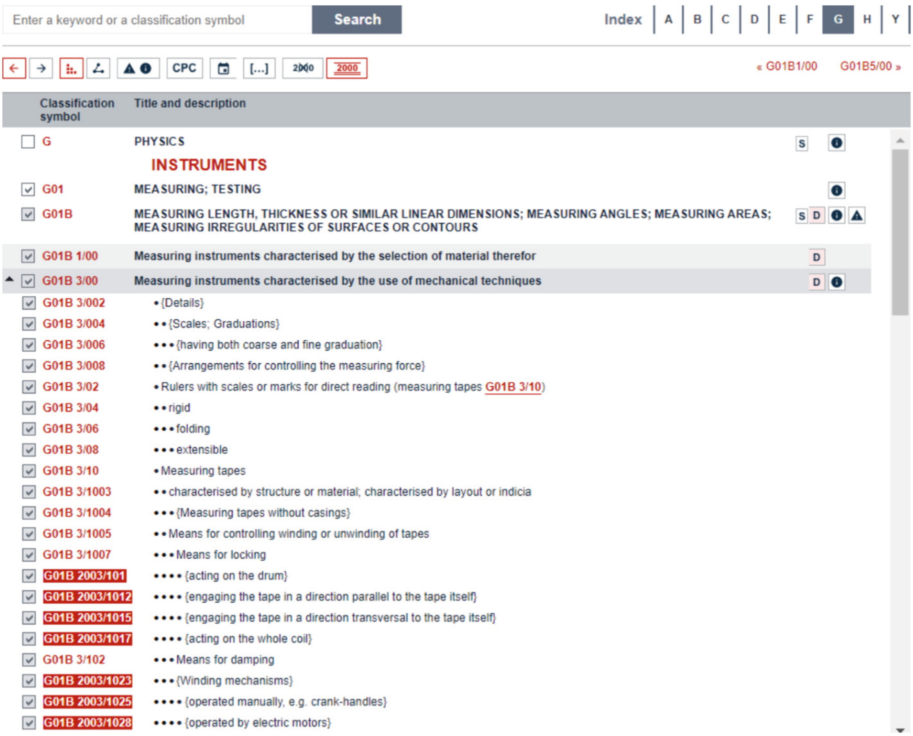

Fig. 5. CPC Code Classification Search Portal (Source: Instituto Nacional da Propriedade Industrial) (Instituto Nacional da Propriedade Industrial, 2023).

In this research exercise, the selected patents were identified and classified using the nomenclature presented in Table 3. This table provides the count and grouping of various patents extracted from the IPC page, specifically for the current study. The patents were organized from the most to the least trending, with the percentage of each code's participation relative to the total relevant patents for our research also included.

The analysis of patent classification based on IPC codes reveals a distribution focused on technological categories. Notably, the G06Q code stands out, representing 40% of

Table 3. Classification and Total Count of IPC Codes.

IPC Code	Description	Patents	Participation
G06Q	"Information and communication technology [ICT] specially adapted for administrative, commercial, financial, managerial or supervisory purposes; systems or methods specially adapted for administrative, commercial, financial, managerial or supervisory purposes, not otherwise provided for"	38	40%
G06N	"Computing arrangements based on specific computational models"	21	22%
G06F	"Electric digital data processing"	20	21%
H04L	"Transmission of digital information, e.g. Telegraphic communication"	6	6%
G09F	"Displaying; advertising"	3	3%
G10L	"Speech analysis or synthesis; speech recognition; speech or voice processing; speech or audio coding or decoding"	2	2%
G07F	"Coin-freed or like apparatus"	1	1%
H04N	"Pictorial communication"	1	1%
G06T	"Image data processing or generation, in general"	1	1%
G06V	"Image or video recognition or understanding"	1	1%
Total		94	100%

Source: Own elaboration

the total, and it focuses on methods and data processing systems in the managerial field. Following closely is the G06N code with 22%, addressing AI-based computing techniques and machine learning. The G06F category, related to digital information technology and computational methods, contributes 21% of the total. Additionally, a range of codes reflects the breadth of covered areas, from voice signal processing to payment systems and image signaling.

To contextualize the information from Table 4, the same methodology of filtering and organizing patent codes was followed, as seen in Table 3. The primary difference is that, in this case, the codes were obtained from the CPC coding platform. This allowed for the counting and classification of various patents linked to the central theme of our research, along with their corresponding percentage of participation.

The table provides the distribution of patents according to CPC codes, where the G06Q category stands out with 47% participation, related to information and communication technologies tailored for administrative and commercial purposes. Following is the G06V category, focused on image or video recognition, representing 18%.

Categories like G06N (computation based on specific models) and G07F (coin-operated mechanisms) hold a participation of 12% and 6%, respectively. Additionally, categories such as Y02D (technologies for mitigating climate change in ICT) and H04N

Table 4. Classification and Total Count of CPC Codes.

IPC Code	Description	Patents	Participation
G06Q	"Information and communication technology [ICT] specially adapted for administrative, commercial, financial, managerial or supervisory purposes; systems or methods specially adapted for administrative, commercial, financial, managerial or supervisory purposes, not Otherwise provided for"	8	47%
G06V	"Image or video recognition or understanding"	3	18%
G06N	"Computing arrangements based on specific computational models"	2	12%
G07F	"Coin-freed or like apparatus"	1	6%
Y02D	"Climate change mitigation technologies in information and communication technologies [ICT], i.e. Information and communication technologies aiming at the reduction of their own energy use"	1	6%
H04N	"Pictorial communication, e.g. Television"	1	6%
G10L	"Speech analysis or synthesis; speech recognition; speech or voice processing; speech or audio coding or decoding"	1	6%
Total		17	100%

Source: Own elaboration

(pictorial communication), along with G10L (voice analysis and synthesis), each contribute 6%. This landscape suggests a significant emphasis on information technologies for administrative and commercial purposes.

5 Conclusions

Throughout the year 2023, in the context of the Industry 4.0 era, the adoption and implementation of Artificial Intelligence (AI) in the field of marketing has evolved into an essential necessity to maintain competitiveness among companies globally. This transformation has facilitated hyper-personalization in the customer experience in various aspects. With this premise, a thorough analysis of emerging AI patent documentation applicable to different marketing approaches was conducted between January and August 2023. This analysis was based on primary research sources, providing a detailed insight into how AI has been reshaping processes and decision-making in marketing towards an enhanced consumer experience.

The aforementioned study allows for addressing the initial question of this research, evidencing that AI is increasingly being utilized in various aspects of marketing to improve efficiency, personalization, and effectiveness of applicable strategies in the past year. Similarities were identified among the patents concerning resource optimization and effective investments, with a notable emphasis on revenue enhancement and cost reduction in digital marketing. However, differences were also observed in the specific fields of execution for each patent, such as e-commerce, marketing management, digital advertising, and consumer behavior influence, among others. Furthermore, variations in comparison criteria were highlighted, such as user experience personalization and consumer behavior prediction.

The findings of this exercise include:

a. Diversity of AI Applications in Marketing: AI applications encompass a wide range of areas, from personalized advertising campaigns to efficient data management, improved customer experience, and data-driven decision-making.
b. Focus on Personalization and Customer Experience: AI is used to understand individual preferences, predict future behaviors, and offer real-time personalized experiences to enhance loyalty and engagement.
c. Optimization of Processes and Data-Driven Decision-Making: Artificial intelligence is not only used to enhance customer interaction but also to optimize internal marketing processes, such as publisher selection, campaign effectiveness evaluation, and efficient management of large datasets. "Data-driven decision-making" and predictive analysis are fundamental elements for the performance of marketing strategies.
d. In summary, the various patenting trends indicate a strong and consistent focus on the development of AI tools, especially those adaptable for administrative and commercial purposes. These tools can be highly optimal in the marketing area to enable process automation, experience personalization, and advanced data analysis for effective strategic decision-making. Additionally, image and video recognition stand out as a key and disruptive area with significant potentials applicable to visual marketing strategies.

However, within the limitations, it is important to consider the analysis period and that the analyzed patents correspond to applications under the Patent Cooperation Treaty. Future work could include studies on the economic effects of AI implementation, discussions on ethics, privacy, AI, and marketing.

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Thermal Imaging System for the Detection of Varicose Veins in Adult Patients

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Abstract. Varicose veins are produced by dilations of the veins due to the agglomeration of blood fluid in the different parts of the patient's body, presenting various symptoms or common discomforts in the lower extremities of the patient based on the present progress of the disease, likewise, it represents a frequent problem in the world population with about 30% of affected that are associated with the age of the person, family inheritance, trauma problems, overweight, among other factors that are witnessed in active people, increasing notoriously in sedentary patients, therefore, the early detection of varicose veins will prevent their progression even if it is slow, although there are many prevention treatments, they are expensive and painful after the operation with slow recovery that can even affect other nerves. In view of this problem, in this research a thermal imaging system was developed for the detection of varicose veins in adult patients, in such a way that the degree of varicose veins that affect patients is detected and indicate the state in which the disease is located, likewise, it will allow monitoring varicose veins that do not manifest in the lower extremities through the image processing developed in MATLAB at Integrate the thermography technique. Through the development of the proposed system, it was possible to appreciate its functionality with an efficiency of 94.97% in the detection of varicose veins on adult patients with a high reliability with respect to the analyses performed.

Keywords: Histogram · Thermal imaging · MATLAB · Image processing · Varicose veins

1 Introduction

The blood arteries serve to transport oxygen-poor blood from the heart to the periphery of the body or lungs (Salazar et al., 2023; Santos Martínez & others, 2022; Triantafyllou et al., 2024), as the blood arteries dilate, they cease to fulfill their function by causing blood flow to reverse and return to the person's leg (Álvarez Pérez et al., 2021; Ibrahimi et al., 2023; Vásquez et al., 2024), which causes dilation to increase and a swelling problem in the leg part (Grande Castillo & Sanz Corral, 2023). This chronic venous insufficiency, also known as varicose veins, are swollen veins that are caused by an abnormal accumulation of blood caused by a weakness in the walls and valves of the superficial veins (Castillo De La Cadena, 2022), causing the veins to extend and dilate, which would allow blood to pool considerably when a person stands for long periods of time (Marín et al., 2020; Shah et al., 2023; T et al., 2023).

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This chronic venous insufficiency is considered one of the costliest diseases due to the discomfort it causes in people's lower extremities, such as the leg, as it is more than 3 mm in diameter (Vila Coll & Avilés Sierra, 2022). Varicose veins are visualized below the surface of the skin, although they usually affect the part of the leg of the person, they are not the only parts of the body where they can manifest, as they have also manifested in the back of the calves (Henry et al., 2021). According to the WHO (World Health Organization), varicose veins are highlighted by the enlargement of superficial, cylindrical, or vascular veins due to a microcirculatory deficiency that affects and complicates people's health by increasing the number of cases considerably over the years (Auza-Santiváñez et al., 2023; Lesmana et al., 2020), presenting discomfort and progressive pain associated with cramps, distal weakening and swelling in the lower extremities caused by standing (Ángel Arango & Donado More, 2020; Castillo, 2023).

Varicose veins are a frequent problem with around 30% of the population worldwide affected by this condition (Header et al., 2023), being manifested with greater predominance in the female sex as opposed to the male sex and presenting prevalences of 20 to 60% in developed countries (Muñoz Cedeño et al., 2021). The risk factors associated with varicose veins are older people, relatives related to varicose veins, a history of trauma to the lower extremities, obesity, clothing that hinders venous return, among other factors, being a figure that occurs in active people and that increases when they reach a sedentary lifestyle (Barragán Villafuerte et al., 2020). Varicose veins can be classified into four grades: Grade I, is the stage in which thin purplish veins are visible in some parts of the lower extremities with aesthetic problems. Grade II is the stage in which the veins extend and dilate, manifesting the initial symptoms. Grade III, is the stage in which the veins are most extended and dilated, presenting a progressive increase in symptoms and changing the pigmentation of the skin due to swelling. Grade IV, is the stage in which dermatitis and ulcers manifest in the lower extremities, making it difficult to treat as it quickly becomes infected (Rojas Valenciano et al., 2020).

Based on the characteristics of varicose veins, the early detection of this disease in the lower extremities of people would prevent varicose veins from progressing further in degree even if it is a slow progression (Jimenez & others, 2022), although there are many prevention treatments for this disease, if it is in an advanced stage it requires a conventional surgery through stripping that, During the postoperative period, it causes a lot of pain and functional impotence to the patient with a slow recovery, and can cause injuries to other nerves near the area affected by this disease (Caiza Ango et al., 2023). Therefore, it is important to detect this disease by applying thermography, a technique that allows determining the temperature variation at a distance over the patient through thermal images of the affected lower extremities, showing the thermal composition according to the temperature range predetermined in the algorithm, which can be processed by software for the detection of internal ailments.

The objective of this research work is to perform a thermal imaging system for the detection of varicose veins in adult patients, in such a way as to detect the degree to which varicose veins are found even if they are not witnessed in the patient's lower extremities and indicate their corresponding treatment by superimposing the thermal image and the RGB image to determine their correct detection. For the development of this system, the FLIR ONE Pro thermal camera was used to capture both images in real time and, through the image processing developed in the MATLAB software, the thermography technique will be integrated to determine the temperature in the areas of the lower extremities, specifically in the legs, at a distance without physical contact between the system and the patient.

In Sect. 2, a literature review of some research papers that deal with varicose veins will be carried out. In Sect. 3, the methodology will present the development of image processing for the detection of varicose veins in adult patients. In Sect. 4, the results based on the tests of the imaging system will be presented, In Sect. 5, the discussion of the system will be presented by highlighting the importance of its functioning on the disease. Finally, in Sect. 6, the conclusion and recommendation of the system will be presented.

2 Literature Review

The detection of varicose veins is based on a series of tests or medical analyses that allow the functioning of the valves with respect to the blood fluid to be discovered, varying in costs and results for patients if the degree of this disease is advanced by requiring a surgical intervention with anesthesia, resulting in pain and impotence in the patient's movement with respect to movements after the postoperative period. For this reason, systems must be used to detect the degree or progress of varicose veins in patients to determine a correct diagnosis and can be treated by the corresponding doctor. For example: In (Rajathi et al., 2022), researchers mention that varicose veins can cause deep wounds in patients if the progression of this disease is not treated in time, causing ulcers by not allowing the body's blood to flow normally when the pressure in the dilated veins increases, presenting on the sides of the legs, Expanded edges with a distinctive appearance due to the poor circulation of blood fluid in these lower extremities, causing progressive pain in patients due to a lack of medical intervention when the progression of this disease already becomes ulcerative wounds, being expensive when starting their medical treatment, therefore, they decided to develop a wireless monitoring system for the analysis of varicose veins and ulcers in older adults. The methodology applied by the researchers is based on developing a wireless local area network for the emission of data, as well as the reception of patient information using wireless antenna modules connected to an Arduino, being necessary a tracking webcam through a simple protocol between OpenCV and Arduino for the acquisition of images of the patient in the part of the ankles. Being visualized by means of a computer by establishing a USB connection with the Arduino board by differentiating the pigmentation of the skin affected by varicose veins. As a result, they presented an 82.47% efficiency in the analysis of varicose veins and ulcers in older adults, concluding that their proposed system facilitates the analysis of varicose veins wirelessly by establishing a simple protocol between OpenCV and Arduino.

In (Zhorina et al., 2023), the researchers mention that chronic venous insufficiency is considered one of the most costly diseases that affect more than 40% of the citizenry in developed countries, emphasizing that the WHO specifies that this pathology is a civilized disease, likewise, the researchers indicate that this disease of dilated veins develop due to the abnormal changes that occur in the vascular walls of the arteries, Accompanied by little ability to flow blood through the affected lower extremities due to an increase in pressure and temperature in the area with dilated veins shown in an expanded way, therefore, they decided to develop a thermographic system for the evaluation of varicose veins in the lower extremities based on a mathematical model. The methodology applied by the researchers is based on evaluating patients suffering from varicose veins using infrared sensors connected to a Raspberry Pi 3 Model B, modeling a mathematical equation that demonstrates the distribution of heat affected by varicose veins in the lower extremities and comparing it with the thermographic technique, using a mathematical model of heat extension in the affected area to demonstrate the variables with the conduction equation of heat, showing that varicose veins in the affected areas lose the ease of blood flow when pressure is present. As a result, they presented an 86.12% efficiency in the evaluation of varicose veins presented in the lower extremities of patients, concluding that their proposed system aims to carry out an evaluation of this disease based on a mathematical model to determine the defective functioning of the patient.

In (Rithika et al., 2023), the researchers mention that veins are composed of valves oriented in a single direction to maintain blood flow to the part of the heart, a normal situation in healthy patients, while varicose veins present conditions or complications in the blood valves when they are damaged that influence the accumulation by not allowing the return of blood flow, Commonly visualized in older adult patients and pregnant women due to the pressure they cause in the lower extremities, being able to counteract the discomforts of pain, itching, ulcers, wounds, etc., through therapies or medical treatments that subject patients to a long recovery, therefore, they decided to develop an optimal pressure assessment system in the lower extremities for the treatment of varicose veins. The methodology applied by the researchers is based on performing compression therapy for varicose veins, where a specific pressure is applied to maintain the adequate treatment of this disease that limits the patient's movement, likewise, they highlight that there is still no equipment or method that allows controlling the pressure in the affected lower extremities while covering the area. Therefore, this system provides a pressure indicator through a resistive force-sensing component and light-emitting diodes integrated into the compression bandage. As a result, they presented a 90.36% efficiency in indicating the pressure exerted by the bandage on the lower extremities affected by this disease, concluding that their proposed system applies a new method to counteract the discomfort caused by varicose veins.

In (Shumkov et al., 2020), the researchers mention that varicose veins are a progressive disease that over the years has been manifesting itself in a total number of people affected by this disease, which can cause some disability in patients by affecting their lower extremities, mentioning that specialist doctors reach the point of performing surgical operations on varicose veins by opening them and extracting them with the corresponding care because it is a surgery In addition to the great pain after surgery accompanied by a slow recovery, and the high cost to perform it, they therefore decided to develop an automatic system of radiofrequency ablation of varicose veins applied in overweight patients. The methodology applied by the researchers is based on developing an ablation prototype performed by means of electromagnetic waves applied to the varicose veins manifested in the lower extremities of overweight people, for this, they use a comparative methodology on patients with conventional surgical removal versus the conventional operation applied with wave-emitting sensors that detect the lack of blood fluidity in the varicose veins of Patients, likewise, through the use of these sensors, are able to identify the part where blood fluid accumulates. As a result, they presented an 88.99% efficiency in the detection of the venous point where the blood fluid of overweight patients accumulates, concluding that their proposed system applies sensors that manage to identify the critical points of varicose veins without inconvenience.

In (Das et al., 2023), the researchers mention that varicose veins of the lower extremities develop due to a pathological change of enlarged and twisted veins, located mainly in the part of the patient's leg tissue, likewise, the normal functioning of the blood valves is inefficient by not allowing blood flow to circulate again through the upper extremities, causing reflux accompanied by symptoms of pressure on the veins. This varicose vein disease causes various complications in the affected area of the patient by not circulating blood fluid correctly, which makes patients feel pain, tiredness, fatigue, etc., limiting their free movement, therefore, they decided to develop an automatic system for the early detection of varicose veins by applying IoT technology on elderly patients. The methodology applied by the researchers is based on developing a prototype that detects this disease in older adults to alleviate the pain manifested when applying IoT technology, using a microcontroller to control the devices, force and tilt sensors for the acquisition of information on the lower extremities, a pulse oximeter to diagnose the patient's vital signs in the blood, among other electronic components that allow an automation of the process of detection of varicose veins, identifying the stages manifested by this disease that would assist doctors. As a result, they presented a 91.33% efficiency in the early detection of varicose veins over elderly patients to relieve the manifested pain, concluding that their proposed system allows to see the results of varicose vein detection using IoT-based electrical components.

3 Methodology

The methodology is based on developing a system that allows the detection of varicose veins in adult patients, in such a way that varicose veins are shown even if they cannot be visualized in the patient's lower extremities through the application of image processing techniques that facilitate the evaluation of varicose veins and can indicate their treatment with the corresponding doctor by superimposing the thermal image and the color image. Taking into account the details mentioned, a block diagram is made that describes the internal structure of the system, as admired in Fig. 1.

According to Fig. 1, the internal structure of the system is represented by a series of steps that are subjected to thermal imaging to detect varicose veins on patients, describing each step below to finally visualize varicose veins.

3.1 Thermal Camera

The acquisition of the images is carried out by means of the FLIR ONE Pro thermal camera, an electronic device used to capture and store electronic photographs for subsequent analysis and detection of varicose veins that affect adult patients by manifesting

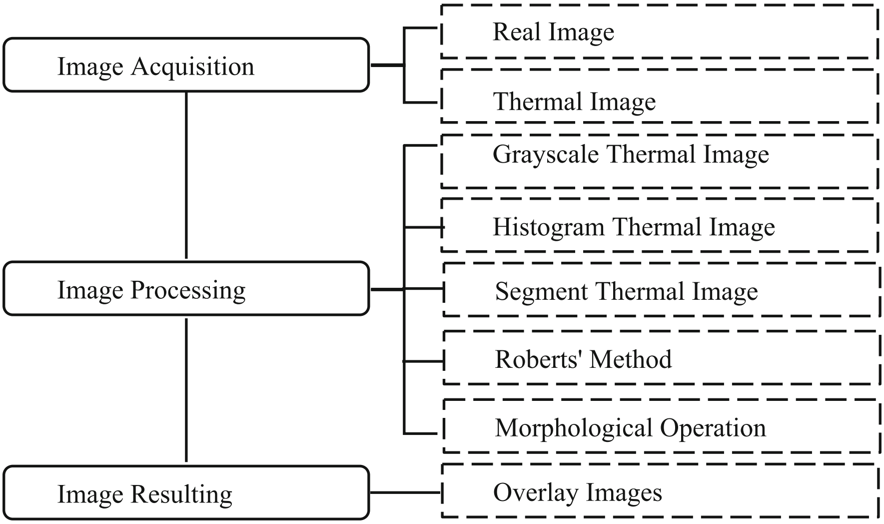


Fig. 1. System Block Diagram

in the lower extremities, causing discomfort due to the signs presented by the disease. Likewise, this electronic device allows us to capture color images and thermal images by having two lenses in its design, as admired in Fig. 2, having moderate sensitivity that non-invasively detects the variation of temperature on the photographed object, presenting its own platform on mobile devices for visualization, Editing or deleting images captured by both lenses, finally its type-C connector allows this electronic device to work normally on any mobile model.

Fig. 2. Thermal Camera

The thermal camera is an electronic device capable of measuring temperature and representing it by means of a thermal image from the infrared radiation emissions of the photographed object, initially created for the detection of faults on electronic boards or circuits that are not easily visualized, improving its design and quality of the device to perform tasks in a short time by recognizing the details of the hot spots, Therefore, it has been used by various professionals for being a practical and effective tool for detecting a point where there is a temperature variation at a certain distance from the photographed object.

Table 1 shows the characteristics of the thermal camera (Nuñez Tapia et al., 2021).

Table 1. Characteristics of Thermal Camera.

FLIR ONE Pro	
IR Sensor	160 × 120 Sensor
Mobile	FLIR ONE
Temperature	−20 °C 400 °C
Weight	35.99 g
Connector	Type-C
Accuracy	º ±3 °C

3.2 Image Processing

The image processing part initially requires the images acquired by the thermal camera declared in the Matlab programming for subsequent treatment, first, the color or RGB image of the patient's leg part captured at an estimated distance of 40 cm from the point of the thermal camera is declared, As shown in Fig. 3(a), the thermal image of the patient's leg captured at an estimated distance of 40 cm from the point of the thermal camera is then declared, as shown in Fig. 3(b).

The image processing follows a detailed order in Fig. 1, which allows the process of superimposition between the color image and the thermal image to be carried out for the visualization or detection of varicose veins in the patient's leg, likewise, the code made in Matlab is supported by the reading of the image in imgX.jpg format from a corresponding time to store them in a folder created by the system, highlighting that a specific time is considered by the readings of the color image and thermal image declared in the initial part.

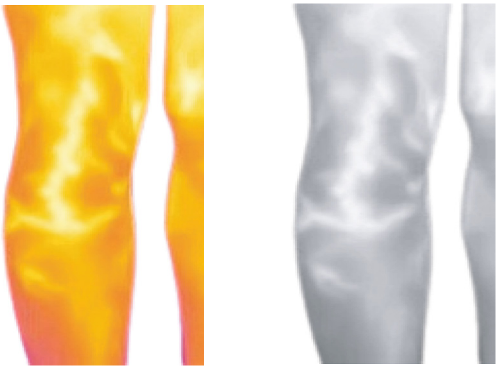
```
CLC
clear all
close all
%Read an image
x = imread ('imgColor.jpg');
figure
imshow (x)
%Read an image
y = imread ('imgThermal.jpg');
figure
imshow (y)
```

(a) (b)

Fig. 3. (a) Color image of Tibial Muscle. (b) Thermal Image of Tibial Muscle

After declaring the reading of the color image and the thermal image acquired by the FLIR ONE Pro camera, we continue with the processing of the thermal image by performing a grayscale conversion to speed up the use of resources, being a conversion in which the thermal image will be represented by shades of gray by varying each pixel value of the thermal image in equivalent gray value by means of the The following formula performs the grayscale (RGB2GRAY conversion process), as shown in Fig. 4.

```
CLC
clear all
close all
%Read an image
x = imread ('imgColor.jpg');
figure
imshow (x)
%Read an image
y = imread ('imgThermal.jpg');
figure
imshow (y)
% Declare variable for grayscale
r = rgb2gray (y);
% Show image
Figure
imshow (r);
```



(a) (b)

Fig. 4. (a) Thermal Image of Tibial Muscle. (b) Grayscale of Tibial Muscle

After converting grayscale (RGB2GRAY) to thermal image, we continue image processing by creating a histogram for the grayscale thermal image using the "imhist" function, represented by a graph detailing the intensity assignment of the grayscale thermal image. The graph created by the "imhist" function shows a histogram with "n" cells of the same separation distance, of which it expresses a range of values, and then counts the number of pixels located in each range for the identification of the segments of the thermal image, as shown in Fig. 5.

```
CLC
clear all
close all
%Read an image
x = imread ('imgColor.jpg');
figure
imshow (x)
%Read an image
y = imread ('imgThermal.jpg');
figure
imshow (y)
% Declare variable for grayscale
r = rgb2gray (y);
% Show image
Figure
imshow (r);
% Histogram Thermal Image
imhist (r);
```

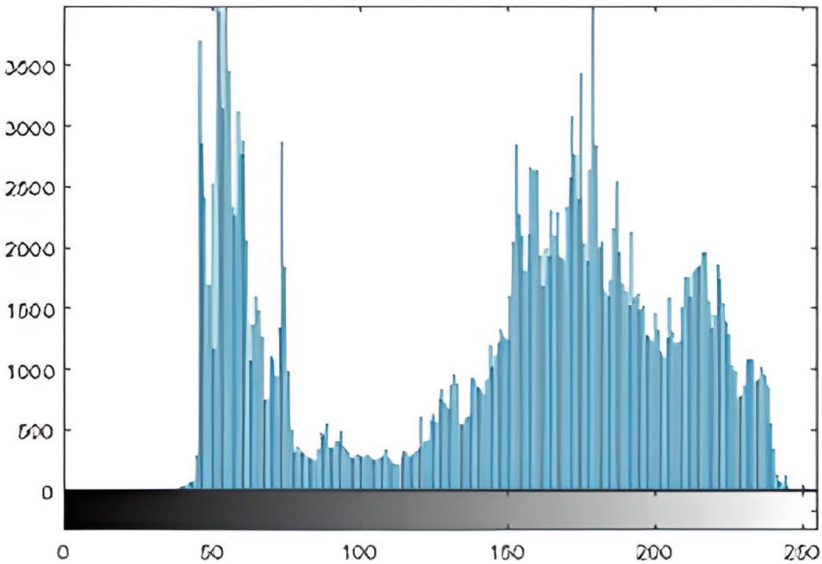


Fig. 5. Histogram of Thermal Image

After developing the histogram of the thermal image converted into grayscale, we continue with the image processing by identifying the peaks of each segment manifested by the histogram of the image that will be superimposed to acquire the areas of higher temperature, being a process that performs the partition of the image by determined regions based on the characteristics of the pixels. In such a way, its operation is carried out by means of the “imageSegmenter” function for the reduction or expansion of the specific lines of the image of the patient’s leg, as admired in Fig. 6.

```
CLC
clear all
close all
% Read an image
x = imread ('imgColor.jpg');
figure
imshow (x)
% Read an image
y = imread ('imgThermal.jpg');
figure
imshow (y)
% Declare variable for grayscale
r = rgb2gray (y);
% Show image
Figure
imshow (r);
% Histogram Thermal Image
imhist (r);
% Image segmentation
imageSegmenter(r)
imshow (r);
```

Fig. 6. Segments of Image Histogram

After joining the segments of the histogram, we continue with the image processing to determine the edges of the areas with the highest temperature using the Roberts formula, being a formula that allows us to easily detect angular edges present in the image when filling in the spaces presented, as well as the image of the Astronomical Triangle 7. This Roberts formula identifies the edges of the image using the "edge" function, allowing you to locate the changes in intensity using your criteria for drawing varicose veins.

```
CLC
clear all
close all
% Read an image
x = imread ('imgColor.jpg');
figure
imshow (x)
% Read an image
y = imread ('imgThermal.jpg');
figure
imshow (y)
% Declare variable for grayscale
r = rgb2gray (y);
% Show image
Figure
imshow (r);
% Histogram Thermal Image
imhist (r);
% Image segmentation
imageSegmenter(r)
imshow (r);
%Roberts' formula
bw = edge (r, ' Roberts')
imshow (BW);
```

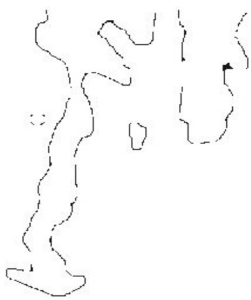


Fig. 7. Edge identifications

After identifying the edges of the image by applying Roberts' formula using the "edge" function, we continue with the processing of the image to improve the edges obtained by this formula through the morphological operation applied to the image. This morphological operation consists of each pixel in the image being arranged according to the values of other nearby pixels, using the "imdilate" function so that the value of the output pixel is the maximum of all the nearby pixels, by generating that the lines are displayed thicker, and the existing gaps are filled with a transparent color. Improving the visibility of varicose veins by overlaying the segmented image and the RGB image, as shown in Fig. 8.

```
CLC
clear all
close all
% Read an image
x = imread ('imgColor.jpg');
figure
imshow (x)
% Read an image
y = imread ('imgThermal.jpg');
figure
imshow (y)
% Declare variable for grayscale
r = rgb2gray (y);
% Show image
Figure
imshow (r);
% Histogram Thermal Image
imhist (r);
% Image segmentation
imageSegmenter(r);
```

Fig. 8. Overlay Image

4 Results

The development of this system correctly carries out the proposed objective of detecting varicose veins in adult patients manifested in their lower extremities by performing it through image processing, applying techniques to the thermal image acquired by the camera to monitor the progress of this disease on the patient's leg. With this, a wise decision can be made about the patient's treatment by allowing the doctor to have another opinion on the progress of varicose veins visualized by the system.

The development of this image processing system was carried out in order to meet the expectations on the detection of varicose veins, testing its functionality on adult patients and corroborating the timeliness of its results by presenting an efficiency of 94.97% in the detection of the disease. It is a reliable system due to its high efficiency in the detection of varicose veins obtained through the application of the thermography technique by allowing the infrared radiation of the electromagnetic spectrum to be captured for its corresponding treatment.

The results of the proposed system show that the detection of varicose veins obtained through image processing presents similarity compared to other developed systems, highlighting its own characteristic of allowing to show those varicose veins that are not shown superficially over the affected area, likewise, its implementation requires specific devices. Such as the thermal camera and the computer connected for the acquisition of thermal images and their subsequent image processing that will facilitate the monitoring of varicose veins.

The results show that the processing of thermal images acquired by the camera presents a homogeneous protocol with respect to the characteristics that allow the acquisition of images correctly to avoid possible problems with the final result of the processing of the system, likewise, the distribution of varicose veins in the patient's leg would be visualized by means of a final image with clarity. by filling it with a light color so that the doctor can evaluate it and determine the affected area along with the possible symptoms that the patient may have.

In accordance with Table 2, the elementary characteristics of the thermal imaging system for the detection of varicose veins in adult patients are estimated, detailing the fundamental data of the system for its benefit on the detection of varicose veins in the lower extremities, generating greater safety and confidence by respecting the values so that the analysis is carried out efficiently. Therefore, distance, software, and thermal imaging values will indicate the progression of the disease.

Table 2 details the characteristics of the proposed system.

Based on the results obtained by the system, it is determined that its operation on adult patients is essential to cope with the disease that has been growing over the years, likewise, it can be used by any person or medical personnel since the system works by itself, without the need to manipulate it. It is only a matter of respecting the indicated characteristics so that it does not present problems in the analysis carried out by the final software of the patient with varicose veins.

Table 2. System Characteristics.

System evaluation	
Distance	40 cm
Software	MATLAB
Images	Color and Thermal
Range	15 °C to 40 °C
Body analysis	Leg, Tibial muscle
Efficiency	94,97%

5 Discussion

Varicose veins are a disease that has been treated and researched by many specialist doctors as there is an increase in the number of cases of patients per year affected by this disease, this interest is based on the constant cases in which patients are unaware of the suffering of this disease, as well as the degree or progress in which these varicose veins are found that with their advancement can affect the quality of their condition. Health of the patient, as well as a limitation of movement freely due to the pain caused by this disease.

This thermal imaging system for the detection of varicose veins in adult patients is essential for the early detection of this disease by applying a new methodology that distinguishes it from the other research works mentioned below, for example, the research work developed by (Rajathi et al., 2022), where the researchers proposed to perform a wireless monitoring system for the analysis of varicose veins and ulcers in older adults. Achieving as a result an efficiency of 82.47% in the analysis of varicose veins and ulcers on older adults, but this system proposed by the researchers works with an Arduino board for the connection of the wireless modules, presenting a limitation in its ability to scale if it is necessary to monitor more patients, likewise, It lacks instruction regarding the treatment of the images obtained by the webcam by simply analyzing the pigmentation of the patient's skin in the part of the ankle, being able to alter the result if the patient had a blow or injury prior to the analysis of this system.

We also have the work developed by (Zhorina et al., 2023), where the researchers proposed to make a thermographic system for the evaluation of varicose veins in the lower extremities based on a mathematical model. Achieving as a result an efficiency of 86.12% in the evaluation of varicose veins presented in the lower extremities of patients, but this system during its operation does not manage to define the variation of the heat variable through the formula used, not making it clear if its methodology is better than the thermographic technique, likewise, its evaluation on patients generates uncertainty by not visualizing the heat map, limiting its evaluation function if the patient presents with advanced degree varicose veins since the variables introduced by the authors would not consider blood flow, they also do not specify the time variable when evaluating patients with their system.

We also have the work developed by (Rithika et al., 2023), where the researchers proposed to perform an optimal lower extremity pressure assessment system for the treatment of varicose veins. Reaching as a result an efficacy of 90.36% in indicating the pressure exerted by the bandage on the lower extremities affected by this disease, but this system uses a force sensing resistance (fsr) that changes its values as it exerts more pressure, so this data could confuse users if there is no pressure, Since it would act as an infinite resistance through an open circuit, likewise, looking at it from the patient's point of view, it does not generate comfort in the affected lower extremities, in addition to warming up due to its constant operation and the fragility of the components if that affected area of the patient sweats or presents a wound.

We also have the work developed by (Shumkov et al., 2020), where the researchers proposed to perform an automatic system of radiofrequency ablation of varicose veins applied in overweight patients. Achieving as a result an efficacy of 88.99% in the detection of the venous point where the blood fluid of overweight patients accumulates, but this system proposed by the researchers proposes an ablation of varicose veins on overweight patients, and they are only based on detecting the critical point of this disease in the affected lower extremities. Using sensors without specifications on their operation and efficiency that they may have during their operation, lacking confidence about their implementation on patients, as well as little information on the cost of implementation as medical equipment for surgical intervention in cases of complexity when the disease is advanced.

We also have the work developed by (Das et al., 2023), where the researchers proposed to carry out an automatic system for the early detection of varicose veins by applying IoT technology on elderly patients. Achieving as a result an efficacy of 91.33% in the early detection of varicose veins in elderly patients to relieve the manifested pain, but this system uses basic electronic components, without efficiency and quality control, so its evaluation and detection of varicose veins may vary based on the climatic conditions in which this system is used on elderly patients, Likewise, the architecture presented about its internal connection of the system is not convincing, especially when handling vital signals and not considering the filters that would prevent external noise from affecting the analysis of the system. A comparison will then be made in Table 3 of this described system (a) versus our proposed system (b).

Table 3 describes the comparisons of the two specified systems.

Table 3. Comparison of System.

	a	b
System	Automatic	Automatic
Information	Sensors	Thermal camera
Patient's condition	Rest	Rest
Software	MPLAB	MATLAB
Analyzed part	Leg	Leg, Tibial muscle
Accuracy	91,33%	94,97%

6 Conclusion and Recommendations

It is concluded that this system performs thermal image processing for the detection of varicose veins that affect adult patients, which in most cases do not manifest on the patient's lower extremities, being able to visualize their path, as well as their treatment according to the doctor's indications after analyzing the result acquired by the system.

It is concluded that this system allows the doctor to have greater visibility of varicose veins that are not visualized on the surface of the affected area, likewise, its implementation is advantageous on any patient who presents symptoms of varicose veins so that they have a complete examination and can prevent this disease from continuing to advance. as it would complicate their medical treatment. (Shamim, Rejuwana, and Al, 2024; Khouibiri.N and All, 2024, Farhaoui, Y, 2024; Folorunso, S.O. and All, 2024; Adeniyi, A.E. and All, 2024; Awotunde, J.B. and All, 2024; Triantafyllou, Serafeim A. and All, 2024).

It is concluded that this system presents a friendly manipulation so that any medical personnel can evaluate the patient with varicose veins, with an advantage of the proposed system by performing the evaluation automatically, that the doctor will be able to visualize the final result and corroborate the degree of progress that this disease presents to treat it in time. In the same way, its implementation is not complicated.

It is concluded that this system analyzes thermal images through the processing techniques presented internally, allowing the detection of varicose veins that have been affecting patients with fundamental information about the failure of the valve system that generate high pressure in the veins of the lower extremities, being able to avoid painful ulcers in the affected skin due to accumulation of blood fluid in the long term.

It is concluded that this system uses a novel methodology, combining image processing techniques to detect a disease that has been affecting many patients, therefore, it is essential for the contribution in the health area as it has a low cost with respect to implementation, as well as its analysis without contact with the patient by respecting the biosecurity measures for the doctor and the person evaluated.

As a future work, a distance sensor could be added to respect the characteristics of image acquisition, likewise, the analysis of the system could be improved with respect to varicose veins that are very deep that require a more complex intervention to treat it and prevent its progression, making it a more efficient system for the detection of varicose veins.

It is recommended to respect the characteristics specified above, especially with the focusing distance of the camera for a correct analysis of the system, as well as the detailed steps of the image processing techniques performed in Matlab for the detection of varicose veins.

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Determinants of Educational Inequalities a Macroeconomic Approach on Panel Data

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Abstract. Macroeconomic research on inequalities in education focuses mainly on the possible impacts of this form of inequality on a number of economic and social variables such as growth, income inequality, health, etc. The determinants of this form of inequality remain little explored. The purpose of this paper is to explain educational inequalities through a macroeconomic approach by estimating a fixed-effects model for a panel of developing countries observed over the period 1980–2014. The model-dependent variable is the Gini index of the average number of years of study of the population aged 15 and over. The results indicate a strong negative correlation between inequalities in education and two educational variables namely the literacy rate of the population aged 15 and over and the percentage of primary school students enrolled in private school. They also indicate a strong negative correlation between the dependent variable and the following socio-economic variables: per capita income and urbanization. The model indicates that public spending on education does not have a significant impact on educational inequalities. The latter are also not sensitive to poverty, income inequality, employment in industry and trade openness.

Keywords: Inequalities in education · Fixed-effects model · Panel data

1 Introduction

While income inequalities have long focused the interest of researchers (Lambert, 1993), the non-monetary dimensions of inequalities have gradually been imposed to give rise to a rich literature over the last two decades. Among the latter, educational inequalities now occupy a prominent place, while until recently, researchers (Dessus, 2001) still complained of the scarcity of work in this area due in particular to the lack of internationally comparable databases.

Since that date, undeniable progress has been made in the production of statistical information. Also, many databases have been developed and made available to researchers, such as those of Thomas et al. (2001), Castelló and Doménech (2002), Checchi (2004), Lim and Tang (2008), Jorda and Alonso (2016) and Benaabdelaali (2017).

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Inequalities in education refer to an unequal distribution of educational achievements among individuals. They can be measured from quantitative or qualitative indicators. Quantitative indicators include the enrolment or completion rate of a certain educational cycle and the average number of years of study of the population or a certain age group. With regard to qualitative indicators, research often retains indices measuring the achievements of students at a certain level of education. These latter indicators are mainly used by microeconomics work on the factors of academic achievement. In this paper, we will refer to the average number of years of study of the population aged 15 and over which is the most used quantitative indicator in the literature.

Research on very long series indicates an unequivocal downward trend in educational inequalities at the global level since the beginning of the 20th century thanks to progress in schooling, which leads Morrisson and Murtin (2009) to call it the century of education. However, the progress made has failed to overcome inequalities in education; nor has it enabled developing countries to bridge the gap between them and developed countries in this area. The still high level of these inequalities and especially in developing countries has prompted many economists to take an interest in this subject. However, their work focuses on the possible causal links between educational inequalities and different economic and social variables. Thus, Castelló and Doménech (2002) and Castelló (2010) focused on the correlation between inequalities in education and economic growth, while Checchi (2004), Földvári and Van Leeuwen (2014) studied the links between educational inequalities and income inequalities. Lim and Tang (2008), Morrisson and Murtin (2010 and 2013) addressed the possible links between these inequalities and the expansion of schooling. For their part, Galea et al. (2007), Lê et al. (2010) and Hori (2011) studied the impact of educational inequalities on health. Patrawart (2010) introduces them in a model dedicated to the explanation of corruption.

Most of these writings retain the proxy measuring educational inequalities among the explanatory variables. Otherwise, it is the impacts of educational inequalities that attract the attention of economists and not their determinants that are mainly studied by microeconomic research. For this reason, we decided to explore the factors that can impact educational inequalities. Indeed, this work aims to verify the correlations between educational inequalities and variables of the socio-economic environment. Our intention is to highlight the educational and socio-economic variables likely to influence educational inequalities and therefore the effectiveness of public policies aimed at strengthening the equity of the education system.

The study covers a sample of developing countries observed over the period 1980–2014. The outline of the paper is presented as follows; in the first section will be presented the conceptual framework while the second is reserved for the presentation of the study variables, in the third section will be presented the econometric model and the results while the last presents the synthesis and concludes.

2 Conceptual Framework

Inequalities refer to the possession by some individuals of resources that are socially enviable. This is a delicate subject insofar as inequalities are difficult to tolerate in modern and democratic societies that aspire to equality of conditions (de Tocqueville, 1831).

In education, inequalities refer to the concentration of the distribution of educational achievements. These inequalities are measured through several indicators such as the inter-quantile ratios, the coefficient of variation, the standard deviation, the Gini index, the Theil index, etc. However, the Gini index of education remains the most recognized measure to assess the level of concentration of educational inequalities. It is therefore this indicator that will be retained in this paper.

Morrisson and Murtin (2009) show that educational achievements measured by the average number of years of schooling have increased significantly throughout the 20th century throughout the world. They indicate that the sharp rise in this indicator is accompanied by the decline in differences between countries. Thus, while in 1870, schooling appeared as a monopoly of Western Europe and the new countries (4.5 years of schooling compared to less than 2 years in the other regions of the world); in the year 2000, the situation changed considerably. On the one hand, some countries such as Japan have caught up with the level of schooling observed in Western countries, and on the other hand, in the majority of regions, the average duration of schooling exceeds 6 years with the exception of South Asia and sub-Saharan Africa. Despite this positive development, the authors find that the absolute gap between the best- and worst-ranked countries has increased over the period. The authors conclude that educational achievements are conditioned by its initial level. They deduce that the convergence observed in education is not absolute but rather relative (Farhaoui, Y, (2024)).

The improvement in the general level of schooling is accompanied by a sharp decline in inequalities. Indeed, in another study published in 2008, the same authors compare educational inequality and income inequality. They find that globally, the Gini index of education increased from 0.79 in 1870 to 0.39 in 2000. During the same period, the Gini index of income increased from 0.55 to 0.64. The sharp decline in educational inequalities has been accompanied by a significant shift in the distribution of educational achievements between regions of the world. Thus, in 1910 three quarters of individuals classified in the 10th global decile were Western Europeans; in 2000, there were many more Asians than Westerners among individuals ranked in the 10th global decile.

The decline in inequalities in education is a lasting trend that can be explained, on the one hand, by the decline in illiteracy and, on the other hand, by the existence of a limit to the accumulation of years of study. However, the progress achieved cannot overshadow the persistence of educational inequalities, particularly in developing countries. Indeed, according to Benabdelali (2017), the Gini index of education in 2010 is 0.36 in developing countries compared to only 0.19 in developed countries.

These inequalities are for many economists obstacles to the development process (Müller, 2014) because they promote other forms of inequality, and also because they condition the ability to adapt to cultural and technological changes. Some even believe that they decrease the level of well-being and threaten social cohesion (Green, 2011; Farhaoui, Y, (2024).).

As a result, inequalities in education must be limited by adequate public policies. However, the success of the latter requires highlighting the factors that have the greatest impact on said inequalities. Unfortunately, macroeconomic research on this subject remains very rare.

In an article published in 2008, Murtin and Viarengo show that the convergence of educational achievements between European countries between 1950 and 2000 results mainly from those of the number of years of compulsory schooling. The two authors seek to explain the evolution of this variable by several factors that they group into three theories namely the technological approach, the political economy and finally the theory of the role of the State. They believe that the increase in the level of compulsory education can be explained by the need for qualified labour generated by the openness and by the specialization of said countries in products with a high technological content. As a result, Murtin and Viarengo (2008) include in their model one indicator of openness and another of technology per capita. According to the two authors, the number of years of compulsory schooling can also be influenced by the political regime and the level of income inequality. Also, they introduce a democracy index and the income Gini index into their model. Finally, under the heading of factors relating to state intervention, the authors group together some characteristic variables of the socio-economic environment such as per capita GDP growth, population growth, urbanization and literacy.

The results obtained indicate that the number of years of compulsory schooling depends mainly on its past value and openness. They conclude that the convergence of the duration of compulsory schooling in European countries during the second half of the 20th century results, firstly, from diminishing returns to education which impose ceilings on the process of increasing the duration of compulsory schooling and then, commercial openness which, by intensifying competition, increases the need for qualified labor, and leads the governments of countries lagging behind in this area to extend the duration of compulsory education.

Using data from a panel of 146 countries observed over the period 1960–2015, Ziesemer (2016) experiments with many simple regressions of the Gini coefficient of education on different variables. It finds a significant and negative link between educational inequalities and the average number of years of study. The author also highlights a negative link between the rate of enrolment in higher education and educational inequalities. According to his study, extending the duration of schooling and ensuring that as many people as possible have access to higher education is a good way to limit inequalities in education. The author notes that these inequalities are linked to GDP per capita by a non-linear relationship; also, the increase in GDP leads to the increase of inequalities in the first stage before leading to their decrease in a second stage once a certain threshold is crossed.

The thesis of non-linearity of the relationship educational inequalities- GDP per capita is also defended by Benabdelali (2017) who estimates a polynomial model integrating powers of order greater than 1 to highlight it.

Referring to the results of this literature, we will estimate an econometric model to explain inequalities in education measured by the Gini index of the average number of years of study of the population aged 15 and over. The explanatory variables of our model are educational, economic and social. The first category includes the literacy rate of the population aged 15 and over, the amount of public expenditure on education expressed as a percentage of GDP and the share of primary school students enrolled in private schools. For economic variables, we selected GDP per capita, the Gini income index, the opening rate and the share of industry in employment. Finally, the model uses the urbanization rate and the income poverty rate as social variables.

3 Presentation of Variables and Descriptive Statistics

The study variables, as well as their sources, are indicated in Appendix 1.

Educational variables vary little from year to year. Therefore, we decided to retain five-year data.

The sample consists of 64 countries distributed as follows: South Asia (5), East Asia and the Pacific (8), Europe and Central Asia (9), the Middle East, North Africa (6), Sub-Saharan Africa (23), Latin America and the Caribbean (13). (See Appendix 2).

The education Gini declined sharply over the period, from an average of 0.58 in 1980 to an average of 0.42 in 2010. However, gaps between countries remain large. Thus, the absolute difference increased from 60 percentage points in 1970 (for extreme values of 0.32 and 0.92) to 69 percentage points in 2010 (for extreme values of 0.13 and 0.82). There is also a strong dependence on the initial value; thus, the correlation between the 1980 and 2010 values amounts to 0.78.

Data on adult literacy are less numerous and less regular, which makes it impossible to trace their evolution over the period. Nevertheless, there is an upward structural trend in this variable, from an average of 62% in 1980 to 77% in 2010.

Government expenditure on education looks different. Indeed, this variable does not show a clear trend over the entire period and for all countries. Also, the 1980 average is 4.25 and the 2010 average is 4.37% of GDP. The correlation coefficient between the values of the initial year and that of the final year is 0.48. Only 23 countries in the sample have data for these two periods; of these, spending on education increased in 16 countries and decreased in 7 countries.

With regard to GDP per capita, there is an upward structural trend in this variable but at different rates from one country to another. Thus, the average of the sample goes from 2026 $ per capita for the period 1980–1984 to 3486 $ per capita in 2010–2014. The value of GDP per capita of the last period is only lower than that of the first for 8 countries in the sample. The correlation coefficient between the values of the two periods mentioned above amounts to 0.88, which reveals a strong dependence of the current values on the initial values.

The data are less numerous and irregular for the Gini index of income, which makes it impossible to trace its evolution. Notwithstanding this observation, we note that the average of this variable, for the sample, increased from 32% for the period 1990–1995 to 44% in 2010–2014. The correlation coefficient between the values of the two periods mentioned above amounts to 0.74 indicating a high inertia of this variable over time.

Correlation between variables.

It can be seen that the Gini of education is strongly and negatively correlated with the adult literacy rate and with GDP per capita (Figs. 1, 2).

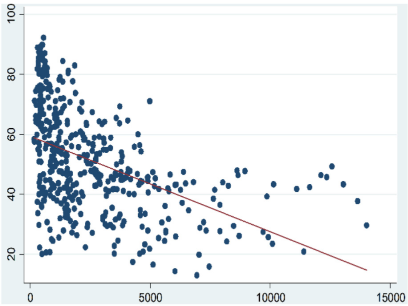

Fig. 1. GINI Education and Adult Literacy Rate

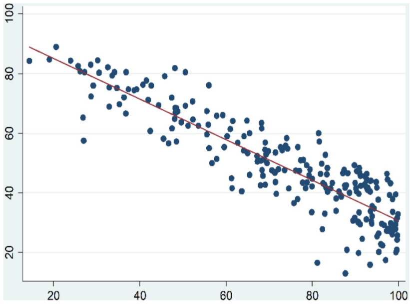

Fig. 2. GINI Education and GDP per capita

4 Results

The expression of the model is as follows:

$$\mathbf{Gini\ education_{it}} = \boldsymbol{\alpha_0} + \boldsymbol{\alpha}\mathbf{X_{it}} + \boldsymbol{\eta_i} + \boldsymbol{\varepsilon_{it}}$$

where:

$\mathbf{X_{it}}$**:** a series of determinants.

$(\mathbf{i}, \mathbf{t})$**:** the transverse and temporal dimensions of the country panel.

$\eta_{\mathbf{i}}$**:** the fixed country effects.

$\varepsilon_{\mathbf{it}}$**:** the error terms**.**

Even though the fixed-effect model is largely dominant in the literature, we verify its relevance by the Hausman test. The latter confirms the absence of correlation between the error term and the individual effect.

From the above equation, we have estimated three variants of the model (Table 1).

In the first variant of the model, inequalities in education are expressed in terms of the literacy rate of people aged 15 and over. This model indicates that this variable alone is able to explain 44% of the intra-individual variability and 85% of the inter-individual variability of the dependent variable. The coefficient of the variable is significant at the rate of 1%.It indicates a negative relationship between literacy and educational inequalities.

In the second variant, the three educational variables are taken into account. This variant of the model also makes it possible to account for a significant part of the intra and inter individual variability. All coefficients are significant and show negative signs. Otherwise, the increase in public expenditure on education is accompanied by a decrease in inequalities at school. Similarly, the increase in the share of students enrolled in private schools does not lead to growing educational inequalities. This result indicates that the increase in private enrolment in primary education is generally observed in countries where schooling is higher and therefore educational inequalities are lower.

The introduction of socio-economic variables leads to the loss of significance of Government expenditure on education but not that of other educational variables. The latter are robust to changes in the number and nature of socio-economic variables.

Table 1. Estimation in Fixed-effects models

Dependent Variable: GINI index of education			
Explanatory variables	Model 1	Model 2	Model 3
Adult literacy rate	− 0.58887* (0.83101)	− 0.58330* (0.06025)	− 0.36097* (0.08572)
Government expenditure on education as % of GDP	-	− 1.02749*** (0.45364)	− 0.34368 (0.43591)
Share of primary school pupils enrolled in private education		− 0.17661* (0.0330)	− 0.26217** (0.12596)
GDP per capita	-	-	− 0.00100* (0.00035)
Gini Index of income	-	-	− 0.13078 (0.14064)
Opening rate	-	-	− 0.03830 (0.03983)
Urbanization rate	-	-	− 0.40168*** (0.22009)
Poverty rate			0.093533 (0.07790)
Share of labor force employed in industry			0.39594 (0.41490)
Constant	92.074* (0.01632)	97.947* (4.7891)	98.142* (9.90566)
R-Squared R^2:			
Within	0.44	0.59	0.73
Between	0.85	0.78	0.51
Overall	0.79	0.78	0.54

Note: p-values in parentheses: * $p < 0.01$ ** $p < 0.05$ *** $p < 0.1$

The results of the educational variables are consistent with those obtained by some reference work. This is the case of the significant and negative link between educational inequalities and adult literacy highlighted by Morrisson and Murtin (2012). These two authors show that the sharp decline in inequality in education observed during the 20th century is mainly explained by the decline in illiteracy. From global data, they measure a Gini index of education for the school population alone; they find that the latter decreases very little between 1870 and 2010. Indeed, from 0.244 in 1870, this indicator increased to 0.281 in 1950 before decreasing to 0.229 in 2010.

It emerges from the results of this last variant of the model that economic and social factors are not significant with the exception of per capita GDP and urbanization. In addition, the link between educational inequalities and income inequalities is not statistically significant. The same applies to poverty, trade openness and the labor force employed in industry.

The coefficients of GDP per capita and urbanization are negative; inequalities in education are therefore decreasing with the increase in GDP per capita and urbanization.

For the other variables, we note that the signs of the coefficients of some of them are in line with our expectations. Thus, inequalities in education increase with the increase in monetary poverty and decrease with the increase in trade openness.

Only the sign of the income inequality coefficient seems paradoxical; indeed, the result of the model indicates that educational inequalities tend to decrease as income inequalities increase.

Finally, the significant coefficient of the constant in all variants of the model indicates that inequalities in education are partly explained by institutional factors omitted by the model.

5 Conclusion

Educational inequalities have significant effects on many socio-economic variables. The fight against this form of inequality is an objective of education policy in many countries. Through this paper, we questioned several educational and socio-economic variables likely to influence inequalities in education. Looking at data from a wide range of developing countries, we found that educational inequalities are highly dependent on adult literacy. We also found that the enrolment of primary school students in private schools does not lead to an increase in educational inequalities. Our model showed that public expenditure on education does not have a significant effect on this variable. Which leads us to question the effectiveness of its spending. Our model revealed that the increase in GDP per capita and urbanization is accompanied by the decrease in inequalities in education. This confirms that the gaps between educational achievements are high between urban areas and rural. Similarly, this result indicates that the persistence of inequalities in education can become an obstacle to the growth of the countries in the sample.

These results indicate that reducing inequalities in education requires setting up programs to eradicate illiteracy and by focusing education policy efforts towards rural areas and poor populations.

Appendix 1. The Variables and Their Sources

No	Variables	Sources
1	Gini index of education	Jorda and Alonso (2016)
2	Adult literacy rate	World Development Indicators
3	Government expenditure on education as % of GDP	World Development Indicators

(*continued*)

(*continued*)

No	Variables	Sources
4	Share of primary school pupils enrolled in private education	World Development Indicators
5	GDP per capita	World Development Indicators
6	Gini Index of income	World Development Indicators
7	Opening rate	World Development Indicators
8	Urbanization rate	World Development Indicators
9	Poverty rate	World Development Indicators
10	Share of labor force employed in industry	World Development Indicators

Appendix 2. List of Sample Countries

Regions	Country
East Asia and the Pacific	China, Fiji, Indonesia, Lao People's Democratic Republic, Malaysia, Mongolia, Myanmar, Papua New Guinea, Philippines, Thailand, Tonga, Viet Nam
Europe and Central Asia	Albania, Armenia, Bulgaria, Kazakhstan, Kyrgyzstan, Romania, Russian Federation, Serbia, Tajikistan, Ukraine
Latin America and the Caribbean	Belize, Bolivia, Brazil, Colombia, Costa Rica, Dominican Rep., Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Paraguay, Peru, Venezuela
Middle East and North Africa	Algeria, Egypt, Iran (Islamic Republic of), Iraq, Jordan, Morocco, Syrian Arab Republic, Tunisia, Zambia
South Asia	Bangladesh, India, Maldives, Nepal, Pakistan, Sri Lanka
Sub-Saharan Africa	Benin, Botswana, Burundi, Cameroon, Central African Republic, Congo, Cote d'Ivoire, Democratic Republic of the Congo, Gabon, Gambia, Ghana, Kenya, Lesotho, Liberia, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Rwanda, Senegal, Sierra Leone, South Africa, Eswatini, Togo, Uganda, Zimbabwe

Appendix 3. Summary Statistics

Variables	Observations	Mean	Standard deviation
Gini index of education	448	50.81766	17.05425

(*continued*)

(*continued*)

Variables	Observations	Mean	Standard deviation
Adult literacy rate	224	72.54984	22.36167
Government expenditure on education as % of GDP	327	4.040462	1.67586
Share of primary school pupils enrolled in private education	372	9.162311	11.21038
GDP per capita	434	2569.628	2565.63
Gini Index of income	315	42.25996	9.452597
Opening rate	429	67.75566	33.08003
Urbanization rate	448	43.8992	19.55476
Poverty rate	290	24.41343	23.76156
Share of labor force employed in industry	320	18.2219	8.614743

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