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THE REVOLUTION OF WAREHOUSE INVENTORY MANAGEMENT BY USING ARTIFICIAL INTELLIGENCE

Case company: Warehouse of Company X in Finland

International Business

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ABSTRACT

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In the fourth industrial revolution (4.0), Artificial Intelligence (AI) is widely applied in various industries in Finland including supply chains. A large part of logistic companies around the globe are progressively embracing automation and data exchange, machine learning, deep learning in their operations. These innovations are essentially changing the operation of the supply chain.

Particularly, in Finland, AI has strongly expanded in inventory management which is one of the principle stages in supply chain management. The pairing of Artificial Intelligence (AI) with inventory management has promoted remarkable improvements in warehouse management. The benefit of AI and its impact on this field have also attracted plenty of researchers and businesses around the world.

This thesis emphasizes on the transformation of inventory management in warehouse operation based on the innovation of AI. First, the author decides to illustrate the current impact of AI on inventory management. Then the author continues to evaluate the challenges, the opportunities as well as the expectations of AI development in controlling inventory in the next few years. Following the structure of the thesis, audiences will have a comprehensible view for the revolutionizing of inventory management from the present to the future when implementing AI.

The case company is one of leading Finnish logistic companies. They are one of the few companies that pioneered the utilizing of AI technology in their warehouse operations especially in inventory management. The quantitative method is selected to collect the data from employees in warehouse of company X. The result will demonstrate the level influence of AI applications on inventory controlling and the awareness of employees in the transforming pace of managing inventory when applying AI. Furthermore, the result from people who have experienced in the warehouse of company X will be considerable and assessed.

Keywords Artificial Intelligence (AI), inventory management, warehouse, revolution, machine learning, sorting, forecasting, applications.

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AI	Artificial Intelligence
ANI	Artificial Narrow Intelligence
AGI	Artificial General Intelligence
ASI	Artificial Super Intelligence
ANN	Artificial Neural Network
SCM	Supply chain management
SC	Supply chain
WSM	Warehouse management system
WIP	Work-in-process
ASR	Autonomous Scanning Robot
AS/RS	Automated Storage and retrieval systems
AGVs	Automated guided vehicles

1. INTRODUCTION

1.1 Background to the study

In modern and energy life, Artificial Intelligence (AI) has expeditiously grown into a trending topic of business conferences, international competition and research. Smart systems with huge information processing capabilities are developing as a logic tool to support businesses and organizations in decision making, business orientation, marketing, recruitment, training, policy and controlling.

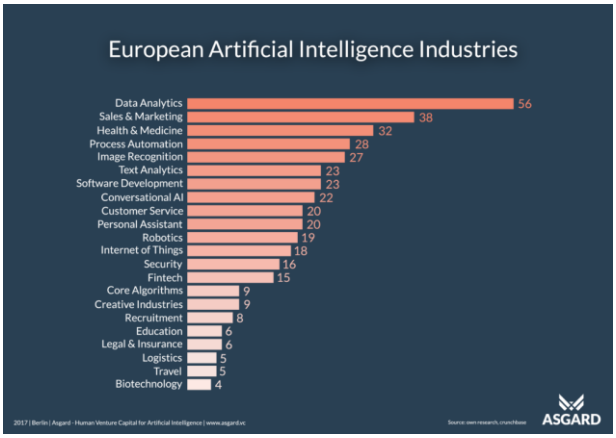


Figure 1. Industries using AI in Europe (Source: Asgard)

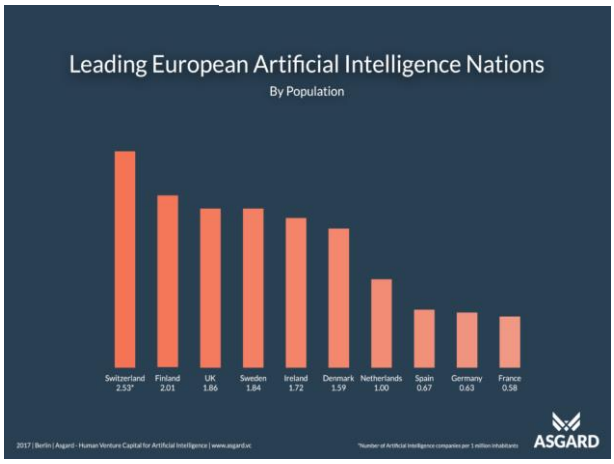


Figure 2. Leading countries in Europe using AI (Source: Asgard)

According to Asgard - human Venture Capital for AI, the “Data Analytics' ' industry has been growth dramatically in Europe relying on AI needing data and its emergence from Cloud and Big Data. Especially in Finland, the current trend of most industries is to apply AI to bring the high performance. Finland is the second country in Europe to have a large number of AI companies per capita.

Pekka Ala-Pietilä – who is the head of the steering group which sculpted out a project for Finland's AI program – had stated: "Finland has huge potential to become one of the leading countries in exploiting the benefits of AI. The idea is to make it easy for businesses to utilize AI, and to support the public sector in building predictive, AI-powered digital services based on people's major life events. We want to keep our country wealthy, our businesses competitive, our public sector effective, and our society well-functioning." Therefore, in the future, the application of AI will produce significant impact on various industries in Finland. In recent years, the investigation of AI has been introduced as the university lectures and become the hottest scientific disciplines in Finland.

Being one of the biggest logistic groups in Finland, company X has possessed many different types of warehouses. In addition, they are also one of the companies whose warehouses have been applied AI technology in their operation process. This is a main reason for X company to be a designated case company of the thesis. Moreover, the network with employees in company X support the reliability of this thesis.

1.2 Research questions

In the subject "International Supply Chain Management" at Vamk, University of Applied Sciencies, the basic theoretical foundations of AI were introduced by the lecturers Emmanuel Ndzibah and Kodjovi Lotchi. However, the influences of AI on specific sectors in the supply chain especially in warehouse operation were not mentioned in detail. Therefore, this thesis aims to emphasize the impact of AI on inventory management in warehouses. Furthermore, the thesis also displays the expectation for the future of the AI development on warehouse sectors in Finland. At the level of International Business field, an in-depth study of the system and how AI works will be limited. Following these factors above, this study suggests four big questions:

- Question 1: What is the current AI's application in inventory management in the warehouse of case company?
- Question 2: How is AI impacting on inventory management in the warehouse's company?
- Question 3: What are the challenges and opportunities of AI in inventory management in the company X?
- Question 4: What are the expectations and the predictions for AI in the inventory industry in the case company?

Results of the research questions above can explain how Artificial Intelligence is revolutionizing inventory management in warehouses in case company X.

1.3 Methodology of the research

The quantitative research method would be appropriated to implement the research. Online survey is an acceptable tool to congregate the data for evaluating the level impact of AI on inventory management from the employees and the supervisor's perspective in company X. The answer of the respondents who had worked in warehouse of company X are still credible.

1.4 Thesis structure

The structure of the thesis is divided into seven chapters which are Introduction, Literature review, Research methodology, Empirical Analysis, Conclusion, Validity and Reliability, and Limitation and Recommendations.

To begin with, the introduction of the thesis initiates background to the study, the questions research and the methodology using in the research. Next, the literature review chapter contains of the theories of Artificial Intelligence, warehouse operation, inventory management and the revolution of inventory management by applying AI. The third chapter illustrates deeply the research methodology which is quantitative method. The following chapter is the empirical analysis part which includes the crucial data of the research. In conclusion chapter, the author concludes the finding of the case company and continues presenting the validity and reliability in chapter sixth. Lastly, the author proposes some limitations and recommendations for the thesis.

2. LITERATURE REVIEW

In this chapter, the fundamental literature correlated with thesis topic will be introduced. There are four principal segments in this chapter. At the beginning, the definition of Artificial Intelligence will be discussed. Secondly, the section will provide some general information related to warehouse operation. Next, the section will concentrate on inventory management – one of the fields of warehouse. Finally, the literature review emphasizes on the revolution of AI in warehouse management including the challenges and opportunities of AI applications.

2.1 Concept of Artificial Intelligence

2.1.1 Definition of Artificial Intelligence

2.1.1.1 General definition

Artificial Intelligence (AI) is a term to define the intelligence of a machine which is simulated by humans to program thinking like humans and mimic their actions. There are different interpretations of AI. In this section, the denotation of AI will be illustrated by eight disparate definitions based on four approaches for its ability to think like humans, act like humans, think rationally and act rationally (Stuart & Peter, 1995, p.4-5). Thus, with respect to these distinctive features, four AI categories could be displayed into two specific dimensions. The definitions on the left side of **Figure 3** belong to terms of fidelity to "Human performance" while those right definitions describe "Ideal performance" which can be called "Rationally".

Thinking Humanly	**Thinking Rationally**
"The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense." (Haugeland, 1985)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985)
"[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly	**Acting Rationally**
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990)	"Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998)
"The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)	"AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

Figure 3. Definition of AI (Stuart & Peter)

2.1.1.2 Types of Artificial Intelligence

There are many methods to classify the types of AI. However, the types of AI (**Figure 4**) can be divided based on its capabilities and functionality (DataFlair Team, 2019).

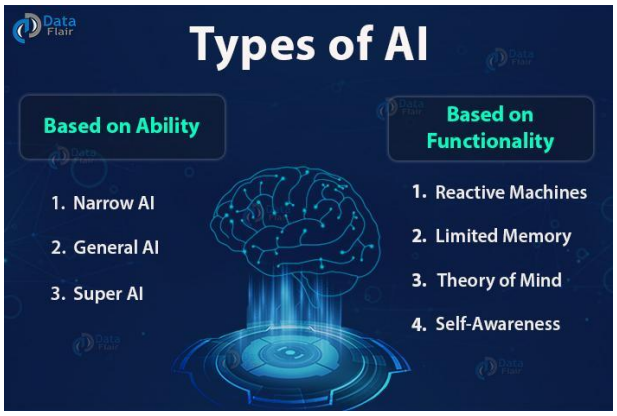


Figure 4. Types of AI (Source: DataFlair Team)

For the "Ability" aspect which can be called "Type-1 AI", there are 3 sub-types: Artificial Narrow Intelligence – (ANI), Artificial General Intelligence (AGI) and Artificial Super Intelligence (ASI). ANI is known as weak AI which refers to performing only a narrowly defined set of specific tasks. At this stage, the machine can work uniquely in a precision-trained situation without any thinking ability. Intelligent systems such as Siri of Apple, Alexa of Amazon or Alpha-Go of Google are one of the most popular examples of ANI which are run by machine learning, pattern recognition, data mining or natural language processing.

On the other hand, AGI and ASI are defined as Strong AI which machines can work with actual minds. In specific, AGI is a machine that can have the ability to think and perform any task with efficiency equal to human (Element of AI course, University of Helsinki, 2019). Meanwhile ASI is the intelligence explosion in which the capability of AI will be superior to human across all fields. In truth, there are no specific or existing applications of ASI currently. The vertical line (**Figure 5**) indicates the current development of AI and within the following 10 years, the scientists believe that the transition to the AGI stage will

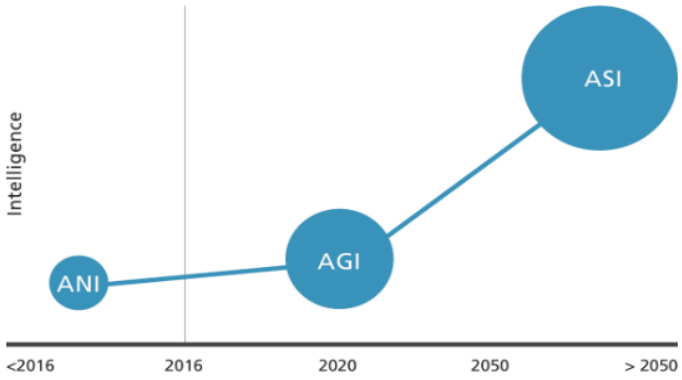


Figure 5. The evolution of AI (Source: UBS)

be completed soon. However, the rapid growth of AI beyond human control could be a threat to human existence. In the future, human's aspiration is to create a machine which can be as smart as a human.

Contrary to ability aspect, the functionality sector which is "Type-2 AI" involves reactive machines, limited memory, theory of mind and self-awareness:

Reactive Machines

With regards to reactive machines, it is possible to mention the event Deep Blue, IBM's chess-playing supercomputer won by world chess champion Gary Kasparov (Stuart & Peter, 1995, p.137-138). Reactive machines are types of AI that operate merely depending on the present data to inform current decisions. It does not have any form of memories or have any ability to remember everything in the past experiences. Therefore, during the match, a reactive machine was applied to Deep Blue to analyze the current data by identifying the pieces on a chess board and predicting how each move. Subsequently, Deep Blue confirmed the most optimal decision from its forecast. (Arend Hintze, 2016)

Limited Memory

Limited memory AI is kindly familiar with reactive machines. Nonetheless, it can organize a small memory to judge the situation and improve the verdict future actions (Dataflair Team, 2019). A self-driving car is an acceptable example. It uses the data collected in the past as a sensor tool to rejoin accurately the road signs such as lane markings, traffic lights, civilians crossing the road (Zulaikha Lateef, 2019). Nowadays, self-driving cars are becoming a trend for car manufactures such as Tesla, Google car, Audi, CMU Navlab, etc.

Theory of mind

Presently, theory of mind AI has not existed yet. It can be seen as an advanced type of AI. Theory of mind is a term to explain the ability to predict the actions and behavior of self and others (Carruthers and Smith, 1996). Human are good at working together because they use theory of mind to attribute their ability such as beliefs, desires, capabilities, goals and mental states to others (David and Guy, 1978). Therefore, humans can deduce about the others' opinion and behaviors and predict the situation.

For the intelligent systems, learning and implementing human behavior became big challenges. The philosophers and psychologists are proposing the human mind involving thoughts and emotions which can be implemented in computers or machines to process information (Benjamin Erb, 2016). Even though the results of Theory of mind from human has been working inefficiently in machines, the scientists will offer methods to organize the intelligent systems that can collaborate with human better in the future.

Self-awareness

This is the last stage of AI evolution which currently exists uniquely in hypothesis. The self-awareness AI is an AI that has developed self-awareness as human can. It can evoke the emotions in those it interacts with and can control it needs, beliefs, and desires of its own. However, the strong development of AI can lead to catastrophe. In this stage, AI will easily outsmart the intellect of any human brain and planning the sophisticated decisions to take over humanity.

2.1.1.3 Sub-field of Artificial Intelligence

In addition to the types of AI mentioned above, AI also consists of many sub-fields including Machine Learning, Expert system, Robotics and Fuzzy Logic.

Machine Learning

The term Machine learning was invented by Arthur Samuel (1959) – the pioneer of computer gaming field. The machine learning expert Tom M Mitchell defined "Machine learning is the study of computer algorithms that allow computer programs to automatically improve through experience."

In simple words, machine learning was designed to explore methods in which computers can absorb the knowledge immediately from data and thus learn how to figure out the

problems. Machine learning algorithm is classified into amounts of categories (Luger, G.F., 2002):

- ***Concept learning*** which is created to remember or set up the concepts relevant to future decision-making procedure.
- ***Decision tree learning*** focuses on assigning the data where it is continuously split according to certain input. Decision tree can be drawn by decision nodes and leaves. The leaves represent the final decision or outcomes while the decision nodes are a place for breaking data.
- ***Perceptron learning*** aims to obtain the functional knowledge, decrease the error and handle the decision complications using a single layer network 'perceptron".
- ***Bayesian learning*** allows computers to practice the ability of probabilistic functions. The probability can be indicated arithmetically as a statistic index with the scope between zero point (an absolute impossibility) to unity (an absolute certainty) (Michael Negnevitsky, 2005).
- ***Reinforcement learning*** aims to implement the actual situation by distinguishing the certain actions to maximize the reward. Machine is not allowed to know the hint of actions but instead it must discover which action can generate the most reward.

One of the parts of Machine learning are Artificial Neural Network (ANN) and Deep learning. ANN was designed as biological human brain to build a computational system which inspired by storing knowledge, processing method and learning ability (Haykin, 1999). ANN can be arranged in multi-layer network that consists input layer, intermediate layer, out-put layer. Each neuron (**Figure 6**) receives the input data then process the signal to provide a set of behavior in intermediate layer (hidden layer). In output layer, the multiple

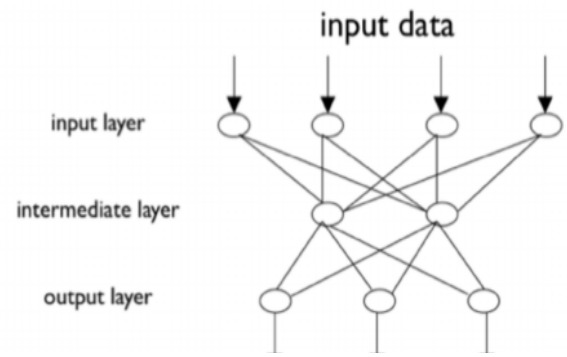


Figure 6. Basic AI neuron (source: Mehdi Khosrow - Pour, ANN Tutorial, 2015)

"simple" functions can transfer into exceedingly difficult functions. Deep learning works same method with ANN, but it uses multi hidden layer of ANN.

Expert system

During the 1950s, the early areas of consideration were "theorem proving" and "problem solving". Theorem proving is a part related to demonstrating hypotheses automatically from given a set of truisms by computer. While problem solving accentuated general capacity for solving various types of problems in computer systems. In both fields of "theorem proving" and "problem solving", the expansion of computer systems emphasized the capability of offering resolution for explicit domain at the level of extra-ordinary human intelligence and expertise. The best-known Expert system is MYCIN which was designed in the 1970s for medical segment (Peter J.F.Lucas & Linda C.van der Gaag, 1991).

The expert system consists of the following given components: Knowledge Base, Inference Engine and User Interface. The knowledge Base stores the amount of knowledge about the problem domain which was collected from different experts of a specific field. The inference Engine is defined as a "brain" of the expert system which contains a large number of rules so solve issues. From the Knowledge Base, the Inference Engine prefers acceptable facts and rules to provide the answer for user's query. The user Interface absorbs the data from the user's inquiry in readable form and transfers it to the inference engine. When the inference engine completes the process of solving problems, the user interface has responsibility to display the results to the user. In other words, the interface is a tool to connect the user with expert system (Awad, 1996).

Robotics

Robotics is one of the essential subfields of Artificial Intelligence technology to the community. It comprises Mechanical, Computer Science and Electrical Engineering. Robots are the artificial agents which create for the intention of manipulating the heavy objects by perceiving, picking, moving, modifying the physical possessions (Neha Singh, 2018). Most robotics was built to simplify working style and increase work productivity. In the past, the traditional Robotics were applied AI design procedures to conduct robot activities. Nevertheless, the modern Autonomous Robotic methodology requires that robots could ameliorate and control themselves independently and regularly. In the US, the use of production

robots in many factories lead to significant saving costs regarding labor and products. According to BCG news, they had assumed that the cost for human labor becomes 15 percent higher than the cost for robotics labor (Hal Sirkin & Michael Zinser & Justin Rose, 2015). Robots can be classified according to the specific fields and the tasks they indicate (**Figure 7**). The first side of robotics accentuates industrial fields which includes logistics and manufacturing. The robot can be required to maneuver objects in different positions or identify divergent items that need to be packaged in the right order. Moreover, transporting goods to and from warehouses is considered an essential part for robots. Nowadays, the flexibility of robots should be added when the industrial robots interact more with humans.

The second side of robotics concentrates service fields that consists of medical, home, ed-

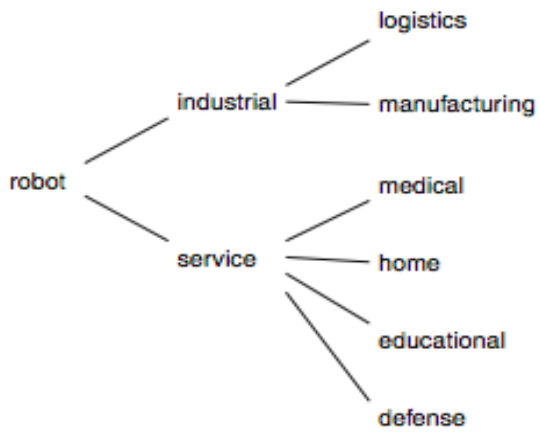


Figure 7. Classification of robot (source: M.Ben-Ari & F.Mondada, 2018)

ucational and defense. Most of these robots were created to assist humans in their own tasks. Vacuum cleaning robots or reconnaissance drones is one of the popular samples. Furthermore, the use of robots in medicine such as surgery, rehabilitation and training has been escalating. (M.Ben-Ari & F.Mondada, 2018).

Fuzzy Logic

People transmit the information primarily by natural language which can be used to communicate daily in human society such as English, French, Finnish, Vietnamese, … Although the limitations of natural language sometimes are lack of precisions and vagueness, human can understand what others explain with them. Therefore, the scientists and mathematicians aim to develop the ability of machines to interpret and process information, which can act as human brain. Nevertheless, the big problem is how the computer can

understand and process the knowledge by natural language. In order to achieve this ambition, scientists need to initiate a mathematical logic theory that allows an accurate description of the meaning of pluralistic clauses.

In traditional logic, the clauses have only obvious values such as true/false or yes/no. For example, clause “today is rainy” can be true if today has the rain. If not, this clause is false. Nonetheless, there are many clauses that contain unclear information. For instance, clause “Anna is a good person” comprises uncertain data because the level of good person is difficult to estimate precisely. These clauses involve the inaccurate and incomplete information can be call Fuzzy data.

In 1965, Professor Lotfi Zadeh had built successfully about the theory of fuzzy logic and fuzzy logic set (Lotfi A. Zadeh, 1968). This invention allowed humans to value the fuzzy propositions. Thereby, some information is conveyed to machines by natural language and the machines can understand quite accurately the content of that information. Fuzzy logic utilizes the expert opinion as input data to classify “good” and “bad” areas of each variable (Tanaka, 1997)

2.1.2 Artificial Intelligence history

Over hundreds of years, humanity has undergone three significant industrial revolutionary milestones. The first Industrial Revolution happened in Europe and United States in the mid-18th century with the transition of manufacturing process using steam power. The second Industrial Revolution occurred from the late 19th century to the early 20th. During the second revolution, rapid standardization and mass industrialization has increased with the advancement of electricity usage, petroleum and steel production.

The third Industrial Revolution began with the emerging power of information technology and the digital transformation of many manufacturing industries all around the world. The cornerstone of this period was the innovation of internet technology and renewable energies that has brought solutions to establish business infrastructure and the production model for many business sectors. For many reasons, the capability of Internet Technology has

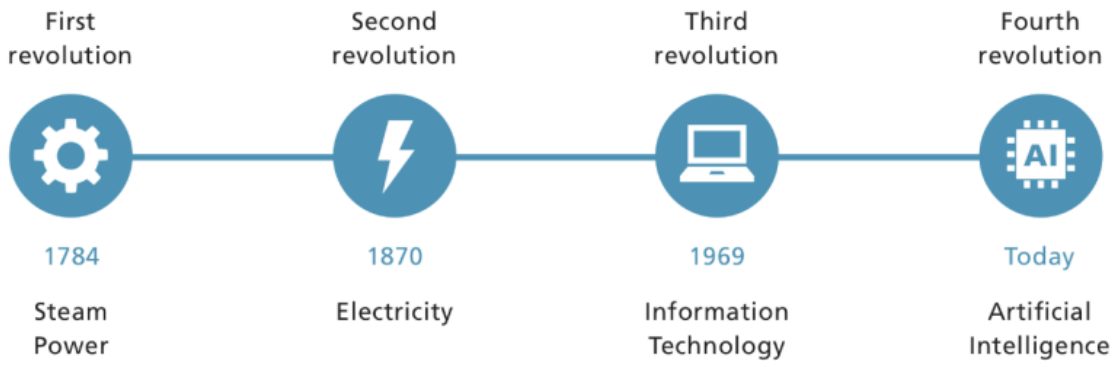


Figure 8. The industrial revolution (source: UBS)

outlined more aspects of society across civilizations than any former invention in the past industrial revolutions.

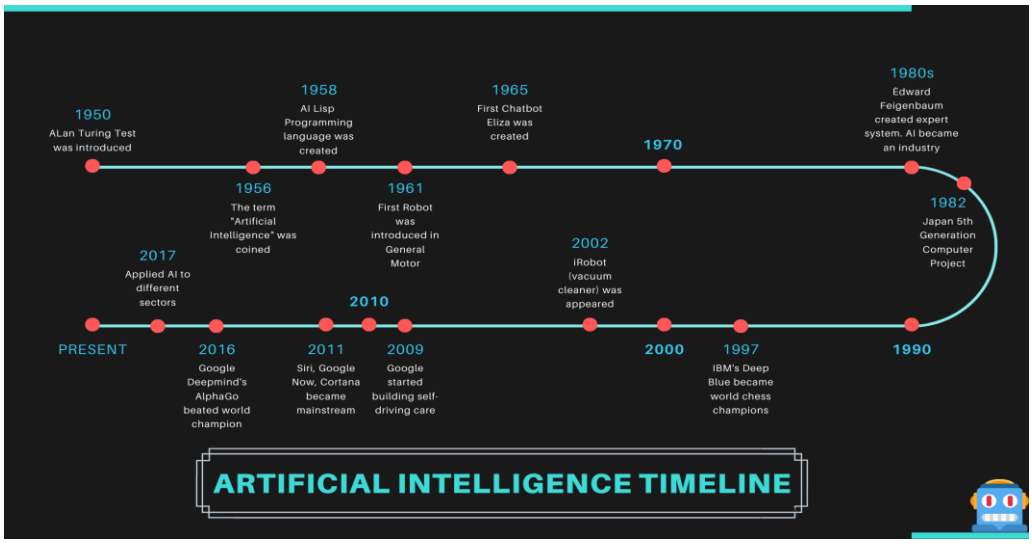


Figure 9. Timeline of Artificial Intelligence – Own making based on different sources

Up to date, humanity has stepped into the fourth Industrial Revolution, an era that will be determined and driven by the intense modernization of artificial intelligence and automation. AI's potential has captured the attention of not just scientists and physicians but also politicians and business entrepreneurs. In the upcoming years, AI is expected to become an immense sector that unleashes a stream of financial opportunities and will provide industry pioneers, both governments and corporates, with an exceptional technological advantage.

From 1938 to 1946, it was called “Golden Age of Science Fiction” (Rockwell Anyoha, 2017). Particularly, in 1943, the two scientists Warren McCulloch and Walter Pitts had

published the book “A Logical Calculus of Ideas Immanent in Nervous Activity”. The authors had proposed a model of artificial neuron that could be active inside a brain which was characterized as being “on” or “of” and detecting a learning neural network.

In 1950 (**Figure 9**), Alan Turing introduced the Turing test, machine learning, genetic algorithms and reinforcement learning in his article “Computing Machinery and Intelligence”. The test was given as a method to verify the machine’s intelligence behavior.

In summer 1956, it was represented “The Birth of Artificial Intelligence” when the term AI was coined by McCarthy at the first AI conference (Stuart & Peter, 1995, p.17). After two years, John McCarthy initiated the Lisp programming language which is one of the typical functional languages used in the AI field.

After the revolutionizing technology in the world, in 1961, the first industrial Robot named Unimate was introduced on an assembly line at General Motor by George Devol and his co-workers (Rebecca, 2011). The two years following, the first chatbot Eliza was designed by MIT AI professor Joseph Weizenbaum depending on the Natural Language Processing (Manisha, 2016).

In the 1980s, the scientist Edward Feigenbaum constituted the expert systems which simulated the knowledge and analytical skill of one or more human experts. Nowadays, expert systems are applied to analyze the future data, statistics and predictions (Rockwell Anyoho, 2017).

A special tournament between humans and computers was taken in 1997. Ironically, the world chess champion Gary Kasparov was defeated by IBM’s Deep Blue – a chess playing computer program by a score of 3.5 to 2.5 in a match (Stuart & Peter, 1995, p.29)

As Raymond Kurzweil (1990) writes: “Today, many thousands of AI applications are deeply embedded in the infrastructure of every industry”. Up to date, there were various programs which were produced to serve human life such as autonomous vacuum cleaner, Siri, Google Now, self-driving car, etc.

2.1.3 Impact of Artificial Intelligence on supply chain management

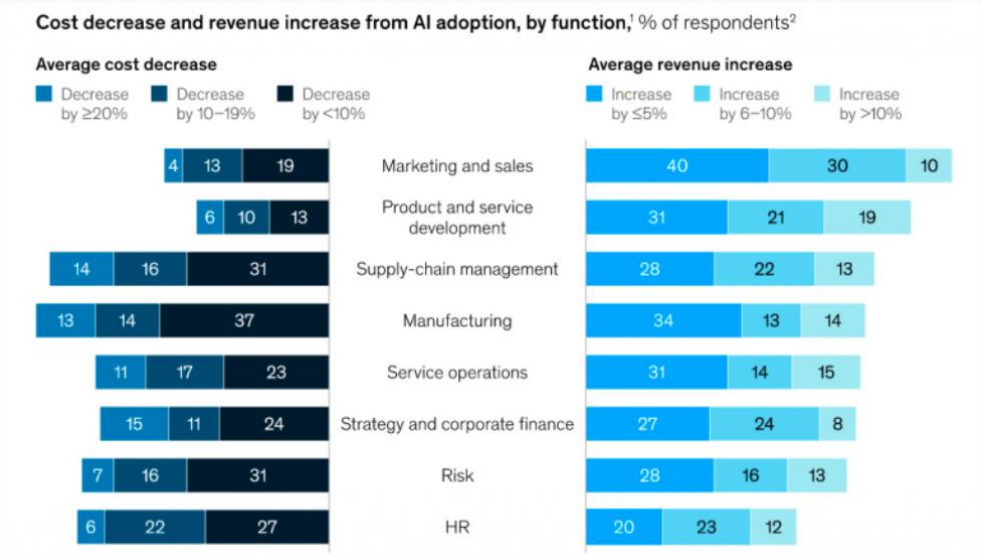


Figure 8. Cost decrease & revenue increase from AI adoption (source: McKinsey global survey)

According to The Supply Chain Council, supply chain management can be clarified as a process of management supply and demand, selection of raw materials, manufacturing and assembly, warehouse and inventory tracking, distribution and delivery of the finished product to the customer. In supply chain 4.0, the future of supply chain management mainly focuses on the Artificial Intelligence, Internet of Things (IoT), Industrial Internet of Thing (IIoT) and Blockchain. The pioneering of AI is going to be profound in the fourth industrial revolution even though the potential of AI including solving complex issues and searching for information in the SCM area has not been capitalized in the past (Hokey Min, 2010).

Since the field of AI came to existence in 1956 by John McCarthy (McCarthy, J., Minsky, M.L., Rochester, N., & Shannon, C.E., 2006), the AI including its subordinate dimensions such as expert systems and machine learning have been vastly invaluable to SCM (Rupa Dash, Mark McMurtrey, Carl Rebman, Upendra K.Kar, 2019). According to A McKinsey global survey about the question related to the cost and revenue impact of AI adoption across 33 cases and 8 business functions, the impact of AI in the SCM was ranked third in the total 8 business functions.

There are 61% of respondents indicating that AI adoption can be saved the cost of operation and 63% of respondents agreed that they were able to achieve the revenue bumps (**Figure 10**).

Nowadays, the information has been more intensive in different aspects in SCM including inventory & warehouses management, planning transportation and production, logistic and communications. Identifying the value of information in supply chain, the SC experts have inquired various procedures to better manage the information and execute it to make business decisions.

AI in Transportation and Fleet Management.

Artificial Intelligence especially machine learning is establishing a new generation of transportation management solutions. AI fleet management is the tool to control the fleet operation by eliminating human error from the transport process. AI can optimize the real-time fleet analytics by collecting data such as traffic and road conditions, hazards during the road, weather forecast, and technical error to predict the incoming situations. A fleet management system allows the center machine to format the optimal routes, schedules, maintenance delivery that limit the transportation risk and control the cost-efficiency (Foxy, 2019)

AI in Warehouse Management (Inventory control and planning)

A warehouse management system (WMS) is integrated with AI capabilities to respond the increasingly complex and dynamic nature of modern warehouse. Intelligent WMS (Smart-WMS) is an innovative system which can optimize all core warehouse management processes. For instance, if the product is scanned at the entrance, the algorithms in system can autonomously determine available position and define the most efficient routes to place the product. AI can also help warehouse managers to estimate the time of task completion and order processing to implement workflows more productive and logical.

AI can also support warehouse to manage the inventory plan. According to Timme and Williams, the annual cost of holding a single unit of inventory occupied approximately from 15% to 35% of its value (Timme and Williams, 2003). Recognizing this problem early, in 1986, Allen initiated an expert system named the Inventory Management Assistant (IMA) to aid the US Air Force Logistics Command refilling various spare aircraft components and minimize the safety stocks. In the result, the effectiveness had been increased by 8-18% by reducing the inventory errors.

AI in Demand planning and Forecasting

Information about future demand is foundation for the firm's strategy planning, workforce scheduling, inventory control, new product and promotional campaigns. However, due to the instability of future demand and the varying of levels of uncertainty, the development of AI techniques to accurate forecasting becomes a dauting task. Some of predicting techniques are tested for a short-term projection that work better for a long-term projection. However, in recent years, new AI techniques have been proposed as feasible options for demand planning and forecasting.

For example, in 2008, experts Min and Yu had explored the forecasting system that has functions to analyze and predict end customer demand through the exchange of information between the different parts of SC (Min and Yu, 2008). The system framework had learnt from the past forecasting experiences and human expertise to estimate the demand of new product. In the future, there are more innovative services that can be useful for predicting demand precisely.

AI in Procurement – Purchasing

One of the most important factors of a procurement process is make-or-buy decision. It is predominately focused on consideration of choosing goods and services that are manufactured internally or purchased those from external sources. Although the make-or-buy decision is simple in theory, it include a huge of factor to implement it. Different decisions will lead to different scenarios (Baily et al, 2005). Due to the complication of scenarios, AI was applied to sourcing bots to understand and operate autonomously the sourcing process. For instance, Nissen and Sengupta proposed intelligent software agents. They propounded the program that could select autonomously the processes of examining for prospective suppliers through online catalogs, checking qualification of suppliers and accomplishing the purchase order.

Generally, AI has been put forward in the SCM as a functional decision-aid tool that support company connect its customer, suppliers and partners. The use of AI in the supply chain will assist the businesses managing risks, reducing cost operations and using resources effectively.

2.2 Warehouse operation

Warehouse is known as a central department of logistics system. It is playing as an intermediate role between supply chain segments that affect both supply chain costs and service (Kiefer and Novack, 1999). In this chapter, the foundations of warehouse will be mentioned.

2.2.1 Warehouse industry in Finland

For the past few years, Finland has been recognized as one of the most important and increasingly lucrative logistics hubs for the international trade and especially the EU commerce which has been significantly impacted by the activeness of various emerging Asian economies, a pace of globalization and a steady growth of Russia business. Thus, it is crucial in this circumstance to determine the challenges encountered by logistics and warehousing industry as well as to measure how the prospect of international trade growth and employment in Finland are likely to be escalated. As becoming an important international hub between West and East side, it has helped to create more competitive opportunities for Finnish businesses and export industry.

The streamlined logistics and the supply chain are significantly important to international trade competitiveness and domestic employment. The duty of warehouse's service capability and performance potentiality are spotlighted in the current amid situation of globalization and changing business environment. Growing demand of goods shipping cost efficiency, agility and punctuality express a requirement of terminal and warehousing infrastructure development and compact cooperation between logistics enterprises and custom authorities.

However, a lucrative opportunity for Finnish logistics development comes with various crucial challenges which are to maintain a competitive price advantage as an international logistics hub and warehousing service excellence compared with other Baltic neighboring countries such as Estonia, Latvia and Lithuania meanwhile facilitating several core Finnish export industries to European countries and Asia. One of the potential solutions for expanding Finland's export and import activities and transit logistics is to improve the custom clearance procedure and the international border control practices accompanied by the application of advanced technology and process innovation (Vammalan Kirjapaino team, 2005).

2.2.2 Warehouse operation

Figure 9. Warehouse operation process – Own making

Over the last few years, warehouses had been transforming into a science with mathematical and computer models. The main purpose of transforming is enabling companies to improve warehouse activities more efficiently. Furthermore, customer service and demand variability are optimizing. Although warehouses are used for many different purposes, they operate on the same logical pattern of material flow (**Figure 11**).

Unloading

Unloading is considered as receiving goods which is the first warehouse process. In this step, the goods should be verified to ensure that warehouse will receive the right product, right quantity, right condition and at the right time. When the warehouse receives the notification of the arrival of goods, they will schedule receive and unloading to coordinate efficiently with all subsequent operations within the warehouse. Product is likely to be scanned and inspected to register its arrival. If there are exceptions such as damage, incorrect counts or wrong descriptions, they will be recorded. Optimizing the warehouse unloading process is to avoid the amassing at the receiving docks. Power pallet trucks and conveyors will be supported tools to unload the cargo and empty the dock areas faster. Moreover, the labor management systems and dock schedulers can accurately envisage upcoming shipments to appropriately assign the right amount of personnel.

Put-away

Put-away can be defined as a process of transferring material from a harbor or a dock to a warehouse's storage. In practices, a distribution manager or logistics specialist might put away the goods on the same day of their arrival in order to utilize the storing space, shipping cost and limit the congestion and undesirable damage. Before starting the process, it is very crucial to identify the appropriate storage location because it will help to retrieve the product for the customer swiftly and efficiently. Therefore, the warehouse manager needs to

promptly know the availability of the warehouse spaces as well as their capacity and temperature to ensure the best storing condition for the material.

When the goods are put away, the storage location needs to be scanned to create a record in the system and avoid double stockpiling. This information is particularly important to establish a picking list and guidance for the order-pickers in collecting the right product for customers. The put away process usually comprises of around 15% of warehouse operating expenses (Hackman & Rosenblatt, 1990).

Order-picking

Picking is the warehouse process that assemble the goods in a warehouse to accomplish customer orders. On receipt of customer order the warehouse must check the available inventory. Then the warehouse needs to provide pick lists to navigate the order-picking. The picking list will include the item and quantity requested. Order-picking process typically occupies 55% of total warehouse operating costs (Hackman & Rosenblatt, 1990). Therefore, to optimize this process, most warehouses apply warehouse management system (WMS) which arranges all steps in the cycle to match with layout and operation of the warehouse for greater efficiency. For example, if customer has ordered 15 of unrelated items, the WMS may check the fastest route to pick these items and how the items is packaged. If 12 of the items can be grouped in a carton, WMS may automatically arrange 12 items in one carton and the other for 3 items left. Additionally, the system can also calculate the stock and order the new ones when the minimum level of stock is not reached. Order-picking is extremely important in warehouse process. Inaccurate orders do not irritate customers by interrupting their business, the return cost is also expensive (up to ten times the cost of shipping the product).

Packing & Loading

The packing procedure is performed to merge picked items in a sales order and formulate the shipment to customer. The main purpose of packing task is to ensure that the best condition of the goods is maintained all the way from the warehouse to customer destination. Besides that, packing duty can avoid any damages or insurance claims. The packaging must be followed the general standards so as not to increase the weight of the products and minimize packaging costs. Most customers normally prefer to receive all the items of their order in same time. This means that the warehouse must try to get all the parts of an order

and pack it together. However, the package must be delayed for shipping until they have suitable vacancy in container.

Before the products have been shipped, the packed product may be scanned to register customer order for shipping. Based on the registered item code, the tracking of the cargo can be checked by customers and the warehouse when it begins to leave the warehouse. When the product is loaded into freight carriers, the final state of the warehouse – shipping - has been started. It is considered successful if the right order is sorted and dispatched to right customers on time and safely.

Storage

Storage is known as a process that products are placed into the most appropriate storage space. Taking full advantage of all the available space in the warehouse will bring an efficient storage process. It helps to keep stock organized and limit the overload of goods. If the warehouse is not compiled functionally, it often run out of storage due to factors such as rapid growth, seasonal peak and slow sales (James A. & Dale A., 2004). It is inevitably to increase a considerable investment of time and money in the effort of optimizing the warehouse storage activities. Nonetheless, the long-term consequence will produce a huge amount of benefit. There are five steps to optimize the storage process (Hector Sunol, 2020).

- Step 1: The warehouse storage utilization must be calculated
- Step 2: The KPIs of company should be measure in order to define the sides that the warehouse storage need to be improved including carrying cost of inventory, storage productivity, space utilization, inventory turnover, and inventory-to-sales ratio.
- Step 3: Diminishing redundant aisle space will increase much needed storage.
- Step 4: The right warehouse storage method should be performed productively to maximize the space.
- Step 5: Containers need to be made available in various sizes to expand the storage capacity.

Inventory management

Inventory management is one of the most crucial components of warehouse operations. Inventory contains a substantial portion of a company’s assets such as raw materials, work

in process, all supplies used in manufacturing, and finished goods (Max Muller, 2003). Inventory management concerns managing availability of company's goods. It has a function to coordinate and administer the flows of goods requested for business to operate. Inventory management also has responsibility for ordering and re-ordering of stock, product sorting, inventory forecast analytics and ensure safety stock is accessible for manufacture or supply. In ***section 2.3***, the theory of inventory management will be discussed more thorough.

Nowadays, artificial intelligence is present in variety of business industry including inventory management. It provides powerful insights for companies, catching latest trend from customer demand, processing large volumes of data that help warehouse departments to better control the routine assignments of inventory management. Many applications of AI had been used to understand a multitude of real-time inventory management that impact on inventory stock levels. Depending on the collected data, AI can predict the scenarios, suggest appropriate solutions and even work independently or with human acceptance.

Due to the importance and uprising of AI application in warehouse operation especially in inventory management, the ***section 2.3*** will describe further how AI work on different segments in inventory management.

Warehouse safety and security management

The operation of warehouse should be accompanied by safety and security management. Running a safe and secure warehouse will avoid the risk for occupational and distribute positive work environment that prioritizes employee health and well-being. There are different warehouse safety and security management procedures that company can adopt to enhance safety in the industry (Azian Ibrahim, 2020).

- Conducting warehouse risk assessment: An entire risk evaluation includes condition of equipment available for employees, physical stressors on workers, racking and falling object judgement, calculation of warehouse vehicle traffic routes and worker safety heights when they are on ladders, forklifts or operating elevator.
- Eliminating any potential hazards to secure the products: The potential threats contains theft, pilferage, heat and humidity, vandalism, fire, loss of electricity and violence.
- Designating clearly hazardous zones: The warning signals must be place in dangerous area for worker caution.

- Providing training course for employees: Company should promote the awareness of safety and security management as well as solutions when there is breakdown happening to workers.

Waste management

Even though waste management seem like an important part in the warehouse process, it might be forgotten or less focused attention at the planning stage. Building a long-term waste management proposal in warehouse might be complicated and costly, but in the future, it can bring several long-term benefits and positive impact surrounding environment:

- Diminishing waste in warehouses can save the spaces, time and money.
- Using recycling methods effectively will benefit warehouse's reputation. Customers are becoming more eco-aware and sustainability and they use this factor to value the business operation. Adopting green packaging in warehouse can earn the respect of customers.
- Collecting and storing waste with the right method in right place contributes the workplace cleaner and safer, reducing the labor accident ratio and ensuring employee health.

2.3 Inventory management of warehouse

In this chapter, the two main fields of inventory management including ***Inventory sorting*** and ***Inventory forecasting*** will be introduced. The current implications of AI on each field will also be covered in detail. Moreover, the transformation of the inventory management by applying AI is an essential part of this chapter.

2.3.1 The fundamental of inventory management

The author has stated the definition of inventory management in ***section 2.2.3*** above. In order to have a good warehouse management, the inventory levels must be determined. Since inventories normally become a sizable investment in supply chain, question can be posed regarding how inventories can exist as well as the functions that they perform. Generally, inventories are divided into the five categories of stocks (Arnoldo C. & Dan, 1984):

Pipeline stocks consist of the units that are in transit between locations such as from distribution center to the retail outlet. The pipeline stocks contain of those products that are being worked on company's shipping chain even it has yet to reach its destination. If the recipient has yet to complete the payment, the items that are in transit still considered to be

part of the shipper's warehouse. And when the receiver pays the cargo, even if they have not taken real custody of the cargo, the pipeline stocks will be on the inventory list of receivers.

Cycle stocks are the amount of inventory which is arranged to use during an assigned time frame. This period is usually determined as the time between orders for raw materials, or the time frame between production cycles for WIP and finished goods. Cycle stock levels is often defined based on the forecast and demand planning. The historical data including product seasonality, latest trend, or product lifecycle elements can be used as a proxy to consider the market volatility.

Seasonal stocks are inventories that have high demand during special times of the year. Managers need to be proactive in preparing for building seasonal stock during low demand periods to mitigate the tension of peak demand duration. Moreover, controlling the waning of demand should be conjectured to avoid over-stock after the seasonality.

Safety stocks or buffer stocks are inventories which are not listed in the original plan of consumption. They are carried for emergency usage. Safety stock is often used when the market demand overreaches the initial forecast level. It plays as instrument for preserving safety level to cope with uncertain demand and supply uncertainties.

Stock holding for other reasons may perform the important functions of decoupling stocks for maintaining production, reserving raw material stocks, or anticipating an expected increase in price and demand.

In addition to five categories stock above, there are two essential factors that ensure the efficient flow of managing inventory in warehouse which are Inventory sorting and Inventory forecasting.

2.3.2 Inventory sorting

2.3.2.1 The definition

Inventory sorting is a procedure that organize reasonably the inventory classifications in warehouse. If the inventory is structured and arranged scientifically, the foundation for the operation of the warehouse is more productive. Not only shortening the time of import and export, the logical inventory sorting also assists to enhance the preservation of goods and optimizing the usage of warehouse space.

2.3.2.2 Types of product sorting

In fact, warehouses often must deal with many different types of inventories daily and seasonally (***section 2.3.1***). In order to classify the items, there are various solutions in which some of the most notable ones are as follow:

Stock Keeping Units (SKUs). Silver et al (1998) had introduced SKUs as items of stock that are totally specific as to its function, model, size, color, or location. In real-life, SKUs are used as commodity codes consisting of a string of characters (letters and/or numbers) that is assigned to an item to mark the location of this item in the warehouse.

Figure 10 SKU example (source: CFI)

For example (**Figure 12**), SKU of the product above is BLU-TEE-MED-CF26 which includes:

- BLU refers to blue
- TEE refers to the type of product T-SHIRT
- MED refers to the size of the product MEDIUM
- CF26 refers to the manufacturer code

SKUs are not applied to the standard templates. Distinct company develops its own version of creating SKUs for their products. Coding the items correctly can help to track inventory and reference items from the lists, invoices and order form. SKUs are thoroughly and commonly used by retail stores, warehouses and fulfillment centers.

ABC inventory classification. During the very first time 1951, General Electric is a pioneer of implementing 'Inventory Classification' with ABC methodology in its warehouse. This method was proposed by H.Ford Dickey based on sales volume, lead-time, cash flow and stockout costs (Martin, 2018). The ABC analysis is an inventory organization method which designates a class to each item or SKUs where the group A involve items that has the highest impact on business's line, while the group C contain items with lowest influence. Particularly, this method developed depending on the Pareto Principal (Vilfredo, 1896) which presented approximately 80% of the consequences are produced by 20% of the causes. Therefore, in inventory management, the rule was applied on different classification as following (**Figure 13**):

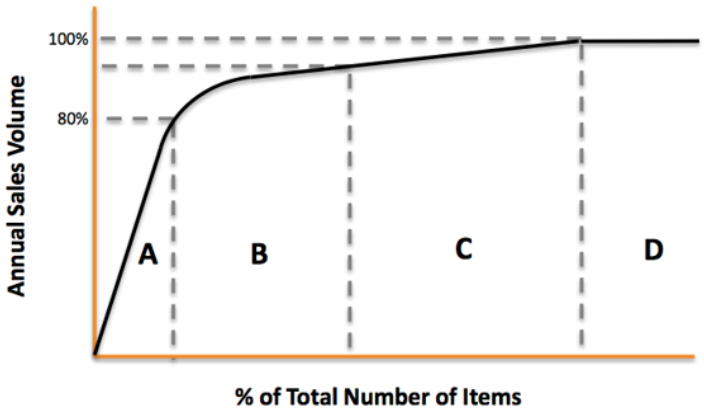


Figure 11. ABC analysis (source: Eazystock)

- Group A inventory comprises of 20% of warehouse items and 80% of annual sales volume.
- Group B inventory accounts for 30% of the items and 15% of annual sales volume.
- Group C inventory consists of 50% of the items and 5% of annual sales volume.

The ABC framework allows company to set the different service levels, safety stock level and re-ordering parameters for each category. Each of class will be stored in distinct area to monitor the stock level in right order and avoid the loss of high-value inventories. Generally, the aim of ABC inventory classification is to help manager prioritize the management of inventory control policies based on the category classification.

FIFO Principle (First in, First out). In inventory management, FIFO is defined as a method which sustain and arrange the stock based on the date (receiving and sales). The first batches entering the warehouse are the first batches used or sold. The FIFO method

maintains the remaining stocks are fresh and dealing with limited shelf lift stocks (Khan & Faisal, 2018). The FIFO practice is often used in perishable warehouse or raw material warehouse where the inventories have a truly short shelf life or likely to be obsolete.

LIFO Principle (Last in, First out). This is an effective method to store the goods without expiration date. The newly imported items will be prioritized for usage or export. Inventory management can apply LIFO to sort some kinds of stock including coal, sand, brick, steel, plastic or construction materials. However, this method is yet to be common in Europe.

FEFO (First Expiry, first out). The FEFO method is relatively like FIFO method. Nevertheless, the contrast is the expired date. FIFO procedure use the receiving and selling date while FEFO prefer the expiry date to sort the items. In practice, FEFO is highly efficient to control the stock of medical product, groceries, and pharmaceutical which are swiftly perishable. Even though the main purpose of FIFO and LIFO is indistinguishable, the FEFO technique is exceptionally ensure the frequent checking of expired date.

It depends on a variety of both the external and the internal factors including a category of stock which has been clarified in the above section and a level of usage in order to apply an appropriate inventory sorting technique for warehouse operation. For the products which have been tagged with a steady degree of consumption, a warehouse manager and workers would possibly assign a storing place close to a dispatch and packaging terminal. Meanwhile, there are some kinds of seasonal inventory which peaked highly in some periods of time within a year. They should be sorted into a seasonal category and stored at a specific area.

2.3.3 Inventory forecasting

Inventory strategy is an important factor of the overall supply chain management with highly impacts on both customer service and distribution logistics tactics especially in warehouse management. Obviously, forecasts can be implemented for many purposes such as weather forecasts, cost forecasts, technologies forecasts, etc. However, in this segment, the demand forecast using in production and inventory control will be discussed.

2.3.3.1 Definition

According to Kerkkanen (2010), there are many companies that are enabled to perceive their demands. Therefore, it could be difficult to make decisions in manufacturing planning, sourcing and inventory management in both long and short term. Constant change of inventory's demand has been affected by many trend factors and those are seasonality and economic issues (Bon and Chong, 2009). Inventory demand forecast analytic is an ideal solution to optimize better demand volatility and stock variability.

Forecasting is an estimation of future event or activity which is out of organization's control. While inventory demand forecasting means an estimation of future demand for product that is under control of organizations. The forecasting provides a basic data for managerial planning and reduces the risk of under stocks and overstocks in warehouse (Kerkkanen, 2010). The data can support the logistics management to decide how much of each product must be stored in or transported to warehouse. Forecasting inventory demand often require solid understanding of the demand fluctuation which is analyzed by descriptive approach and explanatory approach (Brown, 1977):

- ***The descriptive approach***: It can be called historical data demand forecasting which applies the past demand collection of information and merge it with algorithm to regulate the upcoming performance. The essential factors containing of the base, trends, and seasonality are usually extracted precisely from the time series (or historical demand) and then estimated to the future. The more data available, the more accurate the predictions will be.
- ***The explanatory approach***: This is an economic model that rely on educated deductions, expert knowledge and experience of how the market works. Qualitative forecasting might consider few factors to predict including the impact of new sales promotion, the effect a new technology, the new versions of the product and the product life cycle. This forecasting method can help company to have a good decision when placing new orders, control the market demand and avoid the dead stock in their warehouse. **Figure 14** shows the demand patterns which are significantly useful in inventory management.
    a. The base pattern illustrates a central propensity of time series at any given time
    b. The trend procedure represents a stable shift of the average within long period

c. The seasonal graph depicts cyclic variation commonly within one-year period (annual average demand)

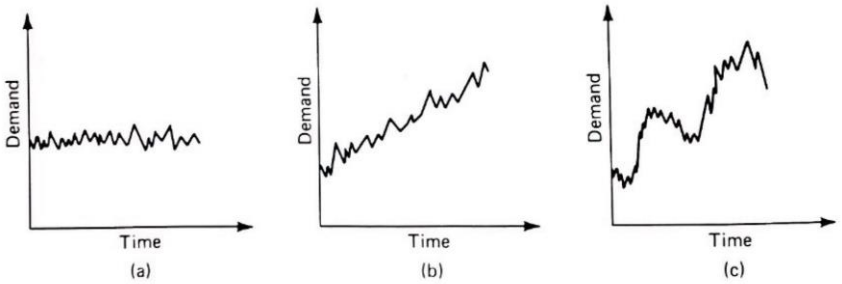


Figure 12. Demand Patterns (Source: Brown R.G, 1977)

2.3.3.2 The importance and challenges of inventory forecasting

Importance

As mentioned before, the inventory forecasting is extremely crucial to any manufacturer, wholesaler or retailer. Most firms cannot stand by for demand to emerge and then response to it. Instead, they must anticipate and prepare for future demand so that they can react actively to customer orders. However, if the inventory forecasting is incorrectly, there can be drastic implications on business and the following are a few of elements (Nick, 2017):

Customer dissatisfaction

The companies usually lose a lot of money due to poor customer service. The main reason to explain customer dissatisfaction is low shipping speed. The poor inventory control, disorganization, lack of resources or stocking too little inventory can lead to delayed delivery. Therefore, inventory forecasting can be used as a tool to stay organized and ensure the resource will fulfill enough during high demand periods and then reduce unhappy customers and a damaged reputation.

Inventory stockouts

Stock out is a reason for loss of sales. Inventory forecasting provide an accurate view of future sales and the amount of product needed. These figures will be reported to answer the question of when and what to reorder to prevent shortage of stocks.

Higher storage fees

Many companies must hire the space in warehouse to store their inventory for a certain period. If the company has conducted an inventory forecasting non-precisely, the additional space of storing would be expanded. This leads to an obligation to pay supplementary fee for storage.

Product obsolescence

Some items in the warehouse will become obsolete after a long time. Using inventory prediction will identify the obsolete items and limit the ordering of those items. Additionally, the outdated items stored in the warehouse for too long will occupy the area of the warehouse.

Challenges

In addition to the benefits and the importance of inventory forecasting, companies also face the challenges in implementing and controlling the prediction systems. Some of difficulties will be named as following:

- Inaccuracy of inventory data: Forecasting can be erroneous due to the fluctuation of customer demand and factor including incorrect inventory data which can affect the process in supply chain.
- High investment: Implementing a solution that can administer all the components of a company supply chain and maintain the flow of data required an essential investment. Especially, deploying the inventory forecasting system as an advanced software and high-quality talent will be costly.
- Lack of expertise: The advanced system needs qualified employees to operate and monitor that represent another obstacle for the company to overcome
- In general, the aim of inventory forecasting is to estimate the amount of stock arriving or leaving the warehouse and accompanying service that the customer will order at some points in the future. Based on the forecasts, the warehouse management can arrange the stock display and volume and limit the incident of warehouse emptiness.

2.4 The revolution of inventory management by using AI

Inventory management has derived before the Revolution of Industry and become an imperative factor to protect company's resource. However, the crude inventory management techniques had been outdated after the Industrial Revolution where mass production was

required. Therefore, the development of techniques in inventory management is necessary to meet the demands of the market. This chapter will indicate the current applications of AI and its impact on inventory management as well as its challenges and opportunities in the future.

2.4.1 The revolution of inventory management

The following is the reform of inventory management in distinct stages (James Lusk, 2017).

Manual counting

Prior to the Industrial Revolution, the calculation of the number of goods sold or leaving the warehouse in a day has been used manual counting method. Shopkeepers and merchants would count the number of units at the end of each day and determine how many items were sold. Moreover, the merchants usually forecast future demand depending on their intuition and working experiences. The process of manually counting the inventory would takes hours or even up to days if the volume of the stock were overloaded. This method is prone to errors and the accuracy is not high.

Punch card

When the proficiency and mass production became the crucial objectives of businesses, the industrial revolution has driven completely a change in inventory management process. In the 1930s, the researchers at Harvard University had introduced the punch card system which were used to track inventory from manufacture to the warehouse and to the point of sale. The small holes in paper allowed punch card to correlate with available brochure items that were readable by computers. Nevertheless, this method was exorbitant and labor intensive to continue widely used and to catch up with climbing business challenges.

The barcode

The first model of barcode was evolved in the 1940s and 1950s including ultraviolet light-sensitive ink and a reader to accumulate label of items and track inventory. From 1980s to 1990s, the development of computer and software has boosted the barcode method more flourish and efficient up to date. At this time, the manually inventory tracking was substituted by scanning equipment, however, loading data into systems was completed traditionally by human.

The Radio Frequency Identification (RFID)

As mentioned above, the RFID uses a microchip to transfer information about the code, function, types, producers and serial number to data collective center. The establishment of RFID technology can help to eliminate the manual data-entering associated with bar-codes and reduce the burden of time and prevalence of errors. This technology also allows to update the databases and constant access to real-time sales data.

Robots and Drones

This is a latest stage for the revolution of inventory management. Currently, many warehouses have applied robots to their operation systems. Theses robots have been used AI to achieve the speed and accuracy in production, sales and transportations. The more modern robot is, the more it can perform various tasks. In the early phase of applying robots in operation of supply chain and especially warehouse industry, there is a limitation to the ability of perceiving all the elements in the environment. The element includes both movable and non-movable items. The warehouse robots are designed with pre-defined navigation and various sensors such as visual, audial, and thermal one which help them to detect and measure temperature in the surrounding area.

With a revolution of Artificial Intelligence (AI), warehouse robots have re-programmed with more sophisticated AI-aid and machine learning system that enable them to analyze the perceived data and make decisions based on their resources.

Moreover, many companies have also been increasing the use of drone in their intelligent automation of supply chain and warehouse operation. One notable case is Amazon, an American giant retailer who has been implementing drones lately and intelligently robotic packaging machines in their distribution centers and warehouses to enhance the productivity and operational accuracy and precision. Alike the warehouse AI-programmable robots, the automatic drones can fly and hover swiftly and flexibly, avoid any obstacles and land precisely on the designated area such as inventory shelf, loading and packaging location. The advantages captured from drones are considerable and magnificent which requires a constant research and development investment in Artificial Intelligence and warehouse automation.

2.4.2 The current impact of AI on inventory management

2.4.2.1 On product sorting

In recent years, the research and development of AI has been actively promoted. There are many huge AI projects that were created to serve human life and industrial activities. According to Felix and Dirk (2019), from 1970s to 1980s, AI had been started in sorting system which were depended on optical sensors and electronics to differentiate gray values. The electronic circuit applies ratio between these values to implement rules-based decision whether to keep or reject the material. At the beginning of 1990s, customized camera technology was integrated with object recognition to classify and assign each pixel with a specific class of material.

During 2000s, Artificial neural network became popular for identifying and sorting errors in data processing. Based on the ability of defining clusters in multidimensional space, the class of this AI was instigated in various industries. For example, in the supply chain, the typical applications are expanded to optimize the inventory sorting as following:

- Autonomous scanning robot (ASR)
- Automated storage and retrieval systems (AS/RS)
- Articulated robotic arms (Assembly line robot)
- Automated guided Vehicles (AGVs)

Autonomous scanning robot (ASR)

Traditionally, inventory circulation is one of the most heavily operations involved with handling and checking inventory in the warehouse. There could be a limitation for human resource concerning the management of the inventory in warehouse where the volume is significantly substantial. Therefore, the use of AI is an effective and automated method in control. One of the most application for inventory monitoring is Autonomous scanning robot (ASR).

Each type of inventory will be assigned Radio Frequency Identification (RFID) tag which include a microchip storing information including barcode, function, magnetic security strip, tracking and identification about specific item (Ken et al, 2010). ASR roams around

Figure 13. Walmart's scanning robots (source: James Vincent, 2017 - The Verge Newspapers)

warehouse to scan the RFID code and the microchip will transmit the information back to the warehouse management system. ASR scanning robot relies on maps and sensors to navigate more flexible routes and scan more accurately. The collected data from robot will show the specific inventory counts at pre-determined times or intervals to better plan for future orders and reduce rack space devoted to overstock. Moreover, when the inventory counts dropping below the limit standard, ASR can issue alerts and automate replenishment workflows. Additionally, some modern scanning robot systems can be constructed to automate re-ordering, reducing backorders and stockouts (Will Allen, 2020). During 2017, when robots are already a popular sight in warehouses, Walmart had been tested ASR (**Figure 15**) in around 50 retail stores in US. These robots are produced by California-based Bossa Nova Robotics. ASR are considered to save worker's time and carry the tasks that are repeatable, predictable and manual (James Vincent, 2017).

Automated Storage and Retrieval System (AS/RS)

Automated storage and retrieval system, often called as AS/RS, can be defined as an inventory management system established by an assortment of computer-based systems that automatically place and retrieve products or materials from predefined storing locations in a warehouse with a high qualification of swiftness and accuracy. These systems have been

implemented in a variety of manufacturing plants and logistics facilities including distribution centers and warehouses. Normally, AS/RS systems are designed with several machines moving in a specified direction through storage aisles in order to check and retrieve loads of products (Ed Romaine, 2020).

The automated storage and retrieval procedure function precisely with an assistance of computerized management, sustaining an inventory of items in a storage facility. Furthermore, an activity of retrieving product is achieved by identifying the specification and volume of an item. The supply chain programmed computer determines the storage area and correct spot of an item needed to be retrieved and then constructs a schedule for retrieval approach. When a command has been initiated, the computerized system navigates an automated storage and retrieval machine to the item's location where it is stored and administering it to deliver the item to a destination (Will Allen, 2020).

The two main types of automated storage and retrieval system (AS/RS) consists of unit-load AS/RS and mini-load AS/RS system.

- Unit-load AS/RS: Within a system, machines handle the large loads on pallets with storage rack structure, using movable-aisle cranes or fixed-aisle cranes.
- Mini load AS/RS: Machines handle lightweight loads using cranes or shuttles.

These AS/RS systems have brought up the numerous advantages for supply chain management and specifically inventory management. Initially, the systems equip inventory managers with significantly increased inventory control and monitoring, including greater flexibility to adapt to rapidly changeable business circumstances. The major benefits of an AS/RS system refer comprehensibly to a reduction of human resource for transporting and loading item, simplification of inventory level, increased accurate monitoring of inventory, and economizing of storage space. The savings of storing capacity are due to a more density of items in AS/RS systems compared to manual retrieving procedure (Ed Romaine, 2019).

On the other hand, companies are possibly cope with several drawbacks of AS/RS system despite the advantages that have been presented above. The first feasible downside refers to the initial establishing cost for the equipment which is considerable and substantial, demanding an outstanding upfront investment and great changes to the warehouse infrastructure and layout. Additionally, implementing automated storage and retrieval solution essentially demand a notable large financial capital and continuous commitment to assemble and maintain the system's performance.

Figure 14. NewIcon robot in medical & pharmaceutical industry (source: Denso Finland)

Robot-Articulated Robotic Arm

An articulated robotic arm is defined as a robot with rotary joints that allow it to perform different pre-computerized movements with a high standard of precision and speed. The robotic arms are used commonly for tasks such as placing-picking item, welding, and packaging in many manufacturing facilities and logistics warehouses. Assigning these articulated robotic arms for tedious work helps to freeing up human employees and increase the resources for further complex duties (Tim Hornyak, 2019).

Currently, several companies have been developing and testing more sophisticated AI-powered robotic arms to increase their intelligence, productivity and accuracy that are still being limited in different aspects of technology. The available articulated robotic arms in various warehouses globally are restricted to manage classification of items of various sizes, forms and material types (James Vincent, 2018).

The major advantages of articulated robotic arms are constant pace of rapidity and consistency. The moveable robotic arms can be customized to fulfill the manufacturing requirement of different companies specifically, and they are feasibly AI-powered to perform

more complex and multiple works. Besides that, the design of the articulated robotic arms is flexible and compact which make them become ideally for use in various types of warehouse regardless of storage space. Furthermore, the robotic arms also contribute to the inventory management process and increase of productivity output.

Automated guided Vehicles (AGVs)

Type of AGVs were published within 1954. AGVs represents the programmable mobile vehicle which is used to transport inventory from one location to another on the facility floor within warehouse without any help from accompanying operator (Hassan & Arman, 2014). AGVs operate relying on tracks or magnetic strips which is placed in scheduled travel paths or connected with sensor camera vision to abstain from impediments.

AGVs include forklifts, unit load and tow (driverless train) which have been used in distribution, fulfillment and manufacturing warehouses. It has responsibility to move the large and heavy products such as pallets, rolls, racks, carts and containers, etc. Nowadays, by adding more AI in AGVs, it brings a various benefit to inventory management (Chris, 2016):

- Reducing labor costs: For AGVs, a company need to only pay the initial investment for the equipment. While they must pay the ongoing costs for human worker such as healthcare coverage, payroll taxes, salary increases or holiday time, etc.
- Tracking activity productively: AGVs using AI can constantly remap the warehouse and create the most efficiency route to transport the inventory. AGV operates with a stable frequency. It can run 24/7 whereas human personnel are limited. Some modern of AGVs can automatically recognize type of inventory which is prioritized to be transport. In addition, AGVs can perform in different conditions that human is not able to work optimally in, such as in extreme high or low temperature or around hazardous materials.
- Increasing safety: It also help to assist in determining the cause of damaged products or infrastructure leading to avoiding labor accident. AGVs are programmed like a machine learning with full of cameras, lasers and other sensors that allow them to identify surrounding objects to avoid collisions in warehouse. Human always has the potential to become exhausted or preoccupied and that is one of the causes of working accidents while there are no concerns when using AGVs.

2.4.2.2 On inventory forecasting

The concept of AI is becoming more popular in supply chain management especially AI has been powerfully used in inventory forecasting. Overstock and stockouts are consequential complications for inventory management. Overstock levels can trigger off loss of revenue because of increased storage, labor, and insurance costs. While out-of-stock items can cause sales and customer satisfaction decrease. Therefore, most of warehouses are focusing more predictive analytics AI techniques in order to improve redundant costs and increase productivity.

In the past, the traditional statistical forecasting models such as Autoregressive Integrated Moving Average (ARIMA), exponential smoothing models create a populated predetermine prototype depending on historical inventory demand. The difficulty is that these prototypes is not applicable efficiently. The major reason is the deviation of different inventories within the seasonal period during a year and these models are getting outdated (Nicolas, 2019). However, machine learning can work functionally. The algorithm of machine will absorb the connections from training dataset based on real-time data using internal and external sources and improve the accuracy of forecast results. According to Kandananond (2012), forecasting with machine learning had more competitive standardized consequences than traditional models.

Artificial Intelligence and especially machine learning administer complex algorithms and mathematics to detect figures automatically, apprehend surrounding signals and capture impenetrable interconnections in mass databases. In addition to absorb and analyze large amounts of information, AI-aid systems continuously readapt formations, configuring them to variable conditions thus confronting volatility. These innovations and potentialities allow Machine Learning-based systems to bring out more precise and dependable forecasts of inventory in complicated scenarios.

With the power of Artificial Intelligence and especially Machine Learning, the inventory forecasting software such as Symphony RetailAI, NetSuite by Oracle or Future Margin enable companies to improve inventory management, forecast accuracy and reduce the tedious manual workload and mistakes. These AI-powered solutions contribute to enhance stock availability by reducing shortage of inventory together with gaining a more desirable and proficient understanding of supply chain process and sales demand.

Carrefour, a famous French multinational retailer has shown their interests towards AI for inventory and demand forecasting recently. According to Franck Noel-Fontana, Forecasting Director at Carrefour France, Carrefour has deployed SAS Viya which is an analytics platform powered by artificial intelligence (AI) technology to capture more accurate insights from data gathered from various channels including the company's global retail stores, ecommerce activities and logistics warehouses. The software has enabled Carrefour to focus better on developing supply chain strategies and strengthen the process of inventory management and demand forecasting to fulfill customers' expectations and reduce operational cost.

Addressing the innovation and trend, Nike Inc and Mars Drinks also take up the strategic change to apply AI technology in their inventory management. These companies have equipped AI technology for the computer to improve the stock level and demand forecasting based on contextual elements such as weather, social community change and holidays.

2.4.3 Challenges and opportunities of AI application in inventory management in warehouse

2.4.3.1 Challenges and opportunities

The wonders of AI are achieving more fields of dynamic industry each day. In order to stay ahead of competitors, various companies had embraced AI into their operations in controlling inventory to process easier for human. As AI is the classic of outstanding transformations in business though, executing change productively can be difficult and time-consuming. It is the reason why managers in inventory controlling needs to be aware not only for the prospect of the opportunities AI in inventory management but also for the challenges that it introduces along the way.

Opportunities

The novel coronavirus has affected almost every country in the world and the modern supply chain face unprecedented stress. When the social distancing policies are applied, most of workers are required work from home. However, some of tasks cannot be performed remotely, especially sorting tasks. If the employees are obliged to come to the workplace, there would be an increasing chance of spreading the virus infection. But on the other hand, if the workers are restraint to accomplish their tasks, the flow of work are delayed and directly affect to economic. It is totally true when the Global Economic Prospects June

2020 illustrates the baseline forecast envisions a 5.2 percent shrinkage in global GDP in 2020. This is the deepest global regression in decades (World bank, 2020).
Therefore, the warehouse managers are likely to reconsider the overview of operation process and it is a good opportunity to be more proactive in AI applications and automate machines.

Challenges

Besides the opportunities, the application of AI in inventory management is also facing various difficulties. Basically, AI performance must be integrated in wider networks. Consequently, inventory management using AI requires the organization to be flexible and innovative to catch the information flow of supply chain. Businesses are confronting with the number of obstacles:

High initial investment and lack of clear roadmap for investment

The total expense for AI project is often quite large. AI technologies require extremely complex software and high-performance hardware which is exorbitant to deploy and sustain. Moreover, the term of AI is wide leading to the lack of clear direction for investing in AI. According to WebFX – Digital marketing company, they stated that project of custom AI solution often cost from 6000€ to 300000€ per solution. Most AI consultants charge from 200€ to 350€ per hour. For the small enterprises, it will be large investments.

Technical problems

Technology is not totally perfect. In case of software or hardware crashes, it is difficult to detect the source of error. Furthermore, tasks implemented by humans can be traced. But with machines and inbuilt algorithms, the liability for error could be hard to assign to specific person. A recent example is self-driving Uber car kills pedestrian in Arizona, San Francisco (Daisuke, 2018). On the other hand, it takes a long time to fix the problems and the cost is generally high.

Inadequate expert knowledge of staff

In most of the companies, there is an insufficiency of AI brainpower and talent. The demand for machine learning skills is raising rapidly but it is hard to obtain the appropriate training. To operate the AI technologies, companies need to employ the specialists who have deep knowledge of modern AI application and its limitations. It will take a long time

and a lot of effort for company to find well-trained experts with the powerful skills and competitive salary package that can initiate AI solutions.

A lack of reputable suppliers

Sourcing a prestigious and competitively-price supplier for establishing AI-based machinery and management application in a warehouse is highly crucial for any warehouse managers and logistics businesses.

Security risk

Many recent researches have defined that AI can find certain bugs in computer systems a lot faster than humans can. Therefore, AI is a powerful instrument to support hackers to scan system software for vulnerabilities and then exploit the data. Hackers could also use AI to create virtual purchase order with huge quantities and then force company to produce and reserve the inventory. However, when the delivery has been completed but the company has not received any payment from hackers. In some cases, the hackers can terminate the order at the last minute before the delivery date.

2.4.3.2 Expectations and predictions

AI is already powerful and continue to grow in the next following years. The main expectations for AI implementation and development in warehouse industry are their capabilities of expediting the tasks of managing the inventory with a high standard of precision, accuracy and swiftness. Another vital belief is that they could reduce inventory sorting or picking errors during operation which would contribute to the accurate demand forecasting and decision making. Additionally, the collaboration of warehouse employees and AI-programmed machines would also be expected to achieve the goals faster and more successfully. In the next following years, the strong growth of AI for different fields in warehouse will boost the transformation of automation warehouse.

The most advanced technological applications in inventory management is drones. Drones or autonomous flying machines are the expectation of warehouse innovation. It is given their ability to fly and hover autonomously, avoid obstacles, navigate indoors without GPS, real-time high-quality video recording and precisely provide data to center. From 2015, Posti carried out experiences to test robotic helicopters in e-commerce and mail deliveries. In next few years, the use of drones in warehouse management generally and particularly inventory management will be more popular in Finland (Posti, 2015).

One of the biggest questions when mentioning to AI is ‘Will AI replace the human in the future?’. In the supply chain and logistics industry, AI are proving to be critical term. Many companies have realized its potential to solve the complexities of running a global logistics network especially in inventory management. The new software and hardware application such as RFID tags, ASR, AS/RS, AGVs or inventory forecasting system are minimizing the demand for manual inventory counts, accounting and order entry positions. These changes have been recognized throughout the supply chain from warehouse to the retail stores.

However, human is smarter than AI. AI may perform particularly task much better than human can, but human is more creative than AI. Currently, AI and automated robot mainly take over repetitive and predictable roles. The tasks that they are involved are commonly pre-programmed based on data collection and analytics and lack of creativity in performance. According to author opinion, AI-configured robots and machines may be agile and persistent, but human workforce is continuously innovating and creating with more sophisticated ideas that end up with a significant improvement outcome.

3. RESEARCH METHODOLOGY

Research is the academic process of a search for knowledge. It can also be known as a scientific and systematic search for relevant information on a certain topic. According to Oxford, research is defined as 'a careful investigation or inquiry specially through search for new facts in any branch of knowledge' (Albert S.H, Edward V.G, H Wakefield; 1952).

In this chapter, author will describe the methodology of thesis research consisting of inclusive data collection.

3.1 Research methodology

The qualitative and quantitative research are the method for researching. The quantitative method is depended on the mensuration of quantity or amount. It emphasizes on the statistical, mathematical or numerical of data collected. The quantitative method is designated as polls, questionnaires and surveys. While the qualitative research is concerned with the qualitative phenomenon through open-ended and conversational communication. The result of qualitative methods is obtained by interviews (one-one-one or focus group) (Kothari C.R, 2004).

The table below presents the key differences between qualitative and quantitative methods based on Minchiello et al, 1990.

Table 1. The differences between Qualitative and Quantitative methods (Own-making table depended on Minchiello et al, 1990)

Key perceptions	Qualitative research	Quantitative research
Purposes	Understanding human behaviors from the informant's perspective	Perceiving facts about social phenomena
Data collection	One-on-one interview Focus groups	Surveys Polls Questionnaires
Scale of data	Small	Large
Output of data	A description of opinions	Statistical analyses

In this thesis, the author implemented quantitative methods during the research stage. The thesis aims to research how AI impact and revolutionize the inventory management in company X. The quantitative method allows the author to collect data from large cluster of respondents including the employees in company X and the others who had been experienced in warehouse of case company. Instead of collecting depth opinions, the thesis targets to accumulate real statistics and figures expressing the level of awareness among the respondents towards revolutionizing inventory management by approaching AI. In this circumstance, quantitative method is appropriate in this research.

3.2 Data collection

Data collection is the procedure of congregating and evaluating relevant answers which were responded by target participants (Pritha, 2020). The collected data will affect directly to the research analysis. Data collection consists of primary data and secondary data. The execution of assembling these data used for the theorical and empirical research will be proposed.

3.2.1 Primary data

Primary data for this thesis was obtained through a survey via a digital tool named Google Survey. The survey is designed depending on the four main research questions above (***Section 1.2***). Its contents were divided into five principal segments. The first part is composed to classify the position of targeted respondents who are working in company X. The second part is conducted to present respondents' knowledge of AI and its applications in company's performance. The third part is preferred to the level impact of AI on inventory management in warehouse's company X. The fourth part is presented the challenges and opportunities of AI that company X is facing. The last part is stated for the expectation and prediction of employees for AI development in inventory management of case company.

The survey is sent out to employees' e-mails via invitation letters. The purpose of sending survey through invitation mails is to avoid being spam mails. The survey is valid within two weeks starting from the delivery date. The survey and the invitation letter will be attached in **Appendix 1** and **Appendix 2**.

3.2.2 Secondary data

For the secondary data, the author has gained a thorough understanding and consolidation of fundamental knowledge from creditable sources and English references. They are divided into two categories. The first type are the academic books and educational paper articles. The second one is internet publications including e-books, online articles, online journals, reports and online courses.

4. EMPIRICAL ANALYSIS

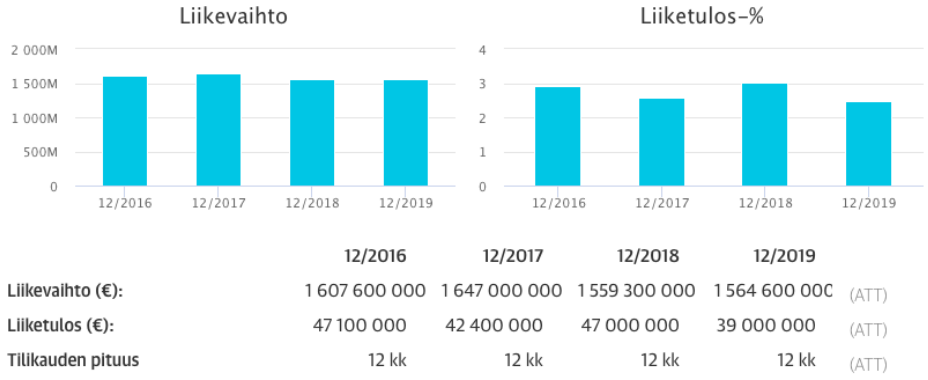
In this chapter, the empirical research of the thesis will be carried out based on the data of the survey collecting from the warehouse's workers in company X. The analysis contains of virtual survey, company's materials such as released financial statement and statistical figures on company website. The data collected from survey are measured by the Microsoft Excel application.

The empirical analysis begins with the overview of company. Then the author continues with personal information of respondents. The following part is the analysis of the study which depicts the four key research questions. The analysis is conducted based on the selected major research questions in a correlation with the literature chapter above. In the final section of this chapter, the author concludes the perspectives and opinions of participants in order to expose the review of the revolution inventory management by using AI from current situation to the upcoming years in warehouse of company X.

4.1 Company X overview

With nearly 400 years old history in Finland, X Oyj is known as the Finnish state-owned pioneering postal and logistics service group. X Oyj offer the supply chain solutions, such as warehousing and in-house logistics services within eight countries in EU but its operation mainly focus on Finland. They employ roughly 21,000 workers. Compared with 2018, the net sales (Liikevaihto) of 2019 was slightly increased but the operational profit (Liiketulos) of 2019 was intensely reduced (Kauppalehti, 2020).

In recent years, the company has developed the digitalization and intelligence technology to innovate their customer-oriented services. The X company has created and tested step-by-step different kind of AI solutions especially machine learning and its algorithms for



	12/2016	12/2017	12/2018	12/2019	
Liikevaihto (€):	1 607 600 000	1 647 000 000	1 559 300 000	1 564 600 000	(ATT)
Liiketulos (€):	47 100 000	42 400 000	47 000 000	39 000 000	(ATT)
Tilikauden pituus	12 kk	12 kk	12 kk	12 kk	(ATT)

Figure 15. X Oyj's financial data (source: Kauppalehti, 2020)

reducing and transferring repetitive manual tasks to machines in their warehouse operations. Moreover, X Oyj has boosted the robotic automation in the warehouse to proceed the works more efficiently. To combine AI technology with the company operation, X Oyj has linked with Aalto Executive Education to provide an online AI course for all X's employees.

4.2 Respondents background information

The personal data of participants consist of names, ages, genders, and email contact were excluded from the survey. Because the core topic of survey focuses on the aspect of warehouse logistic, it was mainly sent to the employees working as manager, supervisor or ordinary workers (including both full-time and part-time) in warehouse of company X and the person who used to work in warehouse of company X. After two weeks of delivering the survey, there were 63 responses.

The first question of the survey (**Appendix 1**) was designed to divide the classification of the participants into two categories: the person who are working in warehouse of X company and the person who had worked in the case company. **Figure 18** below presents two classifications of respondents in which 92.1% are working in the warehouse and 7.9% used to work in warehouse of company X.

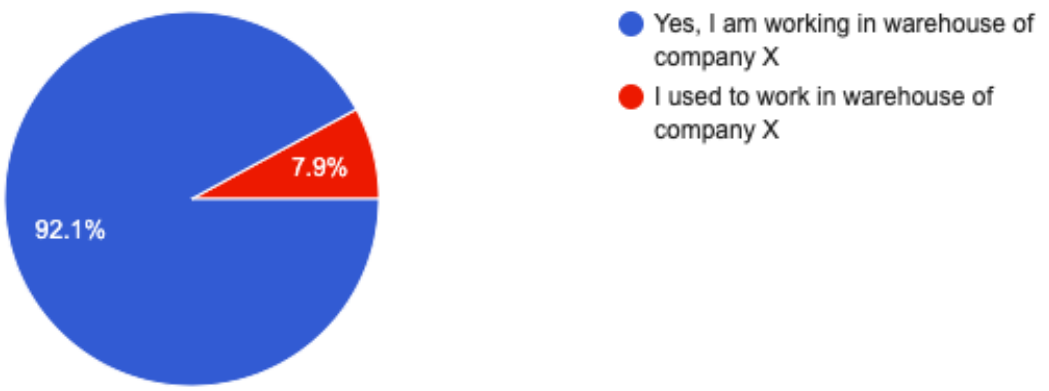


Figure 16. Classification of the participants (Answer for question 1)

Within total 63 answers, there were 50 which occupied 79.4% (**Figure 19**), while the superior level accounted for 20.7% (13 people containing of manager and supervisor). According to the question fourth (**Appendix 1**) about the respondent's experience, astonishingly more than half of participants (48 people) have been committed to warehouse of company X for more than 3 years.

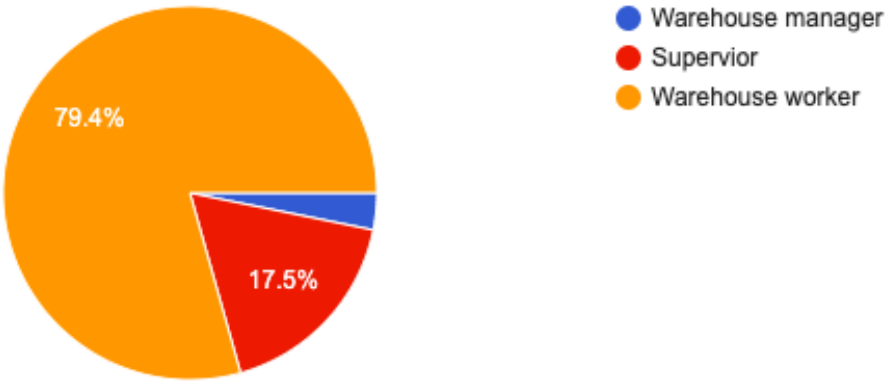


Figure 17. Positions of participants in company X (Answer for question 2)

The third question illustrated the departments in the warehouse which the respondents belong to. According to the result, 26 people (41.3%) were coming from Order picking & Packaging team. While the remaining 22 people were from Inventory management and 13 people were from Shipping team. On the other hand, only 2 (3.2%) people are working in other departments.

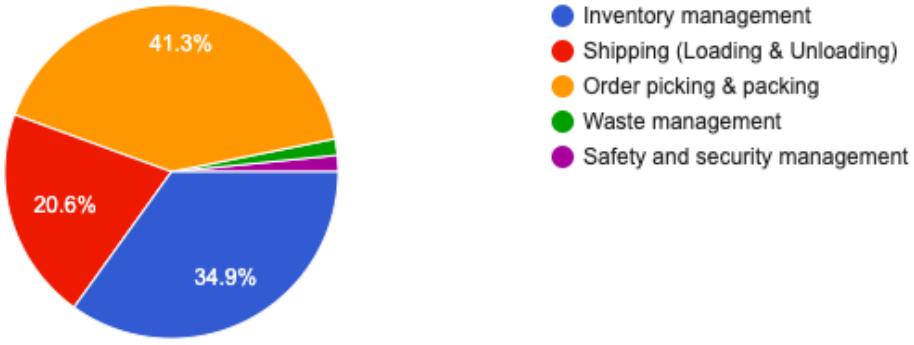


Figure 18. Divisions of tasks in warehouse (Answer for question 3)

4.3 Analysis of the study

This segment will analyze particularly the main points of the thesis to fulfil the four key research questions.

4.3.1 The current application of AI in the warehouse of company X

According to the result of question four about the frequency of AI occurrence in the warehouse of company X (Table 2), 32 people gave the evaluation at level 3 which was the medium scale. While there were 30 people evaluating at level 4 and 5. Only one person rated it as the low score (level 2).

Table 2. The frequency of AI occurrence in X's warehouse (Answer for question 4)

	Scale from 1 to 5 (1 is the lowest score, 5 is the highest score)				
	1	2	3	4	5
The number of respondents	0	1	32	27	3
The number of respondents by percentages (%)	0%	1,6%	50,8%	42,9%	4,8%

From the above statistic, the majority of respondents had perceived the occurrence of AI usage in X's warehouse which were relatively high.

Question five and six of the survey (**Appendix 1**) mentioned the current types of AI and the common AI's applications in the warehouse case company. According to the result of the survey, the automation field and machine learning are the most popular type of AI in the warehouse operation, respectively 62 and 50 people chosen occupying 98.4% and 79.4%. The remaining fields of AI including expert system and fuzzy logic account for exclusively 1.6% (**Table 3**).

Although numerous aspects of AI are presenting in the X's warehouse operation, there is a lack of knowledge about AI among the warehouse workers of company X leading to the lack of accuracy about the observations.

Table 3. Current types of AI & common AI's applications in warehouse case company (Answer for question 5 & 6)

Types of AI	Total	Respondents	Respondents (%)
Automation/Robotic	63	62/63	98.4%
Machine learning		50/63	79.4%
Expert systems		1/63	1.6%
Fuzzy logic		0/63	0%
AI's applications			
ASR	63	7/63	11.1%
AS/RS		28/63	44.4%
AGVs		42/63	66.7%
Assembly line robot		37/63	56.7%
Predictive demand & forecasting systems		26/63	41.3%

For the common AI's applications in warehouse company X (**Table 3**), Automated guided vehicle (AGVs) was selected by 42 people in total 63 warehouse employees which comprised of 66.7%. Being a second position with 37 people choosing is Articulated robotic arms (Assembly line robot) accounting for 56.7%. Besides that, there were 28 people (44.4%) voting for Automated storage and retrieval systems (AS/RS) while the Predictive

analytic demand forecasting systems was plumped by 26 workers (41.3%). The number fell to 11.1% of warehouse workers who chose the Autonomous Scanning Robot (ASR).

Through the data above (**Table 3**), the current applications of AI in X's warehouse are mainly related to automation and warehouse management system. In the result of the survey, there were only 22 workers from inventory management field in X's warehouse who are aware of the existent of the Predictive analytic for demand forecasting systems. Meanwhile the other participants might only perceive the automation field. Therefore, it could be rarely some of them are conscious of the Predictive analytic for demand forecasting systems occurrence in the workplace.

4.3.2 The Level impact of AI on inventory management in the warehouse of case company

Continuing to the seventh question related to the fields in the warehouse operation, in total 63 participants, 44 people (occupying 69.9%) admitted that Inventory management field is mostly impacted by AI compared to other segments including Shipping, Order picking & Packing, Waste management, and Safety & Security management.

Table 3. The level impact of AI on inventory management (Answer for question 8)

	Scale from 1 to 5 (1 is the lowest score, 5 is the highest score)				
	1	2	3	4	5
The number of answers	0	0	19	**25**	**19**
The number of answers by percentages (%)	0%	0%	30.2%	**39.7%**	**30.2%**

Resulting from 44 answers concerning the above issue, the level of impact on inventory management due to the development of AI in X's warehouse is evaluated from scale 4 to 5 by all of them. The remaining 19 respondents rated the matter at the medium level (**Table 4**).

Following the question nine of the survey, the respondents were asked to rate the level impact of AI on each segment containing of Human Resource, Finance and Efficient production in inventory management in the warehouse of company X.

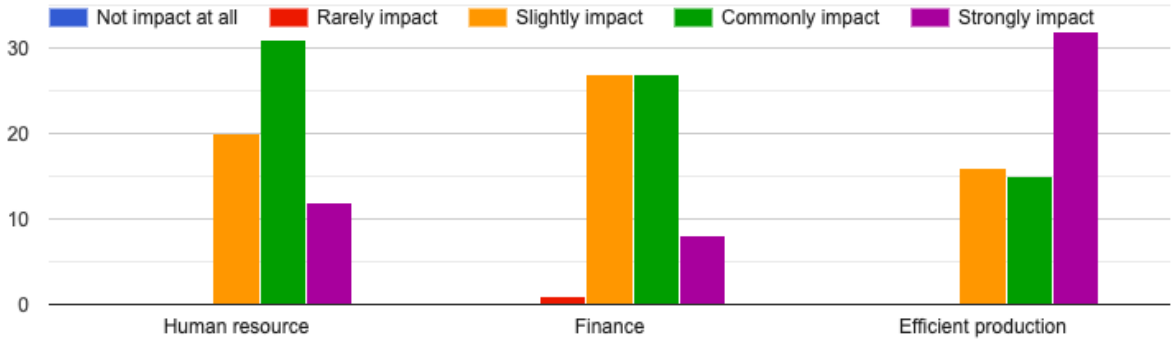


Figure 19. The impact of AI on each segment in inventory management in warehouse case company (Answer for question 9)

In **figure 21**, for the 'Human resource' segment, 31 people agreed that AI has 'commonly impacted' on this segment, while only 12 people evaluated as 'strongly impact'. For the 'Finance' aspect, 27 participants believed that AI has 'slightly impacted' and 27 respondents stated that AI has 'commonly impacted'. In contrast, 8 respondents rated the impact of AI on 'Finance' segment in the inventory management field as 'strongly impact'**. Figure 21** also illustrated the largest number of people (occupies 32 respondents) who chose the 'strongly impact' for 'Efficient production' aspect.

According to the statistic of **figure 21**, the impact of AI on three core segments in inventory management was high (from medium to high level). Therefore, the innovation of AI has influenced inventory management significantly.

In the theory part, the author divided the inventory management into two components which are 'Inventory sorting' and 'Inventory forecasting'. The question eleventh was designed to compare which component was affected most by AI. As can be seen from the result of question ten (**Figure 22**), there were 66.7% of the respondents (equals to 42 people) selecting the 'Inventory sorting' and 33.3% of the respondents picked the 'Inventory forecasting' (accounts for 21 people).

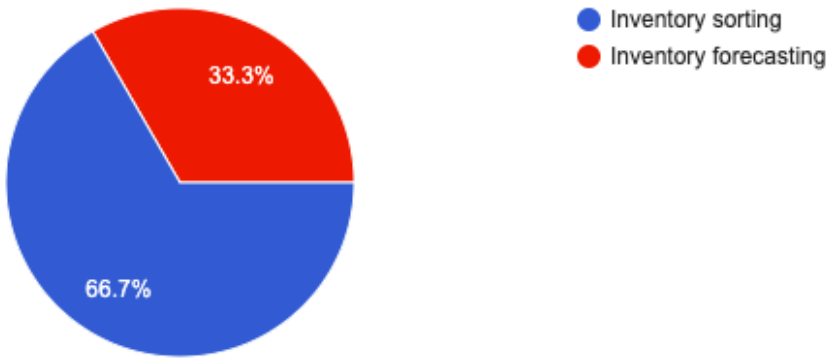


Figure 20. Components of Inventory management (Answer for question 10)

Following the components of inventory management in the previous question, the next question was built to evaluate more deeply the kind of AI used most in 'inventory sorting' and 'inventory forecasting'.

Table 4. Types of AI used mostly in 2 components of inventory management (Answer for question 11)

	Types of Artificial Intelligence			
	Machine learning	Automation/Robotic	Expert systems	Fuzzy logic
Inventory sorting (The number of respondents)	2	61	0	0
Inventory forecasting (The number of respondents)	60	0	3	0

Table 5 represents the number of participants choosing the types of AI for each array of inventory management in the warehouse of the case company. 61 respondents thought that 'Inventory sorting' applied most the 'automation' in the procedure while only 2 respondents favored 'machine learning' applications. On the other hand, 60 participants assumed that 'machine learning' related mostly to the 'Inventory forecasting' processes. The remaining 3 answers referred to the influences of 'expert systems' to 'Inventory forecasting'.

In general, all the figures above presented the high-level impact of AI on inventory management field. Moreover, there were two major categories of AI applied crucially on inventory management consisting of 'Automation' and 'Machine learning'.

4.3.3 The challenges and opportunities of AI in the company's warehouse

The three following questions of the survey were created to explain the difficulties and opportunities of artificial intelligence in the warehouse of case company.

For question twelve of the survey, the author focused on the limitations of AI when being implemented in warehouse of company X. Four answers were given by the author which were 'Technical problem', 'Inadequate expert knowledge', 'A lack of reputable suppliers' and 'High initial investment' (**Table 6**).

Table 5. Limitations of AI in warehouse company X (Answer for question 12)

	Limitations of AI			
	Technical problem	Inadequate expert knowledge of staff	A lack of reputable suppliers	High initial investment
The number of respondents	43	32	10	53
The number of respondents by percentage	68.3%	50.8%	15.9%	84.1%

As can be seen in **table 6**, 84.1% of respondents which is equivalent to 53 people, selecting the 'High initial investment' factor. 'Technical problem' and 'Inadequate expert knowledge of staff' factors were chosen by 43 and 32 respondents respectively 68.3% and 50.8%. Only 15.9% of participants (accounts for 10 people) picked 'a lack of reputable suppliers' factor.

It is totally match with the theory that the author mentioned above in ***section 2.4.3.1***. 'High initial investment' is always an important factor that needs to be considered when building the AI systems in the warehouse. The cost can reach thousands of euros for a solution. In

addition, the ‘Technical problems’ were happened regularly in the warehouse of company X leading to the high maintenance fee during the operation of the AI.

Besides these challenges above, AI also has created a huge of opportunities in warehouse innovation. One of the big questions was given by author in the survey during the Covid-19 pandemic is ‘Does Covid-19 pandemic become a good opportunity to strongly develop AI application in warehouse of company X?’. In total 63 respondents, 61 participants agreed with answer ‘Yes’ accounting for 96.8% while only 2 respondents disagreed with this issue (**Figure 23**).

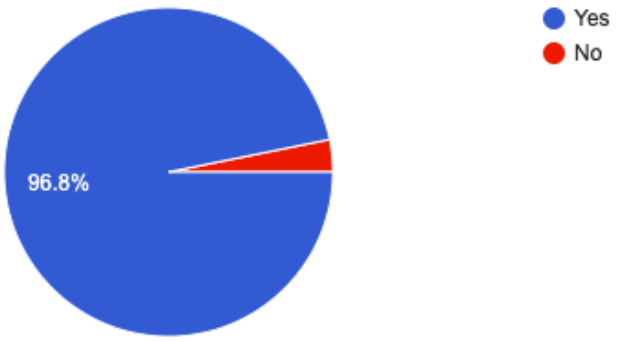


Figure 21. Opportunity to develop AI app during Covid-19 (Answer for question 14)

On the other the hand, surprisingly, 100% of respondents chose ‘Yes’ answer (**Figure 24**) with the question of the survey ‘Do you think the Inventory management operational performance will be improved by the implementation of Artificial Intelligence?

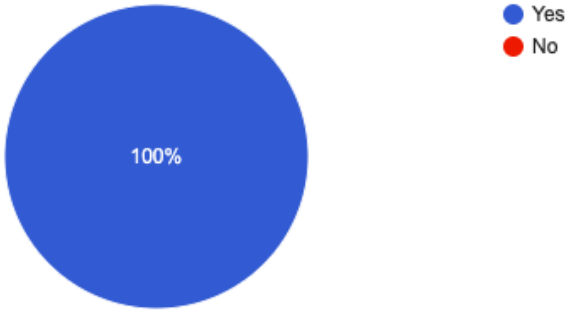


Figure 22. The improvement of inventory management performance by the implementation of AI (Answer for question 13)

4.3.4 The expectations and predictions of AI for company X in upcoming years

The three last questions of the survey were designated to present the expectations and predictions for AI in inventory management in the next following years. For the fifteenth question, the author referred to the cognition and intuition of the employees toward the performance between AI-programmed and human in the warehouse of company X. In the result, 62 respondents equivalent to 98.4% strongly believed that AI will be able to implement tasks much better than human can (**Figure 25**).

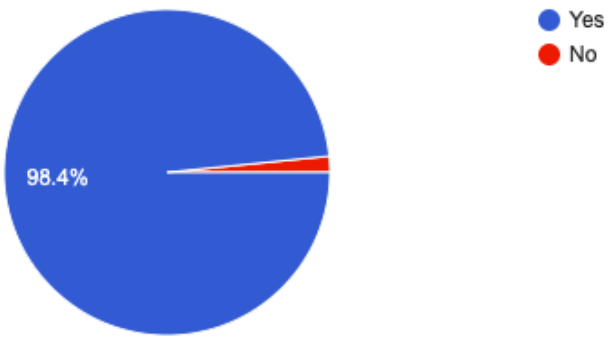


Figure 23. Comparison between AI and human performance (Answer for question 15)

However, in the result of question seventeenth, 90.5% respondents occupying 57 people stated that AI-empowered systems are unable to replace the human workforce. These 57 employees of the warehouse believed that AI will be installed alongside current human (**Figure 26**).

It is hard to confirm that AI will replace the human workforce within the duration of the

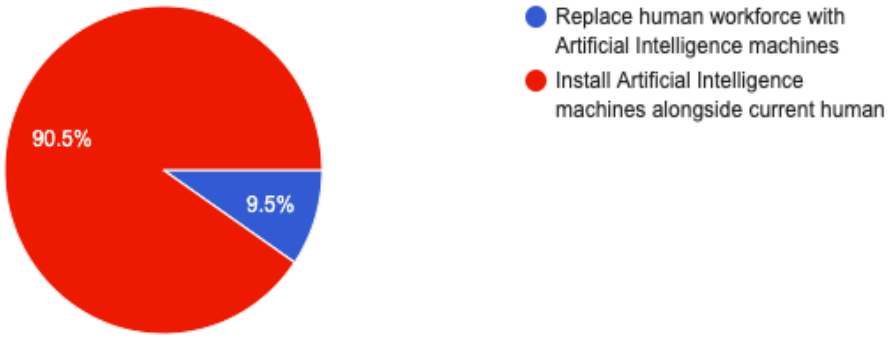


Figure 24. Scenario of AI in upcoming years in warehouse operation of case company (Answer for question 17)

increasing unemployment. With 62 participants agreed 'Yes' from **figure 25,** they expect that AI will perform the repetitive tasks with high standards of accuracy and rapidity in order to limit the errors in inventory sorting and inventory demand forecasting.

In the era of AI, the adoption of AI with drones (the self-driving fly machines) is increasing in popularity. In this segment, the question related to drones in the survey was mentioned by the author. If the drones are applied commonly in warehouse of company X, will it deliver high efficiency? 58 warehouse workers endorsed that drones will be efficient applications if it will be used the warehouse. In contrast, 5 workers opposed the productivity of drone applications (**Figure 27**).

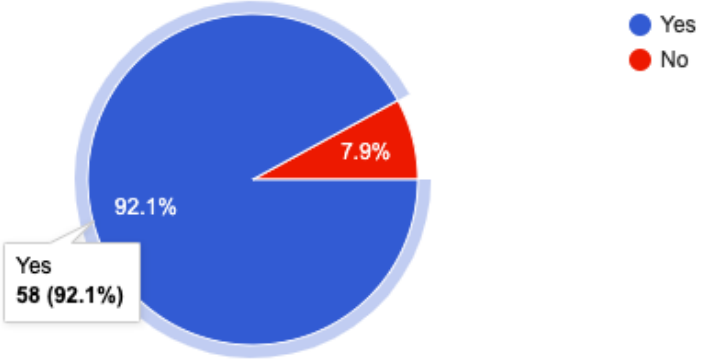


Figure 25. The efficiency of Drones (Answer for question 16)

5. CONCLUSION

In the conclusion, the summary of the research and the answer for the four main research questions will be expressed. The learning outcomes is an important part of the bachelor's thesis in which the author can set the further stage for various new researches. The topic of this thesis concentrates on the revolution of inventory management by applying AI. To consolidate the thesis theories section, the quantitative method was choosing as digital survey that carried out to collect the primary data from the warehouse workers in the case company.

The author set the target respondents around 30 to 40 responses. Practically, the author had received 63 accomplished participants within two weeks from the delivery date. The survey was sent as invitation letter to avoid the spam emails and it was forwarded to others. After collecting the data, the Excel and Google Form were used to analyze the data.

Based on the research questions and the secondary data, company X was considered to be the best choice for this thesis. Being one of the oldest logistic company in Finland, warehouse operation of company X has gone through different milestones for innovation in inventory management which is extremely important to catch up with the modern situation and maintain the competitive advantages. The operation and environment have been transformed from the primitive process to the era of digitalization and automation. Recently, it continues intensively to the era Artificial Intelligence. It can be seen obviously that the appearance and the impact of AI-based machines and software have been implemented in distinct departments of warehouse specially in inventory management.

Based on the result from the bachelor's research, the author can straightforwardly collect the answer from the employees of warehouse to evaluate the revolution of inventory management by using AI in company X. The first question of the research is 'What is the current AI's application in inventory management in the warehouse of case company?'. Currently, the recent applications which are served for inventory and warehouse management in company X are mainly emphasized on automation, robotic and machine learning. It includes Automated guided vehicles (AVGs), Automated storage and retrieval system (AS/RS), Articulated robotic arms and predictive analytics for demand forecasting. In addition, the frequency of AI incident in the warehouse of company X was evaluated at an average level.

Regarding to the second question of the research, ‘How is AI impacting inventory management in warehouse’s company?’, the answers of 63 workers proved that AI has been strongly affecting on inventory management than the other fields in the warehouse operation. More than half of respondents recognized that AI has been intensively impacting on efficient production segment in controlling inventory, expressly in sorting inventory. According to the 63 warehouse workers in company X, automation field of AI has been vigorously exerting influence on inventory sorting, while machine learning field has been proficiently developed on inventory forecasting.

Following the third question in the research, ‘What are the challenges and opportunities of AI in inventory management in company X?’, the author proposed the different limitations when implement AI in inventory management. Most of workers assumed that ‘High initial investment’ and ‘Technical problem’ are two crucial factors which can restrict the growth of AI in managing inventory. On the other hand, the opportunities for AI are high increasing when the inventory management operational performance will be improved by the applying of AI. In the past, the operation had been belonged to labor workforce and manual task in sorting and classifying the items. Since these AI applications have been applied in inventory management, the process has been transformed with high efficiency. Moreover, the errors have been significantly reduced which contribute to expedite the overall operation process of company X. The demand inventory forecasting has been also capable of showing real-time tracking in order to help warehouse manager to make suitable and accurate decisions. Specially, during the Covid-19 pandemic, this is a good opportunity to strongly evolve more AI applications in the warehouse of company X when the social distant policy is still applying.

Finally, the final question of the research is to present the expectations and the predictions for AI in the inventory industry in case company. AI is a relatively broad field which is needed to be further developed in the future. Most of workers expected that AI will be able to perform the particular task much better then human, but it cannot be replaced the human workforce. Over the next few years, the company X continues to innovate their warehouse by combining the human with AI instead of fully transforming the process automatically. In addition, the author proposed some notable and feasible applications consisting of Drones, which are likely to be implemented in controlling inventory. In 2015, company X

had tested the ability of Drones in parcel delivery and experienced its potential. If the company X maintains the development of Drones and decided to apply in warehouse logistic especially in inventory management field, it would be a break-through in monitoring the volume of inventory.

6. VALIDITY AND RELIABILITY

'Validity' and 'Reliability' are frequently implemented in quantitative research to accurately measure the standard of the research. Validity mentions the precision of measure in the duration of effectiveness. The validity must be authentic and official information which are from the books, articles and trustworthy organizations. While reliability focuses on the consistency of measure. (Roberta & Alison, 2015). It is important for the author to maintain a decent standard of validity and reliability of the data collection instruments when conducting a quantitative research. The proof of validity and reliability are essential to guarantee the integrity and quality of a quantitative research. (Kimberlin & Winterstein. 2008)

The measurement procedure consists of survey items or interview questions in qualitative research. The measure should come up with a precise and accurate representation of the theory it is measuring and provide the author with a value of validity. In quantitative research, there are different elements or variables which make up the research. In term of reliability, these variables need to be constant and be able to present similar outcome for different segments of respondents. Meanwhile, the validity aspect focuses on whether the research instrument covers all relevant perspectives of the variables. (Roberta & Alison, 2015)

Even though, it is challenging to expose an exactly accurate calculation of reliability and validity, the author is still required to consider an estimate of them during gathering the data.

Referring to the reliability of the research, the author anticipates the extent of the sample of the quantitative survey is 100 respondents which would present a proper standard of authenticity and low level of margin of error to the audience. Practically, there were X responses collected within the specified survey time that were not corresponding to the suggested amount and increased the margin of error. Although the amount of answers was not relatively high, the general rate of reliability is optimistic and confident because the author successfully accumulated some responses from supervisors and managers.

Referring to the validity of the research, the author ensures the academic level of resources of theory used in the bachelor's thesis which would also be published to both the university's library and thesis database of Finnish universities of applied sciences. Besides that,

the author applies a wide range of references and an appropriate research method to conduct a thorough data analysis and produce a genuine result to the audience.

Additionally, the case company chosen for the study is one of the leading players in warehouse logistics in Finland which was believed to be ideal for reflection of the research. The survey's content was rigorously constructed from the relevant theories in the research which was assessed and advised by the thesis's supervisor. With the help of the supervisor and personal networks from the case company, the author assured a proper standard of accuracy and validity of the information.

7. LIMITATIONS AND RECOMMENDATIONS

In this chapter, the author will present specifically the indisputable limitations during the thesis process. Additionally, the author also proposes the genuine recommendations based on the research result.

7.1 Limitations

The academic knowledge of Artificial Intelligence of the author was restricted to major aspects of international business rather than technology perspective since the author has had a background of business administration. Thus, the author was limited to illustrate some compound keystones of feature and operation process of Artificial Intelligence-based application which have been implemented in a warehouse.

Another restriction while working on the thesis was several responses gathered for the quantitative survey which has been limited due to a small cluster of participants and ongoing holiday season in July and August. The result of a survey was incapable of presenting the most precise and validated statistics to the audience that would cause a confusion of information and cognition. Moreover, although AI has been using in warehouse of company X for long-term, the extend of AI knowledge among warehouse workers is still limited. Therefore, the accuracy of the result from the survey is slightly low.

Last but not least, the author faced a difficulty to access to some valuable sources of fundamental knowledge and latest virtual articles as well as research works which were necessary for composing a theory section due to a high price of purchase and covid-19 pandemic situation in Vaasa, Finland. The university's library and public ones were closed and rarely open during this Summer holiday.

7.2 Recommendations

The author decided to apply quantitative research as a key method to collect data and responses from several respondents in order to answer those major research questions mentioned in the above section. The researcher designed a survey's content with different categories of questions related to revolution of inventory management using a magnificent power of Artificial Intelligence in warehouse of company X in Finland.

Since company X is a biggest and leading player in warehouse logistics in Finland, the author faced an indisputable obstacle to provide some practically helpful recommendations. However, the author dedicated her time and efforts to research and carry out an in-depth analysis of study to express her opinions and perceptions.

From the research's result, most of the respondents believed that using drones-based AI in a warehouse for managing inventory would be feasible and highly potential which has been evidenced by the fact that Amazon and Walmart have already been applying drones in their warehouse operation lately. Thus, the author would voice that idea and express it in the thesis.

Additionally, it can be observed from the survey's results that even though employees are aware of Artificial Intelligence applications and impacts on inventory management and other warehouse processes generally, but they lack the necessary fundamental knowledge and skills to operate and monitor the machines and software. Therefore, that leads to another recommendation for the warehouse manager to organize some on-the-job learning courses internally for warehouse employees to enhance the staff's competence and facilitate the upcoming development of further Artificial Intelligence projects in the warehouse.

8. ACKNOWLEDGEMENT

In this chapter, I would like to show my sincere thankfulness for the partners who collaborated with me during the thesis process.

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Secondary, I would like to thank my friends and their colleagues in warehouse of company X who have agreed to engage in my thesis survey. Especially, Mr.Jari Auvinen and Mrs. Phuong Huynh who are the supervisors of X's warehouse in Vantaa and Tuusula have given me the valuable recommendations for composing the survey.

Third, I would like to show my gratefulness to my family and my friends who are always by my side to encourage me physically and mentally. Finally, I have checked thoroughly various times my grammar, vocabulary and information. However, there will be handful of inaccuracy that were not expected.

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APPENDICES

APPENDIX 1 – QUANTITATIVE METHOD (SURVEY)

Topic: The revolutionizing inventory management in warehouse in Finland
Case company X (in warehouse industry)

PERSONAL INFORMATION

1. Are you working in warehouse of company X?
   - ☐ Yes, I am working in warehouse of company X
   - ☐ I used to work in warehouse of company X

2. What is your main position in warehouse of company X?
   - ☐ Warehouse manager
   - ☐ Warehouse supervisor
   - ☐ Warehouse worker
   - ☐ Others

3. What field are you working in warehouse of company X?
   - ☐ Inventory management
   - ☐ Shipping (Loading & Unloading)
   - ☐ Order picking & packing
   - ☐ Waste management
   - ☐ Safety and security management
   - ☐ Others

CURRENT APPLICATION OF AI IN THE WAREHOUSE OF COMPANY X

4. How do you evaluate the frequency of AI occurrence in the warehouse of company X?

	1	2	3	4	5	
Low	☐	☐	☐	☐	☐	High

5. What types of current Artificial Intelligence in the warehouse of company X?
   - ☐ Automation/Robotic
   - ☐ Machine learning (Neural network, Deep learning)
   - ☐ Expert system
   - ☐ Fuzzy logic
   - ☐ Others

6. What are the common & current application of Artificial Intelligence in the warehouse of company?
   - ☐ Autonomous scanning robot (ASR)
   - ☐ Automated storage and retrieval systems (AS/RS)
   - ☐ Automated guided vehicle (AGVs)
   - ☐ Articulated robotic arms (Assembly line robot)
   - ☐ Predictive Analytics for Demand Forecasting systems
   - ☐ Others

LEVEL IMPACT OF AI ON INVENTORY MANAGEMENT IN THE WAREHOUSE

7. Which FIELD IN the WAREHOUSE of company do you think will be mostly impacted by Artificial Intelligence?

- ☐ Inventory management
- ☐ Shipping (Loading and Unloading)
- ☐ Order picking & Packing
- ☐ Waste management
- ☐ Safety and security management
- ☐ Others

8. Are you aware that there will be an impact on inventory management due to the development of Artificial Intelligence in the warehouse?

	1	2	3	4	5	
Not aware	☐	☐	☐	☐	☐	Strongly aware

9. Please rate the level impact of AI on the following segments in Inventory Management in the warehouse.

	Not impact at all	Rarely impact	Slightly impact	Commonly impact	Strongly impact
HR	☐	☐	☐	☐	☐
Finance	☐	☐	☐	☐	☐
Production	☐	☐	☐	☐	☐

10. Which aspect of INVENTORY MANAGEMENT below is using Artificial the most in company X?
    - ☐ Inventory sorting
    - ☐ Inventory forecasting

11. In your opinion, what type of AI used in the warehouse of company X has the most impact on:

	Automation	Machine learning	Expert system	Fuzzy logic
Product sorting	☐	☐	☐	☐
Inventory forecasting	☐	☐	☐	☐

CHALLENGES & OPPORTUNITIES OF AI IN COMPANY X

12. Which of the following is a limitation to Artificial Intelligence being implemented in warehouse (Inventory management)?
    - ☐ Technical problem
    - ☐ Inadequate expert knowledge of staff
    - ☐ A lack of reputable suppliers
    - ☐ High initial investment
    - ☐ Others

13. Do you think the Inventory management operational performance will be improved by the implementation of Artificial Intelligence?
    - ☐ Yes
    - ☐ No

14. During the COVID-19 pandemic and the following years, is it a good opportunity to strongly develop AI application in warehouse of company X?
    - ☐ Yes
    - ☐ No

EXPECTATIONS & PREDICTIONS

15. Do you think Artificial Intelligence will be able to perform a particular task much better than a human can?
    - ☐ Yes
    - ☐ No

16. Do you think DRONES (self-driving fly machines) will be efficient applications if applied in the warehouse of company X?
    - ☐ Yes
    - ☐ No

17. In the following years, which scenario will occur if AI is increasingly applied in warehouse operation of company?
    - ☐ Replace human workforce with Artificial Intelligence machines
    - ☐ Install Artificial Intelligence machines alongside current human

APPENDIX 2 – THE INVITATION LETTER

Dear the employees and ex-employees of warehouse department in Company X,

My name is Hieu Dinh, the fourth-year student at Vaasa University of Applied Sciences. I am doing a survey analyzing and acknowledging the impacts of Artificial Intelligence (AI) on inventory management in warehouse of company X. The survey is a part of the author's bachelor thesis project which mainly focuses on supply chain management aspect and its digital transformation. The survey is targeted to the respondent whoever either has worked in company X's warehouse and possessed relevant knowledge.

I would be glad and appreciated that you could complete the brief questionnaire that includes 17 multiple questions classified in 4 different sections. This survey should only take about 3-5 minutes for you to complete and be assured that all your answers will be stored confidentially. If there is a faculty member in your team who also has been involved in this field, please forward this survey to him or her so that I am able to gather more valuable results.

Thank you for your participation.

The link of the survey is attached in the file.

Sincerely,

Hieu Dinh