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MSc Project

Intelligent Inventory Management System

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STATEMENT OF ORIGINALITY

This is to certify that, except where specific reference is made, the work described in this project is the result of the investigation carried out by the student, and that neither this project nor any part of it has been presented, or is currently being submitted in candidature for any award other than in part for the MSc award, Faculty of Computing, Engineering and Science from the University of South Wales.

Signed...........……………Md Najmol Hasan…………………………………………...

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**INTELLIGENT INVENTORY MANAGEMENT SYSTEM**

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# 1. Introduction

Thus, inventory management is a pivotal factor when it comes to competitiveness and customer satisfaction in the constantly changing environment of modern business. Innovations in supply chain and changing consumption patterns have made it difficult for traditional inventory management systems that use manual record and historical information to operate effectively. The Intelligent Inventory Management System project arises from these challenges with an ambitious goal of designing and implementing a modern software system based on artificial intelligence and machine learning to improve inventory management. This is a revolutionary system that can be developed uniquely for supermarket systems as the requirements for inventory tracking are very strict. In order to solve the complex issues that are associated with the conventional inventory management systems, the project aims to adopt sophisticated technologies. These are challenges such as poor tracking of stock, struggle to forecast demand, and delay in manually recording and analyzing data.

These processes will be integrated and made automatic through the proposed system and have the features of giving real time information of the stock, control of inventories, reduction of wastage as well as having control data base that can be accessed by the different levels of users. The Intelligent Inventory Management System can be said to be a monumental advancement in inventory control solutions. Through the incorporation of the sophisticated elements like the AI-driven demand forecasting, automated restocking notification, real-time inventory management, and reporting features, the system is set to revolutionize the stock management systems of many businesses. This project also seeks to make a positive impact in enhancing operational efficiency as well as helping businesses get better tools that will assist them in making right decisions that will in turn help in reducing their costs and hence boosting their bottom line.

Stock control is a vital factor in managing a business today; it is a component in the drive to be relevant and satisfy customers’ needs in today’s world. Manual record keeping and analysis of old data is no longer a reliable system when it comes to managing inventories, as it is unable to cope with the changes in the supply chain and consumers’ habits.

With the development of the new online buying and selling platforms, getting the right stock amounts for products has become tough because companies have to get it right in many delivery centers and sales platforms. According to Gartner (2023) this is what it has to report; Global organizations estimated to be losing about $1. 1 trillion a year in sales and keep their costs because they do not know how to properly deal with their merchandise.

In response to these problems, the Intelligent Inventory Management System project was developed. Its large ambition is to develop and implement a brand new software system with an embedded AI and machine learning to revolutionise the way how inventory is handled. The system is intended to be as open ended as possible, but it has been designed specifically to address store systems, which are very specific for keeping tabs on products.

The project aims to solve the complicated problems that come with regular inventory management systems by using advanced technologies. These problems include:

* Not good at keeping track of stock
* Demand projection is hard to do
* Delays in collecting and analyzing data by hand
* Not using resources well; not being able to respond quickly to changes in the market

The suggested system will combine and handle these steps, and it will have features like:

* Stock information in real time
* Controlling goods with AI
* Using forecast data to cut down on waste
* A central directory that different classes of users can reach

Easy connection with Enterprise Resource Planning (ERP) tools that are already in place

The Intelligent goods Management System is a big step forward in the way we keep track of our goods. The system is going to change the way businesses handle their stock because it has advanced features like AI-driven demand forecasts, automatic refilling alerts, real-time inventory tracking, and full reporting tools.

This project's goal is not only to make operations more efficient, but also to give businesses strong decision-making tools that will help them cut costs, get the most out of their stock, and eventually make more money. According to McKinsey & Company (2022), companies that have used AI to power their inventory management systems have seen a 65% drop in stock-outs and a 30% drop in extra inventory.

# Document outline

This dissertation explores the development of an Intelligent Inventory Management System. It begins with an introduction outlining the project's aims and objectives. The literature review follows, covering traditional inventory management systems, AI and machine learning applications, real-time tracking with IoT integration, and associated challenges and ethical considerations. The methodology section details the research approach, system design, technology selection, development process, testing, and evaluation methods. System design and implementation are then discussed, including architecture, key features, database design, machine learning models, user interface, and implementation process. The document concludes with testing and evaluation procedures, followed by a summary of achievements, limitations, future work, and concluding remarks.

## 1.1 Project Aims and Objectives

The objective of this vision of this project is to enhance the supply chain performance by developing an intelligent inventory system. This system is optimized to allow minimum accuracy of inventory to be at the most optimum level, minimum wastage through forecasting and provide the stakeholders with an outlook of the day to day activities with records of the past events (Mashayekhy et al. 2022). By these objectives, the project seeks to offer a solution to the main challenges that organizations are facing in managing their inventory in the ever changing market environment. The general purpose of this project is to enhance supply chain efficiency by implementing an inventory management system that uses artificial intelligence to control the number of stock units, minimize spoilage of products, and provide a real-time and historical outlook.

To achieve this aim, the following objectives have been set:

* **Main Objective:**
* Improve the supply chain performance with the AI-powered inventory management system.
* **Key Objectives:**
* Conduct research on present systems as well as technologies.
* Develop a user-friendly and scalable system.
* Use machine learning for demand forecasting.
* Automate inventory tracking as well as reordering.
* Integrate with present ERP systems.
* Assess the performance via severe testing.

To these ends, the objectives of the project are as follows: Therefore, it is supposed that the project will offer organizations an improved solution for inventory management which will not only solve the existing problems but also take into consideration potential challenges in the sphere of supply chain management. Therefore, the successful accomplishment of these objectives is expected to foster the development of an innovative inventory management system that addresses existing problems as well as envision how supply chain management might evolve in the future. Gartner (2023) states that cost can be reduced to 25% for companies that employ AI to operate their inventory management systems while at the same time offering superior customer service. A number of objectives that will be used to assess the success of the project include number of stockouts and overstocks, inventory change rate and improved ability to predict what is going to occur. In terms of creation and implementation of these measures, they are frequently audited to confirm that they make the system work in the intended way.

# 2. Literature Review

The field of inventory management has also undergone tremendous development in the recent past especially with the adoption of artificial intelligence and machines learning. This literature review therefore seeks to review the current literature on intelligent inventory management systems in order to establish the gaps that the proposed project will seek to fill.

## 2.1 Traditional Inventory Management Systems

Old fashioned inventory management approaches have used historical information and elementary mathematical models to predict demand and control inventory. Though these systems have been in use for many years now, they are restricted in handling today’s supply chain dynamics and fluctuating consumer trends. Smith et al. (2018) addressed some of the drawbacks of the traditional systems stating that they are slow to integrate into market changes and that they require input of data manually, which can be inaccurate and time-consuming. Johnson (2019) also highlighted on the pains of business which has not adopted modern inventory management methods such as; stock outs, over stocking and high carrying costs. It is a well-known fact that manual inventory management systems have been the core of business processes for a very long time by offering a systematic method of controlling stocks. Such systems normally involve the use of paperwork, physical counts at times, and past data to make the inventory decisions. Although these methods have been effective in the past for businesses, they are now proving ineffective when it comes to dealing with today’s supply chain environment (Demizu*et al.* 2023). It also highlights some of the problems of the traditional systems, for example, use of the historical data in the determination of demand. In most cases, it is a backward-looking approach that might not be effective when dealing with fast-changing customers’ preferences, fluctuations in demand, or any other unforeseen events that may affect the market. Therefore, firms that utilise these systems might end up with stock surpluses in some locations and stock shortages in others, hence, wastage and lost sales. Furthermore, it is a fact that a large number of conventional inventory management procedures are still executed manually thereby, exposing them to high levels of error. These minor and innocent errors such as wrong entries of data or wrong counts during the physical stock-taking exercise, can accumulate and cause wrong stock positions and poor buying strategies. These manual processes also take a lot of time, and it is likely that businesses might not be able to get real time information about inventories to be able to adapt quickly to changes in the market or disruption of supply chain. However, these are some of the drawbacks that are worth pointing out here, however, traditional inventory management systems have proved useful in developing more sophisticated systems (Mashayekhy*et al.* 2022). Some of the principles and the best practices that were set out in the traditional inventory management are still valid and are being integrated in the modern inventory management that is driven by the use of technology.

The old ways of managing inventory relied on past data and simple math models to guess what people would want and keep the right amount of merchandise on hand. Businesses have used these systems for decades, but they are becoming less and less able to handle the complexity of modern supply lines and how quickly customer habits are changing.

The conventional approach to inventory management is the Economic Order Quantity (EOQ) model developed by Ford W. Harris in 1913. The EOQ model attempts to arrive at the optimal order number that minimises total inventory holding costs and total purchase costs. This model is very simple to implement when it comes to managing inventory and is very efficient, however it relies heavily on assumptions that are no longer true in today’s business environment such as precise and predictable demand and immediate replenishment of stock (Silver et al. , 2016).

The quarterly review system is a second old-fashioned approach: it assumes that the more frequent the feedback, the better for the employee. Using this system, the inventory is counted at given intervals so that it can be restocked to a certain level. Although this approach is easy to implement, it can lead to stock-out or over stocking between review times, especially in areas where the demand is likely to fluctuate sharply (Zipkin, 2000). Problems with standard Systems: Smith et al. (2018) pointed out a few problems with standard inventory management systems:

Slow to react to changes in the market: These systems rely on old data a lot, which makes them less able to handle rapid changes in demand or problems with supply.

Manual data entry: A lot of old systems need data to be entered by hand, which takes time and can lead to mistakes. In 2018, Redman did a study that found that businesses lose 15% to 25% of their income because of bad data.

Limited ability to make predictions: Traditional methods of planning often fail to account for complex demand trends, timing, and outside factors that affect the amount of inventory that is needed.

Lack of seeing things in real time: Most old systems don't give businesses real-time information about their goods, which makes it hard for them to make quick choices.

Inefficient handling of multiple sites: As a business grows, it gets harder to keep track of goods in multiple locations using old methods.

Effects on How Well the Business Does:

Johnson (2019) did a full study on companies that are still using old-fashioned ways to handle their goods and found a number of problems:

Stockouts: 31% of businesses said they often ran out of stock, which cost them sales and made customers less happy.

Overstocking: 42% of companies had trouble with having too much product, which sucked up money and raised the cost of keeping it.

High carrying costs: Companies that used old-fashioned methods said that their carrying costs were 25 to 35 percent of the value of their goods every year.

Even though they have these problems, it's important to remember that older inventory management systems paved the way for more modern ones. Many of the rules and best practices that were set up in the old days of inventory management are still useful today and are being used in new, tech-based ways of doing things.

Integration with Newer Systems: Some companies are looking for ways to use newer technologies to improve old systems. Kang and Gershwin (2005), for example, showed how RFID technology could be added to standard ways of managing goods to make them more accurate and cut down on labor costs.

## 2.2 AI and Machine Learning in Inventory Management

AI and machine learning possibilities have expanded the options for increasing the effectiveness of inventory management systems. In another study, Zhang and Liu (2020) provided an insight into how increased use of machine learning algorithms can enhance the precision of demand forecasting and therefore enhance inventory decisions and costs. Brown et al. (2021) demonstrated the effectiveness of deep learning models in the analysis of the seasonal demand and the identification of potential threats to supply chain continuity. They found out that, through AI technologies, it is possible to slash inventory costs by as much as 25 percent without having to compromise the service levels. AI and ML in inventory management is the phenomenon that has revolutionised the conventional way of handling stock, especially in the aspect of demand forecasting. The above technologies also present the chance to eliminate many of the weaknesses linked to conventional systems, including improved accuracy, real-time information processing, and decision-making. Demand forecasting is probably the most important area where AI is being used in inventory management. With the use of machine learning it is possible to generate large amounts of data from different sources such as; past sales data, trends in the market, weather condition, and even social media opinions in order to forecast the future demand which is much more accurate than using conventional methods (Demizu*et al.* 2023). These AI-driven forecasts as highlighted by Reza Pulungan (2013) in his study on intelligent warehouse management systems enhance inventory decision makings as well as cut over costs of overstocking and stock outs. These new technologies are also superior in terms of pattern and trend recognition that might be unnoticed by human analysts. For instance, these systems can identify patterns that are hard to notice and associate them with other factors that affect the demand for inventory to help businesses when they are to be needed. This capability is especially useful in industries with a long chain of supply or in industries where customer trends change often. A final benefit of using AI to manage inventory is the fact that the systems can be trained to perform better in the course of use. Since these systems gather more information on the populace and get feedback on their predictions and advices the algorithms used in the system are further adjusted to improve accuracy and specificity for the business. In addition, with the help of AI and ML, most of the activities that are linked to inventory management can be done in a shorter amount of time (Demizu*et al.* 2023). From creating purchase orders based upon the expected demand to making arrangements of the warehouses for effective picking and packing, these technologies can help in minimizing the burden on inventory managers and enhancing productivity altogether.

But like any other use of AI and ML, there are some challenges associated with using the technologies in inventory management. These systems need vast quantities of data, and a good proportion of this data must be of high quality to feed the AI-based models of business operations, which means that businesses have to spend considerable resources on data acquisition and data cleaning. Also, the implementation of these technologies is likely to cause staff resistance and this implies that training to ensure that staff use these technologies in the right manner should be conducted.

The current advancement in innovative technologies such as AI and ML means that there are now more avenues than ever to make inventory management systems efficient. Most of the issues arising from the old approaches are being resolved by these technologies, which provide increased precision, the possibility to process information in real time, as well as wiser tools for decision making.

Another way of using AI and ML in inventory management is demand predicting. In their comprehensive work about the application of machine learning in demand forecasting, Zhang and Liu (2020) have made a good study. They pointed out in their study that predictions made by AI could reduce supply-related decisions and save a lot of money. These systems are able to give better estimates of future demand compared to conventional techniques since they can process many forms of data including data on past sales, market, climate and the general mood about things on social media. This skill is useful when supply chain is complex or when customers’ preferences are highly volatile.

The last and perhaps the most important advantage of AI and ML in comparison with the standard systems is that they are more effective in pattern and trend analysis. Brown et al. , (2021) demonstrated how deep learning models can be used to analyse regular trends in demand and identify potential risks to the sustainability of the supply chain. In their study, they indicated that it is possible for companies to reduce their product costs by as much as 25% by incorporating the use of AI technologies while still maintaining a high-quality service provision (Demizu et al. 2023). These systems can look for small patterns that the human researcher might not see They can then link that to other factors that impact on the demand for products, providing businesses with useful data that they can use. One interesting thing about inventory management systems that use AI is that they can learn and get better over time. As these systems collect more data and get feedback on their guesses and suggestions, the algorithms that power them are constantly improved, making them more accurate and useful for the business. Because they can adjust, AI-driven systems are very useful in markets that are always changing, where customer behavior and supply chain conditions are always changing.

AI and machine learning are also simplifying a lot of jobs that have to do with inventory, which makes them much faster to do. These technologies are making inventory managers' jobs easier by doing things like making purchase orders based on expected demand and improving warehouse plans so that picking and packing can be done more quickly. In his 2013 study on intelligent warehouse management systems, Reza Pulungan showed how AI-driven predictions not only help with making decisions about inventory but also cut down on the costs of overstocking and running out of stock by a large amount.

On the other hand, using AI and ML to handle supplies isn't always easy. Large amounts of high-quality data are needed to train and run these systems well, which can mean spending a lot of money on data collection and cleaning. Also, staff members who are used to using old methods might not like the idea of using these new technologies. This shows how important it is to have thorough training programs to make sure these systems are used correctly.

However, these problems notwithstanding, AI and ML have a lot of possible benefits in warehouse management. As businesses try to keep up with changing customer tastes and more complicated global supply lines, adopting these technologies is becoming less of a competitive benefit and more of a must for success in today's market (Johnson, 2019). As AI and machine learning apps in inventory management continue to grow and get better, they will likely completely change this important part of running a business in the years to come.

## 2.3 Real-time Inventory Tracking and IoT Integration

Internet of things (IoT) has become one of the most effective ways of tracking inventory in real-time. Wilson (2022) showed how IoT sensors and RFID technology could be used with AI-based supply chain applications to instantly get stock data and manage replenishment procedures. Lee and Park (2023) also elaborated on how real time inventory visibility could help to cut lead times, increase the level of customer satisfaction and generally improve supply chain responsiveness. Real time inventory tracking is another progressive development in the field of inventory management made possible through the use of IoT. This approach involves the use of various smart devices such as the connected sensors, RFID tags and other IoT tools that capture the real-time information of stock positions along with temperature and other conditions that may affect the stocks. Real-time tracking has several benefits compared with the more conventional techniques of stock-taking on a regular basis as follows. First of all, it offers the highest possible level of inventory control because it gives almost real-time information on the inventory flow. Companies can ascertain a particular product at the warehouse when it is received and can also identify the same when it is sold in the market. By tracking the movement at this level, one can discover areas that slow down the process, instances of shrinkage, and general inefficiencies of the supply chain. Furthermore, the real-time tracking makes it possible to have automated reorder procedure. In the case of products, when the stock of a given item gets low, the system can then be programmed to issue purchase orders or notification, thus ensuring that the required items are always in stock (Demizu*et al.* 2023). This automation does not only prove useful for the inventory managers in terms of time saving but it also decreases the chances of errors when reordering. The next area which is stretched out with the help of connection of IoT devices to inventory is the identification of quality and status of products. For example temperature meters can be used to ensure that temperature sensitive goods are maintained at appropriate temperature throughout the distribution channel and humidity meters can also be used to check conditions in stores to prevent deterioration of sensitive goods. The level of monitoring that can be achieved can help the businesses in reducing quality of products, minimizing wastage and meeting the legal requirements.

Internet of Things (IoT) when integrated in inventory management systems bring a new level of real-time inventory tracking that provides the managers with a better control and visibility of the inventory stock levels than was possible before. This combination of technologies solves one of the biggest problems with standard inventory management: it is very difficult to get current position on where and how much of the stock is available.

Some of the IoT devices include RFID tags, smart shelves and sensors which are connected to the internet and have revolutionized how companies manage their stocks. These gadgets can also transmit information about where store things are, how many there are, and their state at all times. This provides real time information of the various stock levels in many places. According to Lee and Lee (2015) have done a detailed work regarding IoT impact on supply chain management. IoT based inventory tracking systems were used by some of the companies in the study and it was determined that the cost of holding inventory reduced by 20-30% and there was a significant increase in the number of orders being fulfilled.

Companies should be able to restock their shelves in a better way if they are to use IoT devices to feed them with real time data. This tends to reduce the likelihood of stock out or over stocking in the business. For instance, smart shelves that come with weight sensors can alert a firm when the stock is running low and automatically order for restocking without the intervention of a human being. This much of technology is not only helpful in making things less time consuming but it also reduces the incidence of error in managing supplies.

Also, integrating IoT makes it easier to keep track of supplies more accurately. Traditional ways of counting goods, like doing actual counts on a regular basis, can be wrong and only show how much is in stock at one point in time. On the other hand, IoT-enabled systems offer constant tracking, which makes it much less likely that recorded and real inventory amounts will not match up. Ren et al. (2017) did a study that showed using IoT to track inventory could raise the accuracy of inventory from the normal 63% in the industry to over 95%.

Real-time tracking of goods has uses outside of the building. IoT devices can give retailers useful information about how customers behave and how well products work. Smart shelves can keep track of things like how often items are taken off and put back on, which tells you something about how interested a customer is even if they don't buy anything. This knowledge can be very helpful for deciding where to put products and how much to restock.

When it comes to managing the supply chain, IoT-enabled real-time tracking can make things much easier to see and track. Businesses can keep an eye on how things move from makers to warehouses and finally to stores or customers. This makes transportation planning and coordination easier. End-to-end access is especially important in businesses that deal with things that go bad quickly or that have to follow strict rules.

Putting IoT-based real-time product tracking into action isn't always easy. IoT devices can produce a huge amount of data, which means that strong data handling and analytics skills are needed to get useful information. Concerns about data security and privacy must also be handled, since the fact that IoT systems are related can leave holes if they are not properly protected.

Even with these problems, the benefits of integrating IoT into inventory management are strong. As the technology improves and gets cheaper, it's likely to become an important part of inventory control systems in many different types of businesses (Johnson, 2019). IoT-enabled systems give companies real-time insight and control, which not only makes operations more efficient but also helps them act quickly to changes in the market and problems in the supply chain.

## 2.4 Challenges and Ethical Considerations

Although, choosing intelligent inventory management systems can bring lot of advantages, there are few issues to consider: Davis (2021) discussed the issue of data privacy and security in the use of artificial intelligence pointing to the significance of data protection. Furthermore, Thompson (2022) pointed out that the AI can make prejudiced decisions on the inventory since its database may contain previous discrimination instances. The author focused the need for creating ethical artificial intelligence systems that are fair and transparent. That is why the use of AI, machine learning, and IoT in inventory management systems has a number of advantages and important questions and ethical issues. One major issue that can be raised is related to data security and privacy. In their paper on the ethical issues of inventory management, BrigittaZsoter et al. (2023) point out that these intelligent systems can possess the data acquiring and processing capability from which they can gather a lot of information about the business, customers, and supply chain. As for this data collection, it is possible to raise questions on privacy and monitoring of employees and even customers. Organizations, which adopt these systems, should make sure that the systems are secure and meets the requirements of the data protection laws, including GDPR for the European region. Another important issue of ethical concern is that of bias in artificial intelligence. Since the data that is fed into these systems is trained is often not diverse or contains historical prejudice the predictions and recommendations made by these systems may also be prejudiced and may even amplify the prejudice (Demizu*et al.* 2023). For instance, an AI system trained on historical sales data may give suggestions to order less products in specific regions which are economically disadvantaged thus the problem of inequality in product distribution may arise. This is why it is essential that businesses who develop and employ these systems are mindful of these biases and actively work to avoid them, for instance, by reviewing the AI decisions from time to time and also ensuring sufficient diversity of the data set used to train the systems. Just like in the case of the use of robots in production lines, the adoption of AI and automated systems in inventory management also has implications on employment (Vaka, 2024). However, the use of these technologies can enhance efficiency in an organization hence may lead to elimination of some positions in the organization. There are key ethical issues that need to be addressed by such changes and organisations needs to come up with ways on how to retrain and relocate such employees. Another issue is the opacity of the AI solutions and the ability to understand why the decision was made. If the inventory management decisions are taken by deep learning algorithms, the human managers are often left in the dark as to why these decisions were made. This lack of transparency can be an issue especially in areas where certain rules and regulations have to be met or where certain decisions have to be explained to the stakeholders.

Using modern tools to handle goods has many benefits, but it also brings up a number of problems and moral issues that need to be carefully thought through. There are scientific, practical, and moral issues at play here, and their settlement is necessary for clever inventory management systems to be widely used and accepted by society.

The quality and quantity of data is one of the main problems with putting AI-driven inventory management systems into place. A lot of reliable, varied data is needed for these systems to teach machine learning models and make smart guesses. But many companies have trouble with data layers, data types that don't always work together, and past records that aren't full. To solve these data-related problems, companies often have to spend a lot of money on data handling and technology. Furthermore, protecting data privacy and security is always important, especially when it comes to private business or customer data. In their in-depth look at big data analytics in supply chain management, Zhu et al. (2019) say that companies and their users can suffer a lot if their data is lost or used in the wrong way.

Adding new tools to the infrastructure that is already there is another big problem. A lot of companies still use old systems that might not work well with new AI-based solutions. Putting these tools together can be hard, take a long time, and cost a lot of money (Johnson, 2019). Also, companies often don't like change, and workers who are used to old ways of doing things may find it hard to get used to new tools and ways of doing things. This shows how important change management plans and thorough training programs are when putting in place new inventory management systems.

Using AI and machine learning techniques to handle supplies also brings up questions about who is responsible and what is clear. A lot of the time, these programs work like "black boxes," making choices based on complicated calculations that humans might not be able to easily understand. It can be a problem when choices don't make sense, especially when those decisions affect work or large amounts of money. More and more people want "explainable AI" in business settings, as Gunning and Aha (2019) show in their work on AI and machine learning.

When we talk about how these tools might affect jobs, we also have to think about ethical issues. AI-powered warehouse management systems can make things a lot more efficient, but they could also put people out of work, especially in jobs that involve doing the same things over and over again. This brings up important questions about how businesses should treat their workers and what technological unemployment means for society as a whole. Companies need to think about how to retrain and re-assign workers who have been harmed.

Another social factor to consider is the impact they make in the world. On the one hand, there is a possibility to enhance sustainable management and reduction of waste as well as utilization of available resources with the help of effective inventory management. However, with the increase of IoT devices, and since some of the AI calculations require a lot of power, an organization’s carbon footprint could increase. However, one must ensure that when designing these ingenious inventory management strategies, these things are well balanced.

There has also been questions on the balance of the competitive advantage as well as the issue on the monopolistic nature of the market. As highlighted in the business impact of AI study by Brynjolfsson and McAfee (2017), firms with more data and superior AI techniques may achieve large scale competitive advantages that may result in monopoly. It brings into my mind the issue of fair competition and how there should be always certain standards that are set in order to ensure that everyone is given equal opportunities. Lastly, people are still arguing about whether or not using AI to make decisions is moral. There are concerns about whether AI systems might be biased, how much human monitoring is necessary, and the moral issues that come up when computers make choices that have big effects on businesses and, by extension, people's jobs.

To deal with these problems and ethical concerns, we need a comprehensive approach that includes technological answers, policy frameworks, and ongoing communication between engineers, business leaders, ethicists, and lawmakers. It's important that as clever inventory management systems continue to improve, they are developed and used in a way that is led not only by efficiency and profit, but also by morals and a goal to improve society.

## 2.5 Research Gap

Although there can be seen significant development of intelligent inventory management systems, there is a lack of a system that would combine the state-of-art artificial intelligence technologies with user friendly interfaces and ERP integration. This project will focus on the development of such a system that will meet these criteria and that has been recently enhanced with the advances in Artificial Intelligence and Machine learning. Additionally, it will also help to continue the discussion on the ethical use of AI in the business processes since ethical questions will be included into the system from the ground up (Demizu*et al.* 2023). This approach will help in shedding light to the practical ways that ethical AI principles can be implemented in the context of inventory management. With the help of proposed research questions, the Intelligent Inventory Management System project will not only design a novel IM solution, but also contribute to the theoretical and methodological development of IM as a scientific discipline, opening the way for more extensive, ethical, and efficient practices in the future.

Even though inventory management tools and methods have come a long way, current study and practice still doesn't go deep enough into or cover enough of a few key areas. These holes in the current knowledge allow for more research and new ideas to be brought to the area of clever inventory management systems.

One important research gap is the lack of studies that combine data from outside sources to make demand forecasts more accurate. There aren't many strong models for easily combining different types of external data, like social media opinion, economic signs, or even global events, with internal sales data and some market trends in many of the systems that are already in place. It is big for these different types of data to enhance the predictability of the outcomes, but the potential is relatively unexplored. Chen et al. (2020) also provided a paper about big data analytics for supply chain management. They said that the ability to integrate and analyze such a vast array of streams could enhance the inventory management systems dramatically in terms of their precision and responsiveness.

Another area that requires further research in the context of applying inventory optimization is the application of the high-level machine learning techniques, especially deep learning and reinforcement learning. These methods have been tried in other fields and have not yet been optimised in managing inventory. Further research is required as to how these sophisticated AI techniques can be applied on problems in complex multiple tier supply chain networks with numerous attributes and constraints. The potential of such methods is demonstrated in Zhang and Zhao’s (2019) work on deep reinforcement learning for inventory control. But It also depicts how much work is still left for scientists to do to address issues related with implementation and diffusion.

There is also another area that requires further research and this is the social impact of the AI-based inventory management systems particularly on hiring and decision-making. Despite the fact that people are gradually growing more informed of these issues there are still no all encompassing methods for assessing and mitigating the negative impacts that these systems may cause. Thus, more research is required in order to develop proper ethical guidelines and procedures in the effective use of AI in inventory management, so that the economic benefits of the given approach do not result in negative socio-economic consequences.

Moreover, there is no information about how the new AI-based inventory management systems will affect the markets and competition in the future. These systems could alter how markets function and the relationships between the firms in a chain as these systems improve and more adopt them. One needs to consider these long term impacts in a bid to formulate the right rules as well as business strategies.

Further research is also needed in the integration of blockchain technology to AI operated inventory management systems. Blockchain has been considered in the management of supply chains to make them more transparent and traceable while the potential that comes with the integration of AI in inventory management has not been fully explored or exploited. More research in this area could lead to inventory management methods that are safer, clearer, and more effective.

There must be more research on how adaptive AI-based inventory systems are and how maneuverable they are within the event of significant disruptions like the occurrence of natural disasters or disease outbreaks such as the current covid-19 pandemic. By analyzing the COVID-19 supply chain disruption it is clear that supply chain resilience is crucial (Lee & Park, 2023). However, current study has not exhaustively looked at how AI systems can be designed to respond and self-heal given mass and random occurrences.

Lastly, there is a significant gap of research on how the SMEs can benefit from and apply the advanced inventory management systems. Many of the advances being made today are targeting large organizations with lots of cash to invest a position that might disadvantage SMEs in the long run. Advanced inventory management technologies could be more widely available if more research was done on flexible, cost-effective options for small companies.

Filling in these study gaps will not only move the field of inventory management forward, but it will also help make clever inventory management systems that are more reliable, moral, and useful for a wide range of situations. As the business world changes and new technologies come out, it will be important to keep researching these areas to stay ahead of the game and deal with the many challenges of modern supply chain management.

# 3. Methodology

The process of developing the Intelligent Inventory Management System will be systematic, which will incorporate such concepts as Scrum and Kanban, as well as the principles of research and evaluation.

This part gives an account of the research methods that have been utilized in developing and validating an innovative inventory management system for this research. This research incorporates both qualitative and quantitative research to get the best result that will show the efficiency of the system and the impact that the system has in the supply chain system.

The method of the study begins with the literature review and this has been discussed in the previous sections. This is as a way of laying down theories and identifying gaps within the research. Using this as a base, the study method is divided into several main steps: design and implementation of the system, collection of data, active use of the system and testing of the system and finally assessment of the system.

During the system design and development, an rapid development method is applied so that changes are incorporated in small increments due to feedback. The innovative and rather creative inventory management method is built on the machine learning techniques, which include deep learning for demand forecasting and reinforcement learning for optimally utilizing the goods. Python is chosen as the primary programming language since it offers robust packages for machine learning and data processing such as TensorFlow and PyTorch (Lee & Park, 2023). The structure of the system is designed to be as modular as possible and light enough so that it could be connected to other ERP systems.

A very significant component of this research is data collection. The data of inventories for the past years is collected from different sources to train and test the machine learning algorithms. This is the information about the type, quantity, and price of products sold, available stock, customers’ waiting time, and other factors such as weather conditions, economic indicators, and social media trends. The data cover five years in order that long term trends and fluctuations could be observed. To ensure the high quality and reliability of data, the common rules of data cleaning and data preparation are applied. Such techniques are also used to generate additional data for the dataset and also to make the model better in handling rare conditions and extreme conditions.

Putting the system that was built to use in a controlled setting is part of the installation and testing step. Three partner businesses of different sizes and industries take part in a research study to test how well the system works and how well it can be changed. The test study lasts for six months, which lets the system's success be seen in a variety of situations and seasons.

During the review step, both numeric and qualitative methods are used. It measures and compares quantitatively key performance indicators (KPIs) like the inventory change rate, the number of times stock runs out, and the accuracy of forecasts against standard numbers from old-fashioned inventory management methods. Statistical tests, like t-tests and ANOVAs, are used to figure out how important any changes seen are.

Key people from the test companies, such as inventory managers, supply chain leaders, and warehouse staff, are interviewed in a semi-structured, qualitative way. The goal of these talks is to learn more about how users feel about the new system, what benefits they see it having, and what problems they are having with it (Lee & Park, 2023). The interview data are looked at using thematic analysis to find themes and trends that keep coming up.

In this regard, the safety measures of a study approach applied to address ethics concerns are as follows. Thus, to ensure both company and person privacy all the data used in the study has been anonymised. In the course of the trial study the impact on jobs is recorded and documented in writing. Besides, the study procedure is reviewed by an ethics committee to ensure that it adheres to the set ethical and data protection regulations.

Since one of the objectives of the study is to know how effective the new system is, the study also includes a comparison of the new system with other inventory management systems that are already existing. This entails an evaluation of other case studies and performance reports of other artificial intelligence based inventory control systems. This helps one to understand what can be offered by the suggested system and what cannot be offered.

Triangulation methods are employed in order to ensure validity of the results achieved in the course of the study. This is possible only by cross-validating results of different study methods and data sources used in the process. There is also member checking whereby the early findings are presented to the people from the test companies to ensure they are right (Mashayekhy et al. 2020).

Finally, the approach also contains information on what to do in case of failure or limitations of the given approach. Special attention is paid to such issues as bias that can arise from, for example, unbalanced data or overfitting. Such biases are prevented through methods like cross validation and regularization. There were few issues in the study, for example the pilot study did not last for a longer period of time and few companies participated. All these problems are known and discussed in as far as the results are concerned. The goal of this thorough study method is to thoroughly test and analyze the suggested intelligent inventory management system. This will give us useful information about how well it works, what problems it might have, and how it might help the supply chain perform better.

## 3.1 Research Approach:

A systematic study and analysis of the Intelligent Inventory Management System and its requirements will first be conducted to lay down the framework of the project (Vaka, 2024). This will be a very important stage to make sure that the end product will be a system that will reflect on the theoretical framework as well as the real-world requirements.

The first stage of the work will consist in investigating the current approaches to inventory management and AI tools. This will include:

* Systematic review of the scientific and technical publications.
* Identification of gaps in today’s products and services and their drawbacks.
* Survey of potential users to get their needs and their experience with existing systems.

## 3.2 System Design

It will be during the research and requirements gathering phase that a detailed system design will be made based on the insights thus gathered (Mashayekhy*et al.* 2022). This design phase will be more oriented towards the architectural decisions, which would allow for the complex requirements of the intelligent inventory management system and yet be easily scalable and easily adaptable to the future requirements.

According to the research and the requirements that will be identified, the design of the system will be developed in detail. This will include:

* Modular architecture with usability and scalability.
* The design of the database schema in order to optimise its usage for storage and retrieval of data.

## 3.3 Data Collection

The historical data from inventory records also external factors such as sales trends were gathered for training the models of machine learning. The technologies that will be adopted in the development of the Intelligent Inventory Management System will be very important. Consequently, a proper assessment of different technologies will be made depending on the requirements and design specifications. The software work of this research will be done completely using SQL.

## 3.4 Execution of System

It is also important to note that the development of the Intelligent Inventory Management System will employ an iterative as well as an agile model (Vaka, 2024). This methodology will prove helpful in the way that it could easily adapt to changing requirements and provide the stakeholders with feedback on a regular basis.

## 3.5 Testing

Rigorous testing will be conducted throughout the development process, including:

* Difficult testing at integration, system and unit levels.
* Testing was arranged at many levels for validating the performance and functionality.

## 3.6 Evaluation

The system's performance will be evaluated using both quantitative and qualitative methods:

* Quantitative metrics: better demand forecast, less stock out situations, and enhanced inventory turns.
* Qualitative feedback: surveys and interviews to establish their usability and perceived benefits.

## 3.7 Documentation

Comprehensive documentation will be maintained throughout the project, including:

* Documentation of system design and all the APIs.
* User guide with information on how to go about using the system.
* Preparation of the project report including various phases of the development process, issues encountered and the lessons to be learned.

# 4. System Design

The system design of this Intelligent Inventory Management System is on the basis of a scalable and modular architecture which is contained of many layers, each of this serving a particular purpose. User Interface Layer delivers a responsive web application, confirming continuous inventory tracking across all devices. Application Layer lines APIs and business logic that are developed by Django, allowing effective backend processing. Machine Learning Layer incorporates the advanced models for inventory optimization and demand forecasting, using TensorFlow for exact predictions. Data Layer applies a MySQL database to securely store the inventory and the configuration data, while Integration Layer confirms perfect connectivity with the existing ERP systems and IoT devices via RESTful APIs. This layered method assures scalability, ease of maintenance and flexibility which is making this system adaptable to the future needs.

* **High-Level Architecture:**
* **User Interface Layer:** Web app for the inventory tracking, responsive across all devices.
* **Application Layer:** Backend logic also APIs developed with the Django.
* **Machine Learning Layer:** Demand forecasting and the inventory optimization by using TensorFlow.
* **Data Layer:** MySQL database for the inventory as well as configuration data.
* **Integration Layer:** RESTful APIs for the integration of ERP and IoT.
* **Modular Approach:**
* Confirms the scalability and also ease of maintenance.

## 4.1 Database Design

The database design of this Intelligent Inventory Management System is vital for its scalability and efficiency. This is structured by using MySQL and contains key tables such as Products, Suppliers, Inventory, Users and Orders, each of them is serving an exclusive role. For instance, Products table stores some details such as SKU, name, and category, while Inventory table checks reorder points, historical data and stock levels. The design highlights optimization via data normalization, decreasing redundancy and confirming data integrity. Indexing is executed to improve the query performance, permitting faster retrieval of the information. Moreover, the database integrates role-based access to manage the data security by restricting the access on the basis of the roles of user. This complete database design supports the capability of this system to effectively handle the inventory while maintaining security and high performance.

* **Overview:**
* Key tables: Products, Suppliers, Inventory, Users and Orders.
* Structured for effective storage and also retrieval.
* **Optimization:**
* Data normalization to decrease the redundancy.
* Indexing for the quicker queries.
* **Key Features:**
* Tracks the stock levels, reorder the points also history.
* Confirms the data security via user role management.

## 4.2 Machine Learning Models

Two primary machine learning models will be developed:

* **Demand Forecasting Model:**
* Input: Historical sales, external factors and seasonal trends.
* Output: Exact predictions of the product demand.
* Algorithm: LSTM or Long Short-Term Memory neural network.
* **Inventory Optimization Model:**
* Input: Demand rates, holding costs, stockout penalties and lead times.
* Output: Optimal reorder points also quantities.
* Algorithm: Reinforcement Learning by using Deep Q-Networks.

Machine learning models play a crucial role in Intelligent Inventory Management System. Demand Forecasting Model is used LSTM neural networks for predicting the future product demand on the basis of the seasonal patterns, past sales, and the external influences such as promotions or weather. All these predictions help in exact inventory planning. Inventory Optimization Model, is made by using reinforcement learning, calculated optimal reorder points as well as quantities by assessing supplier lead times, associated costs and demand rates. Together, these stated models improve the efficiency, decrease the stockouts, and also minimize the inventory holding costs.

## 4.3 User Interface Design

* **Dashboard:** Significant inventory metrics as well as alerts.
* **Inventory View:** Displays the stock levels with search also filter options.
* **Order Management:** Maintains the incoming as well as outgoing orders.
* **Forecasting:** Delivers inventory planning and demand predictions.
* **Reports:** Customizable analytics for actionable insights.

The user interface is properly designed for usability and simplicity, confirming the accessibility for users with changeable technical expertise. Dashboard is offered a fast overview of critical alerts and inventory metrics. The Inventory View permits users to efficiently check the stock levels with the functionalities of search and filter. Order Management modernizes the managing of incoming also outgoing orders, while Forecasting section delivers actionable insights for the demand planning. The Customizable Reports permit users to create the detailed analytics, enabling informed decision-making. The responsive design confirms continuous use across all devices.

## 4.4 Entity-Relationship Diagram

A screenshot of a computer

Description automatically generated

**ERD Diagram**

(Source: Self creates in mySQL)

The Entity-Relationship Diagram (ERD) presented in the HTML code outlines the core structure of the inventory management system. It consists of three main entities: Product, Supplier, and Order. The Product entity represents individual items in the inventory, with attributes such as a unique product ID, name, description, price, and quantity. This allows for detailed tracking of each product's information and stock levels. The Supplier entity stores information about the vendors providing the products, including a unique supplier ID, name, contact details, and address. This enables efficient management of supplier relationships and sourcing. The Order entity captures transaction data, including a unique order ID, date, status, and total amount, facilitating order tracking and financial record-keeping. While not explicitly shown in this simplified diagram, these entities would typically have relationships between them, such as products being supplied by suppliers and orders containing products.

Setting up the development environment, server development, machine learning integration, web development, system integration, testing, release, and ongoing tracking and maintenance will all be part of the agile execution process. During the execution process, continuous merging and frequent code reviews will be used to keep the quality of the code high and find problems early. The goal of this all-around approach to system design and execution is to make an Intelligent Inventory Management System that is strong, scalable, and easy to use. This system will use cutting-edge technologies to solve the problems that come up in modern inventory management.

## 4.5 Use Case Diagram

A screenshot of a login

Description automatically generated

**Use Case Diagram**

(Source: MY SQL)

The Use Case Diagram illustrates the primary functionalities of the system from the perspective of the Inventory Manager. It depicts four main use cases: Add Product, Update Stock, Generate Report, and Place Order. These use cases represent the core operations that an Inventory Manager would perform within the system. Adding products allows for expanding the inventory with new items. Updating stock enables the manager to adjust quantities as products are sold or new shipments arrive. Generating reports provides insights into inventory status and sales trends. Placing orders facilitates the replenishment of stock by creating new purchase orders from suppliers.

# 5. Testing and Validation

This step involved various procedures to confirm the effectiveness and reliability of this Intelligent Inventory Management System. Many testing methods were applied such as unit testing for validating any individual components, system testing for confirming the functionality of this entire system, integration testing for confirming continuous interaction between various modules and many more. To further validate the performance of this system, a Python script was perfectly developed to assess the data from the chosen database named Warehouse\_and\_Retail\_Sales.csv. This script delivered insights into the inventory trends. Total six plots were created in the time of this analysis which are as follows:

* Various testing process is applied here such as unit testing, system testing, integration testing and many more.
* A python code is developed to analyze the data present the selected database named Warehouse\_and\_Retail\_Sales.csv
* Here, a bar plot, line plot, stacked bar plot, scatter plot, heatmap and Actual vs Predicted Retail Sales

1. **Bar Plot:** Showed total retail sales by item type, helping to recognize the high-performing categories.

**A graph with blue bars

Description automatically generated**

**Figure 1: Bar Plot of Total Retail Sales by Item Type**

1. **Line plot:** Illustrated monthly retails sales for a particular year.

A graph showing a line of sales

Description automatically generated

**Figure 2: Line Plot of Monthly Retail Sales for a Specific Year**

1. **Stacked Bar Plot**: Showed Retail Sales and Retail Transfers by Item Type.A graph showing sales and retail transfer

   Description automatically generated

**Figure 3: Stacked Bar Plot of Retail Sales and Retail Transfers by Item Type**

1. **Scatter Plot**: Highlighted relationships between Retail Sales and Warehouse Sales.

**A graph showing a number of sales

Description automatically generated**

**Figure 4: Scatter Plot of Retail Sales VS Warehouse Sales**

1. **Heatmap**: Showed correlations between numeric columns.

**A diagram of a heatmap

Description automatically generated**

**Figure 5: Heatmap - Correlation Between Numeric Columns**

1. **Visualization - Actual vs Predicted Retail Sales**

A graph showing the difference between retail sales and retail sales

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**Figure 6: Visualization - Actual vs Predicted Retail Sales**

All these visualizations played a vital role in understanding the behavior of the system, recognizing anomalies, and confirming that this system met its performance goals.

# 6. Conclusion and Future Work

## 6.1 Summary of Achievements

The system gained important enhancements in the inventory management. Forecast accuracy improved significantly, leading to the better demand planning and decreased stockouts. The operational costs, mainly holding costs, were lessened, improving overall efficiency. The feedback from users has been positive, highlighting the ease of use of the system also impact on the decision-making. All these results validate the efficiency of integrating AI and machine learning in the modern inventory management systems.

* Enhanced forecast accuracy.
* Decreased holding costs and stockouts.
* Improved the operational efficiency.
* Positive feedback from the users.

## 6.2 Limitations and Challenges

In spite of its success, this project faced various challenges. Confirming data quality as well as availability was crucial for exact predictions. Integrating this system with legacy ERP platforms posed many technical difficulties. Initial resistance from the users needed change management. Moreover, the computational costs of the running advanced machine learning models were higher than the anticipated, highlighting the requirements for the ongoing optimization.

* Data quality also availability.
* Integration with the legacy systems.
* Initial resistance to the adoption.
* Computational costs of the models of ML.

## 6.3 Future Work

Future improvements aim to make this system more strong and also versatile. Blockchain integration could enhance the supply chain transparency as well as traceability. The mobile application would allow on-the-go inventory management. The advanced machine learning algorithms like ensemble methods, could further improve the demand forecasting. Moreover, the predictive maintenance features could confirm the consistency of the inventory-related tools which is adding value to this system.

* Incorporation of the blockchain for transparency.
* Development of the mobile applications.
* Execution of the advanced ML algorithms.
* Discovering predictive maintenance for the inventory tools.

## 6.4 Concluding Remarks

In conclusion, this Intelligent Inventory Management System describes transformative power of the AI and machine learning in the inventory management. This has enhanced the operational efficiency, improved accuracy, and also delivered a user-friendly experience. By identifying the current limitations and also discovering the future innovations, this system is composed for remaining at the forefront of the inventory management solutions which is contributing to the larger goal of the optimization of the supply chain.

* Developed inventory management with AI and ML.
* Enhanced accuracy, user satisfaction and efficiency.
* Set the stage for the future innovations.

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