Journal of Theoretical and Applied Information Technology
31st May 2024. Vol.102. No. 10

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

EXPLORING ARTIFICIAL INTELLIGENCE IMPACT ON SUPPLY CHAIN'S FIRMS: A CASE STUDY OF INDUSTRIAL FIRMS IN MOROCCO

MERIEM RIAD[1] , MOHAMED NAIMI[2] ,CHAFIK OKAR[3]

[1]Laboratory of Analysis and Modelling System for Decision, National School of Applied Sciences Berrechid, Hassan 1st University,Settat, Morocco

[2]Laboratory of Analysis and Modelling System for Decision National School of Applied Sciences Berrechid, Hassan 1st University,Settat, Morocco

[3] Abdelmalek Saadi University, Tétouan, Morocco

[1]m.riad@uhp.ac.ma, [2]mohamed.naimi@uhp.ac.ma, [3]chafik.okar@gmail.com

ABSTRACT

Digital transformation had a significant impact on the supply chain management of enterprises. Additionally, the growing of data generated from several sensors provides opportunities to improve decision-making and profitability for firms. In this new environment, a suitable use of Artificial Intelligence technologies within the Supply Chain could lead to significant gain for firms. To ensure successful implementation for these new techniques, many factors and considerations must be taken into account. In a rapidly evolving business landscape, where efficiency and agility are paramount, organizations are increasingly turning to AI for streamline operations and enhance decision-making. The present paper aims to evaluate the implementation of Artificial Intelligence technologies, especially Machine learning techniques in industrial enterprises in Morocco, and their impact on the Supply Chain. This study delves into the strategic implementation of Artificial Intelligence (AI) in optimizing supply chain management processes. Throw a case study analysis, the research employed an in-depth interviews with industry experts, managers, and technicians to capture their experiences, perspectives, and challenges related to implementing Machine Learning solutions. Than the work offers a roadmap for organizations aiming to explore Machine Learning techniques in Supply chain under firms. However, the study also highlights challenges encountered during the implementation phase, including data quality issues, organizational resistance to change, and the need to up-skill the existing workforce to leverage AI technologies effectively.

Keywords: *Machine Learning, Artificial Intelligence, Supply Chain, Supply Chain Management, Moroccan supply Chain's sector.*

1. INTRODUCTION

In the industrial world, it becomes crucial to manage all supply chain functions (procurement, manufacturing, inventory, shipping, customer demand, sales), regardless of the type of firm's activity. Industries looking to increase operational effectiveness, reduce costs, and boost customer satisfaction have recently given the application of machine learning in the supply chain a lot of attention. On the other hand, the rise of Artificial Intelligence has prompted corporations to research Machine Learning methods and their use in supply chain field. The application of Machine Learning based on several algorithms (Naive Bayes classifier, Decision tree, Clustering, Logistic Regression, Support Vector Machine, Deep Learning, Genetic Algorithms, etc…). Industrial context necessitates novel information processing, techniques to enable supply chain optimization. Digitalization, however, calls for a new strategy .The significance of integrating AI into supply chain management within industrial firms becomes evident upon examining the inherent challenges that these organizations face in the contemporary business landscape. However, adoption of AI in supply chain area presents notable challenges for industrial entities. These en-compass issues related to data integration, quality assurance, organizational change management, and the

imperative of cultivating a skilled workforce proficient in AI technologies. The entire industrial sector is attempting to acquire access to machine learning's contextual intelligence by exploring new supply chain network disciplines. Therefore, in spite of the usefulness of such frameworks, there are critical gaps in the field of applying Machine Learning techniques in supply chain management field. The present work tried to provide a roadmap of difficulties and possibilities of applying Machine Learning through supply chain's functions. The study tries to find responses of some research questions presented afterwards. Therefore, the objective is to explore further avenues for research in understanding the impact of Machine Learning on the supply chain.

2. CONTEXT OF APPLYING MACHINE LEARNING IN SUPPLY CHAIN MANAGEMENT

In this chapter, a background theory about key concepts of Machine Learning and supply chain are going to be laid out. Furthermore, a context of applying Machine Learning techniques in Supply Chain throw literature is elaborated.

2.1 Artificial Intelligence and Machine Learning

2.1.1. Artificial Intelligence

Within the field of science, Artificial Intelligence (AI) is evidence of humankind's attempt to surpass the limitations of biological intelligence and reproduce intelligent behavior in computational systems. Alan Turing, whose groundbreaking work in the 1950 paper "Computing Machinery and Intelligence" created the conceptual framework for the Turing Test and the notion of machine intelligence, is one of the luminaries who have contributed significantly to this subject. Continuing from this basis, a plethora of research projects have been undertaken in the ensuing decades, all of which have added to the growing body of knowledge regarding artificial intelligence. At its core, AI seeks to endow machines with the capacity to perform tasks that typically require human intelligence. This encompasses a broad spectrum of capabilities, including learning from data, reasoning under uncertainty, understanding natural language, and perceiving and interacting

2.1.2. Subfields of artificial intelligence

Artificial Intelligence (AI) is a vast field that encompasses several subfields and techniques[1]. AI is a broad field encompassing various subfields and techniques, including machine learning, deep learning, natural language processing, computer vision, robotics, and more[2]. Some key aspects of Artificial Intelligence are presented thereafter:

- ✓ Machine Learning: is a subset of AI that focuses on developing algorithms and statistical models that enable computers to learn from and make predictions or decisions based on data. It involves training algorithms on large datasets to recognize patterns and make inferences without being explicitly programmed[2].
- ✓ Deep Learning: is a specialized form of machine learning that uses neural networks with many layers (hence the term "deep") to extract complex features from data. It has revolutionized fields such as image recognition, speech recognition, and natural language processing, achieving state-of-the-art performance in various tasks[3].
- ✓ Natural Language Processing (NLP): NLP is a branch of AI that deals with the interaction between computers and humans through natural language. It enables computers to understand, interpret, and generate human language, allowing for applications such as language translation, sentiment analysis, and chatbots.
- ✓ Computer Vision: is a field of AI that focuses on enabling computers to interpret and understand visual information from the real world. It involves tasks such as image recognition, object detection, facial recognition, and scene understanding, with applications in fields like autonomous vehicles, surveillance, and medical imaging[3].
- ✓ Robotics: it combines AI, sensors, and actuators to create intelligent machines capable of performing physical tasks in the real world. Robots can be used in various domains, including manufacturing, healthcare, logistics, and entertainment, to automate repetitive tasks, assist humans, and explore hazardous environments[4].
- ✓ Ethical and Societal Implications: As AI technologies become more advanced and pervasive, there are increasing concerns about their ethical and societal implications. These include issues related to privacy, bias and fairness, job displacement, and the overall impact of AI on society[5].

2.1.3. Machine Learning pipeline

Machine Learning is a branch of Artificial intelligence (AI) and computer science which focuses on the use of data and algorithms to imitate the way that humans learn, gradually improving its accuracy. The study of statistically modeling a problem to carry out a task without explicitly defining the rules and instructions to do so is known as machine learning[6].

In contrast to conventional programming in which the intended result is calculated by applying a certain set of rules to the data already present. In machine learning programming, pre-known data and the desired result are represented in a way that leads to the discovery of a previously unidentified set of rules [6]. A machine learning pipeline refers to the sequence of processes and steps involved in creating, training, evaluating, and deploying a machine learning model. It encompasses all the stages from data preprocessing and feature engineering to model selection, training, and deployment. Machine learning pipeline consists of five steps (on a high level) [7] as it is shown in the Figure 1.

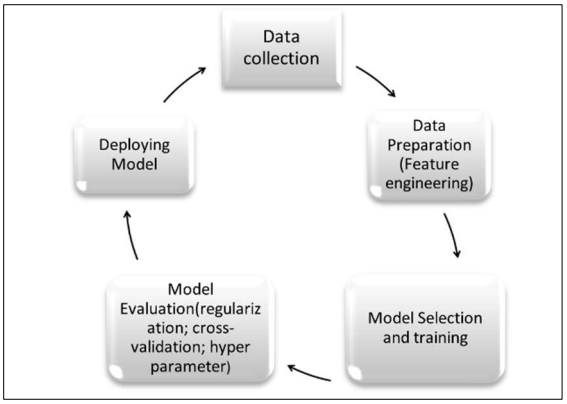

Figure 1 : Machine Learning Pipeline

The first step in the process consists of collecting data which is based on gathering the raw data relevant to the problem statement. The process of data preparation is based on selecting and creating relevant features that will be used as inputs for the model using the feature engineering technique that will be explained in the next part. Then the training process is used to train the model, the validation set is used to tune hyperparameters, and the testing set is used to evaluate the final model's performance. Finally, the deployment of the model to a production environment once satisfied with the model's performance, requires a production environment where it can make predictions on new, unseen data.

The final stage of the machine learning pipeline involves ongoing monitoring and continuous improvement of deployed models. This includes tracking model performance metrics, detecting deviations or drifts in data distributions, and retraining models as needed to maintain optimal performance.

In summary, the development of a Machine Learning pipeline for supply chain management within industrial firms entails a systematic approach encompassing data collection, preprocessing, feature engineering, model selection, training, evaluation, deployment, integration, monitoring, and continuous improvement. By leveraging advanced machine learning techniques and methodologies, industrial firms can unlock valuable insights from data, optimize decision-making processes, and drive tangible business outcomes across their supply chain operations.

2.1.4. Machine Learning Categories and Algorithms

Machine learning methods and tasks are broadly divided into four categories as follows [8]:

- ✓ Supervised Learning: consists on concluding a function from labeled training data [9].
- ✓ Un-Supervised Learning: Without requiring labeled data, the technique can identify patterns and relationships between data.
- ✓ Semi-supervised learning: presents a paradigm that falls between supervised learning and unsupervised learning, it has a dataset that contains both labeled and unlabeled examples [1].
- ✓ Reinforcement Learning: the optimal solution in this category is unknown to the system at the beginning of the learning phase and therefore must be determined iteratively [10].

These approaches contain each a number of algorithms and tasks [1]. In [11], authors described the prominent Machine Learning algorithms as it is presented in the Table 1.

Table 1 : Descriptions of some Machine Learning Algorithms

Machine Learning Algorithms	Descriptions
Bayesian network	Bayes' theorem-based classification algorithm that determines the output class by computing the class conditional probability and prior probability [11].

Decision tree	This algorithm classifies the data into smaller subsets where each subset contains (mostly) responses of one class (either "yes" or "no") [11].
Ensemble learning	Techniques combining the predictions of multiple models to produce a more accurate result. It includes Random Forest, Gradient Boosting, and Stacking.
Regression Analysis	Classical predictive model that expresses the relationship between inputs and an output parameter in the form of an equation [11].
Support Vector Machine	A boundary detection algorithm that identifies/defines multidimensional boundaries separating data points belonging to different classes [11].
Artificial Neural Network	Computational and mathematical model inspired by the biological nervous system. The weights in the network learn to reduce the error between actual and prediction [12].
Clustering	such as k-means find k centroids by dividing the data into k clusters[13].
Deep Learning	Deep ANNs are referred to as Deep Learning because of multiple hidden layers [11].
Genetic Algorithm	Genetic algorithms are evolutionary computational and stochastic search algorithms that are often used in ML applications [14].

In addition to the various types of Machine Learning algorithms, there are also several techniques that are commonly used in the field of machine learning. Some of these techniques include: Feature engineering, regularization, cross validation, Ensemble methods, Transfer learning and the hyperparameter tuning. Afterwards, definitions of each of the techniques mentioned above are presented:

- ✓ Feature engineering : creating new features or modifying existing features to improve the performance of a machine learning model [15].
- ✓ Regularization: is a technique used to prevent overfitting, which occurs when a model is too complex and fits the training data too well but doesn't generalize well to new data.
- ✓ Regularization adds a penalty term to the loss function to discourage overly complex models [16].
- ✓ Cross-validation: is a technique used to evaluate the performance of a machine learning model by dividing the data into training and validation sets and using the training data to fit the model and the validation data to evaluate its performance [17].
- ✓ Transfer learning: is a technique used to apply knowledge learned from one task to a related task, allowing for faster and more accurate model training [18].
- ✓ Hyperparameter tuning: This involves selecting the best values for the hyperparameters of a machine learning model, which control the complexity and behavior of the model [19].
- ✓ These techniques can be used in combination to build effective machine learning models and solve a wide range of problems in various fields such as computer vision, natural language processing, and recommender systems.

2.2. Supply Chain

A supply chain is a network of entities, directly or indirectly interlinked and interdependent in serving the same consumer or customer [20]. It encompasses all activities involved in the production and delivery of a product or service, from sourcing raw materials, to delivering the final product to the customer[20]. The traditional supply chain is made up of manufacturers, warehouses, logistical hubs, and channel providers, it is also known as a logistics network system. The supply chain networks developed by different businesses have diverse business nodes [21]. The management of the enterprise's logistics, cash flow, and information flow, however, forms the basis of the supply chain. the procedure that takes commodities through the company's sales logistics network from the point of production or raw material purchase until they are finally delivered to clients [22].

2.2.1 Supply chain functions

To clear investigation of Supply Chain field, a presentation of the Supply Chain functions is needed. Functions of a supply chain can be divided into several categories, including:

- ✓ Planning and Forecasting: involves forecasting demand for products and services, determining production and delivery schedules, and coordinating the flow of materials and information within the supply chain [23].
- ✓ Procurement: This involves sourcing and

acquiring raw materials, components, and supplies from suppliers. This can include negotiating contracts, establishing supplier relationships, and managing the purchasing process. Function created a link between internal and external businesses, procurement has developed into a crucial business activity [24].

- ✓ Production and Operations: involves the conversion of raw materials into finished products through processes such as manufacturing, assembly, and testing. This function also includes managing the flow of materials and information within production facilities and ensuring that products are manufactured in a timely and cost-effective manner [25].
- ✓ Inventory Management: involves managing the flow of materials, components, and finished products within the supply chain. This includes deciding when and how much to order, managing inventory levels, and monitoring inventory performance [26].
- ✓ Logistics and Transportation: includes planning and executing the movement of products from one location to another, including storage, handling, and transportation. This also includes coordinating the delivery of products to customers and managing the return of goods and reverse logistics[20].
- ✓ Customer service: This involves managing customer orders, providing product information, and addressing customer inquiries and complaints. This function also includes managing the delivery of products to customers and ensuring customer satisfaction [25].

These functions are interrelated and interdependent, and they must be effectively managed to ensure the regular operation of the supply chain. Knowing well that a well-designed and well-managed supply chain can help organizations to reduce costs, improve efficiency, and increase customer satisfaction. Figure 2 presented resume of functions constituting the Supply Chain system.

2.2.2 Supply chain strategies

Supply chain Management involves balancing several competing objectives, such as reducing costs, increasing efficiency, improving product quality, and responding to changes in consumer demand. The rise of globalization and technological advancements have made it increasingly important for organizations to have efficient supply chain systems in place to remain competitive[27]. But it is declared suitable to take an overview of Supply Chain strategies used under firms. Different manufacturing process strategies result from Utilization of inventory and capacity by businesses[28]. Make-to-stock (MTS), build-to-order (BTO), and make-to-order (MTO) are the three main strategies that manufacturers use to meet client demands. Different methods of managing capacity, inventory, and production are needed for these three approaches [28].

The MTS manufacturing approach involves holding items in stock for immediate delivery to minimize customer delivery times. This strategy is an applicable choice for standardized products, high volumes, less variety, and reasonable accurate forecasts. The competitive priority is low-cost manufacturing. Additionally, a manufacturing paradigm known as BTO manufacturing places an emphasis on smaller batches, modular production, responsive operations, and employees with the necessary skills to handle erratic demand. In addition to emphasizing inventory control and other concerns related to lowering production costs, BTO places a strong emphasis on supplier development, outsourcing, flexibility, and agility. As a result, strategic alliances and collaboration are crucial to the BTO supply chain [28]. Furthermore, MTO manufacturing method produces products in small quantities to customer specifications. MTO frequently begins from scratch and incorporates both product design and manufacturing [28].

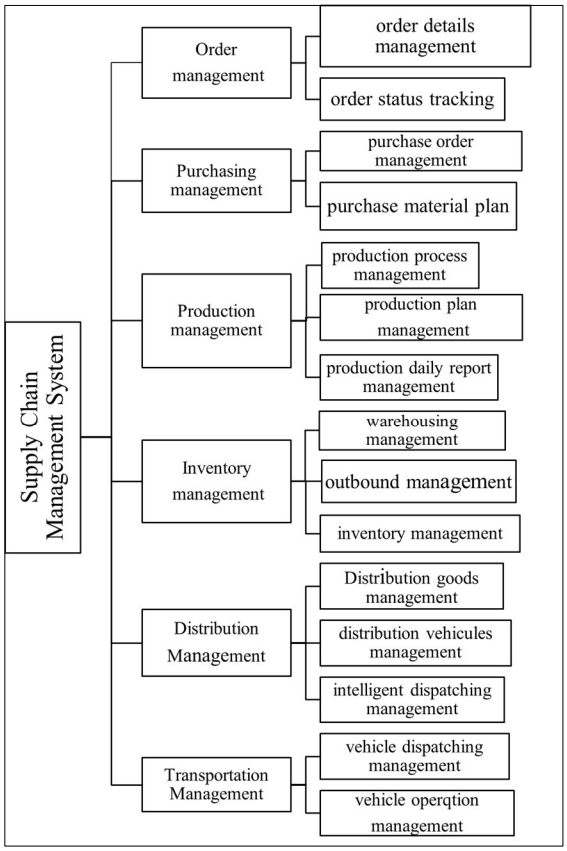

Figure 2 : Function diagram of SCM system

Finally, in today's business environment, many companies seek efficiency and flexibility, but have struggle, because of the luck of an optimal supply chain's strategies. This is often due to insufficient knowledge about the costs involved in maintaining supply chains and the impact of the supply chain on their operations [29]. Consequently, these companies find it difficult to manufacture at a competitive cost and respond quickly and reliably to market demand. Indeed, the next part tries to present an investigation of using Machine Learning in the Supply Chain through existed literature.

2.3. An overview of literature on Machine Learning In Supply Chain Management

As it is cited in [22], new methods of machine learning are declared very helpful in business in general but particularly in supply chain management. So far, Supply Chain Management (SCM) has been increasingly important to the growth of industrial enterprises in recent years. A trustworthy prediction is particularly necessary for the optimization of the supply chain, which is a significant concern [20]. The supply chain's various participants are intricately linked and dependent on one another. As a result, achieving success in one sector of the supply chain does not guarantee that the company's performance will increase. For this aim, many works of researchers throw literature tried to deal with the subject.

[1] conducted an assessment of the literature that covered the historical track record of successful Machine Learning applications to identified the most fruitful SCM applications, and drew conclusions concerning the employment of machine learning techniques in SC. Supply chain management includes forecasting as a key component [30]. So, it becomes a crucial subject for investigation. Numerous works are connected to this investigation. In[31], the author examined the efficacy of advanced non-linear machine learning techniques for forecasting demand signals in the extended supply chain. The author compares the results between using Support Vector Machine, Neural Network and more basic techniques like moving average, naive, and trend methods in demand forecasting. Thus, it is crucial to use machine learning technologies in prediction methods. Using information provided by a Hong Kong fashion retailer, [32] investigated the extreme learning machine (ELM), a relatively novel neural network method, and its application to forecasting fashion sales.

Additionally, several research studies have focused on the use of machine learning in inventory control. The author of [33] investigated a temporal demand heteroscedasticity-related inventory control problem, and it was discovered that this had a considerable impact on the firm's inventory expenses. Also, [34] proposed a reinforcement learning system suitable for supply chain inventory control.

Furthermore, [29] examined the unique needs and limits relating to the textile industry's supply chain and sales projection, and they presented the cutting-edge forecasting techniques now used by apparel companies. In [35], authors presented an intelligent system based on SVMs to address issues with model allocation and discovery while accounting for the bullwhip effect. A study in 2019 examined the trade-off between prediction accuracy and interpretability by putting the framework into practice and using it to forecast delivery delays in a multi-tiered industrial supply chain [36].

In a recent study conducted in Europe, researchers investigated the use of AI-driven demand forecasting models in retail chains. By leveraging machine learning algorithms and historical sales data, retailers were able to accurately predict future demand for

products, resulting in optimized inventory management and reduced stockouts[37]. The study demonstrated how AI technologies can help European retailers adapt to changing consumer preferences and market dynamics, ultimately improving operational efficiency and customer satisfaction.

Meanwhile, in manufacturing facilities across Asia, AI-powered predictive maintenance systems have been implemented to enhance equipment reliability and minimize downtime[38]. By analyzing sensor data and machine performance metrics in real-time, these systems can identify potential equipment failures before they occur, allowing for proactive maintenance interventions[38]. This proactive approach not only reduces maintenance costs but also ensures uninterrupted production schedules, thereby increasing overall productivity and profitability.

Logistics companies are leveraging AI-based route optimization algorithms to streamline delivery operations and minimize transportation costs[39].In north America, analyzing factors such as traffic patterns, weather conditions, and delivery schedules, these algorithms can generate optimal routes for fleet vehicles, reducing fuel consumption and transit times. This not only improves operational efficiency but also enhances customer satisfaction by ensuring timely and cost-effective deliveries.

Finally, we point out that most of the research focuses on prediction performance while ignoring the significance of interpretability, which enables supply chain practitioners to make decisions that can reduce or avoid risks from occurring. While Machine Learning and Artificial Intelligence have made significant inroads in various industries, including supply chain management, there are still some challenges and limitations when it comes to their adoption in industrial firms Indeed, despite the promising applications of AI in supply chain management, there are still several challenges and limitations to its adoption, particularly in industrial firms in emerging countries like Morocco. The forthcoming section will provide further elaboration on this matter.

3. RESEARCH METHOD

The supply chain sector in Morocco has undergone substantial growth in recent years be cause of internal and international causes. In this part, we tried first to provide an overview of the state of the art in the supply chain sector in Morocco, highlighting its key components, challenges, and opportunities for Moroccan economy. In the second part of this section, we tried to elaborate our case study dealing with the transformative role of Machine Learning (ML) within this sector and its impact in industrial firms in Morocco.

3.1 Context and Objectives of Study

Through an examination of real-world of industrial firms' implementations, challenges, and outcomes, the study aims to offer insights into the practicality, benefits, and limitations of integrating Machine Learning into diverse functions of Supply Chain.

Our study focuses the case of industrial firms in Morocco. The findings provide valuable insights for industrial leaders, decision-makers, and practitioners seeking to leverage machine learning to enhance their operations. By highlighting successful strategies and addressing potential pitfalls, the study offers a roadmap for organizations aiming to harness the power of machine learning to achieve sustainable competitive advantages in the rapidly evolving industrial landscape.

3.2 Supply chain's sector and AI in Moroccan Economy

In other side, during the last years Morocco was actively working to develop and modernize its supply chain infrastructure and logistics sector. However, it's essential to note that the specifics of the supply chain developments in Morocco are based on some strategies and visions. Morocco has established several free trade zones, such as the Tangier Free Zone, to attract foreign investments and boost manufacturing and logistics activities Should area and subareas under investigation [40]. Also, the country has been developing logistics parks and industrial zones strategically located near major transportation hubs. These parks are designed to facilitate warehousing, distribution, and value-added logistics services. Furthermore, the growth of e-commerce has also contributed to the development of supply chain infrastructure in Morocco. Many logistics companies and e-commerce platforms have expanded their operations in the country to meet the increasing demand for online shopping. The Moroccan government has launched various initiatives and policies to attract foreign investment and promote economic development. These initiatives often target sectors with high potential for supply chain and logistics growth [41]. Morocco has entered into various trade agreements, including with the European Union and African countries. These agreements facilitate trade and open up new opportunities for supply chain development [42].

The integration of AI in the supply chain sector is having a profound impact on the Moroccan economy. It is fostering competitiveness, reducing operational costs, and improving the quality of goods and services. This, in turn, enhances Morocco's attractiveness as a manufacturing and logistics hub.

Furthermore, the development of AI technologies and the growth of the tech industry are creating high-value job opportunities and driving innovation in other sectors of the economy. Morocco is increasingly positioning itself as a regional leader in AI adoption, and this is likely to drive economic growth and diversification in the coming years.

Hence the importance of investigating the field and discussing the opportunities that can offer the use of AI specifically ML techniques to ensure the continuity and development of the SC sector in industries in Morocco. Morocco, as an emerging market, presents unique challenges and opportunities for supply chain management within its industrial sector.

By harnessing the power of Artificial Intelligence, it is hypothesized that Moroccan industries can overcome these challenges and unlock new levels of efficiency and competitiveness. The suggested solution involves the development and implementation of AI-driven solutions customized to the specific needs and dynamics of the Moroccan market. This entails leveraging AI technologies such as machine learning, predictive analytics, and intelligent automation to optimize various aspects of the supply chain, including demand forecasting, inventory management, logistics planning, and risk mitigation. A case study can effectively address the hypothesis by providing a detailed examination of a real-world scenario where AI-driven supply chain management solutions were implemented within an industrial firm in Morocco. This is what will be examined later in the following section.

3.3 Case study Process

A presentation of the research methodology is required prior to the case study. Eight phases are used to elaborate a case study as it is showed in Figure 3 [43].

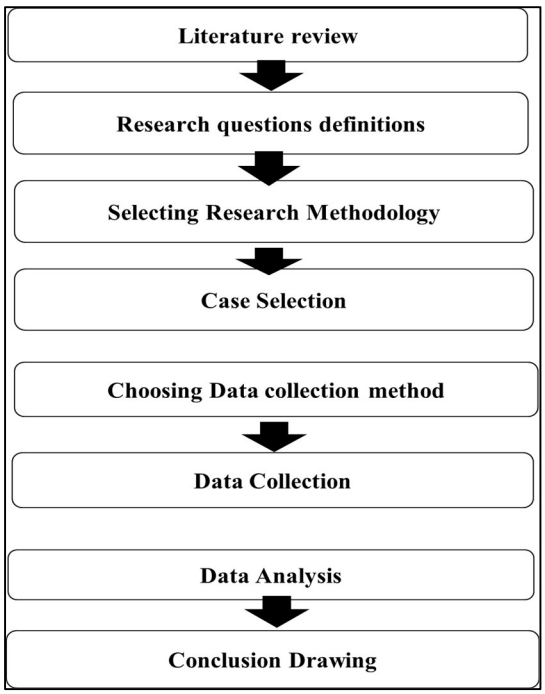

Figure 3 : The Research Process For Case Studies

3.4 Case Study Elaboration

3.4.1. Research questions and methodology

Our examination of the literature creates a classification structure that links different levels of Machine Learning models and methodologies to specific Supply Chain functions. By relating Machine Learning models and methodologies to Supply Chain functions. Ultimately, this case study seeks to provide a comprehensive overview of the evolving landscape of supply chain management in Morocco, where ML is serving as a catalyst for increased efficiency, cost savings, and enhanced competitiveness. By examining the successes, challenges, and future prospects of ML in the Moroccan supply chain sector, we aim to offer valuable insights for businesses, and stakeholders looking to navigate the complexities of modern supply chain management in this dynamic North African nation. The study attempts to address the following questions:

1. What are the challenges associated with the adoption and implementation of machine learning in Supply Chain management?

2. In what supply chain functions the implementation of Machine learning techniques can be useful?

3. How can machine learning algorithms be used to optimize and improve these functions?

4. What impact does the use of machine learning have on supply chain performance?

5. What are the key success factors for implementing machine learning in supply chain operations, and how can companies overcome potential barriers to adoption?

6. Referring to the aim of our work which is to present a complete description of the use of machine learning techniques in the field of Supply Chain in industries ; the research methodology is a descriptive case study [44].

3.4.2. Case sample selection and data collection

The appropriate method of collecting data for our research questions and the case(s) being studied is interviews with key stakeholders. Case selection is crucial as it determines the quality of the model's output[43].Also, the selection of cases should be based on the research question, availability and quality of data, and the model's intended application. Research questions previously presented should guide the selection of cases. The suitable instrument of development of the study is a questionnaire. In this context, a standard questionnaire was created using the ML and supply chain criteria from the literature study. Furthermore, the questionnaire underwent pre-testing to confirm that its design and format were adequate for companies. The expert panel recognized the questionnaire's complete applicability to industrial companies in addition to the fact that it was standard based on literature, the estimated sample size is 30 due to the small statistical population in this study.

The questionnaire was submitted through e-mail for 40 directors and supply chain managers of all 50 industrial companies in Morocco, so this research is a case study of Morocco because the data are collected only from industrial companies in Morocco. After eliminating incomplete questionnaires, 23 questionnaires from companies were deemed accurate and usable.

3.4.3. Data analysis

Apply appropriate data analysis techniques to the collected data. This may involve organizing, summarizing, and categorizing the data, as well as performing statistical analyses to identify patterns, relationships, and trends [45]. Begin by describing the dataset, including the number of observations and variables (survey questions).We will Provide summary statistics for each survey question to understand the distribution of responses.

We have to process by important steps from Data Cleaning and Preparation to exploratory data analysis:

- ✓ Clean the data by checking for missing valuesand, outliers
- ✓ Convert categorical variables into numerical format if necessary, using techniques such as one-hot encoding or label encoding.

Normalize or standardize numerical variables to ensure comparability across different scales.

After collecting responses of questionnaires and obtaining the first analysis in the Figure 4 that identify the most strategy used under industrial firms in our case are Make to Order (MTO) and Make to Stock (MTS).

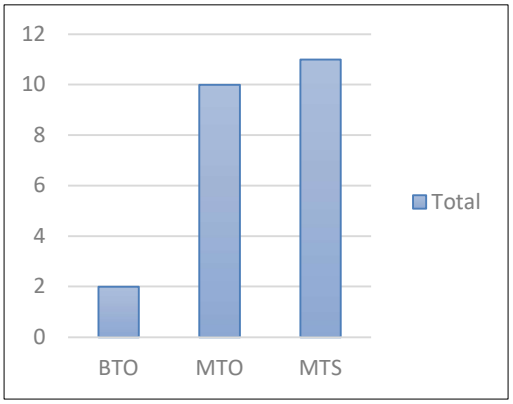

Figure 4 : Distribution Of Supply Chain Strategies Used Under Firms In The Study

The result of most Supply Chain's strategies used in our case study provide a global interpretation on the functions of the supply chain that could be developed. As implementing a successful "Make to Order" (MTO) strategy within firms, requires careful planning, execution, and continuous monitoring. MTO is a production strategy where products are only manufactured after an order is received, as opposed to "Make to Stock" (MTS), where products are produced based on demand forecasts. Both strategies needed a suitable demand forecasting and inventory management.

Journal of Theoretical and Applied Information Technology
31st May 2024. Vol.102. No. 10

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

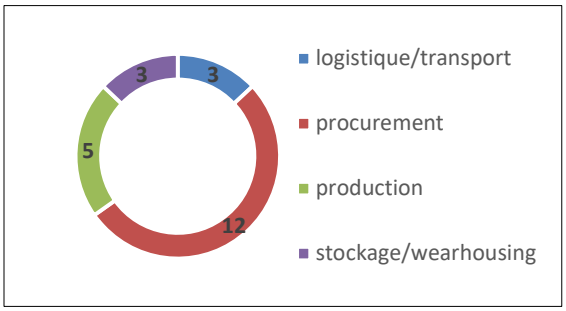

Figure 5 : Distribution Of The Costliest Functions In Supply Chain's In Firms

The (Figure 5) illustrated functions of Supply Chain that taking most costs: respectively Manufacturing, transport and procurement. Results joined the finding in the literature.

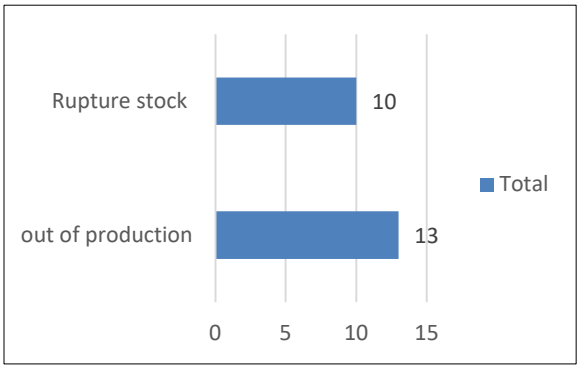

Figure 6 : Risks Generated In Supply Chain Functions

In our survey, the major risks held when these functions are reached are Production shutdown and Shortage of raw materials .60,9% declared that level of loss generated by these risks is very high. Additionally, these responses proved that the suitable method to manage those risks is the preventive method as it is illustrated in the Figure 7. But the knowledge and assimilation about Machine Learning techniques still limited.

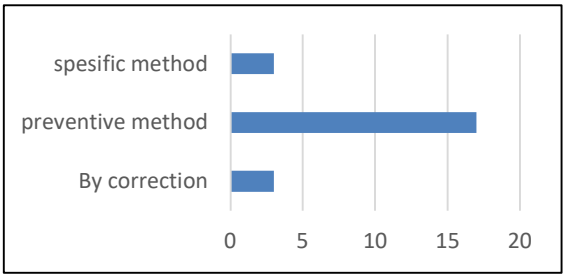

Figure 7 : Suggested Risk Treatment Methods

We note that preventive attitude is considered through the answers collected as the suitable solutions to the risks cited above. A preventive attitude in supply chain management involves taking proactive steps to prevent problems before they occur. This can help to minimize disruptions of manufacturing and control inventory and warehousing. Although, it remains that the methods used have not yet been able to leave the classical framework as it is showed in the Figure 8. Industries continued to employ the conventional system such as the ERP (Enterprise Resource Planning) and its leading providers which is the SAP software and related applications, unifying several corporate operations and activities into a single, centralized system. These include finance, human resources, inventory management, and supply chain management.

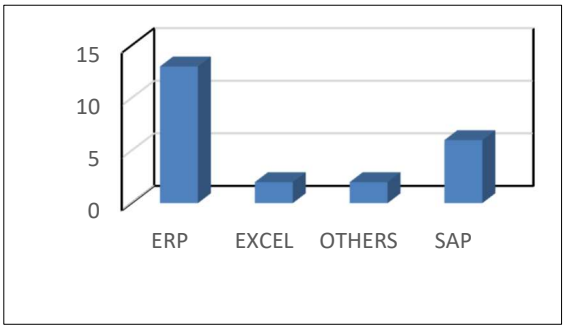

Figure 8 : Systems Used For Assessment Of Risks Generated In Supply Chain

Through the investigation in the study, Decision Tree is the most known algorithm under industrial firms. The lack of information and training in the field of Artificial intelligence especially the Machine learning techniques is a real obstacle to the introduction of these new tools inside firms.

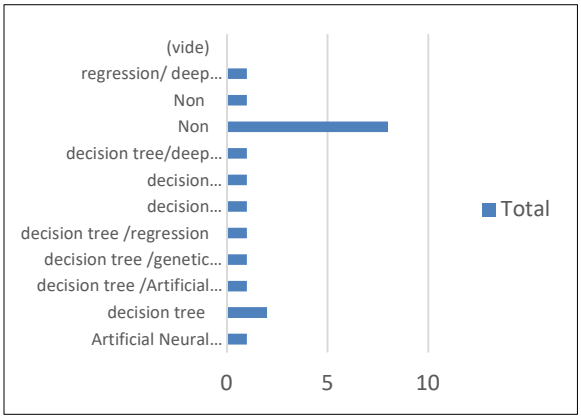

Figure 9 : Level of Knowledge of Algorithms in industries

4. DISCUSSIONS AND RESULTS

4.1. Discussion

To enhance its efficiency and competitiveness, many companies are exploring the adoption of machine learning (ML) technologies in their supply chain's field**.** In this context, our study was conducted to illustrate various benefits challenges, benefits and examples of this use within firms in Morocco. One of the relevant results is about the commonly used supply chain's strategies which are: MTO and MTS. That can provide a useful insight about the supply chain's functions that need special treatment, exactly that need the implementation of ML techniques. That leads us that functions could generating benefits from this use are: Manufacturing, Procurement, Demand Forecasting and, Inventory Management. In fact, based on the result of our study, they represent also the costliest functions for companies.

The benefits generated for the implementation of ML techniques differs from one function to another. These benefits are justified through our results since the major risks generated during a disruption of a supply chain's function are: production shutdowns and stock loss as it illustrated in the fig.6. The elimination of these risks presents the potential benefit of the usage of ML techniques in the field. Specifically, advantages resulting from usage in Manufacturing is specifically oriented towards the Predictive maintenance and the quality control. In this sense, algorithms can examine sensor data from machinery and equipment to find patterns and foretell the need for maintenance. This proactive strategy lessens downtime and increases the overall performance of the equipment[8]. To identify potential quality problems and predict errors, ML algorithms can analyze data from a variety of sources, including sensors, production logs, and quality records. This enables quick remedial measures and lowers scrap and rework[8].

In order to effectively forecast demand, Machine Learning algorithms can evaluate previous data and spot patterns. This enables businesses to optimize inventory levels and lessen stockouts or surplus inventory. Obviously, the preventive method is the approach recommended by the businesses who took part in this study as it showed in the fig.7.

Additionally, Machine learning algorithms can optimize inventory levels by examining data on product demand, lead times, and supplier performance, ensuring that stock is available when needed and lowering carrying costs[46]. In industrial word, there are many instances that show how AI has been successfully incorporated into supply chain management to increase operational effectiveness, reduce costs, and enhance customer experiences, Coca-Cola and Amazon are two of the most notable examples[47]. The business employs machine learning algorithms to improve delivery routes, manage warehouse operations, and forecast client demand. Robots and automation systems powered by ML are used in fulfillment centers to increase efficiency and speed up order processing.

However, despite the fact that using ML in the supply chain sector has many advantages, there are a number of issues that need to be resolved. Integrating ML into the supply chain calls for cross-functional cooperation and organizational reforms. Difficulty to integrate existing supply chain infrastructure, such as enterprise resource planning (ERP) systems, warehouse management systems (WMS), with AI systems is a challenge requiring a careful planning to guarantee seamless integration, scalability, and compatibility with legacy systems. Moreover, findings in our study indicates that the most used systems for the assessment of risks generated in supply chain's process is the ERP as it is illustrated in fig.8.But it remains that leverage technology such as Enterprise Resource Planning (ERP) systems allowed to streamline operations and communication and subsequently ensure seamless integration of ML techniques. To support the organization's seamless adoption and acceptance of ML technologies, changing management initiatives, training teams and increasing their knowledge of the field are required. Based on the fig.9 presented above, many algorithms seek to be popular such as decision tree, regression, and Artificial Neural Network (ANN) but do not move to the applied or implemented level.

According to the case study that was conducted above, adopting Machine learning has proved to be the most significant decision for organizations. ML is said to be important in a number of additional supply chain domains.

Thus, to have generalizability, this research adopts a multiple case-based research approach. The sample size (number of cases) doesn't allow to provide a generalization of outcomes. However, cases selected for the study should satisfy the boundary of the aim of research in order to connect with the research questionnaire. More conclusions and future directions based on the results and discussions of the study are presented thereafter.

4.2. Results

Both case study and literature highlight the potential benefits of adopting ML technologies in supply chain management, including efficiency improvements and cost reduction. They both acknowledge the challenges associated with ML adoption, such as cross-functional cooperation and integration with existing systems.

The case study provides specific examples of ML implementation in Moroccan firms, while the literature offers broader insights and examples from various industries and regions.

Both sources emphasize the importance of change management initiatives and employee training for successful ML adoption in supply chain management.

Overall, the case study results align with the literature in terms of identifying the benefits and challenges of adopting ML technologies in supply chain management, while also providing specific insights into the Moroccan context.

✓ Scope and Focus:

The case study focuses specifically on the adoption of machine learning (ML) technologies in supply chain management within firms in Morocco, providing detailed insights into the challenges and benefits within this context.

In contrast, existing literature offers a broader perspective, encompassing studies from various industries and regions, including successful examples of ML integration in supply chain management such as Coca-Cola and Amazon.

✓ Identification of Key Functions:

Both the case study and literature recognize key supply chain functions that could benefit from ML techniques, such as Manufacturing, Procurement, Demand Forecasting, and Inventory Management.

However, the case study goes further by providing specific examples of how ML can be applied to these functions within the Moroccan context, such as predictive maintenance and quality control in manufacturing.

✓ Examples of Successful Integration:

The case study provides examples of successful ML integration in supply chain management, citing Coca-Cola and Amazon as notable examples.

Similarly, the literature also highlights these examples, emphasizing the benefits of ML in optimizing warehouse operations, demand forecasting, and route optimization.

✓ Challenges and Solutions:

Both the case study and literature acknowledge the challenges associated with ML adoption in supply chain management, such as cross-functional cooperation and integration with existing systems.

5. CONCLUSIONS AND PERSPECTIVES

The present study is based on a case study to investigate the adopting of Machine Learning techniques in supply chains of industrial organizations in Morocco. The study reveals considerable benefits and challenges of this use. Results demonstrate that the implementation of Machine Learning still in theoretical section; so more conceptual frameworks for the supply chain functions demanding an optimization by researchers and practitioners is needed. Important impact result from applying these methodologies, particularly to: Procurement, Manufacturing, Demand forecasting and Inventory inside the industrial firm under consideration.

A general overview of some potential findings and benefits that may arise from adopting ML in the supply chains of industrial firms, based on trends and common observations are:

✓ Improved Demand Forecasting: By examining past sales data, market patterns, and external factors, ML can increase demand forecasting accuracy. This can result in fewer instances of stockouts and overstocks, optimum inventory levels, and cost savings.

✓ Optimized Inventory Management: By foretelling when and what to order, ML algorithms can aid in controlling inventory levels effectively. This lowers the danger of obsolete inventories and lowers carrying expenses.

✓ Improved Supplier Selection: Using historical performance data, ML can help find the most dependable and affordable vendors, guaranteeing a steady supply chain.

✓ Reduced Lead Times: By streamlining the supply chain process and lowering the lead times for manufacturing, procurement, and delivery, predictive analytics can help.

✓ Cost-saving opportunities can be found in the supply chain by using ML, such as logistics route optimization, energy consumption optimization, and waste reduction.

✓ Machine learning can be used for real-time quality control, assisting in the detection of flaws or deviations in production processes, which will improve the quality of the final product.

✓ Risk management: ML can scan data from a variety of sources to spot risks that could affect the supply chain, like disruptions brought on by bad weather, geopolitical unrest, or supplier concerns. This makes proactive risk minimization possible.

✓ Utilizing Machine Learning (ML) in industrial businesses requires a systematic approach to fully capitalize on the potential advantages and

successfully navigate hurdles. Here are some fresh guidelines to take into account while applying ML in an industrial setting:

✓ Human-Machine Collaboration: Promote collaboration between humans and ML systems to leverage the strengths of both. Rather than replacing human workers, use ML to augment their capabilities. Ensure that employees understand how ML can assist them in making better decisions and improving processes.

✓ Explainable ML Algorithms: Prioritize the adoption of explainable ML models, especially in critical processes. In industries where transparency and interpretability are essential (e.g., manufacturing, healthcare), choose ML models that can provide explanations for their predictions and decisions. This builds trust and facilitates regulatory compliance.

✓ Interoperability and Standardization: Embrace industry standards and interoperable ML solutions. Ensure that ML systems can integrate seamlessly with existing industrial equipment and systems. Adhering to industry standards promotes compatibility and scalability.

According to the findings of this study, ML adoption will make up a significant portion of this sector and will contribute more to supply chain management in the future than they do now. A prediction model based on real-time production data could be potentially useful, as a tool to alert inspection teams to prioritize batches likely to be defective, or even as a way to learn the causes of some of the main quality issues. However, since the information systems had not undergone expansion at the time of data collection, there was a lack of detailed data available about the assembly processes. Although, if the preliminary study could deliver a feasible prediction system or useful learnings, then the general method used could be adapted to similar effect with a dataset containing more features pertaining to process and machine data.

However, the case study offers insights into potential solutions within the Moroccan context, such as leveraging existing technology like Enterprise Resource Planning (ERP) systems for seamless integration. Both sources emphasize the importance of change management initiatives and employee training for successful ML adoption in supply chain management. The study provides specific recommendations for organizations in Morocco, highlighting the need for training teams and increasing their knowledge of ML technologies to support seamless adoption.

In summary, while the case study offers specific insights into ML adoption within the Moroccan context, existing literature provides a broader perspective and additional examples of successful integration from diverse industries and regions. By comparing and synthesizing these sources, researchers can gain a comprehensive understanding of the challenges, benefits, and best practices associated with ML adoption in supply chain management.

Overall, applying ML to the supply chain results in decision-making that is more data-driven, which can help businesses react rapidly to shifting market conditions and boost productivity. It's critical to remember that the actual outcomes of applying ML to supply chains might differ significantly depending on the use cases, data quality, maturity of ML implementations, and level of system integration. In order to leverage the advantages of this technology for increasing operations and competitiveness, it is crucial to undertake more well-defined conceptual frameworks in the field. It should be flexible enough to accommodate the organization's particular requirements and limitations while still keeping up with ML and technological improvements.

REFERENCES

[1] C. Guide, "Front cover Course Guide Artificial Intelligence Analyst 2019," 2019.

[2] S. K. Rogers, M. Kabrisky, K. Bauer, and M. E. Oxley, "Computing machinery and intelligence amplification," *Comput. Intell. Expert. Speak*, pp. 25–44, 2003, doi: 10.1109/9780470544297.ch3.

[3] A. Hopwood, "u3a Computing Group," no. September, 2023.

[4] U. Awan, N. Kanwal, S. Alawi, J. Huiskonen, and A. Dahanayake, "Artificial Intelligence for Supply Chain Success in the Era of Data Analytics," in *Studies in Computational Intelligence*, vol. 935, 2021. doi: 10.1007/978-3-030-62796-6_1.

[5] S. J. Thomas, M. L'Azou, A. D. T. Barrett, and N. A. C. Jackson, "Fast-Track Zika Vaccine Development — Is It Possible?," *N. Engl. J. Med.*, vol. 375, no. 13, pp. 1212–1216, 2016, doi: 10.1056/nejmp1609300.

[6] V. Manasas, "Supply chain optimization using machine learning methods. A manufacturing case study," no. June, pp. 0–4, 2020, [Online]. Available: https://repository.ihu.edu.gr/xmlui/handle/11544/29510

[7] S. Makkar and G. N. R. Devi, *Applications of Machine Learning Techniques in Supply Chain Optimization*, vol. 1. Springer Singapore, 2020. doi: 10.1007/978-981-13-8461-5.

[8] M. Riad, C. Okar, and A. Ghaouta, "The potential use of Machine Learning in firms: The evidence of industrial enterprises," *2020 13th Int. Colloq. Logist. Supply Chain Manag. LOGISTIQUA 2020*, pp. 2–4, 2020, doi: 10.1109/LOGISTIQUA49782.2020.9353881.

[9] S. Datta and J. P. Davim, *Machine learning in industry | ATRIA Innovation*. [Online]. Available: https://www.atriainnovation.com/en/machine-learning-in-industry/

[10] H. Wenzel, *A Literature Review on Machine Learning in Supply Chain Management*. 2019.

[11] R. Sharma, S. S. Kamble, A. Gunasekaran, V. Kumar, and A. Kumar, "A systematic literature review on machine learning applications for sustainable agriculture supply chain performance," *Comput. Oper. Res.*, vol. 119, p. 104926, 2020, doi: 10.1016/j.cor.2020.104926.

[12] U. Praveen, G. Farnaz, and G. Hatim, "Inventory management and cost reduction of supply chain processes using AI based time-series forecasting and ANN modeling," *Procedia Manuf.*, vol. 38, no. Faim 2019, pp. 256–263, 2019, doi: 10.1016/j.promfg.2020.01.034.

[13] X. Goldberg, *Introduction to semi-supervised learning*, vol. 6. 2009. doi: 10.2200/S00196ED1V01Y200906AIM006.

[14] J. C. Wu and B. A. Shapiro, "A boltzmann filter improves the prediction of rna folding pathways in a massively parallel genetic algorithm," *J. Biomol. Struct. Dyn.*, vol. 17, no. 3, pp. 581–595, 1999, doi: 10.1080/07391102.1999.10508388.

[15] C. Reid Turner, A. Fuggetta, L. Lavazza, and A. L. Wolf, "A conceptual basis for feature engineering," *J. Syst. Softw.*, vol. 49, no. 1, pp. 3–15, 1999, doi: 10.1016/S0164-1212(99)00062-X.

[16] S. M. Kakade, S. Shalev-Shwartz, and A. Tewari, "Regularization techniques for learning with matrices," *J. Mach. Learn. Res.*, vol. 13, pp. 1865–1890, 2012.

[17] D. Berrar, "Cross-validation," *Encycl. Bioinforma. Comput. Biol. ABC Bioinforma.*, vol. 1–3, no. April, pp. 542–545, 2018, doi: 10.1016/B978-0-12-809633-8.20349-X.

[18] F. Zhuang *et al.*, "A Comprehensive Survey on Transfer Learning," *Proc. IEEE*, vol. 109, no. 1, pp. 43–76, 2021, doi: 10.1109/JPROC.2020.3004555.

[19] Y. Li *et al.*, *TransBO: Hyperparameter Optimization via Two-Phase Transfer Learning*, vol. 1, no. 1. Association for Computing Machinery, 2022. doi: 10.1145/3534678.3539255.

[20] C. Scott, H. Lundgren, and P. Thompson, *Guide to Supply Chain Management*.

[21] J. T. Mentzer, J. S. Keebler, N. W. Nix, C. D. Smith, and Z. G. Zacharia, "JOURNAL OF BUSINESS LOGISTICS, Vol.22, No. 2, 2001 1," vol. 22, no. 2, pp. 1–25, 2001.

[22] H. Lin, J. Lin, and F. Wang, "An innovative machine learning model for supply chain management," *J. Innov. Knowl.*, vol. 7, no. 4, p. 100276, 2022, doi: 10.1016/j.jik.2022.100276.

[23] H. Min, "Artificial intelligence in supply chain management : theory and applications," vol. 5567, 2010, doi: 10.1080/13675560902736537.

[24] C. R. Pereira, M. Christopher, and A. Lago Da Silva, "Achieving supply chain resilience: the role of procurement," *Supply Chain Manag.*, vol. 19, no. January, pp. 626–642, 2014, doi: 10.1108/SCM-09-2013-0346.

[25] M. However, "Defining Supply Chain Management," pp. 11–22.

[26] A. Ghaouta, "Machine Learning for Warehouse Management : A conceptual framework".

[27] H. Wenzel, D. Smit, and S. Sardesai, *A Literature Review on Machine Learning in Supply Chain Management Supply Chain Management*, no. September. 2019.

[28] L. Li, L. Zhang, and M. Willamowska-Korsak, "The effects of collaboration on build-to-order supply chains: With a comparison of BTO, MTO, and MTS," *Inf. Technol. Manag.*, vol. 15, no. 2, pp. 69–79, 2014, doi: 10.1007/s10799-014-0179-z.

[29] P. Economics, "Int . J . Production Economics Sales forecasts in clothing industry : The key success factor of the supply chain management," vol. 128, pp. 470–483, 2010, doi: 10.1016/j.ijpe.2010.07.018.

[30] "DEMAND FORECASTING USING NEURAL," vol. 4, no. 1, 2015.

[31] R. Carbonneau, K. Laframboise, and R. Vahidov, "Application of machine learning techniques for supply chain demand forecasting," vol. 184, pp. 1140–1154, 2008, doi: 10.1016/j.ejor.2006.12.004.

[32] Z. Sun, T. Choi, K. Au, and Y. Yu, "Sales forecasting using extreme learning machine with applications in fashion retailing," *Decis. Support Syst.*, vol. 46, no. 1, pp. 413–421, 2008, doi: 10.1016/j.dss.2008.07.009.

[33] X. Zhang, "Inventory control under temporal demand heteroscedasticity," vol. 182, pp. 127–144, 2007, doi: 10.1016/j.ejor.2006.06.057.

[34] C. Ouk and K. I. Kwon, "Asynchronous action-reward learning for nonstationary serial supply chain inventory control," pp. 1–16, 2008, doi: 10.1007/s10489-007-0038-2.

[35] F. Turrado, L. Javier, G. Villalba, and J. Portela, "Expert Systems with Applications Intelligent system for time series classification using support vector machines applied to supply-chain," vol. 39, pp. 10590–10599, 2012, doi: 10.1016/j.eswa.2012.02.137.

[36] G. Baryannis, S. Dani, and G. Antoniou, "Predicting supply chain risks using machine learning: The trade-off between performance and interpretability," *Futur. Gener. Comput. Syst.*, vol. 101, pp. 993–1004, 2019, doi: 10.1016/j.future.2019.07.059.

[37] R. Carbonneau, R. Vahidov, and K. Laframboise, "Machine learning-based demand forecasting in supply chains," *Int. J. Intell. Inf. Technol.*, vol. 3, no. 4, pp. 40–57, 2007, doi: 10.4018/jiit.2007100103.

[38] A. Ucar, M. Karakose, and N. Kırımça, "Artificial Intelligence for Predictive Maintenance Applications: Key Components, Trustworthiness, and Future Trends," *Appl. Sci.*, vol. 14, no. 2, p. 898, 2024, doi: 10.3390/app14020898.

[39] Q. Liu, "Logistics Distribution Route Optimization in Artificial Intelligence and Internet of Things Environment," *Decis. Mak. Appl. Manag. Eng.*, vol. 7, no. 2, pp. 221–239, 2024, doi: 10.31181/dmame7220241072.

[40] L. Achy and K. Sekkat, "OVERLAPPING TRADE AGREEMENTS : STATUS AND CHALLENGES FOR MOROCCO".

[41] M. Cammett, "Business-Government Relations and Industrial Change : The Politics of Upgrading in Morocco and Tunisia," no. November 2007, 2018, doi: 10.1016/j.worlddev.2007.01.003.

[42] M. S. Jallab *et al.*, "The Free Trade Agreement Between the United States and Morocco . The Importance of a Gradual and Assymetric Agreement To cite this version : HAL Id : halshs-00359098 THE FREE TRADE AGREEMENT BETWEEN THE UNITED," 2009.

[43] R. K. Yin, "Method in Evaluation Research," pp. 283–290.

[44] A. Kähkönen, "Conducting a Case Study in Supply Management," no. February 2011, 2015, doi: 10.31387/oscm090054.

[45] M. Wagner, "No Title," vol. 69, no. 2010, pp. 1553–1560.

[46] A. Ghaouta, "Big Data Analytics Adoption in Warehouse Management : A Systematic Review," *2018 IEEE Int. Conf. Technol. Manag. Oper. Decis.*, pp. 86–93, 2018.

[47] M. Mathews, "Winning Marketing and Business Strategies in a Highly Competitive and Globalized Economic Environment: A Case Study of Fortune 500 companies—Coca-Cola, Microsoft and Amazon," *M. S. Ramaiah Manag. Rev. ISSN - 0975-7988*, vol. 12, no. 02 SE-Articles, pp. 43–52, 2022, doi: 10.52184/msrmr.v12i02.113.