YASAR UNIVERSITY
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MASTER THESIS

DEVELOPMENT OF WAREHOUSING SYSTEMS:A ROADMAP TO WAREHOUSE 4.0

DUYGU OLCAY

THESIS ADVISOR: ASSIST. PROF.DR. ÖMER ÖZTÜRKOĞLU

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MASTER THESIS JURY APPROVAL FORM

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the Master degree.

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Thesis Supervisor, Assist. Prof.Dr.Ömer Öztürkoğlu

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the Master degree.

21.05.2018

Assist. Prof.Dr.Ebru Saygılı

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the Master degree.

21.05.2018

Prof.Dr.Ömür Yaşar Saatçıoğlu

Assoc.Prof.Dr. Çağrı BULUT

DIRECTOR OF THE GRADUATE SCHOOL OF SOCIAL SCIENCES

ABSTRACT

DEVELOPMENT OF WAREHOUSING SYSTEMS: A ROADMAP TO WAREHOUSE 4.0

Duygu OLCAY

Msc, Business Administration

Advisor: Asst. Prof. Dr. Ömer ÖZTÜRKOĞLU

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Master of Business Administration in this study, the main purpose is to categorize and classify warehouse material handling, storage methods and information technologies (IT) capabilities of the sector in İzmir district of Turkey based on evolutionary phases of industry. With regard to this aim, the stages of on-going industrial revolution have been scrutinized in the introduction part. In the first chapter, it is aimed to highlight a brief perspective on the theories and elements of Industry 4.0 with pros and cons approach. Following the literature review on Industry 4.0', the warehouse concept linkages with supply chain management (SCM) and Logistics has been identified. Warehouse performance indicators as cost, time, flexibility and quality have been studied so that in the following part, handling and storage of the industrial production or in other words 'Warehouse 4.0' classifications and categorizations can be correlated for each key performance indicator (KPI). Classification and categorization will be made on a hard criteria based on each indusrial stage's technological aspects. This will be outperformed on a survey, which consists selected warehouses' technical use of Warehouse 3.0 and Warehouse 4.0 equipment that would in return make it necessary to study automation and smart technology utilization of labor force and their interaction with the technology. Depending on the trustable data, the study shades light on mechanization and digitization of sample warehouses, putting forward their capabilities.

Keywords: Warehouse, Mechanization, Automation, Industry 4.0, Warehouse Equipment

ÖZ

DEPOLAMA SİSTEMLERİNİN GELİŞİMİ:DEPO 4.0 YOL HARİTASI

Duygu OLCAY
Yüksek Lisans,İşletme
Danışman: Dr.Öğr.Üyesi Ömer ÖZTÜRKOĞLU
2018

Bu çalışmada temel amaç, sanayinin ve depolamanın evrimsel evrelerine dayalı olarak, Türkiye'nin İzmir ilçesinde bulunan depolama sektörünün malzeme elleçleme, depolama yöntemleri ve bilgi teknolojileri kullanım kapasitelerini sınıflandırmak ve karşılaşmaktadır. Bu amaca yönelik, devam eden endüstri devriminin aşamaları giriş bölümünde incelenmiştir. Birinci bölümde, endüstrinin 4.0'ın artıları ve eksileriyle teorileri ve unsurları hakkında objektif bir perspektiften tanıtılması yoluna gidilmiştir. Endüstri 4.0'a ilişkin literatür taramasının ardından, tedarik zinciri yönetimi ve lojistik ile depo konsepti bağlantıları belirlenmiştir. Maliyet, zaman, esneklik ve kalite olarak depo performans göstergeleri, bir sonraki bölümde, endüstriyel üretimin veya diğer bir deyişle 'Depo 4.0' sınıflandırmalarının ve kategorizasyonlarının ele alınması ile her bir temel performans göstergesi ile ilişkilendirilebilecek şekilde çalışılmıştır. Sınıflandırma ve saptama, her bir evrim aşamasının teknolojik yönlerine dayalı tutarlı bir kriter üzerinde yapılacaktır. Bu durum, seçilen depolarda yapılan anket ile hangi ekipmanların kullanıldığını göstererek daha kavranabilir bir hal alacak ve bu da iş gücünün otomasyon ve akıllı teknoloji kullanımını ve teknoloji ile etkileşimlerini incelemeyi gerekli kılacaktır. Tutarlı verilere bağlı kalarak, bu çalışma örnek depoların mekanizasyonuna ve dijitalleşmesine ışık tutacak ve yeteneklerini ortaya koyacaktır.

Anahtar sözcükler: Depo, Mekanizasyon, Otomasyon, Endüstri 4.0, Depo Ekipmanı

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Duygu OLCAY
İzmir, 2018

TEXT OF OATH

I declare and honestly confirm that my study, titled "Development of Warehousing Systems: A Roadmap to Warehouse 4.0" and presented as a Master's Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions. I declare, to the best of my knowledge and belief, that all content and ideas drawn directly or indirectly from external sources are indicated in the text and listed in the list of references.

Duygu OLCAY

İzmir,2018

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INDEX OF SYMBOLS AND ABBREVIATIONS

Abbreviations

- SCM-Supply Chain Management
- SC-Supply Chain
- LM- Logistics Management
- KPI-Key Performance Indicator
- IT-Information Technologies
- ERP- Enterprises Resource Planning
- SAP- Systems Analysis and Program Development
- CPS- Cyber-Physical Systems
- EDVAC- Electronic Discrete Variable Automatic Computer
- ENIAC- Electronic Numerical Integrator and Computer
- CPU- Central Processing Units
- COBOL- Common Business Oriented Language
- LAN- Local Area Network
- WWW- World Wide Web
- FNC- Federal Networking Council
- FTP- File Transfer Protocol
- ICT- Information and Communications Technology
- IoT: Internet of Things
- WM:Warehouse Management
- WMS:Warehouse Management System
- IoS: Internet of Services
- IM-Inventory Management
- VMI-Vendor Managed Inventory
- RFID-Radio Frequency Identification
- EDI- Electronic Data Interchange
- AGV- Automated Guided Vehicle

Symbols	Explanations
W1	Warehouse 1.0
W2	Warehouse 2.0
W3	Warehouse 3.0
W4	Warehouse 4.0
MHE	Material Handling Equipment
CO	Conveyors
CR	Cranes
TR	Trucks
PE	Position Equipments
UL	Unit Load Equipments
SE	Storage Equipments
IT	Information Technologies
MHES-1	Material Handling Equipment Scale-1
MHES-2	Material Handling Equipment Scale-1
MHES-3	Material Handling Equipment Scale-3
MHES-4	Material Handling Equipment Scale-4
MHES-5	Material Handling Equipment Scale-5
SES-1	STORE EQUIPMENT SCALE-1
SES-2	STORE EQUIPMENT SCALE-2
SES-3	STORE EQUIPMENT SCALE-3
SES-4	STORE EQUIPMENT SCALE-4
SES-5	STORE EQUIPMENT SCALE-5
ITS-1	IT SCALE-1
ITS-2	IT SCALE-2
ITS-3	IT SCALE-3
ITS-4	IT SCALE-4
ITS-5	IT SCALE-4

INTRODUCTION

Studies in management science are generally rooted in the progress of the Industrial Revolution that has started in Eighteenth Century in the Western civilization. Western civilization has already experienced three industrial revolutions that could also, in other words, be defined as system resetting industrial processes that cause higher productivity with a huge need of systemic change (Think Act, 2014). The first step was to improve efficiency through the use of hydropower, by using more steam power and developing machine tools. The second wave introduced electricity use and mass production or assembly lines methods, and the next and previous leap was to make use of automation technology and IT. The fourth industrial revolution has not been yet comprehended but already on its way with the German motto ‘Dinge der Internet’ or ‘Internet of Things’. However, this processes were not so easily adopted and applied, therefore causing leaps; historically we have witnessed that some areas have seen fast and disruptive changes, while others have changed slowly and steadily with a more "evolutionary" pace (Think Act, 2014). Nonetheless, the world has not witnessed any step back.At the forth phase, it is observed that tangible objects are being coherently integrated into the information networks (Think Act, 2014). ‘Internet of things’implies the use of the internet which has become the backbone of commercial life. Along with this transformation in modern life, new business practices and business values are needed to comprehend the occurance and utilize its outcomes. The use of the internet, as a mere communication method, becomes one of the most important elements of our lives, from the production to the experience of customer satisfaction with the quantity of accessible data and the development of data analyses. Within the social experience, smart phones are in the hands of people who are constantly sharing something. One can now gather any information in one or two hours which we used to gather forty-fifty years ago in one-two years. This development has emerged with the wide spread use of technology in production. It has come to a point where companies have power to analyze data by increased speed that enables flows of valuable information through global networks. This newly created system is a performance system that based on dynamic processes and continuous dynamic technology. Cloud systems, computer technology, controlling processes in the supply chains (SC) such as ERP and SAP, online tools used in the production process and logistics process, autonomous vehicle technology, autonomous deliveries, wearable technologies, nano technologies, have started to take place in our lives as elements of the Forth Industrial Revolution(Think Act, 2014). With the Forth Industrial revolution, those systems will be much more compounded to all sub-units, processes, objects in the surrounding, and SC. However, it is expected that the complexity will be much bigger and will necessitate sophisticated marketplace offerings and strategies. IT structures will be built around machines, storage methods and SC models that will followa redefined standard and are now being called as “cyber-physical systems (CPS)” (Think Act, 2014). These systems will be controlled simultaneously.

The world had never experienced such an expansionary need for change before. New challenges are rooted in technological innovation and customer demands for smart technology and services, whichare incrementally reforming the industry. This economic transformation will considerably have an effect on the optimal management structures which heavily depend on the new incentives, and new external factors and context configuration.

Cuturela & Manole (2013) provided that there has been a gradual shift through the structure of the production processes from unitary production centers to sub divided production centers to have optimal logistics and profit maximization at operations. The logistics management (LM) which is now depending more on better logistic strategies, has made it necessary to manage the efficiency of the movement and warehousing of the goods. Backed with technological advancement, today under the Forth Industrial Revolution, several companies have succeeded in making the operational costs, use of the facilities and energy resources more efficient.

Barreto et al, (2017) defines the term “Logistics 4.0” with reference to integration of logistics opertations with CPS. They also provide that Logistics 4.0 comprise use of Smart Services and Smart Products. That is to say Logistics 4.0 relies on no human intervention.

However, warehousing KPI’s and equipment as a phase of logistics, will be in-depth studied by classification of them following the stages of industrialization. However, industry players do not really abandon old fashioned methods sometimes, when it is still strategically important to SCM in old fashioned way, they still apply the same method.

Therefore, human- machine (or technology) interaction will also be argued in relation to forming scales for evaluating warehouse equipment use within evolutionary phases. With regard to this, leaps and difficulties are over-amounted in many cases. In this study, it is aimed to show that with reference to industrial revolution phases of first, second, third and forth, there has been a revolution in the equipment and warehouse performance indicators, therefore in the whole management and operations.

Research problem of thesis, the sole purpose is to find a profound ground for this main problem with four sub-units: In the enlightenment of Industrial revolution, until now how have logistics and warehousing been shaped?

- As one of the most fundamental process of logistics system which is warehousing, consideringly industrial developments, how to do better warehouse management?
- What kind of characteristics needed to have by warehouse management and how to reveal specifications of these characteristics?
- In addition to all these, the study reveals how warehousing system will be innovated during industrial development?

This study aims to make use of concepts of industrial revolution to draw a new framework for warehousing. Based on this framework, Warehouse 1.0, Warehouse 2.0, Warehouse 3.0 and Warehouse 4.0 will be incorporated in to the literature where this research will be a guideline or road map for calculating major KPI metrics of warehouses. Respectively, the theories of industrial revolution will be introduced under the Chapter I (Literature Review). The stages in the revolution with Industry 1.0, Industry 2.0, Industry 3.0, Industry 4.0 will be explained with their pros and cons in a historical order. Within this chapter, elements of Industry 4.0 will be studied in deeper context. Then, under the Chapter II, evolution of SCM with past experiences and future prospects will be introduced, this will be perpetuated with advancements in the WM. Operations of WM will be assessed by some classifications and categorizations of relevant actions under Warehouse 1.0, Warehouse 2.0, Warehouse 3.0 and Warehouse 4.0. This chapter will also include warehouse performance indicators and human-machine interaction ergonomics with relation to scales which will identify mechanization, automation and digital transformation levels of selected companies in İzmir. In the following chapter, material handling, storage and IT equipments will be introduced, as three groups. A survery will be done to outperform this analysis with the data collected from selected companies. The paper is based on data-analysis and interpretation of tables.

1. INDUSTRIAL REVOLUTIONS

1.1. Literature Review

Industrial revolutions represent a series of scientific discoveries and processes that has begun and in the progress since the end of the 18th century, affecting the amount and methods of production, SC, logistics and warehousing. Generally, it is stated that this process started with the development of trade in the 17th century, but we should add mechanization too to this process.

Which energy sources have been historically used, generally define the industrial revolutions. While the energy sources of the First Industrial Revolution are coal and wood, the Second Industrial Revolution relied on explosive motor use and electricity use. Leadership in the Second Industrial Revolution passed from the United Kingdom to the United States and Germany. The second Industrial Revolution led to an increase in production and organization that triggered the First World War. The economic and political structure of the 1929 Great Depression,had caused a transformation in the organization of economies of the world and economy doctrines.

German economist Karl Bucher, asserts that when defining the causes of the Industrial Revolution it is necessary to pay attention to the previous steps. According to him, the first of the previous stages of the Industrial Revolution was the revolution of commerce, which started in the 17th century, the agrarian revolution, which started in the 18th century, and the transportation revolution, which started in the second half of the 18th century. The total effect of these revolutions has led to the industrial revolution. In the process that started with the trade revolution, capital accumulation occurred along with the industrial revolution. Significant steps have been taken in order to use information, which is the most important element in economic changes, in manufacturing, SC, logistics, and warehousing.

1.1.1. Industry 1.0 (1760-1820)

The industrial revolution, when examined in contemporary history, as the concept of Tonybee is to create a dominant economy using mechanization rather than handmade and manual processes under the name of industry.It is assumed that it started in the 18th century in

Britain and spread all over the world. In addition to French authors who lived in previous periods, Arnold Toynbee (1852-83) for the first time has provided this definition.

Today, this concept of Toynbee is still mostly used. According to the concept, the invention that appears at the forefront of the industrial revolution is steam machine. (Krahn &Graham, 1993). Accordingly, the use of coal was necessary to make vapor which functioned the mechanical process. This was the root cause of upcoming revolutions.

First industrial revolution flourishes the emergence and use of instrumentation and measurement techniques, mechanical processes and fabrication, water power, civil engineering, and chemical processes of the plastic (Özkurt, 2016). It would make it necessary to have a look at inventions of that period.

In 1763 the steam machine was invented by James Watt. For Industry 1.0 this was the trigger of the revolution. This discovery accelerated economic growth in America. In 1807, an American named Robert Fulton applied the steamer to the ships. For the first time in 1812, the steam engine began to be used in locomotives. In 1840 the first regular trans-oceanic steam vessel services began. In 1844, Samuel Morse served the first commercial telegraph service in the United States (Müsiad, 2017). Therefore, the communication and transportation have be seen as major steps of industrial revolutions.

In 1876, Alexander Graham Bell found the phone. Between 1830 and 1860, in parallel with the development of more effective mining methods in the UK, coal production increased rapidly. Because high iron and steel demand can be easily met by the technology of the period. From the 1700s onwards, the development of science accelerated. Not only steam-driven machines, but more complex machines have begun to be designed (Brettel et al., 2014). Thus, it is clear that by the time passing, mechanization has become more visible.

The economy of the UK accounted for 40% of agricultural employment of the period. Although capital accumulation was not clear in this period, saving awareness was quite high in society. Coal production has been improving continuously since the 16th century. There were developing financing institutions with reference to the period. Then, serious steps were taken towards education. The economy was growing steadily (Brettel et al., 2014). By this we can understand that industrial revolution has also been effecting sectors which are formed as chains.

Britain had a large colony, leaving behind the countries of its time for the reason that its navy was bigger. Along with the development of maritime, England became a repository of goods brought from its colonies. Trade capital was strengthened, especially by the mercantilism effect and gold and silver stocks before the Industrial Revolution. The industrialization process has been accelerated by the rapid development of the national industry by regulating and strengthening the financial markets. During this period, the commercial population of the UK began to increase. In this period, channel constructions in the roads and rivers as well as efforts to transport of the products to the domestic markets with lower costs have started. Particularly in the second half of the 18th century, the increase in demand along with the increase in urbanization and the increasing population played an important role in the development of the revolution. The transition to private property was faster (Brettel et al., 2014). This can be interpreted as socio-economic embeddedness of the industrial revolution changing the lives of people continuously.

1.1.2. Industry 2.0 (1820–1970)

Second Industrial Revolution Represents the period of economic and social changes followed by the technological changes that took place in the period from the last quarter of the 19th century to the end of the First World War in 1914 (starting from the years of 1870, the end of the First Industrial Revolution) (Müsiad, 2017). In addition to the new technological accumulations created by wars, with the consequences of the 1870 French-Prussian War, the Second Industrial Revolution gave birth to the imperialism.

As a result of the new inventions in the 18th century, new stages were created within the production process and the industry. However, as it has been identified before, this was the first revolution which constituted the first step of upcoming process in the production. Initially, this process, which started in the textile and coal mining sector was followed by other processes at intervals of 20-30 years. Basically, the mechanization of spinning machines in the weaving sector, having the process that started with the use of steam power, was accompanied by the discovery of a petrol-based internal combustion engine in the last quarter of the 19th century with the Second Industrial Revolution. At the end of first stage of the Industrial Revolution, the steam power was used for transportation and the transportation investments connected to it had increased. In the meantime, with the transportation and transportation facilities created by the newly established railway lines, the distribution of the main commodities in the trade had increased, leading to a bigger scale of trade. The steam vessels and trains enabling the movements of goods at farther distances with less cost in less time resulted in increased volume of foreign trade. In addition to this, besides the increase of communication facilities such as telegraph and telephone, the spread of cheap steel production caused railway constructions to be cheaper. The technological transformation created by more durable steel production seemed to be crucial for the second Industrial Revolution. Other technological advances that define this period are related with use of chemicals, oil, and electricity in the industry (Brettel et al., 2014). Thus, it is clear that Industry 2.0 was built on use of new raw-materials and new energy Powers.

The assembly line that the Ford automotive company created for the first time in the history, is the essence of the second industrial revolution. The division of labor has started from this point on. This has meant the work to be done by the workforce who are capable of technology. Proper division within this concept is often more innovative than general purposes of manufacturing (Chin, 1998). Thus, the notion of the Industrial Revolution can also be seen as the rapid growth of innovation in accordance with today's conditions and economy.This definition means that it will never stop. Of course, when we think about it, the analytical advantages are severe, but perhaps the most important is, as an overview of innovation, to focus on progressive developments (Özkurt, 2016). Industrial revolution is a progress of a modernization process going parallel to innovations and technology.

In order to understand the capacity of production by the Second Industrial Revolution, cheaper car production is important in the assembly line, which is called the Fordist production style applied by Henry Ford. The system, which was originally started in 1914, has been influential in production until the 1970s, during World War II, which refers to the 3rd Industrial Revolution. Fordism is essentially an assembly line system that is shaped by production per piece, based on Taylor's detailed division of labor. It has built up its competitive power to produce a large number of commodities cheaply. Before the assembly line began to be used, a worker was responsible for all of the assembly and the assembly of a car was completed in about 9 hours. With the passing of serial production on the assembly line, a worker was now obliged to install only one part of the assembly, for example, a specific screw. In 1908 Ford's T model car was driven to the first market, at $ 850. The same car could be sold for $ 360 in 1916 (Müsiad, 2017). This is a good example to see how tactiques have been forcing the scale economies to feed a growing number of people.

There was mass production at the base of the system. The disadvantage of the system is that it did not allow for diversity. Only then did General Motors produce the same parts with diversified components, for the first time (Müsiad, 2017). At the end of the 19th century, after dropping of the prices, it is seen as a sign of how much the consumption has increased by switching on the assembly line.

This mass production has been the driving force of the industrial revolution in the United States. In examining the Second Industrial Revolution, it is necessary to address the work done to improve industrial productivity, which is called Taylorism and which is theorized by Frederick Winslow Taylor. Taylor made the foundation of business management with his work. One of the most prominent features of this period is the spreading of land transportation, especially due to developments in the automotive sector. Today's giant companies such as UPS, established in this period, are good examples in terms of the logistics sector (Müsiad, 2017). What is more, logistics phases of a product are still key profit making areas and of strategies of remarkably strong companies giving them absolute and comparative advanatages.

The understanding of tightly stuck on an invention is overcome by the progressive process which entails to innovations (Hooper et al., 2008). The second industrial revolution consists the coal gas use in heating and lighting, water transport by steam power, steel production, mass cleaning and maintenance, plastic production, electric telegraph, and hydraulic cement production (Özkurt, 2016). These are also indicators of evolution of material use in the production.

1.1.3. Industry 3.0 (1970-2010)

To understand the Third Industrial Revolution correctly, one should look at the period before and after Internet. The Third Industrial Revolution refers to the period starting from World War II, known as the second world war on sharing, to the 1980s. In the First Industrial Revolution, coal and steam were the source of energy, in the Second Industrial Revolution it was the electrical energy source, and in the Third Industrial Revolution, it is expressed that the main energy source is nuclear energy. For instance, it is known that while the US consumed 283,147 quadrillion BTUs in 1980, it reached 524,076 quadrillion BTUs in 2012 (Brettel et al., 2014). Thus, expansion of embedded global markets with their environmental problems heavily depend on deplation of new energy sources.

According to some theorists who point out that the Third Industrial Revolution comprises changes after the Second World War and happenings of the 1970s. This revolution has been triggered by the use of electricity in mass production and the development of the production line. The most striking feature of this period is the automation of the production processes and the automation in the SC accordingly. The Third Industrial Revolution gives birth to the programmable process that mechanical and electronic technologies in production have left their place to the digital technology (Brettel et al., 2014). Thus, after this point digital technolohy and automation have to be encountered in the analysis.

It is said that it came out with the use of machines. This revolution is slightly different in quality terms from the first two. The basic components of this revolution are micro-electronics, which enable means of communication with information processing techniques, and communication techniques emerging from the widespread use of the internet. This era is called digital revolution. One of the most important features of the Third Industrial Revolution is the reduction of man power in the production processes due to the increase of automation in production.Unlike the other two industrial revolutions, the Third Industrial Revolution has become a period in which almost every day new technologies have been introduced and tested with advanced R&D facilities (Brettel et al., 2014). From this point on, R&D has become an area of competition between companies.

Growth, development or innovation may not always produce positive results. From, this point of view, looking at the outcomes of the first two industrial revolutions, the negative qualities of conditions necessary for natural living environment and the sustainability of life have appeared worldwide (Krahn &Graham, 1993). Thus, the protection of the environment, pollution-free industrialization and the need for renewable energy sources has made the issue of energy consumption critical. Through technological developments, it was aimed to reduce energy consumption leading to the emergence of the Third Industrial Revolution (Wigand et al., 1997). This puts an emphasis on how world economy is developing and each stage bringing different problems to deal with.

The idea that emerged during the studies on the Third Industrial Revolution is based on the development of information and communication technologies in this period and the establishment of the bases by means of communicative means using wireless technology. Issues such as solar, wind, underground and hydrogen energies, zero emission transportation, green economy, widespread relations between industry, globalization of industry and trade can be considered as major important progress of this period (Özkurt, 2016).

SCM, which is one of the most important elements of production life, has become a scientific research area, due to the fact that the economic growth has come into being as a subdivision of institutional resource planning. This was accelerated with the development of the internet increasing the role of technology in manufacturing facilities. Likewise, the logistic operations benefited from advancement of technological revolution. The process of technological advancement started with the development of a mechanically operated calculator, called Z1, and continued with introduction of computer and Internet (Müsiad, 2017). This shows the map on how information and communication technologies have been developing.

Although it belongs to the end of the Second Industrial Revolution, it can be said that computer technology belongs to this period because it developed with the Third Industrial Revolution. In 1949, 'the popular mechanic' magazine, announced that computers will weight less than 1.7 tones in the future (Barreto et al., 2017).Considering size and weight of the smart items of, this information sounds ironic today.

Computer was needed in the beginning of World War II as to function in war strategies. At the basis of these investigations were solutions to meet the needs of the era, such as the drawing of rovers of battle rockets and the resolution of passwords. In 1941, the German engineer Conrad Zuse developed a computer called the Z3 for aircraft and rockets (Müsiad, 2017). This was employed to solve the passwords of the Nazis.

In 1944, the British designed a computer called 'Colossus' that managed to solve the secret codes of Germans' messages. This was a room-size calculator. Colossus was designed to break the Lorenz codes used by the Nazis during World War II. Designed in 1945, electronic discrete variable automatic computer (EDVAC) was also the first computer program drafting device (Müsiad, 2017). EDVAC, the first computer was to perform memory storage, and has led to increased versatility in computer programs.

Designed in 1946, electronic numerical integrator and computer (ENIAC) is the first project of advanced computer technology. The first computer was a huge machine weighing about 27 tons and a width of 167 square meters. The cost of ENIAC was $ 500,000 and consumed about 150 kilowatts of energy. Despite all this, the first computer could only compare equations, solve four main calculations, and calculate the square roots. It won the first computer title because it could do long numerical and logical operations in a quick. ENIAC, controlled by 6 operators, had the ability to perform calculations of manually 20 hours long within 15 seconds. It could do 385 multiplication calculations or square root calculations with 38 divisions. It could keep 200 numbers in its memory. ENIAC was used until 1955, and then removed from use with the advent of new technologies of following period (Barreto et al., 2017).

With the discovery of transistors in 1948, transistors began to take the place of the vacuum tubes used in televisions and computers. With transistors starting to be used on computers, computers got smaller and has started to consume less energy than previous models. However, the high heat dissipated from the transistors caused the computer parts to break down easily. That's why in 1958 Texas Instruments Co. developed an integrated circuit. Today's central processing units (CPU) are based on this circuit. The circuit carried 3 electrons on a small silicon disk made of quartz. In the 1960s, computers, printers, tape units, memory operation systems and programs were added. Different software languages such as COBOL were developed. COBOL is abbreviation of common business oriented language. In 1968, the Apollo Directory Computer was used in Apollo 7's calculations of the Earth's orbit. When the Intel 4004 chips were introduced in 1971, all components of the computer CPU, memory, input and output management were validated. The number of PCs, which was 2 million in 1981, reached to 5.5 million in 1982. Ten years later, 65 million PCs were in use. By 1984, IBM PC and Apple Macintosh competitions had begun for the first time. Machintosh's operating system; It provides users with the ease of carrying an icon symbolized on the computer screen instead of the written commands. They began to connect to each other for more effective use of nearby computers and this gave birth to installation of networks. Each computer on the network began to share information about other computers' memories and programs. The networks created by the connected computers formed the local area network (LAN). These networks are connected to other computer networks. Thus, all the world's computers connected to each other to form the network of networks (Müsiad, 2017). In 2008, HTC Dream, the first commercial phone running on Google's Android operating system, was released. In 2010, Apple filled up the gap between smartphones and laptops with a tablet computer being a bridgehead (Barreto et al., 2017). This was consolidating the practical use of smart Technologies.

In terms of the development of the Internet, we can describe the first stage as the research period. In this period, internet was started for the first time in 1969 with the establishment of ARPAnet in a military program in USA. Since the founding of ARPAnet in 1969, between 1969 and 1977, this network began to include various institutions and universities in the United States. In 1973, the first e-mail address form was created at internetworking project work at Stanford University. The first ethernet local area network protocol was completed in 1974 at Harward University. In 1983, Transmission Control Protocol / Internet Protocol (TCP / IP) was developed. In 1984, DNS studies were started (Müsiad, 2017).

On October 24, 1995, the Federal Networking Council (FNC) issued a statement introducing the Internet. The definition of Internet according to FNC was as follows (Barreto et al., 2017):

i) as an information system consisting of computers logically linked to each other by a global address space based on the IP protocol.
ii) Communicates using TCP / IP or similar IP compatible protocols.
iii) Provides access to high-level services.

The structuring that can be considered as the first backbone of the Internet was realized by the National Science Foundation in 1986. In 1989, the internet was made publicly available. In the process, standards for e-mail, file transfer protocol (FTP) and telnet protocols were established. It was also transformed into an easy to use by non-technical people. The first users of the Internet are universities, research institutes and libraries. The progress on information / file / archive sharing on the established networks started in 1989(Barreto et al., 2017).

The work on web, started in 1989 at the European Laboratory for Particle Physics by British physicist and computer scientist Tim Berners-Lee. In 1991, the www (World Wide Web) protocol was developed and used. The second stage was the period when companies introduced themselves through their website. The third stage refers to the process by which the internet is commenced to be used commercially. In this period, especially in the US e-bay, Amazon companies began to be established. Later on, this current spread to the world, spreading e-commerce activities all over the world, trading on the internet. The use of social media can be expressed as the formation of big data on the internet. The fourth stage is the intelligent home systems that will be defined as the internet of objects, wearable technologies, smart factories and it will be the process of estimating where to go for the daily improvements, including the warhouses. In 1990, the ARPA net project was terminated and replaced by commercial and government backbones in the USA, Europe, Japan and Pacific countries (Müsiad, 2017). Today, one can easily recognize that these parts of the world are economically are the most embedded.

1.1.4. Industry 4.0 (2010- Today)

At the beginning of the 20th century, the birth of industrial production and the birth of the factory triggered a radical transformation in production. This is also the beginning of the era of affordable consumer products for mass consumption (Brettel et al., 2014). In the late 1960s industrial processes were re-optimized with the use of electronics and IT, and automatic manufacturing began.

With the intelligent production, the intelligent machines, systems and networks have been designed in a world where they can exchange the information and respond to it independently to manage industrial production processes. The industry, which is expressed as the fourth industrial age, aims to unite the world with production and network connections within the SC. In this model of the intelligent factory of the future, computerized systems will create physical processes and a virtual copy of these processes. In this way, a process will begin to take decisions with organizational mechanisms and decentralized decisions (Brettel et al., 2014).Fourth Industrial Revolution, will be assessed in detail in the following part.

1.1.5. Results of Industrial Revolutions: Advantages and Disadvantages

As a result of the first two industrial revolutions, the population growth rate followed by the increase in demand and the rapid depletion of resources have appeared (Müsiad, 2017).In the last two stages of the Industrial Revolution after the 2000s, the industry has gained importance for the creating a sustainable economy and developing environmental protection in the World .

As a result of the Third Revolution, in addition to the number of products and the variety of products, productivity has increased with the power of the machine getting its place in the production instead of human power.

Despite the increasing population pressure, this system has become capable of producing more. This has led to a reduction in unit costs. On the one hand, while the unit costs are decreasing, the increase in the quantity produced is also reflected in the unit sales prices which have steadily decreased with the automation. By starting to use the steamer in the transportation vehicles, between cities, even countries, the opportunity to travel has become cheaper and quicklier than ever before. As a result, the markets for manufactured goods have also widened. These are good aspects of the Industrial Revolution, however it should be noted that poor working conditions and low wages have emerged. Since the working conditions are not regulated while production is increasing, it can not be said that this period has had a qualified characteristic regarding employment and working conditions. Depending on the urbanization and population increase, as a result of the decrease of agricultural resources countries have started to trade primary products from cheaper and generally far locations. This has allowed for the development of logistics and, in particular, the continuity of transport innovations. Another effect of the urbanization is that people have started to move to the cities or to immigrate to the western countries to find jobs. Today, migration is one of the main problems of the changing globe. In the cities, the suburbs were formed, causing the population to accumulate to some parts. In 1920s, with the influence of industrialization, 50% of the US population lived in cities (Müsiad, 2017). These newly established regions were unhealthy and unplanned.

1.2. The Fourth Industrial Revolution

Reports from The World Economic Forum in Davos, Switzerland, 2012, reveal that industry is also a fundamental catalyst for innovation, specialized services such as finance, information and communications technology (ICT), logistics, health or education, but also the one that supports the development of transport and mobility infrastructures. According to the Kennedy School of Harvard, the ability to manufacture is an essential engine of knowledge creation, innovation, skills development and economic prosperity (Barreto et al., 2017). Industrial capacity is the greatest predictor of a successful economy, ahead of any other commonly used criterion.

The relationship of the industry with the technology of communication networks has long been established before Internet. Even before the Internet, large industrial groups have contributed, to a great extent, to the development of computer networks. In general, the industry has been pioneer in the use of computers making large investments in technology, in the 1950s in the United States and Japan. This has allowed new forms of organization in companies in the industrial sector (Upton & McAfee, 1996). In 1996, the engineer Upton and the computer scientist McAfee wrote about what they called the virtual factory: the monolithic factory should have already given rise to the virtual factory (a community made up of dozens, if not hundreds of factories, each focused on what it does best and all linked by an electronic network that it will allow them to operate as if they were one, and in a flexible way, regardless of their location).

This network would make it easier for companies that have computer systems to make exchange of information regarding inventory levels and delivery schedules. It has allowed potential suppliers to gain access to the system to bid for materials without any difficulty and to start with a negligible investment. Then, finally it would allow the small manufacturer to have the same access to information as its great partners. No doubt in recent years, the transformation of industries such as that of the automobile industry is very close to the described virtual factory model. Other more traditional industries have been incorporated into a similar model although with different denominations. For example, large shipyards have been renamed "synthetic industries": they put infrastructures and coordinate a large number of suppliers that assemble their products in shipyard docks to give rise to large vessels that control, largely measure, navigate through digital systems (Barreto et al., 2017). The industrial applications of the networks have allowed to reorganize the manufacturing and assembly, but also decentralize design, engineering and management. The manufacturing of the iPad is a good example of current industrial manufacturing (Barreto et al., 2017). A decentralized and collaborative design and manufacturing model is possible due to the breakdown of communication costs.

In this, a combination of manual assembly and automation is used. Samsung in the first quarter of 2014 was responsible for supplying 62% of the panels for the iPad Air. Thus, digital transformation had renedered the competitive companies to collobrate in some areas. These changes disrupted the manufacturing model in a disruptive way (Barreto et al., 2017). Cars or smartphones are manufactured, coordinated and directed in digital ecosystems that group suppliers, distributors and as has been seen, the competitor to supply global markets that depend on advanced digital networks.

Another denomination commonly used to designate the possibilities of efficiency in the industry, is "Industrial Internet". Emerging technologies such as Internet of Things (IoT) allow adding sensors and making smarter and more intuitive machines for people(Barreto et al. 2017).

These new functions allow that the machines can be programmed more easily and be coordinated with more flexibility in the adaptation of the needs to manufacturing in shorter series.

Industry 4.0 is a high-tech strategy project applied by the German government to the industry and large companies(Barreto et al. 2017). In return, the coalition for the leadership of intelligent manufacturing in the United States works on the implementation of intelligence in manufacturing with a similar approach.

In Industry 4.0, the production is combined with state-of-the-art information and communication technology. The driving force behind this development is the rapidly increasing digitization of the economy and society. It is transforming the way in which industrial countries produce and work in the future: After the steam engine, assembly line, electronics and IT, the intelligent factories (so-called "smart factories") are shaping the forth industrial revolution(Platform Industrie 4.0, n.d). The technical basis for this is intelligent, digitally networked systems that enable largely self-organized production: people, machines, plants, logistics and products communicate and cooperate directly with one another in Industry 4.0. Production and logistics processes between companies in the same production process are intelligently interlinked to make production even more efficient and flexible.

1.2.1.Theoretical Perspectives on Industry 4.0

One can consider ‘Industry 4.0’ as one of rapidly extending research topics for both business and academic environment (Hermann et al. 2015). The expression of ‘Industry 4.0’ was first mentioned in the beginning of 21st century, by German scholars.With regard to this, some strategic plans were outlined by the German federal government for the sake of the high-tech production facilities nationwide (Hermann et al. 2015; Koch et al. 2015; Nathan 2015). However, as it was mentioned, there has not been a commonly accepted definition of ‘Industry 4.0’. Hermann et al. (2015) put forward that the main problem is about non-standard definitions, which have been increasingly showing up since the focus or interest of divergent range of sectors. However, some actors have gained the role of key promoters, thus their description can be considered as more profound and useful. Hermann et al. (2015) and Koch et al. (2015) consider the definition provided by “Plattform Industrie 4.0” more reliable, even though they all doubt that it is to disperse to provide essential and vital understanding of Industry 4.0 yet. Accordingly it is defined as: “Industry 4.0 is best understood as a new level of organizational control over the entire value chain of the life cycle of products, it is geared towards increasingly individualized customer requirements. The basis of the fourth industrial revolution is the availability of all relevant information in real time by connecting all instances involved in the value chain" (Platform Industrie 4.0, n.d).

As the definition is not very clear, Hermann et al. (2015) with a purpose to provide key aspects and principles a literature review of 'Industry 4.0'. Accordingly, Cyber-Physical Systems (CPS), Internet of Things (IoT), Smart factories, Internet of Services (IoS) are key factors which address the subject better. In against these factors, Heppelmann and Porter (2014) critically expressed that the Internet is not only a just industry mechanism therefore it can not be seen as a driving force of 'Industry 4.0'.They would rather consider technologies as CPS remarkable for 'industry 4.0. Moreover, Kolberg &Zühlke (2015) described a Smart factory as self-producing, non-human set of smart machines that is already made possible by CPS. Furthermore, Koch et al. (2015) conducted an empirical study by asking 235 organizations in Germany, to obtain an organic definition for Industry 4.0 or what they understand from Industry 4.0.This entailed to know how it wouldreshape the manufacturing facilities. The outcomes were shown as key perspectives and motivations of Industry 4.0:

- The 'industrial internet' (their expression of Industry 4.0) will evolve the whole business and management.
- Industry 4.0 is capable of doing an integrated analysis and making use of data
- It would mean digitalization of outputs as services and products (smart products)
- It would bring new needs to reset the business models, therefore leaps
- It would necessitate innovative, more flattering and horizontal cooperation in the entire value chain.

Koch et al. (2015) made it clear that Industry 4.0 substantially is about generating innovative business models with the advantage of the new possibilities that arise from the use of new technologies or so called 'smart products'. As Koch et al. (2015) put forward that it is only viable only if innovative business models can make the new technologies profitable. Brettel et al. (2014) has also pointed out in their research that relationship between new technologies and innovative business models are promising advancement as long as transforming available data into a meaningful value for the whole value chain is viable. They also suggested that it is the CPS is going to make all this possible.

However, on the demand side the market imposes companies to have a progress on integrating the innovative systems (Prahalad, 2004). Today's consumers have more flexibility to make a choice from multi branch sets of products and services, but they cannot be fully satisfied by their nature (Prahalad, 2004). On this ground, the companies develop strategies to meet customized demands to add value, to maintain their market position,to increase customer loyalty.

From the producers' side, that is also to say, Industry 4.0 necessitates finding possible ways to add value through making use of large volume of data that will interact between businesses and demanders from all over the world (Xie et al., 2016).Importance of this interaction has intensified the meaning of cooperation and team-work as key drivers of the actual on-going change.

The Fourth stage of industrial revolution for the sake of whole value chain makes the adoption of a digitization strategy in manufacturing and logistics necessary. According to a research industry 4.0 will be viable only if certain basic requirements are met. The main requirements are listed below (Müsiad, 2017):

- Standardization of systems, platforms and protocols
- Making changes in the business organization that reflect new business models
- Providing digital security and information protection
- Giving necessary trainings to promote workers' skills
- Ability to conduct the necessary research for investment
- Regulation of legal infrastructure

1.2.2. Features of Industry 4.0

Intelligent Industry or Industry 4.0, expresses development from embedded systems to cyber-physical systems. Industry 4.0 defines the organization of production processes based on technology and devices that communicate with each other autonomously over the value chain. Industry 4.0 is the expression of the future mode of production. Simply put, the industry represents the fourth industrial revolution that will take place on the road to the Internet of objects, data and services.

If industry 4.0 is implemented successfully, it will increase income levels by increasing productivity and will facilitate competition in the changing world. In a model that will provide this, the following features must be found (Müsiad, 2017):

• Interoperability: Through CPS (workbenchers, assembly stations and products), people and smart factories have to have a system that allows them to connect and communicate with each other.
• Virtualization: Combines sensor data with simulation models to create a virtual copy of Intelligent Fabric.
• Decentralization: Systems like 3D printing enable systems to make their own decisions and make local production.
• Real-Time Analysis: It is realized by collecting data, analyzing the collected data and preparing it immediately.
• Service
• Modularity: It should be able to adapt individual modules of intelligent factories according to changing needs and expand them as needed.

1.2.3. Terminology of Industry 4.0

The industry 4.0 process also created its own terms and made them international. These terms mainly consist of "Internet of Objects", "Internet of Services", "Industrial Internet", "Advanced Production and Smart Factory" (Müsiad, 2017).
• Internet of objects: It describes systems and programs that communicate and collaborate with each other and with people. It can be described as a system that links all subsystems, processes, internal and external objects, suppliers and customer networks. According to some estimates, the number of devices communicating with each other has exceeded the number of people who communicate with each other. By 2020, it is estimated that 30 billion devices will be connected to one another from a jetliner to a sewing needle. Industry 4.0 is the application of the Internet to the manufacturing and service environment of the objects.

• Internet of services: It refers to the internally generated services provided by users and cross-referral services directed by cloud systems.
• Internet use device: It is an independent internet-connected device that can be monitored remotely and / or controlled from a remote location.

• Ecosystem of works: It refers to all components that businesses, governments and consumers can connect with the remote control devices through panels, nets, gateways,

• Foundation: This includes businesses, governments and consumers.

• Physical layer: This refers to hardware that makes IoT devices

• Network layer: It is a software that is responsible for transmitting data collected by the physical layer to different devices.

• Application layer: This includes all protocols that allow devices to identify each other and communicate with each other and refer to the layer that contains the interfaces.

• Remote Controlers: This includes smartphones, tablets, PCs, smart clocks, connected TVs and non-traditional controls.

• Control Panel: It shows information to the users about the ecosystem and devices that enable them to control their ecosystem.

• Analytics: They are software systems that analyze the data generated by devices connected to the IoT ecosystem. Analysis can be used for various scenarios such as control development and forecasting.

• Data storage: It is a cloud-like environment where data from IoT devices are stored.

• Nets: It is the Internet communication layer that allows devices to communicate with each other.

• Industrial Internet: It describes the adaptation of the Web to the other forms of economic activity.

• Advanced Production: This term is used for describing innovations and processes in products that develop technology.

• CPS: They are the systems that are embedded in hardwares, such as sensors, processors and communication technologies, and comprising softwares that can autonomously exchange information, initiate actions, and independently control each other.

• Intelligent factory: This term refers to the production sites where production with robots is carried out without human interaction.

It has been provided by Müsiad (2017) that Industry 4.0 is viable only if above factors are obtained:

• Priority should be given to the development of research, technology and training initiatives to achieve lasting leadership in Industry 4.0.

• Methodologies should be developed in system optimization.

• New business models that use technology should be developed.

The success of Industry 4.0 will be possible by combining leading markets and suppliers. The success of this strategy depends on three factors (Müsiad, 2017):

(1) Inter-enterprise networks and communication should be developed through horizontal integration.This refers to the companies which have the same customer type.

(2) The end-to-end digital engineering infrastructure must be created in the product SC

(3) Through developing and implementing a flexible and reconfigurable manufacturing system, vertical integration should be gathered.

1.2.4. Effects of Industry 4.0

1.2.4.1. The Effects of Industry 4.0 On Sectors

Software and telecommunication technology are the sectors that will be most affected. Software developers and providers that can be used for networking and digitization, which can perform large data analysis, will have the opportunity to expand. Machinery and plant engineering, electrical equipment manufacturers, chemical sector, automobile manufacturers and suppliers, logistics sector and agriculture sector, health sector are the sectors that will be affected positively from this change (Barreto et al., 2017). In these sectors productivity growth and expansion are foreseen. Integration with large data analysis will create opportunities for new business models.

1.2.4.2. The Effects of Industry 4.0 on Social Life

Industry 4.0 study is influencing the flexibility, duration of work, health, demographic characteristics and private life, and these effects will continue to increase. Industry 4.0 is expected to bring many advantages to social problems of developed countries, such as the tendency of production to move to low-wage countries will redirected to the home country, leading to the opening of more domestic production sites (Barreto et al., 2017). This is not just a change of location, but also a change of strategic decisions in terms of companies.

The convergence of production close with the consumer markets also contributes to lowering logistical costs, contributing to sustainability but harming low-wage country economies. The traditional labor division in production life will be transformed into more innovative decision-making, coordination and control oriented support services. The flexibility of working time in business life will increase. A more balanced private life-work life will be established and higher income gains will be achieved (Barreto et al., 2017). Depending on this, decision processes will accelerate.

In contrast, various threats will be there in business life. These include threats such as alienation, loss of productivity, reduced creativity, increased polarization between administrative and technical staff, and reduced staff numbers. The quality of the job will also change. The tendency to be naturally fit for work, which takes place in traditional recruitment, will come to an end and posessing technical skills will come to the forefront. The managerial capabilities that see the organization as a whole will also change (Barreto et al., 2017). On an environmental level, these estimates are not certain, as they are just estimates for sustainability in industry 4.0.

1.2.4.3. Potential Contribution of Industry 4.0 to the Economy

The impact and benefits of Industry 4.0, according to the European Union, will vary according to the countries and industries (Barreto et al., 2017). Industries that focus on high quality, such as semi conductors and pharmaceuticals, can benefit from reduced error rates, while industries with high product diversity, such as automotive and food and beverage industries, benefit from a high degree of flexibility.

Some companies are well positioned to serve new markets. Technology providers, infrastructure providers, cloud computing developers, large data storage and processing centers, telecommunication companies will be increasingly important. The impact will also vary depending on the size of the company. New companies and sub-enterprises are likely to develop faster.

The impact between states will vary depending on the readiness to adopt new technologies and on their overall progress in manufacturing. Industry 4.0 may also bring benefits to remote or under developed regions. Because it is possible to make personalized, decentralized and local production with technologies like 3D. The interaction of the real and virtual world, which represents a vital new direction of the manufacturing and manufacturing process, will help to create intelligent object networking and independent process management. In this sense Industry 4.0, by rendering traditional production with technological progress, creates a transitional model from "centralized" to "decentralized" production. By integrating physical objects seamlessly into the information network, it will increasingly contribute to the digitization of the manufacturing industry (Barreto et al., 2017). This will enable future decentralized production and real-time adaptation.

Industry 4.0 will radically link industry and production value chains by combining intelligent factory business models to intelligent systems and production technologies and intelligent manufacturing processes in this new technological age.

1.2.5. Possible Problems of Age of Industry 4.0

Industry 4.0 is based on autonomous communication between the devices in the value chain, so large amounts of data are generated and tracked in a more automated fashion. In this context, CPS and objects' internet will form the backbone of intelligent fabrication. Therefore, a cyber attack will leap into the nervous system of intelligent companies quickly and will be effective in every area of the company, not just a part of the company. For this reason, Industry 4.0 operability depends on how robust the security standards are. It is also important to simplify and facilitate to enable the security of data security standards since they are critical. Data security is not just a technological challenge. At the same time, people also play an important role in data security. The way to prevent this is only viable through education and awareness. A virus is being produced on the Internet every two seconds. Hundreds of malicious software is released daily on the system. According to data of December 2015, 350 million computer viruses are currently available. These viruses carry the intention of attack with information theft. A third of these attacks are carried out in businesses employing more than 250 people. For example, the damage to the German economy by virus attacks amounts to 50 billion euros. It is also stated that data breeding is worth about 3 million Euros per business (Müsiad, 2017).

Turkey, located in the top 10 in terms of the countries that suffered from cyber attacks. In the third quarter of 2015, users were exposed to harmful and highly dangerous mobile applications that they have downloaded 160.717 times these applications.
By Trend Labs 2 681 viruses in these applications that users downloaded have been detected. However, TrendLabs says that the future of the Internet will be more secure. It also asserts that technology sellers will not be able to sell unsafe products. According to Trend Micro, harmful mobile applications that are developed for the Android phones in the world in 2016 was 20 million. Security and privacy have become the primary concern among consumers and

businesses when devices are connected more together through the internet of objects. Cyber attacks are a growing threat as more and more devices are tied together in the world. Hackers can harm systems, critical infrastructure, and even people's homes (Müsiad, 2017). As a result, many technology companies investigate to ensure the confidentiality and security of information.

In 2016, 67.8% of the respondents to a survey on cyber attacks and threats (people working in countries like Japan, Germany, Canada, USA as top level IT managers) expressed that were attacked at some point and number of attacks has increased by 7 %. Again, 88% of the respondents are very sensitive to their data. It is stated that the same report, data is lost not only from the inside but also mainly from the attacks which are financed from the outside. It is also important to note that in the SC both internal factors and external factors draw attention to safety weaknesses. According to the same report, the most conservative estimates are that the number of internally connected devices will be around 20 billion over the next 3 years. Protecting the rights of intellectual property is necessary to prevent the problem of data security. The idea designates the production process of a given product and it is as valuable as design plans as they contain clear and unique information about the product and its manufacture. The ones who have this info would need the right equipment to develop fake products. Data processing within the scope of Industry 4.0 is mandatory. For this reason, protection of data, data protection policies must be determined from the beginning and supported with protocols so that the information of customers and employees is not exposed by a cyber attack(Müsiad, 2017). If customer information is not maintained as a result of a data breach, this can lead to reduced customer loyalty and loss.

2. WAREHOUSING IN RELATION TO SCM AND LOGISTICS

SC includes all successive chains from the supply stage towards the production until final consumption of goods and services (Cooper et al., 1997). In terms of business processes, SC corresponds to sales process, covers production, inventory management, material basis, warehousing, distribution, procurement, sales forecasting and customer service.SCM refers to the integrated management of the material, information and money flows that enables the customer to achieve the right product, at the right time, at the right place, with the right price, at the lowest possible cost for the entire SC. Competition between companies to a great extent relies on competition among the SC chains. Thus, successive parts of SC gives companies a competitive power at upper level competition among businesses and then emong sectors and countries (Handfield& Nichols, 1999). When SCM is effective; we expect there are autonomous or not self-restreaning flows in continuity of productiona and supplies of inputs or raw-materials (Hines, 2004). In terms of efficiency of the whole SCM, reducing the supply period, responding to the changes in the market, Increasing the quality by meeting the consumer demands in the best way, encouraging innovation by using technology, reducing total costs, training the operator to manage all information, material and money flow are important factors. In the SCM, all functions that form the chain must be integrated and competitive so that an effective and efficient SCM is out performed.

In order to reach the end-user of the products, a number of functions on specific tasks and prococess, towards the direction of the targets and objectives should be worked out. There of course, these funtions include all effective and efficient management of (Hines, 2004):

(1) Demand and Order Process
(2) Purchasing
(3) Planning
(4) Inventory
(5) Warehouse
(6) Shipment (Transportation)

The essence of this thesis, relates to all of these functions however, is more embedded in efficiency and effectiveness of inventory management (IM) and WM. Inventory management relates to the product and material stock levels hich are determined according to the company stock targets, and the efficient management of stocks in accordance with the production plan.

In this fuction the key features are given below (Johnson & McGinnis, 2011)

(1) inventory tracking should be done on an integrated system

(2) all inventory movements should be defined and recorded on the system

(3) inventory levels should be minimized with realistic demand planning

(4) inventory tracking systems should be used throughout the supply chain

(5) inventory management should work integrated with budgeting

Effective and efficient WM (Hopp, 2011) relates to

(1) appropriate conditions of the space

(2) appropriate costs of warehouse operations

(3) fast-moving infrastructures

(4) tactical decisions to storage

Essential requirements for these conditions to be met necessitate that WM, procurement, planning and inventory management functions are integrated and centralized rendering dispersed storage operations must be done in a balanced manner with respect to company resources, warehouse layout material. Thereafter, they should be utilized to provide speed and cost advantages from warehouse automation tools or technology.

The concept of SCM, is defined by the Council of Logistic Management (Ayers, 2006; Ballou, 2004; Plenert, 2007) as the systematic coordination of ethical and strategic functions of traditional business by some tactics used through it to the interior of a company and between different processes of a chain of supply in order to improve long-term performance of both the company individually and the entire supply chain in general. Additionally, Ballou (2004)describes that SCM management with an emphasis on the interactions of logistics that take place between the functions of marketing, production, purchasing, and the interactions that take place between independent companies within one the product flow channel.From the definitions,it can be inferred that the SCM aims to guarantee the appropriate interactions of the elements of logistics in an order so that the present flow of products and information optimum can be gathered in the supply chain. This will lead to the reduction of costs and to the increase in satisfactionof the clients. On the other hand, it is indicated thatin SCM three components are identified as logistics sub systems, internal logistics and distribution logistics.

Within these three components of SCM, the key process is to regulate flows between supply and demand, optimize the distribution costs and satisfy the requirements of certain processes and to be productive and flexible. This is achieved by medium of a management premium provided to the production process, and work in process that provide flexibility to production operations, and finished products which should be ready to go in compliance with orders from customers (Mauleón, 2006). On the other hand, Gunasekaran et al. (2008) describe that the WM contributes to effective management of the supply chain because it is directly involved in the exchange of information and goods, among suppliers and customers, manufacturers, distributors and other companies that participate in the operation of the supply chain.

In the SCM and WM some authors have studied the incidence and importance of ICT in its planning, operation andcontrol. Regarding this situation, Van der Vorst et al.(2003) emphasize how some ICT as the VMI (Vendor Managed Inventory) and Collaboration Planning Forecasting Replenishment have a proactive influence on planning and controlof the supply chain and management of warehouses. As ICT tools the RFID (Radio Frequency Identification) and barcodes are used for identification,record of operations andtraceability.On the other hand, other authors (Bourlakisand Bourlakis, 2006; Pokharel, 2005;Sassi, 2006) suggest that ICT in the supply chain and WM can contribute to the reductionof the complexity in their flowsof information, to the improvement ofthe coordination of processes and actors related to the increase inoperational efficiency, the profitability of the company and productivity of the supply chain. This justifiesthe need for these ICTs to be planned, implemented and integratedto companies that needto create new structure of the organization and, capacity of investment and to meet their operational needs. Focusing on the same approach, Hackman et al, (2001) describethe importance of information flowsin WM,which are the basis fortheir planning,operation and control. Additionally, it is alsohighlighted that the use of ICT in the WMS (Warehouse Management System) and the LMS (Labor Management System) supports the managementof such flows efficiently.

2.1. Inventory Management

Inventory management is one of the critical points in SCM. Through a good coordination and sharing of information among the chains in the supply chain, the ambiguities in demand are reduced (Özdemir, 2004).So the firms in the chain do not have to invest much in inventory. This will bring cost reduction.

Each stock level is based on internal dynamics, market structure and customer portfolio. These stock levels should be kept at an acceptable level for emergencies. Customer requests are often uncertain and businesses must endure these stock levels. Apart from this, additional cash outflows or borrowing without selling and operating at high stock levels result in risk for the operations that relate to inventory management (Johnson & McGinnis, 2011).

For example; investments made for products with short production life cycle in food enterprises have the risk of expiration as well as every day storage costs when the product cannot be sold. For the efficient and effective flow of information in the supply chain, it is possible that the sales-marketing department may be able to sell the products but cannot obtain the products which are in the upper stage of the value adding functions. In terms of operating with high stock-levels in such market conditions where demand is always uncertain, it is always a risk (Handfield & Nichols, 1999). This risk can be minimized by effective and efficient information sharing and proper flows of materials on the supply chain.

2.2. Warehouses

Warehouses are closed or open areas in the supply chain, which may be of different sizes and specifications, stacked and stored according to the type of material, for the purpose of protecting and stocking materials for various purposes and for various periods. Warehouses under traditional management concept, are only products stored at places, and they are seen as sales support elements in today's SCM understanding. The warehouses actyally are usually a lot of more protection points, but points of flows (Cooper et al., 1997). Thus, for companies now to get constant information about the stock levels, to have tracking on shipment and to bring about strategic warehouse consolidation decisions are fatally important to be compatitive in its sector.

Warehouses are also protected areas where the products are held in time between unloading and loading operations with proper timing, playing an important role in the continuous realization of the sequence of activities from material supply to product shipment. The warehouse is therefore an important link between the seller and the buyer, ensuring the continuity of the production for the companies, who raise the product with the marketing mix four Ps, and therefore competing in the market. Warehouses also can be called as distribution center ',' silo ',' tank ',' storage' etc. (Handfield & Nichols, 1999). Warehouses might cover the areas of the manufacturing, foreign trade, sales, distribution, wholesaler, transportation, logistics and retail companies and government agencies.

The warehouse is not only a place where we put products to use or ship later, but it has an important place in achieving the desired customer satisfaction level with the lowest cost from logistic point of view. Although they are sources of cost, they maintain their role as a facility that is of great importance for the availability of products (Cooper et al., 1997). Therefore, in order to increase the availability of goods and services for sales and marketing an to reach the targeted customer satisfaction level, warehouses in various capacities and functioning have been employed.

Logistics companies, on the other hand, use warehouses to perform their services in a similar way. Warehouse operations generally are handling, loading / unloading, protection, transferring materials, parts, and end products, and equipment and administrative areas. Multilayer warehouses are often used to increase storage capacity when storage floor space is low. Vertical carriers such as elevators are important in this type of warehouse (Hines, 2004).

Manual, semi-automatic and fully automated systems can be used in the warehouses. In the past, from the concept of warehouse, it was understood that there were few or many products or raw materials stored and protected by them. Warehouse records were mostly hand-executed and frequently causing mis-match problems (Cooper et al., 1997). There were times such as waste of time during the period until the product was found or seperation due to the full shelf life. For this reason, it was necessary to make frequent counts.

Nowadays, manual activities in warehouses are restricted as much as possible, traceability has increased and automation-based management has been employed (Hines, 2004). As a result of switching to automation; labor costs are reduced, processes are speeded up, error rates are reduced, optimization is ensured, new software and barcode, RFID automatic identification systems are used.

The storage requirement is very old. Initially, the aim was to protect the essential requirements from adverse environmental and climatic conditions. Today, when a large number of consumer goods are produced and marketed, it is desired to reduce the losses caused by lack of information during the transportation of semi-products and products from raw materials entering manufacturing and being distributed (Johnson & McGinnis, 2011) That's why every second in warehouse operations are very valuable now. In this sense, systematic quality management is important.

In warehouse activities, the goods / loads from certain points are taken to be delivered, maintained for a certain period, and sent to certain points. "Warehousing" means storing and managing raw materials, components, spare parts and maintenance-repair consumables and auxiliaries which the companies will use in the production process. Storing finished products after production and managing these stocks is called "product storage". The requirements of the storage function vary depending on the product characteristics and the industry structure in which the products are located (Hines, 2004). This concept; includes all functions in the warehouse and distribution center. Most of the material handling is in warehouses relate to handling, stacking / placing, picking and shipment.

Today, competition and customer orientation are increasing, warehouse scales are growing, moving out of the city, new equipment is employed, efficient use of the space becomes more important, more product types are handled, more frequent (more total number of orders) and smaller quantity orders and value added service needs detected, real time information requirement (traceability) increases, more returns, shorter turnovertimes, fewer error margins are expected. All of these, increase the importance of warehouses (Lao et al., 2012).

There are three main functions of warehouse (Handfield & Nichols, 1999): Movement, Stocking and Information Transfer.Within the scope of the movement, goods receipt, placement, goods transfer, picking, cross-shipment and dispatch actions are carried out (Lu & Yang, 2010). Warehouse as a storage can be described as a semi-permanent storage, a safety stock or a seasonal stock.

Information transfer is an important warehouse function that combines the first two functions through inventory management, intra-warehouse movements, in-warehouse locations, etc. The information is presented to the managers as required, and they try their best to make timely and correct decisions (Lao et al., 2012). It enables storage operations to be successful in stock levels, product inputs, stock keeping locations, inbound and outbound shipments, customer data, storage space usage and staff information. Electronic data interchange (EDI) and barcoding have increased the accuracy and speed of this transfer of information.

The main purpose is effevtive and efficient management of the warehouse, in other words, the storage and distribution of the goods in the shortest time and with the least mistakes. Other objectives are (Handfield & Nichols, 1999):

(1) To Carry out the maximum storage at least in the field / volume (efficient use of storage capacity
(2) To make efficient use of the warehouse equipment
(3) To efficiently use the workforce, effectively deploy tasksto reduce the travel time of elements, to achieve the most suitable settlement for the purpose
(4) To act in accordance with warehouse settlement and work plan
(5) To increase the variety of handled product
(6) To reduce costs (increasing profitability in terms of warehouse operation)
(7) To reduce the stocking costs
(8) To meet demands quickly (Fast picking, during the processing period of the order)
(9) ToReduce scrap and loss rates (protection of stored product)
(10) To increase automation levels of warehouse processes
(11) To increase data reliability (Physical stock follow-up)
(12) To provide traceability
(13) To make accurate shipment (Increasing shipment accuracy)
(14) To protect storage assets and products (effective security)
(15) To adapt changing logistics processes (Value-added transactions)
(16) To comply with legal regulations
(17) To improve the streamline
(18) To perform material replenishment between locations in time
(19) To maximize accessibility to all materials

2.3. Supply Chain, Logistics and Warehouse Interaction

SCM requires to meet the targeted customer satisfaction level at the lowest cost, and to integrate suppliers, producers, distributors and retailers in a timely manner to provide goods production and distribution in the right amount and in the right place. The reduction of stock costs of commercial enterprises and the submission of goods at the target market time are points to be taken into consideration. This framing creates a strategic process throughout the supply chain in which firms are located. Warehouse is an important link between the suppliers, producers, distributors and customers involved in a supply network. The warehouse, which is a point in the chain where the movement of goods on the supply chain is arranged for various reasons serves as a means of bringing the flow of the chain into a state of order (Lu & Yang, 2010). Therefore they are cost elements, but they are indispensable in terms of ensuring the optimization of the supply chain by creating scale economies and efficiency in multilateral relation with the next or previous operations.

The concept of logistics is in practice used in the same sense very often with the concept of "SCM". However, the two concepts are different. Supply chain, including the supplier, manufacturer, transportation, warehousing, sales, after-sales service, where a product moves from its existence as a raw material to its subsequent activities after the goods are delivered to the consumer. Management of this chain of operations within the understanding of dependence and relationship management is called "SCM". Logistics, on the other hand, involves all the work that must be done to move or stop the products along a supply chain and the information and risk management that flow along with the product along this chain (Handfield & Nichols, 1999). Therefore, LM is obliged to ensure that these works are performed in a healthy manner and as it is planned.

Logistics involves the physical flow of transportation, storage, packaging and value-added transactions, and service flow consisting of customs, insurance, surveillance, stock management and order management. LM can also be described as the supply chain process phase that includes the planning, implementation and control of goods and services and the storage and forwarding of goods, services and related information between downstream and downstream points to meet customer needs (Lao et al., 2012).

In order to ensure that logistics movements are carried out in a timely and healthy way, it is necessary to securely store, store and record with computer support the quality and quantity of the goods (Lu & Yang, 2010). The warehouse function is one of the important rings of door to door delivery and SCM. Logistics service providers, while carrying out logistics activities, in for example; goods shipment, consolidation of goods, they need the warehouse for processing.

WMS has developed as a separate field of expertise and has become an integral part of logistics activities (Hopp, 2011). WHM is one of the main activities of the logistics system which gives information about raw materials, semifinished products and finished products, stocked and stocked products at the starting and consuming points or between them.

According to classical understanding, Warehouse is regarded as a place where supplies and demands are balanced and products are stored. This may cause loss of products, damage and delays. The development of technology has also reduced warehouse requirements to a minimum (Menachof et al., 2009). On the other hand, especially for fast and economical replenishment of different products the warehouse requirement at the wholesaler level has increased and the "classical warehousing" concept has been replaced by the "distribution warehouse" concept.

The distribution warehouse is a place in a logistics system that focuses on product flow, providing the desired customer service level with the lowest cost to the intended customers (Hopp, 2011). The important thing is to reduce the waiting time of the products, in other words increase the stock turnover speed.We can collect the costs of logistics activities under five main headings (Menachof et al., 2009):

1. The cost of order cycling
2. Storage costs
3. Stock costs
4. Transportation costs
5. General administration expenses

Storage decisions can be strategic, tactical, or operational. Strategic level warehouse design studies mainly focus on the performance of warehouses as technical (process flow, main systems) and economical (least investment or operational costs). Strategic decisions deal with the distribution of logistics resources and they are usually long-term oriented and projected.
In line with the strategic decisions taken, equipment selection, organizational structure, manpower planning, etc. are considered within the scope of tactical decisions.

Tactical decisions include (Cagliano et al., 2011):

(1) Equipment selection
(2) Choice of storage method (static-allocated, dynamic-random)
(3) Determination of organization structure
(4) Resource (manpower, equipment, etc.) planning
(5) Order collection (order, party, regional, market basis, etc.) methods

Operational decisions are decisions about the realization and control of logistics performance. These decisions are usually short-lived and routine, involving labor and equipment operations. Decisions based on the performance and coordination of the logistics system are usually operational-based. For example, distribution of work to the warehouse staff is an operational decision.The operational issues covered by operational decisions are (Hopp, 2011):

(1) Goods receipt and shipment
(2) Batching
(3) Sorting
(4) Determination of dwell point
(5) Automatic storage (AS / RS) operation
(6) Storage, sequencing and sorting

2.4. Warehouse Performance Indicators

A Clearly defined performance criteria are needed to assess a particular warehouse design. Within the storage area, the following criteria can be distinguished: investment cost and operational costs, volume and mixture flexibility, raw material quantity, storage capacity, response time and order fulfillment quality (correctness) (Korucuk, 2015). Relative importance of this certain criteria varies according to warehouse types.

The function of the distribution repository is to store products and meet external customer orders that often occur with large order lines. Each order line specifies the amount of a particular product. Although the number of items per order line in a distribution tile is small, the number of different products may be large. Another important design criterion is the amount of raw materials that will ensure that investment costs and operational costs are minimized. These two value parameters are often combined into a single cost performance criterion. Storage capacity is also an important criterion. The basic design objectives are low investment costs and low operational costs.When a criterion is formulated as a constraint, the criterion requires a predetermined objective value. Technical and physical constraints may be formulated in addition to the constraints that relate to this objective value. Strict constraints on investment costs can lead to the design of a conventional warehouse. Storage measurements are made in different forms. The most common, traditional criteria are cost and efficiency.

Productivity and performance measurement in warehouse management heavily rely on (Menachof et al., 2009):

• the area where the warehouse is installed and the physical environment of the warehouse
• security, discipline and layout regulations,
• quality control systems
• the level of utilization of the equipment and equipment used
• the level of use of physical storage methods
• work efficiency and supervision of warehouse personnel
• applicability of correct inventory methods
• customer service

Scholars have studied warehouse performance indicators under four sub-categories as (Hedler, 2015):

(1) Time related indicators
(2) Cost related indicators
(3) Quality related indicators
(4) Productivity/flexibility related indicators

2.4.1. Time Related Indicators

As the most time consuming operations and the most frequently applied metrics are order lead-time, receiving operation time and order picking time, respectively. Then, in the following there are putaway time, delivery lead-time, queing time, dock to stock time and equipment downtime (Hedler, 2015).

Order lead time studied by Menzer & Konrad (1991), Kiefer & Novack (1999), Yang (2000), Gu et al. (2007), O'neill et al. (2008), Menachof et al. (2009), Yan & Chen (2012), Ramaa et al. (2012), illustrates the time between the customer order has been placed and the item has been received. Receiving time studied by Menzer & Konrad (1991), Gu et al. (2007), Menachof et al. (2009), Lao et al. (2012) encompasses the time of the psysical receipt of an order. Order picking time studied by Menzer & Konrad (1991), Gu et al. (2007), Cagliano et al (2011), Lam et al.(2011), refers to the time of assemblying customer orders. Putaway time studied by Menzer & Konrad (1991), Yan & Chen (2012), Cagliano et al. (2011) demonstrates the time between receipt of a load and the time when it is stored in its final destination within a warehouse. Delivery lead time studied by Menzer & Konrad (1991), Matopulos & Bourlakis (2010), Gallmann & Belvedere (2011) refers to the time between customer order received and the item delivered to the customer. Queing time studied by Cagliano et al (2011), Karaagiannaki (2011) refers to the time for an employee, machine or item to handle a party of work load. Loading time studied by Gu et al. (2007), Wang et al. (2010), Ramaa et al. (2012) refers to the time of loading a party of ordered product to conveyors, packaging, pallets or to trucks. Dock to stock time studied by Ramaa et al. (2012) refers to the time of moving a product from shipping area to the stocks. Equipment downtown studied by Menzer & Konrad (1991), refers to the time during when a machine or item is out of order or function.

In calculation of time related indicators, factors as; volume per man-hour, truck time at the dock, time from receiving to pick location, putaway per man hour, days-on-hand,orders picked per hour, cycle time orders picked per hour, cycle times per hour are measured.

2.4.2. Cost Related Indicators

In warehouse operations, inventory costs, order processing costs and labor costs are the most applied metrics followed by distribution costs, cost as % of sales, and maintenance costs (Hedler, 2015).

Inventory cost studied by Yang (2000), Ellinger et al. (2003), Rimiene (2008), Lu & Yang (2010), Cagliano et al. (2011), Saetta et al. (2012) refers to the cost of holding products in a warehouse. Order processing cost studied by Kiefer & Novack (1999), Rimiene (2008), Ramaa et al. (2012) is defined as sum of costs to realize customer orders including order taking, customer service, stocking and maintaining inventory, shipping and tracking. Labor cost studied by Lu & Yang (2010) and Cagliano et al. (2011) refers to cost of salaries and benefits paid to the warehouse workers. Distribution cost studied by Yang (2000) and Lu & Yang (2010) is described as costs incurring in moving products from production place to place to be consumed or delivered. Cost as percentage of sales studied by Mentzer & Conrad (1991) and Ramaa et al. (2012), refers to cost of handling, storing, maintaining and delivering a product as a percentage of total sales revenues, and is a primary efficienct metric. Maintenance cost studied by Johnson et al.(2010) and De Marco & Guilio (2011), refers to the cost of keeping materials, items, vehicles, and machines in good condition for and effective functioning of a warehouse.In calculation of cost related indicators, factors as; cost per item shipped, cost per shipped order, storage cost per item, cost per line item picked, picking labor costs play important role.

2.4.3. Quality Related Indicators

According to Hedler (2015), the most applied quality metrics as warehouse performance indicators, are on-time delivery, customer satisfaction, and order fill rate. The others cover shipping accuracy, delivery accuracy, picking accuracy, on-time order shipment, cargo damage rate, scrap rate, perfect orders, storage accuracy, physical inventory accuracy, and stock out rate.

On time delivery studied by Mentzer &vKonrad (1991), Lu & Yang (2010), Ramaa et al. (2012) refers to quality of delivery function and on-time delivery rate of a warehouse shows its success in its sector among competitors. Customer satisfaction studied by Kiefer and Novack (1999), Voss et al. (2005), Lu & Yang (2010), Lam et al. (2011), Saetta et al. (2012) refers to the measure of how products and services provided by a warehouse fullfil or surpass customer expectations. Order fill rate studied by Menachof et al. (2009), Lao et al. (2011), Yang & Chen (2012), Ramaa et al. (2012) also known as demand satisfaction rate is percentage of customer orders fulfilled by the stocks available. Shipping accuracy studied by Kiefer & Novack (1999), Rimiene (2008), Wang et al. (2010), Ramaa et al. (2012), refers to the rate of correct shippings that can be related with quantity, stock keeping units, order form, picking document or BOL. Delivery accuracy studied by Lao et al. (2011), Yang & Chen (2012) and Ramaa et al. (2012) relates to the rate of accurate deliveries in terms of quality and time aspects. Picking accuracy is studied by Rimiene (2008), Lao et al. (2010) relates to the rate of accurate pickings for further operations in terms of time and quality aspects. Order shipping on time studied by Voss et al. (2005), Menachof et al. (2009) relates to the rates of orders being shipped on time. Cargo damage rate studied by De Koster & Warffemius (2005), Voss et al. (2015) refers to the percentage of demaged items during the delivery process. Scrap rate studied by Voss et al. (2005), Gallman & Belvedere (2011) is related to rate of items that have been demaged to loose functioning for consumption. Perfect orders studied by Gunasekaran et al. (1999) and Ramaa et al. (2012) is a measure that correctly communicates what is happening in the warehouse in relation to customer satisfaction. Storage accuracy studied by Yang & Chen (2012) is described as compability of traceable stocks from screen with actual and physical stock levels. Physical inventory accuracy studied by Kiefer and Novack (1999) reflects the discrepancies that are present between electronic records and physical state of items. Stock-out rate studied by Kiefer and Novack (1999) is the ratio of stock-out losses to all orders.

2.4.4. Productivity/Flexibility Related Indicators

According to Hedler (2015), first three most important productivity/flexibility metrics in WHM are labor productivity, throughput, and shipping productivity. These are followed by transport utilization, warehouse utilization, picking productivity, inventory space utilization, turnover and receiving productivity. Labor productivity studied by De Koster & Balk (2005), Goomas et al. (2011), Markovitz Somogyi et al. (2011) measures the output of workers for goods and services that are being produced per hour. Throughput studied by Mentzer & Konrad (1991), Kiefer and Novack (1999), De Marco & Giulio (2011), Ramaa et al. (2012) refers to the items, parts or products passing through a system or process per hour. Shipping productivity studied by Mentzer & Konrad (1991), Kiefer and Novack (1999), De Marco & Giulio (2011), Ramaa et al. (2012), Johnson & McGinnis (2011) refers to the packing and shipping labors' productivity encompassed. Transport utilization studied by O'Neill et al. (2008) refers to productivity of items being transported at a time, and effective and efficient management of the process. Inventory space utilization and warehouse utilization studied by Rimiene (2008) and Ramaa et al. (2012) refer to warehouse capacity being used effectively and efficiently. Turnover studied by Yang & Chen (2012) is a measure of how many times the inventory is sold or used in a period of time generally on a monthly or yearly base. Recieving and picking productivity studied by Mentzer & Konrad (1999) also refer to labor productivity in receiving and picking.

2.4.5. Key Performance Indicators (KPI's)

- Receiving-Internal Order Cycle Time: Yang & Chen (2012) have explained that having higher standard material handling and IT equipment in a warehouse would shorten internal order cycle time. What is more, according to Cisco-Eagle (2016), receiving is the first indicator emphasizing the effect that a well- designed and efficient-run receiving area should not be overlooked. These would make it necessary to pay attention to critical measures as time per line item received, volume per man-hour, truck time at the dock, and accurate receipts etc.
- Put Away-Dock To Stock Cycle Time: Ramaa et al. (2012) have expressed that having higher standard in material handling and IT equipment would shorten this KPI. According to Cisco-Eagle (2016) putaway time is another indicator that received inventory is positioned into picking locations, and KPI measurement becomes harder, as order pickers are the primary users of the output of proper putaway. That is why, one should consider the factors relating to putaway accuracy rate and stock cycle time, cost per item put away, time from receiving to pick location, and putaway per man hour.
- Storage-Average Warehouse Capacity Used: Rimiene (2008) has asserted that higher capacity utilized would mean better storage equipment and IT equipment employed in a warehouse. What else, according to Cisco-Eagle (2016) storage capacity relates to whether an operation is utilized through human power or smart storage systems.
- Picking-Order Picking Accuracy: De Marco & Giulio (2011) emphasized that better and smart IT technology would mean higher accuracy to all picking and packing activities. Therefore, any warehouse should be able to utilizing IT opportunities. KPI's for order picking include cost per line item picked, orders picked per hour, picking labor costs, consumables (packing materials, cartons) usage, and cycle times per order. (Cisco-Eagle, 2016).
- Shipping-On Time Shipment: Voss et al. (2015) dealing with the delivery process asserts that better overall mechanization, automation and digitization would mean better on time shipment performances. Accordingly (Cisco-Eagle, 2016), time per item shipped, time per shipped order, labor time consumed per order, percentage of perfect shipments, shipping dock utilization, and time from picked order to departure are the metrics for this KPI.

3. DEVELOPMENTS OF WAREHOUSING

3.1. Warehouse 1.0

The effect of the First Industrial Revolution on Warehouse (1760-1820) would be defined as Warehouse 1.0. It is accepted that this process began in the 18th century in the name of the United Kingdom and spread throughout the world. This was the first time in the period between 1852-83 when Toynbee as well as some French scholars who lived in previous periods tried to explain by a brief history of Britain from 1760 to 1840 . Today, this concept of Toynbee is still mostly used. According to this concept, the steam machine appears to be the predecessor of the industrial revolution (Krahn &Graham, 1993). Accordingly, the use of coal was very important. Burning coal and heating steam to obtain steam power was the most calorified product of that period, and the manner to obtain mechanical forces by passing the steam through various mechanical processes should not be overlooked. Yet Britain should not be forgotten at this point of the Industrial Revolution with its ability to focus on general purpose technology production because the focus with such technologies would have given birth to the concept of labor division, but in the second industrial revolution these concepts have evolved much more in content and context (Christensen, 2013). Within the first industrial revolution, the emergence and use of instrumentation and measurement techniques, mechanical processes and fabrication, water power, civil engineering, grafting techniques, and the chemical process of rubber are the key points.

We can define this information as stacking only, taking into account storage on the Warehouse 1.0. Because people did manual production, there was no improved mechanization, so they were producing uniform type and keeping the same type of products stacked on top of each other. There was almost no concern to be able to send the stored product more effectively and effectively because other business concepts were not sufficiently developed too. Block stacking was the trigger element of stack production and cost at that time. Main functions and locations of warehouses gained importance, storage and material handling equipments, manual registration and tracking were used for the warehousing activities.

3.2. Warehouse 2.0

The effect of the Second Industrial Revolution on Warehouse (1820-1870) would be defined as Warehouse 2.0. The distribution of labor power is the essence of the second industrial revolution. Appropriate distribution of work to be done was often more refreshing and had requirewd improvement from general purpose of technology production (Chin, 1998). Thus, the concept of the Second Industrial Revolution can be evaluated as a rapid growth in accordance with the conditions of the reform and the economy of the 1800s and the introduction of the electricity to the manufacturing sectors. After the production with the machine, the product variety has increased. In the second industrial revolution, coal gas heating and lighting, steam power and water transportation, steel production, mass cleaning and maintenance, plastic production, electricity telegraph, hydraulic cement production concepts come to the forefront.

This information has led to shelf systems in order to separate products from each other for storage in light of warehosuing. Humans have been involved in different activities in storage, in order to separate and combine their products. For example, the concepts of flexibility and quality were now in place in warehousing. Depot officials have also started to make use of different equipment that has begun to follow inventory. In this respect, shelf systems were introduced first and warehouse workers had begun manual labeling to distinguish products.

The concept of distribution center had taken attention by trigger element of diversity (flexibility) and quality management. With respect to this global locations of warehouses had appeared, by value adding activities such locking, labeling, sorting, merging and advanced shelf systems. First examples of flow rack, mobile racking,carousel were incorporated to warehousing activities, and human-machine material handling equipment, conveyors, stock tracking by manual labeling were introduced respectively.

3.3. Warehouse 3.0

The effect of the Third Industrial Revolution on Warehouse (1870- 2010) would be defined as ‘Warehouse 3.0’. Looking at the outputs of the first two industrial revolutions,negative qualities of conditions necessary for natural living environmentand that the sustainability of life around the world were challenging (Krahn & Graham, 1993).

Thus, the protection of the environment,(Wigand et al., 1997), the reduction of energy consumption through technological developments by focusing on renewable energy sources and avoiding pollution-causing industrialization came forefront. On April 21, 2012, The Economist Magazine described the Third Industrial Revolution as the start of the digitization of production. The idea that emerged during the studies on the Third Industrial Revolution was that the development of information and communication technologies in this period and the establishment of the bases by means of communication and communication tools using the satellite and wireless technology and the Internet which had become widespread. Topics such as; solar, wind, underground and hydrogen energies, zero emission transportation, green economy, widespread relations between industry, globalization of industry and trade were considered as important factors of this period.

This information is transferred to the period of modernization even though it stores in order to be able to benefit from the booms of technological developments in order to protect the resources of companies in the light. The e-commerce turnover has also begun, while the quality expectancy had been growing as well since then. RFID tag tracking and follow-up has become the shining star of this era. In addition, the equipment used is as follows (Kay, 2012).

3.3.1 Part To Picker Systems

Such systems are supported with integrated computer-controlled systems that bring together storage medium, transport vehicles, and they are controlled with various levels of automation for quick and right random storage of loads and materials.

Storage/retrieval (S/R) machine in a system of AS/RS funtions through a narrow aisle, feeding rack slots around the aisle; can move horizontallty and vertically simultanenously.Their advantages can be that there will be less number of material handlers, better control over the materials, more securit, and more storage utility.Their disadvanatrages can be summed as they are typically high cost investments and their maintenance costs are higher, and there is less chance to modify them.Although AS/RS were initially projected for storage and distribution, they can now be employed in-process storage as a phase of an automated job shop. An automated job-shop can be defined as a whole system where an AS/RS is tied with an automatic identification system such as RFID, and an automatic transportation system such as automatic conveyors and/or an automotive guided vehicle (AGV) system, to bring about more control over real-time material handling activities.

3.3.2. Automatic Display Systems

As a part of automation, automatic display sytem in combination with 4-way conveyors and grid pick technology, is where an image display system and process are divulged. The image display system consists a typically flat display screen that is subunited into many other display mode modules, each of which comprises multiplied information of storage and distribution elements or loads.

3.3.3. High Density

High-density storage systems have been developed as a prevailing solution for companies which have problems with the size of their warehouse, controlling of their material handing costs, and in efficiency in their warehousing activities.

3.3.4 3D Storage Systems

By using 3D Storage Systems consisting pushback rack systems, the companies are able to increase their storage capacity up to 3 times when compared to standard pallet rack or double deep racking systems.

3.3.5 WMS + ERP

A WMS is generally employed for managing the storage and the transport of the inventory. The system follows back and forward the movement informantion of every inventory material at the certain phases such as the item received, picked, packed and shipped.

3.3.6 RFID

Radio Frequency Identification consists the activities of Identification, tracking and remote data writing, reading and updating of RFID tags located on moving or fixed assets that need to be tracked wirelessly by means of radio waves.

3.4 Warehouse 4.0

The effect of the Fourth Industrial Revolution on Warehouse (2010- onwards) would be defined as ‘Warehouse 4.0’. Industry 4.0, in manufacturing technology, especially in the areas of automation and data exchange, cyber-physical structures, internet concepts of objects and cloud computing systems beyond today's conditions, can be defined as a newly emerging concept (Kagermann et al, 2013). Industry 4.0 inside formations, the cyber-physical processes they use, or the multifaceted thinking they createwith the kind of information that can be considered an intersectionof the cyber and physical world, as a broad evaluation. In this process, information and communication technologies have started to be used for more innovation and troubleshooting of the future’s problematic processes. As globally embedding systems of markets and communication, the internet, cyber networks and data services can still be seen as some basic stones of these formations (Blanchet et al, 2014). In particular, as embedded systems,they have been in the middle of our daily life since they have been invented, 98% of the globally produced processors are frequently used in daily life as they are exploited in the administrative, supervisory or visual tools in manufacturing and warehousing. For example, smart phones and white goods used in the home can be shown as embedded systems whichhave been promoting as intelligent control units (Scheer, 2013).

They are often used with their own specific applications, as they are embedded in the vehicle and the information processing processes. They have taken the name "embedded system" since built- out sensors with built-in sensorsconnect them to the system by processing the data they obtainand provide simultaneously. The integration of the virtual and physical worlds through the Cyber-Physical Systems and the beginning of the gathering of technical and operational processes in a single pavilion are emerging as the concept of the Smart Factory, perhaps the most important product of the Industry 4.0 project. The most supportive of this concept is the deployment of Cyber-Physical Systems within production systems. All the products, resources and processes in Smart Factory are determined by real time high quality resource management and reduced costs to begathered significantly by the time passing (Wong, 2013).

The key points in Industrial 4.0 are sustainability and customer-oriented service capability. These include adaptability, flexibility, self-sufficiency, misunderstanding and self-correction and risk taking (Schmidt, 2013)

LaValle et al. (2011) have provided that to optimize the in-house production processes that can bring about the results by taking into account the real-time conditions such as flexible production systems. It should also be considered that the production advantages are merely beneficial in the production of special products. This kind of cyber physical structures, which can be placed in such a wide network to be formed, adaptable and self-organizing, will be able to achieve the best expected result.

These latest technological treasures will reduce human power to a minimum and respectively the blue-collar warehouse workers will be transferred into the sector as white-collar workers. By reducing the faults, the warehouse entering, the fast operation processes will bring more profitable results. Though not yet in Turkey, the absence of this kind of storage that works with the latest technology, the examples in the world as systemsin which we expect to see robots as triggers of the latest revolution will be provided.By adapting the formative blocks of industry 4.0 materials to warehousing as follows, a classification can be made (Kay, 2015):

3.4.1. Cyber Security

Such systems provide the credibility of information meaning that the system should not be attacked from outside

3.4.2. 3D Printers

To collect customers' order with minimum stock cost it is a system that is developed for creating quick response to the customer orders with unfinished products that can be customized upon inquiry. 3D printers funtion as a complemantary technology to service unexpected demands in an efficient way.

3.4.3. Augmented Reality

This comprise products methods such as google glass, virtual reality, man controlled robots, drones (cycle stock count, parcel shipment, etc.) for small-town, large-city warehouses, intra-city transportation.The warehouse clerk wears that eyeglass to reduce operation errors by showing the right material handle and the right place to store the loads. The work is accelerated, transport time is reduced in the warehouse and the possibility of processing with the wrong product is reduced to almost none.

In addition, it reads and scans the necessary information and after the info immediately falls into the system providing comfortability to monitor the product that is being handled and stored in the warehouse.

3.4.4. Cloud Technology

The data are kept in a cloud assuming to have different repositories that should be synchronized with each other. In this process, the information is kept in common and the users of individual depots are able to make common inventory tracking.

3.4.5. Big Data Analysis

When realizing performance metrics, it commands the operators. With this technological system everything is registered, then it enables operators or managars to make instant efficiency calculations among warehouse operations.

3.4.6. Autonomous Robots

These are the robots that operate in warehouse operations abd can make decisions on their own when an unexpected situation occurs.

3.4.7. System Integration

This means the integration of humans with robots. With Industry 4.0, we longer do the work on our own, as we know that human power will be eliminated. However, in the situations where robots are not able to do the work, human intervanes to teach it. For such situations, the robot gives alert to be commanded.

3.4.8. Simulation

With all this technology, warehouses are now able to simulate and plan their daily activities and orders. For instance, for an unexpected order, operators can change the routine by dismissing different activities to different robots.In a simulation we would generally need robots, big data, instant cargo and expert systems, machine learning and optimization, artificial intelligence, automatic order, inventory sharing and collaborations, wearable technology (Google glass, VR: man controlledrobots), drones (cycle stock count, parcel shipment, etc.).

3.5. Why Warehouse 3.0 and Warehouse 4.0

Constantly developing technology has made it possible for the productivity of the industry to increase significantly since the end of the 18th century with four major waves. Steam powered machines, electrical power generation and the ever-widespread use of robotic automation in the aftermath of 1970 have been the triggers of these new revolutionary revolutions. Nowadays, we are talking about the evolution of the fourth industrial revolution which also include the warehouses triggered by digital technologies. We observe that intelligent robots have a crucial role in triggering this revolution of new technologies, such as massive data, the Internet of objects, 3-D printing, and clouds.

The concept of Warehouse 4.0, which emerged with this revolution, beyond automation or Warehouse 3.0, is the stance where its parts integrate with each other autonomously. The most important feature of integration is that all the value chain steps can communicate in real-time and on a continuous basis with a smart and self functioning system.This vision defines a faster, more flexible, higher quality and more productive industrial journey.

Industry 4.0 concept has been proposed by industrialized countries like Germany and the USA, and gives countries advantage to regain competitiveness in the production they lost over the years. For example, according to Tüsiad and BGC (2016, it is expected that the widespread implementation of Industry 4.0 will have a significant impact on the German economy over the next 10-15 years. When we quantify this effect, it is possible to talk about a cost-reducing effect of 90-150 billion Euros, which is the result of an increase in industrial efficiency, which corresponds to 15-25% of conversion costs for production. In addition to Industry 4.0, the term defined as Warehouse 4.0 emerges as a journey beyond productivity growth, a journey of higher value added, creating its own economy, changing the established value chains and more importantly in the need of human power.

For Turkey, wanting to get involved in a set of high competitiveness of economies, it is inevitable to follow these developments at the global level and to be among the leading implementing economies of Industry 4.0. Factors that underpin Turkey's competitiveness, such as low labor cost and logistical advantage, should be expected to be exposed to significant stress in this period, especially when competitiveness indicators vary and change rapidly.

In this respect, with the Warehouse 4.0 approach, it is confidential that the sustainability of Turkey's competitiveness should be gathered too. Depending on this, to create a Turkish industry that has a high added value and a greater share of the world production value chain is of vital importance.

In this framework, it is expected that the Warehouse 3.0 and Warehouse 4.0 (depending on implementation of Industry 3.0 & Industry 4.0) the transformation will progress in four important categories for companies and countries:

1. More efficient use of resources
2. Stable growth
3. More investment
4. Quality employment

3.6. Warehouse Equipment

In this section, main material handling, storage and IT equipment used in warehouses will be showed as just according to the 'Material Handling Equipment' guideline by Bouh & Riopel (2015). In their work, they have identified most of specific equipment. Most commonly used equipment out of them are as in follows and the definitions will be profivded in the appendix.

Table 3.1 Material Handling Equipment-Cranes (Kay, 2015)

MATERIAL HANDLING EQUIPMENT				
CRANES				
1.Steam Crane	2.Jib Crane	3.Bridge Crane	4.Gantry Crane	5.Stacker Crane

Table 3.2 Material Handling Equipment-Conveyors (Kay, 2015)

MATERIAL HANDLING EQUIPMENT				
CONVEYORS				
1.Hand Crank	2.Wheel Conveyor	3.Roller Conveyor	4.Chain Conveyor	5.Slat Conveyor
6.Flat Belt Conveyor	7.Magnetic Belt Conveyor	8.Troughed Belt Conveyor	9.Bucket Conveyor	10.Vibrating Conveyor
11.Screw Conveyor	12.Pneumatic Conveyor	13.Vertical Conveyor	14.Cart-on-track Conveyor	15.Tow Conveyor
16.Troller Conveyor	17.Power and free Conveyor	18.Monorail	19.Sortation Conveyor	

Table 3.3 Material Handling Equipment-Industrial Trucks (Kay, 2015)

MATERIAL HANDLING EQUIPMENT				
INDUSTRAIL TRUCKS				
1. Hand Truck	2.Pallet Jack	3.Walkie Stacker	4. Platform Truck	5.Counterbalanced Lift Truck
6.Narrow-Aisle Straddle Truck	7. Narrow-Aisle Reach Truck	8.Turret Truck	9.Order Picker	10.Sideloader
11.Tractor Trailer	12.Personnel and Bunden Carrier	13.Automatic Guided Vehicle		

Table 3.4 Material Handling Equipment-Positioning Equipment (Kay, 2015)

MATERIAL HANDLING EQUIPMENT				
POSITIONING EQUIPMENT				
1.Manuel	2.Lift/Tilt/Turn Table	3.Dock Leveler	4.Ball Transfer Table	5.Rotary Index Table
6.Part Feeder	7.Air Film Device	8.Hoist	9.Balancer	10.Manipulator
11.Industrial Robot				

Table 3.5 Material Handling Equipment-Unit Load Formation Equipment (Kay, 2015)

MATERIAL HANDLING EQUIPMENT				
UNIT LOAD FORMATION EQUIPMENT				
1.Self Restraining	2.Pallet	3.Skid	4.Slip Sheets	.Tote Pans
6.Skid Boxes	7.Bin/Basket /Rack	8.Carton	9.Bag	10.Container
11.Crate	12.Intermodal Container	13.Strapping/Tape/ Glue	14.Shrink Wrap	15.Palletizer

Table 3.6 Storage Equipment (Kay, 2015)

STORAGE EQUIPMENT				
1.Floor Storage	2.Selective Pallet Rack	3.Drive in Rack	4.Drive Through Rack	5.Push Back Rack
6.Flow-Through Rack	7.Sliding Rack	8.Cantilever Rack	9.Stacking Frame	10.Bin Shelving
11.Storage Drawers	12.Storage Carousel	13.Vertical Lift Module	14.A Frame	15.Auto Store
16.Automatic Storage/Retrieval System				

Table 3.7 IT Equipment (Kay, 2015)

IT EQUIPMENT				
1.Manual	2.Bar Code	3.RFID	4.Voice Recognition	5.Magnetic Stripe
6.Machine Vision	7.Portable Data Terminal	8.Augmented Reality (Google Class)	9.VR	

3.7. Proposed Conceptual Framework for Warehouse 4.0 Roadmap

In the Chapter IV, sample warehouses from Izmir district with the use of material handling equipment, storage equipment and IT equipment under the light of Industry 4.0 concept will be scrutinized. Warehouse 1.0, Warehouse 2.0, Warehouse3.0 and Warehouse 4.0 have been so far defined under the light of Industry 4.0 concept. Following this, material handlingi storage and IT equipment use of selected companies from İzmir area will be evaluated according to their Warehouse versions as 1.0, 2.0, 3.0, 4.0. This will be viable through a real life survey done with the specialists from selected warehouse companies. From a broad perspective, it is assumed that Warehouse 1.0 heavily depends on human power and proto-mechanics, Warehouse 2.0 allows for limited electricy use and pre-modern mechanization tools, Warehouse 3.0 brings about a greater degree of human-machine interaction and automation and finally Warehouse 4.0 heavily depends on non-human interaction and smart mechanization of self-functioning warehouses.

For the survey part and further evaluation, scales have been identified based on the study by Liu et al. (2011) on human-machine interaction.

Rather than this academic work, to define scales, manager's of the sample companies have been interviewed. Then, according to their opinions and suggesstions following scales have been created.The scale to ratify material handling equipment, storage equipments and IT are defined as shown in table 3.8.

Table 3.8 Classification of Scales

CLASSIFICATION OF SCALES		
MATERIAL HANDLING SCALES	**STORAGE SCALES**	**IT SCALES**
1.SCALE: Human must take all decisions and actions .The level of automation on material handling is zero in other words there is no automation.	1.SCALE: Low density	1.SCALE: The automation/computer offers no assistance; human must take all decisions and actions.
2.SCALE: The equipment is electronic powered and controlled by human . Human performs the task with less power energy.	2.SCALE: Low medium density	2.SCALE: The automation/computer offers a complete set of decision/action alternatives, or narrows the selection down to a few, or suggests one alternative
3. SCALE: The equipment is electronic powered and has a medium level of automation. Thus, the action relies on half human power, half automation.	3.SCALE: Medium density	3.SCALE: The automation/computer executes the suggestion if the human approves
4. SCALE: The equipment is electronic and autonomic; however the decision to start or finish an action relies on human initiative.	4.SCALE: Upper medium density	4.SCALE: Automation/computer executes automatically, then necessarily informs the human
5.SCALE:The material handling equipment is electricity powered and can take its own decisions and actions in other words the equipment can take actions and perform tasks without any human help.	5.SCALE: High density	5.SCALE: The computer decides everything, acts autonomously, ignoring the human.

Overall evaluation of these scales accumulating to a classification of the categories as material handling, storage and IT as components of Warehouse 4.0, Warehouse 3.0, Warehouse 2.0 and Warehouse 1.0 will make it possible to draw a conclusion in parallel to KPIs the warehouses are functioning on. In construction of the scale framwork, idias and suggestions of the warehouse managers, academics, have been taken into consideration while the overall formulation of the each scale is based of Liu et al. (2011), human-machine interaction scale. Then the outcome has appeared to be as in the following:

Scale 1 represents to Warehouse 1.0: This score (1) means that there is no mechanization, automation and digitization, everything is done by totally by human power.
Scale 2 and 3 represents to Warehouse 2.0: This score (2) means that there is a limited level of mechanization but no automation and no digitization.
Scale 4 represents to Warehouse 3.0: This score (3) means that mechanization and automation is in the work, however still there is a need for human interaction
Scale 5 represents to Warehouse 4.0: This score (4) means that the warehouse system is fully mechanized, automated and digitized, no need for human interaction.

Selected KPI's will be evaluated at the conclusion part according to the scores obtained. This scope has been driven according to managerial and academic suggestions (Gamme & Johansson, 2015).

- Receiving-Internal Order Cycle Time: Higher scores in material handling and IT part would shorten this KPI.
- Put Away-Dock To Stock Cycle Time: Higher scores in material handling and IT parts would shorten this KPI.
- Storage-Average Warehouse Capacity Used: Higher capacity would mean higher storage equipment scores.
- Picking-Order Picking Accuracy: Better IT scores would mean higher accuracy.
- Shipping- On Time Shipment: Better overall scores would mean better on time shipment scores.

3.7.1. Warehouse 4.0 Classifications

Table 3.9 Conveyors Classification

CONVEYORS							
W1	**SCALE**	**W2**	**SCALE**	**W3**	**SCALE**	**W4**	**SCALE**
Hand Cranks and Series of Pullies	MHS-1	Slat Conveyor	MHS-3	Screw Conveyor	MHS-4		
Wheel Conveyor	MHS-1	Flat Belt Conveyor	MHS-3	Pneumatic Conveyor	MHS-4		
Roller Conveyor	MHS-1	Magnetic Belt Conveyor	MHS-3	Vertical Conveyor	MHS-4		
Chain Conveyor	MHS-1	Troughed Belt Conveyor	MHS-3	Cart-on-Track Conveyor	MHS-4		
		Bucket Conveyor	MHS-3	Power-and-Free Conveyor	MHS-4		
		Vibrating Conveyor	MHS-3	Monorail	MHS-4		
		Tow Conveyor	MHS-2	Sortation Conveyor	MHS-4		
		Trolley Conveyor	MHS-3				

Table 3.10 Cranes Classification

CRANES							
W1	**SCALE**	**W2**	**SCALE**	**W3**	**SCALE**	**W4**	**SCALE**
Steam Cranes	MHS-1	Bridge Crane	MHS-3	Stacker Crane	MHS-4		
Jib Crane	MHS-1	Gantry Crane	MHS-2				

Table 3.11 Industrial Trucks Classification

INDUSTRIAL TRUCKS							
W1	**SCALE**	**W2**	**SCALE**	**W3**	**SCALE**	**W4**	**SCALE**
Hand Truck	MHES-1	Pallet Jack (b) Powered Pallet Jack	MHES-2			Automatic Guided Vehicle	MHES-5
Pallet Jack (a) Manual Pallet Jack	MHES-1	Walkie Stacker (b) Powered Walkie Stacker	MHES-3				
Walkie Stacker (a) Manual Walkie Stacker	MHES-1	Counter Balanced Lift Truck	MHES-2				
Platform Truck	MHES-1	Narrow-Aisle Straddle Truck	MHES-3				
		Narrow-Aisle Reach Truck	MHES-3				
		Turret Truck	MHES-3				
		Order Picker	MHES-2				
		Sideloader	MHES-2				
		Tractor-Trailer	MHES-2				
		Personnel and Burden Carrier	MHES-2				

Table 3.12 Positioning Equipment Classification

POSITIONING EQUIPMENT							
W1	**SCALE**	**W2**	**SCALE**	**W3**	**SCALE**	**W4**	**SCALE**
Lift/Tilt/ Turn Table	MHES-1	Dock Leveler	MHES-2	Mani pulator	MHES-4	Industrial Robot	MHES-5
Ball Transfer Table	MHES-1	Rotary Index Table	MHES-3				
Air Film Device	MHES-1	Parts Feeder	MHES-3				
		Hoist	MHES-3				
		Balancer	MHES-2				

Table 3.13 Unit load Formation Equipment Classification

UNIT LOAD FORMATION EQUIPMENT							
W1	**SCALE**	**W2**	**SCALE**	**W3**	**SCALE**	**W4**	**SCALE**
Pallet	MHES-1			Palletizer Conventional Stripper Plate Palletizer	MHES-4	Palletizer-Robotic Pick and Place Palletizer	MHES-5
Skid	MHES-1						
Slipsheet	MHES-1						
Tote Pans	MHES-1						
Skid Box	MHES-1						
Bin/ Rack /Basket	MHES-1						
Carton	MHES-1						
Bag	MHES-1						
Bulk Load Container	MHES-1						
Crate	MHES-1						
Intermodal Container	MHES-1						
Strapping/ Tape/Glue	MHES-1						
Shrink-Wrap/ Stretch-Wrap	MHES-1						
Palletizer-Manual Palletizing	MHES-1						

Table 3.14 IT Equipment Classification

IT EQUIPMENT							
W1	**SCALE**	**W2**	**SCALE**	**W3**	**SCALE**	**W4**	**SCALE**
Manuel	ITS-1	Bar Codes	ITS-3	RFID	ITS-4		
Magnetic Stripes	ITS-2	Voice Recognition	ITS-3	Machine Vision	ITS-4		
		Portable Data Terminals	ITS-2	Augmented Reality(Google Class)	ITS-4		
				VR	ITS-4		

Table 3.15 Storage Equipment Classification

STORAGE EQUIPMENT							
W1	**SCALE**	**W2**	**SCALE**	**W3**	**SCALE**	**W4**	**SCALE**
Floor Storage	SES-1	Selective Pallet Rack	SES-3	Storage Carousel	SES-4	Auto Store	SES-5
Cantilever Rack	SES-1	Drive-in Rack	SES-2	Vertical Lift Module	SES-4	Automatic Storage/ Retrieval System	
Stacking Frame	SES-1	Drive-Through Rack	SES-3				
Bin Shelving	SES-1	Push-Back Rack	SES-3				
Storage Drawers	SES-1	Flow-Through Rack	SES-2				
A-Frame	SES-1	Sliding Rack	SES-3				

3.7.2. Warehouse 4.0 Equipment Road Map

Material handling equipment's historical development between W 1.0 and W 4.0 are defined as shown in table 3.16, table 3.17, table 3.18, table 3.19 and table 3.20.

Table 3.16 Material Handling Equipment Conveyors Road Map

MATERIAL HANDLING EQUIPMENT PASSING BETWEEN W 1.0 AND W 4.0			
W 1.0	**W 2.0**	**W 3.0**	**W 4.0**
CONVEYORS			
Hand Crank and Series of Pullies, Wheel Conveyor, Roller Conveyor, Chain Conveyor	Slat Conveyor, Flat Belt Conveyor, Magnetic Belt Conveyor, Troughed Belt Conveyor, Bucket Conveyor, Vibrating Conveyor, Tow Conveyor, Trolley Conveyor	Screw Conveyor, Pneumatic Conveyor, Vertical Conveyor, Cart-on-Track Conveyor, Power and-Free Conveyor, Monorail, Sortation Conveyor	

Table 3.17 Material Handling Equipment Cranes Road Map

CRANES			
W 1.0	**W 2.0**	**W 3.0**	**W 4.0**
Steam Cranes, Jib Crane	Bridge Crane, Gantry Crane	Stacker Crane	

Table 3.18 Material Handling Equipment Industrial Trucks Road Map

INDUSTRIAL TRUCKS			
W 1.0	**W 2.0**	**W 3.0**	**W 4.0**
Hand Truck, Pallet Jack Platform Truck	Pallet Jack, Counterbalanced Lift Truck, Narrow-Aisle Straddle Truck, Narrow-Aisle Reach Truck, Turret Truck, Order Picker, Sideloader, Tractor-Trailer, Personnel and Burden Carrier		Automatic Guided Vehicle

Table 3.19 Material Handling Equipment Position Equipment Road Map

POSITION EQUIPMENT			
W 1.0	**W 2.0**	**W 3.0**	**W 4.0**
Lift/Tilt/Turn Table,Ball Transfer Table,Air Film Device	Dock Leveler,Rotary, Index Table,Part Feeder,Hoist,Balaner	Manipulator	Industrial Robot

Table 3.20 Material Handling Equipment Unıt Load Formation Equipment Road Map

UNIT LOAD EQUIPMENT			
W 1.0	**W 2.0**	**W 3.0**	**W 4.0**
Pallet, Skid, Slipsheet, Tote Pan, Skid Box, Bin/Basket/Rack, Carton, Bag, Bulk Load Container, Crates, Intermodal Containers, Strapping/Tape/Glue Shrink-Wrap/Stretch-Wrap, Palletizers-Manual Palletizing		Palletizers-Conventional Stripper Plate Palletizers	Palletizers-Robotic Pick and Place Palletizer

Storage equipment's historical development between W 1.0 and W 4.0 are defined as shown in table 3.21.

Table 3.21 Storage Equipment Road Map

STORAGE EQUIPMENT PASSING BETWEEN W 1.0 AND W 4.0			
W 1.0	**W 2.0**	**W 3.0**	**W 4.0**
Floor Storage, Cantilever Rack, Stacking Frame, Bin Shelving, Storage Drawers, A-Frame	Selective Pallet Rack, Drive-in Rack, Drive-Through Rack, Push-Back Rack, Flow-Through Rack, Sliding Rack	Storage Carousel, Vertical Lift Module	Auto Store, Automatic Storage/Retrieval System

IT's historical development between W 1.0 and W 4.0 are defined as shown in table 3.22.

Table 3.22 IT Equipment Road Map

IT'S PASSING BETWEEN W 1.0 AND W 4.0			
W 1.0	**W 2.0**	**W 3.0**	**W 4.0**
Manuel, Magnetic Stripes	Bar Codes, Voice Recognition, Portable Data Terminals	RFID, Machine Vision, Augmented Reality(Google Class), VR	

4. CASE STUDY ANALYSIS: DETECTING THE WAREHOUSE EVOLUTION LEVELS IN A GROUP OF COMPANIES IN IZMIR DISTRICT OF TURKEY

A case study has been done on sample companies, to detect their level of automation, mechanization and digitization. This study follows such a formulation that warehouse equipments as material handling, storage and IT are given scores. If a company possesses a specific equipment it is given a base point of '1', if not given a base of point '0' and this equipment posession will be scored with the level of warehouse classification. Thus accordingly as explained warehouse 1.0 represents 1 point, warehouse 2.0 represents 2 points, warehouse 3.0 represents 3 points and warehouse 4.0 represents 4 point. The values will be interpreted in 7 categories as conveyors, cranes, industial trucks, position equipment, unit load equipment, storage and IT. These will then accumulate to main categories as:

1. Material Handling Equipment
2. Storage Equipment
3. IT Equipment

At the end, their overall scores will be evaluated showing their level of automation, mechanization and digitization. Calculations for all equipment and their detail tables are displayed in Appendix.

4.1. Background of the Companies

Due to privacy reasons, names of the companies will not be announced, however in this part the selected companies' profile and position in their sector will be mentioned.Company A is an agriculture company operating in a wide range of fields from animal feeding to cattle breeding, plant nutrition to cultured fish production and processed fish products. It has five production fields around İzmir. Company B is a warehouse of well known Turkish spring water company. They produce different sizes of drinkable water and have a funtioning warehouse. Company C is a motor engine company which is known world-wide. They produce motors for passenger cars and commercial vehicles, including the powertrain and air conditioning technology, such as engine systems, filtration, and electrics/mechatronics. Company D is a LED light bulb producer and seller and has a funtioning warehouse.Company E is too a LED light bulb producer and seller and has a funtioning warehouse.Company F is a warehouse of a well known Turkish company which sells white goods, dried food and alcoholic bevareges.Company G is a warehouse of a well known Swiss company which sells FMCGs in Izmir area and specialized in packaging and warehousing services.

4.2. Scoring of Material Handling Equipment

Table 4.1 below, demonstrates what type of conveyors the warehouses possess, company D having none. The filled cells Show that that equipment exist in that company. The numbers in the graphs shows the score or the level of warehouse systems.

Table 4.1 Conveyor Check List

COMPANY	A	B	C	D	E	F	G
EQUIPMENT							
Transport Equipment							
Conveyors							
1. Hand Cranks and series of pullies							
2. Wheel conveyor							
3. Roller conveyor							
4. Chain conveyor							
5. Slat conveyor							
6. Flat belt conveyor							
7. Magnetic belt conveyor							
8. Troughed belt conveyor							
9. Bucket conveyor							
10. Vibrating conveyor							
11. Screw conveyor							
12. Pneumatic conveyor							
13. Vertical conveyor							
14. Cart-on-track conveyor							
15. Tow conveyor							
16. Trolley conveyor							
17. Power-and-free conveyor							
18. Monorail							
19. Sortation conveyor							

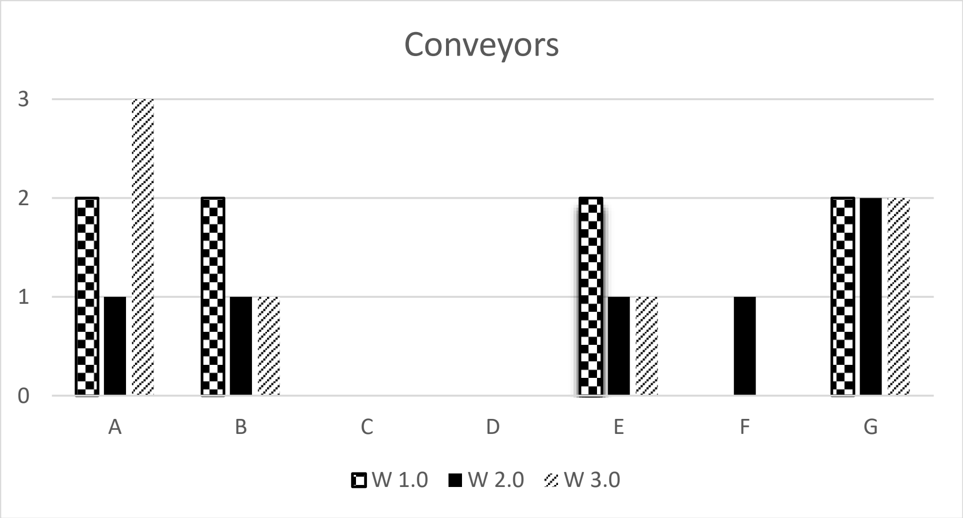


Figure 4.1 Conveyor Scores

Having possesed a conveyor scores as a base point of "1"which is multiplied by the equipment's classification scores has resulted in by the means calculated for the Company A: 2.17, Company B: 1.75, Company C&D: 0, Company E: 1.75, Company F: 2.00, Company G:2.00.

These scores can be interpreted as Company C&D do not have the conveyor work load. Company A scores the highest mechanization in their conveying processes and is at the level of W 3.0 , Company B and E score the lowest mechanization at the level of W 1.0, and the Company F&G have relatively highest mechanized warehouses with their conveyors between the levels of W 2.0 and W. 3.0.

Table 4.2 Crane Check List

COMPANY	A	B	C	D	E	F	G
EQUIPMENT							
Cranes							
1. Steam cranes							
2. Jib crane							
3. Bridge crane							
4. Gantry crane							
5. Stacker crane							

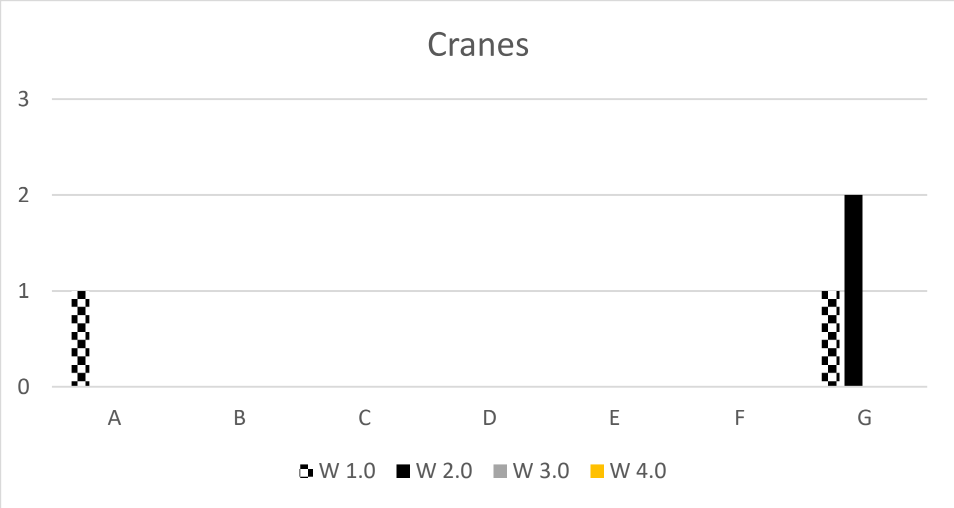


Figure 4.2 Crane Scores

Companies, B, C, D, E, F do not possess any crane, thus they are exempt. However, Company A scores 1, which means they heavily depend on human power for their crane work, and Company G scores 1.67 which means they are more mechanized than all others at the level of W 2.0.

Table 4.3 Industrial Truck Check List

COMPANY	A	B	C	D	E	F	G
EQUIPMENT							
INDUSTRIAL TRUCKS							
1. Hand truck							
2. Pallet jack							
(a) Manual pallet jack							
(b) Powered pallet jack							
3. Walkie stacker							
(a) Manual walkie stacker							
(b) Powered walkie stacker							
4. Platform truck							
5. Counterbalanced lift truck							
6. Narrow-aisle straddle truck							
7. Narrow-aisle reach truck							
8. Turret truck							
9. Order picker							
10. Sideloader							
11. Tractor-trailer							
12. Personnel and burden carrier							
13. Automated guided vehicle							

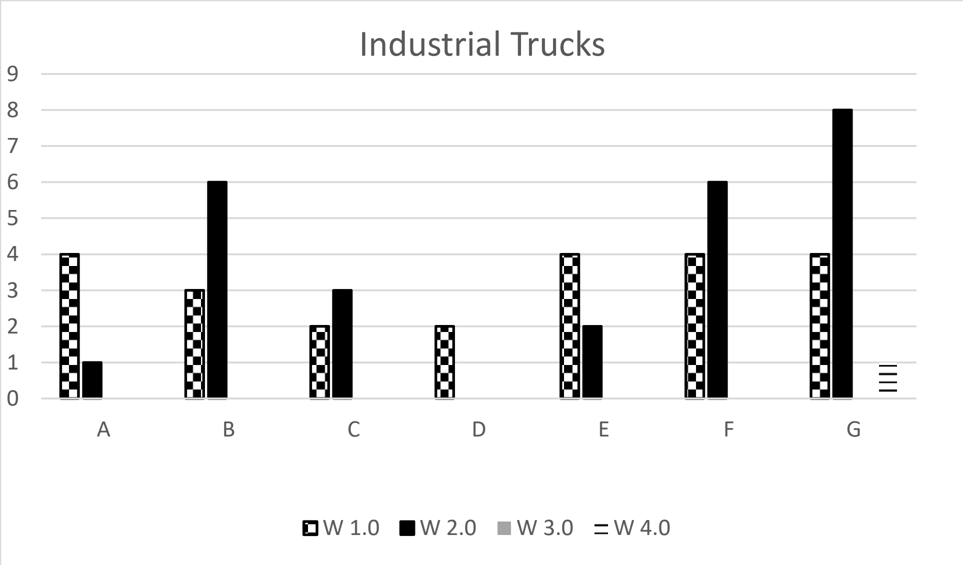


Figure 4.3 Industrial Truck Scores

According to the calculation given in the appendix, Company D scores the lowest level meaning they do not have any mechanization in industrial truck transport, Company A, B, C, E, F are below the score level of Company G which 1.85. Here, we can also see that the Comapany G to a certain level carries the aspects of W 4.0, but mostly it can be classified as a W 2.0 class in term of Industrial trucks. What is more, companies F and B are too mostly W 2.0 class, each posessing a considerable degree of W 1.0., the Company D purely depending on human power.

Table 4.4 Positioning Equipment Checklist

COMPANY	A	B	C	D	E	F	G
EQUIPMENT							
Positioning Equipment							
1. Manual/ no equipment							
2. Lift/tilt/turn table							
3. Dock leveler							
4. Ball transfer table							
5. Rotary index table							
6. Parts feeder							
7. Air film device							
8. Hoist							
9. Balancer							
10. Manipulator							
11. Industrial robot							

Figure 4.4 Positioning Equipment Scores

Accordingly, the Company A and D do not possess any positioning equipment. The Company B and G maintain the highest scores at the level of W 4.0, which is followed by the Company F at level of W 2.0. Lowest scores are obtained from the Companies C and E at the level of W 1.0.

Table 4.5 Unit Load Formation Equipment Check List

COMPANY	A	B	C	D	E	F	G
EQUIPMENT							
Unit Load Formation Equipment							
1. Self-restraining/No Equipment			■				
2. Pallets	■	■	■	■	■	■	■
3. Skids					■	■	
4. Slipsheets		■					■
5. Tote pans							
6. Pallet/skid boxes	■	■	■			■	■
7. Bins/baskets/racks						■	
8. Cartons					■	■	■
9. Bags	■	■	■	■	■	■	■
10. Bulk load containers		■				■	■
11. Crates						■	
12. Intermodal containers							■
13. Strapping/tape/glue		■			■		■
14. Shrink-wrap/stretch-wrap	■	■	■	■	■		■
15. Palletizer	■	■	■			■	■

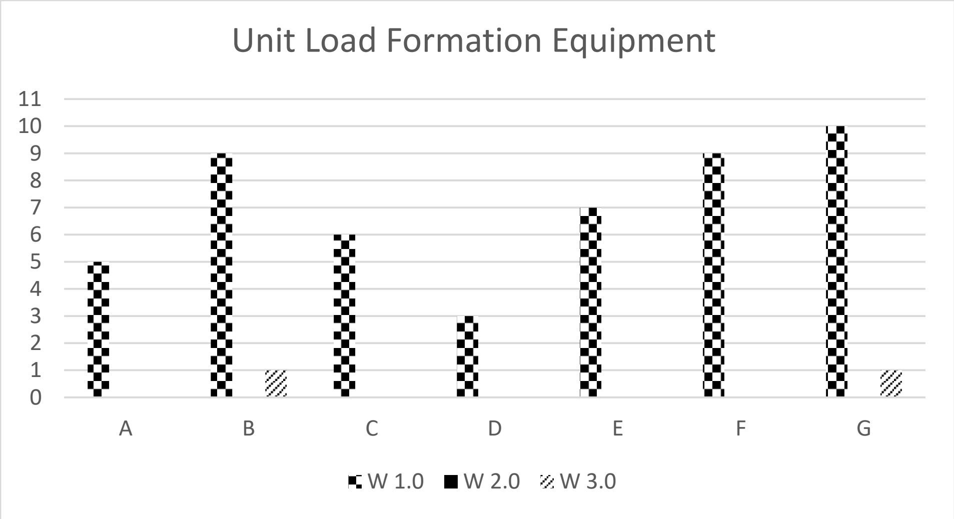


Figure 4.5 Unit Load Formation Equipment Scores

In this case, the Company B has the highest scores with a degree of both W 3.0 and W.4, followed by the Company G which has a more degree of W 1.0. All others have a score of W 1.0 meaning that their unit load formation heavily depend on human power.

4.3. Scoring of Storage Equipment

Table 4.6 Storage Equipment Checklist

COMPANY	A	B	C	D	E	F	G
EQUIPMENT							
STORAGE EQUIPMENT							
1.Floor storage							
2. Selective pallet rack							
3. Drive-in rack							
4. Drive-through rack							
5. Push-back rack							
6. Flow-through rack							
7. Sliding rack							
8. Cantilever rack							
9. Stacking frame							
10. Bin shelving							
11. Storage drawers							
12. Storage carousel							
13. Vertical lift module							
14. A-frame							
15.3-D high density storage system (auto-store)							
16. Automatic storage/retrieval system							

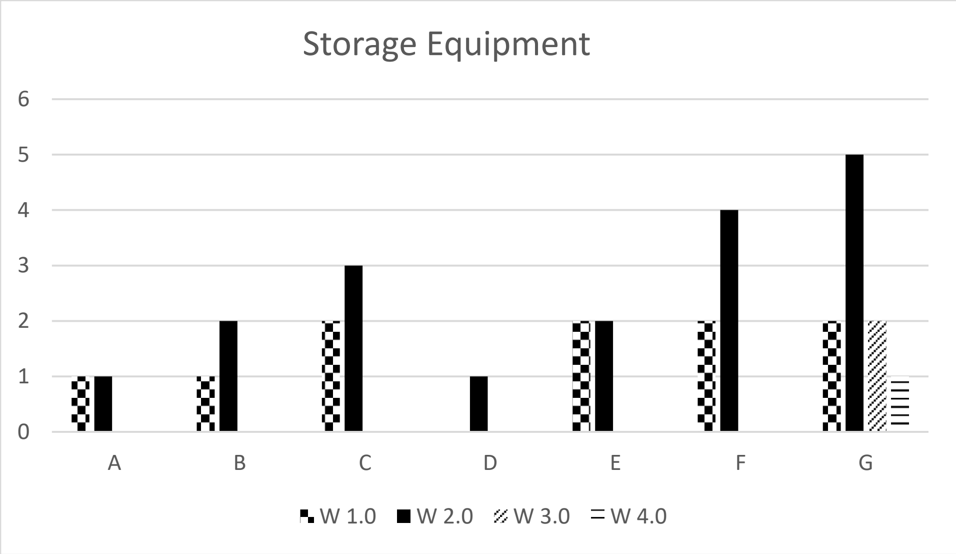


Figure 4.6 Storage Equipment Scores

Accordingly, the Company G has the highest storage equipment scores having a degree of both W 4.0 and W 3.0 followed by the Company F. The Company A and D have shown the lowest scores, while B, C, and F have maintained the moderate level mechanization in the storage case at the level of W 2.0.

4.4. Scoring of the IT Equipment

Table 4.7 IT Equipment Checklist

	A	B	C	D	E	F	G
EQUIPMENT							
IT EQUIPMENTS							
Identification and Control Equipment							
1. Manual/ no equipment							
2. Bar codes							
3. Radio frequency/identification tags							
4. Voice recognition							
5. Magnetic stripes							
6. Machine vision							
7. Portable data terminals							
8.Google Glass (AGUMENTED REALITY)							
9.VR							

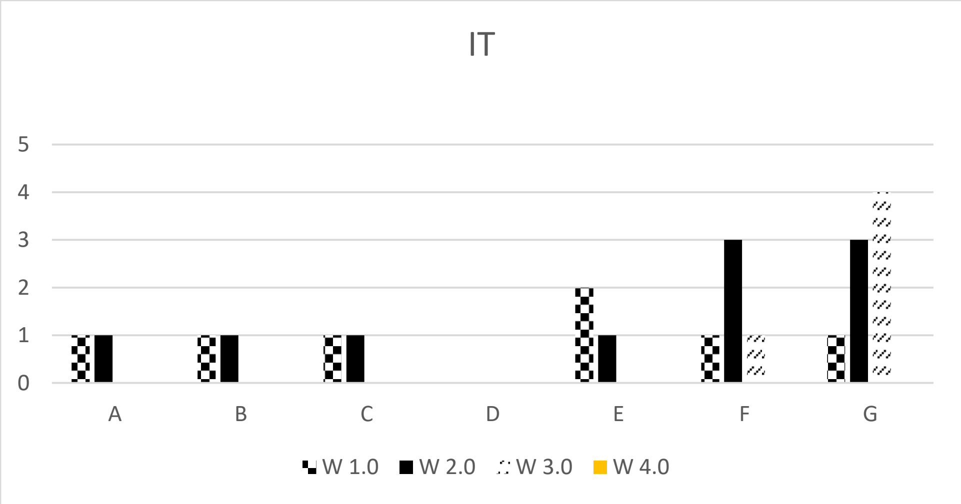


Figure 4.7 IT Scores

In the IT case, it has been found out that the Company D has manual tracking and the Company A B C have the lowest scores and apply barcode tracking method. Company E has moderate scores which means they are at a certain level of automation and are employing magnetic stripes. Then, the Company F has a medium level IT applications containing a degree of W 3.0, while the Company G scores the high level medium of IT applications in its operations at the level of W 3.0.

4.5. Overall Scoring and Recommendations

Table 4.8 Overall Scores

	A	B	C	D	E	F	G
MHE	1,34	1,72	1,20	1,00	1,27	1,65	1,75
SE	1,50	1,67	1,60	2,00	1,50	1,67	2,20
IT	1,50	1,50	1,50	1,00	1,33	2,00	2,38
OVERALL	**1,45**	**1,63**	**1,10**	**1,33**	**1,37**	**1,77**	**2,11**

The Company A has comparatively moderate level overall mechanization score which is 1.45. For the material handling equipment (1.34), it can beter off if it employs cart on track conveyor instead of roller conveyor and flat belt conveyor. It can also make better choices with the cranes. It can may be better off with the stacker crane instead of jib crane. It can may be make use of powered pallet jack instead of the manual one and for better handling operations can get an automated guided vehicle. It also seems to not possess any positioning equipment, however a manipulator or an industrial robot may bring efficiency to its material handling operations. The company empoys manuel palletizer, but it can instead make investment in robotic pick palletizers or conventional stripper palletizers. For storage equipment (1.50), it can may be purchase an auto storage and retrival system to increase its score. For better IT applications (1.50), it can modernize itself with radio frequency identification tags.

The Company B has comparatively moderate level overall mechanization score which is 1.63. For the material handling equipment (1.72), it can transform itself with a monorail and/or a cart on track conveyor, automated guided vehicle and a manipulator for positioning. For storage equipment (1.67), it can modernize itself with an auto-store retrival system. Additionally, for better operations it can upgrade its IT system (1.50) with radio frequency identification tags.

The Company C, has the lowest overall (1.10) of mechanization and digitization score. This can be because, the company is not in need of any conveyor or crane use. It can however, use automated guided vehicle and a tractor trailer for better handling operations. It can also make use of manipulators and industrial robot for picking and sortation. What is more, to get a robotic pick and conventional palletizer instead of manual palletizing could be a good idea for unit making. For storage equipment, it can better off with an auto-store retrieval system. Additionally, it can upgrade its IT system with radio frequency identification tags.

The Company D scores the second lowest (1.33) at the end, considering that it has a very bad score in applying IT equipment and material handling equipment as well. This can be because, the company is not in need of any conveyor or crane use. It can however, use automated guided vehicle and a tractor trailer for better handling operations. It can also make use of manipulators and industrial robot for picking and sortation. What is more, to get a robotic pick and conventional palletizer instead of manual palletizing could be a good idea for unit making. For storage equipment, it can better off with an auto-store retrieval system. Additionally, it can upgrade its IT system with radio frequency identification tags.

The Company E has slightly better level (1.37) of overall score. In material handling, instead of old style conveyors it can employ monorail and power and free conveyor. What is more, an automated guided vehicle and tractor trailer can better of its transport operations. Instead of manual pallet jack, it can purchase a powered pallet jack for more efficiency. For positioning, it can use manipulator and industrial robot. A robotic pick and place palletizer would easen the packing process and unit making. For better storage operations, an automatic storage retrival system would be advatageous. Then, to uprage its overall capacity, it should better use portable data terminals and radio frequency identification tags.

The Company F has comparatively moderate level overall mechanization score which is 1.77. For the material handling equipment (1.65), it can transform itself with a monorail and/or a cart on track conveyor, automated guided vehicle and a manipulator for positioning. For storage equipment (1.67), it can modernize itself with an auto-store retrival system. Additionally, for better operations it can upgrade its IT system (2.0) with enriched reality and VR sytems.

The Company G by so far is the most mechanized and digitized warehouse with a overall score of 2.11. It can be a good example for others in the sector. It scores sufficient levels at both storage and IT equipment, however, it can upgrade its material handling operations with better conveyors and cranes. It can also employ manipulator for better positioning.

When the researchers calculate an average according to whole materials in a warehouse, these warehouses can reach to level of Warehouse 2.0. But, when needed to make the research on more specific area, the researchers can see that some of warehouses are able to use materials of Warehouse 4.0.

CONCLUSION

If the digitization of information has been one of the keys in the industrial revolution of recent times, the most recent technological advances will allow the digitalization to be extended to the physical level. This thesis has proven that even though the world is at fourth stage of industrial revolution in theory, the real warehouses whose mechanization and digitization have been scored in Izmir district of Turkey, still employ old fashioned and manual equipments. This outcome should not be overwhelmed since it might be the fact that manual operations can be less costly and more profitable.

Throughout this paperwork, it has been emphasized that the products, merchandise, machine tools, factories, warehouses and vehicles will be more interconnected and will work autonomously, creating networks where the division between information and the physical will dissipate, with the gigantic potential that is represented by sample companies, will constitute the fourth revolution in warehouses under the light of Industry 4.0.

This tendency to bring digitalization to the physical, will lead to real objects form an information network and create an intersection between people, data and machines. With accessibility to all information by the people involved in the corresponding processes and in real time the information itself will be contained in the product throughout its corresponding value chain, and will be key for production, marketing and maintenance.

This interconnection between the products and the corresponding processes in which they are involved also includes the processes of storage and order preparation, where they have clearly evolved from stock flows to preparing pallets and boxes to preparation of the sales unit or the consumption unit, having increased the levels of committed service, reducing the time elapsed from the transmission of the order until delivery to a few hours, and therefore, rapid response systems are necessary throughout the supply chain, responding to the needs of customers with customized solutions.

In Warehouse 4.0, Logistics 4.0, Industry 4.0, emphasizing mechanization and digitization, there are three elements that are essential for development of warehouse operations:The new processors, which have to be much smaller and consume less energy than the usual processors, will be responsible for managing the information. That’s why IT equipments such as radio frequency identification and portable data terminals are very important.

The sensors, as indispensable as they are sensitive, are responsible for capturing the information in the place where it is produced: the product and the process. That's why automated guided vehichle, robotic pick and paletizers, auto-store are very important.Communication among equipment, operators and managers are of greate importance too since the information stored in a small computer, must be transmitted efficiently to those who immediately need it for better marketing and strategic management decisions. In the case of warehouses, it is the high density storage capabilities.

Finally, in warehouses today and tomorrow, the traceability of products and orders is necessary; without it, we can not really guarantee that we are doing things right. However, it has been proven that we do not even have the certainty that we are doing them just as in Industry 4.0, recommenfing warehouses to go towards more automation of processes, mechanization and digitization.

This work can be used as a roadmap, for further research in the area, for instance, some detailed performance metrics analysis can be developed by following the framework given in this paper work. This study may give an inspiration to the future's warehousing studies through its all specific parts. Receiving, put away, storage, picking and shipping are known as warehousing operational steps. During operational processes of these steps, which equipments are able to enhance to which steps of operation can be determine. Additionally, related equipments can be matched with suitable warehousing operational steps through KPI's. According to these matches and evaluations, which equipments are able to bring more lucrative warehousing operational processes about time and cost spendings can be determine easily. Moreover, new KPI's can be revealed through all of these evaluations.

For better warehouses, one should manage the change of model and be able to equip their capacity processes for the opportunities that will undoubtedly be presented to them by Warehouse 4.0. With respect to this, when we review selected KPIs for the sample warehouses:

- Receiving-Internal Order Cycle Time: The Companies G, F and B seem to have higher standards of material handling and IT equipment in their warehouse. That would indeed shorten their internal order cycle time. This means they have shorter time per line item received, volume per man-hour, truck time at the dock, and accurate receipts etc. Other companies seem to have week overall performances.

- Put Away-Dock To Stock Cycle Time: The Companies G, F and B seem to have higher standards of material handling and IT equipment in their warehouse. That would indeed shorten their stock cycle time. That is why, one should consider the factors relating to putaway accuracy rate and stock cycle time, cost per item put away, time from receiving to pick location, and putaway per man hour. Other companies seem to be under scoring for this KPI.

- Storage-Aveage Warehouse Capacity Used: The Companies D, F and G seem to have higher standards of storage and IT equipment in their warehouse. This means their storage operations are utilized through more with automated and mechanic storage systems. The rest fails to demonstrate an adeaquate storage capacity.

- Picking-Order Picking Accuracy: Only the companies G and F have a relatively better and smart IT technology which would mean higher accuracy to all picking and packing activities. This would related to their cost per line item picked, orders picked per hour, picking labor costs, consumables (packing materials, cartons) usage, and cycle times per order.

- Shipping-On Time Shipment: When dealing with the delivery process that better overall mechanization, automation and digitization scores belong to the company G and F. This would make them better warehouses on time shipment performances, therefore, thy should have relatively shorter time per item shipped, time per shipped order, labor time consumed per order, percentage of perfect shipments, time from picked order to departure.

REFERENCES

ABB, (2017) A new age of industrial production :The Internet of Things, Services and People, retrieved from: https://new.abb.com/docs/default-source/technology/a-new-age-of-industrial-production---iotsp.pdf , (accessed date: 18.04.2018).

Andreji¢, M., Bojovi¢, N., and Kilibarda, M. (2013) Benchmarking distribution centres using Principal Component Analysis and Data Envelopment Analysis: A case study of Serbia. Expert Systems with Applications

Autry, C. W. & Daugherty, P. J. (2003) Warehouse operations employees: Linking person-organization fit, job satisfaction, and coping responses, Journal of Business Logistics, Vol.24, No.1, pp. 171-197.

Ballou, R. H. (2006) Revenue Estimation for Logistics Customer Service Offerings The International Journal of Logistics Management, Vol. 17, No. 1, pp. 21-37.

Barreto, L., Amaral A., Pereira (2017) A Short Historical Perspective on the Evolution of Logistics and its Implications for Globalization. The International Journal of Logistics Management, Vol. 20, No. 5.

Bauernhansl, T., ten Hompel M. and Vogel-Heuser, B. (2014) Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung, Technologien und Migration, retrieved from: https://www.researchgate.net/publication/321612689_Industrie_40_in_Produktion_Automatisierung_und_Logistik_Anwendung_Technologien_Migration , (accessed date: 18.04.2018).

Brettel, M., Friedrichsen, N., Keller, M. & Rosenberg, M. (2014). How virtualization, decentralization and networkbuilding change the manufacturing landscape: An Industry 4.0 perspective. Periodical, 8 (1), 37.

Bough M. A., and Riopel D. (2015) Material Handling Equipment Selection CIRRELT Institute

Cagliano, A. C., DeMarco, A., Rafele, C., and Volpe, S. (2011) Using system dynamics in warehouse management: a fast-fashion case study. Journal of Manufacturing Technology Management.

Chin, W.W. (1998) The Partial Least Squares Approach to Structural Equation Modeling. Mod. Methods Bus. Res. 295, 295–336.

Cisco-Eagle (2016) Key-warehouse-performance-metrics-for-an-effective-operation, retrieved from: http://www.cisco-eagle.com/blog/2016/01/28/5-key-warehouse-performance-metrics-for-an-effective-operation/ (accessed date: 07.04.2018).

Cooper, M.C., Lambert, D.M., & Pagh, J. (1997) Supply Chain Management: More Than a New Name for Logistics. The International Journal of Logistics Management Vol 8, Iss 1, pp 1–14.

REFERENCES (continued)

Colson, G. & Dorigo, F. (2004), A public warehouse selection support system, European Journal of Operational Research, Vol.153, No.2, pp. 332-349.

Cuturela S. C. & Manole, A. (2013) Industry 4.0 implications in logistics: an overview Manufacturing Engineering Society, retrieved from: http://www.revistadestatistica.ro/supliment/wp-content/uploads/2014/05/rrss3_2013.pdf, (accessed date: 11.03.2018).

De Koster, M. B. & Balk, B. M. (2008) Benchmarking and Monitoring International Warehouse Operations in Europe. Production and Operations Management, 17(2):175-183.

De Marco, A. & Giulio, M. (2011) Relationship between logistic service and maintenance costs of warehouses, retrieved from: http://summerschool-aidi.it/edition-2015/images/2.4.pdf, (accessed date: 18.04.2018).

Deloitte, (2016) Challenges and solutions for the digital transformation and use of exponential technologies, retrieved from: https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-en-manufacturing-industry-4-0-24102014.pdf , (accessed date: 18.04.2018).

Ellinger, A. D., Ellinger, A. F., and Keller, S. B. (2003) Supervisory Coaching Behavior, Employee Satisfaction, and Warehouse Employee Performance: A Dyadic Perspective in the Distribution Industry. Human Resource Development Quarterly.

Faber, N., de Koster, M. B. M., van de Velde, S. (2002) Linking warehouse complexity to warehouse planning and control structure, International Journal of Physical Distribution and Logistics Management, Vol.32, No.5, pp. 381-395.

Liu, F. Zuo, M. and Ping Z. (2011) Human Machine Function Allocation In Information Systems: A Comprehensive Approach, School of Information Studies, Syracuse University, Syracuse, NY, USA.

Gallmann, F. and Belvedere, V. (2011) Linking service level, inventory management and warehousing practices: A case-based managerial analysis. Operations Management Research

Gamme, N. & Johansson M. (2015) Measuring supply chain performance through KPI identification and evaluation, Master's thesis in "Supply Chain Management" and "Quality and Operations Management"

Goomas, D. T., Smith, S. M., and Ludwig, T. D. (2011) Business activity monitoring: Real-time group goals and feedback using an overhead scoreboard in a distribution center Journal of Organizational Behavior Management

Gu, J., Goetschalckx, M., and McGinnis, L. F. (2007) Research on warehouse operation: A comprehensive review. European Journal of Operational Research.

Gunasekaran, A., Marri, H. B., and Menci, F. (1999) Improving the effectiveness of ware-housing operations : a case study. Industrial Management & Data Systems, 99(8):328-339.

REFERENCES (continued)

Hedler Staudt F. (2015) Global warehouse management: a methodology to determine an integrated performance measurement, Doctoral Thesis, France, Retrieved from: www.theses.fr/2015GREAI082.pdf, (accessed date: 18.06.2017).

Handfield, R. & Nichols, E., (1999) Introduction to Supply Chain Management. Prentice Hall, Upper Saddle River, NJ.

Hermann, M., Pentek, T. & Otto, B. (2015) Design principles for Industrie 4.0 scenarios: a literature review. Technische Universität Dortmund, Dortmund.

Heppelmann, J.E. & Porter, M.E. (2014) How Smart, Connected Products Are Transforming Competition. Technische Universität Dortmund, Dortmund.

Hines, T. (2004) Supply chain strategies: Customer driven and customer focused. Oxford: Elsevier.

Hooper, D., Coughlan, J., and Mullen, M., (2008) Structural Equation Modelling: Guidelines for Determining Model Fit. Articles.

Hopp, W. (2011) Supply Chain Science. Chicago: Waveland Press.

Johnson, A. & McGinnis, L. (2011). Performance measurement in the warehousing industry. IIE Transactions

Kagermann H., Wahlster W., and Helbig J. (2014) Final report of the Industrie 4.0 Working Group Deutsche Post AG Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0, retrieved from: http://www.acatech.de/fileadmin/user_upload/Baumstruktur_nach_Website/Acatech/root/de/Material_fuer_Sonderseiten/Industrie_4.0/Final_report__Industrie_4.0_accessible.pdf , (accessed date: 18.12.2017).

Karagiannaki, A., Papakiriakopoulos, D., and Bardaki, C. (2011) Warehouse contextual factors affecting the impact of RFID. Industrial Management and Data Systems, retrieved from: https://www.emeraldinsight.com/doi/abs/10.1108/02635571111137278 ,(accessed date: 11.03.2018).

Kay M. G. (2012) Material Handling Equipment, retrieved from:

http://www4.ncsu.edu/~kay/Material_Handling_Equipment.pdf ,(accessed date: 07.02.2018).

Kiefer, A. W. & Novack, R. A. (1999) An empirical analysis of warehouse measurement systems in the context of supply chain implementation. Transportation Journal, 38(3):18-27.

Kolberg, D. & Zühlke, D. (2015) Lean Automation enabled by Industry 4.0 Technologies. IFAC-Papers OnLine, 48 (3), 1870-1875.

Koch, V., Kuge, S., Geissbauer, D.R. & Schrauf, S. (2015). Opportunities and challanges of the industrial internet. 50(4), 22-45.

REFERENCES (continued)

Korucu, S. (2015) Temel Lojistik Bilgisi, p.5-12.

Krahn, J., and Graham S., (1993) Work, Industry, and Canadian Society. Second ed. Scarborough, Ont.: Nelson Canada 430 p. ISBN 0-17-603540-0, 1993.

Lao, S. I., Choy, K. L., Ho, G. T. S., Tsim, Y. C., Poon, T. C., and Cheng, C. K. (2012) A real-time food safety management system for receiving operations in distribution centers. Expert Systems with Applications, The Service Industries Journal, 25(2): 15-45.

Lu, C.-S. and Yang, C.-C. (2010) Logistics service capabilities and arm performance of international distribution center operators. The Service Industries Journal, 30(2):281.

Markovits-Somogyi, R., Gecse, G., and Bokor, Z. (2011). Basic effciency measurement of Hungarian logistics centres using data envelopment analysis. Periodica Polytechnica Social and Management Sciences.

Matopoulos, A. and Bourlakis, M. (2010). Sustainability practices and indicators in food retail logistics: Findings from an exploratory study. Journal on Chain and Network Science.

Menachof, D. A., Bourlakis, M. A., and Makios, T. (2009). Order lead-time of grocery retailers in the UK and Greek markets. Supply Chain Management Journal.

Mentzer, J. T. and Konrad, B. P. (1991) An Effciency/Effectiveness approach to logistics performance analysis. Journal of Business Logistics, 12(1):33-61.

Mirlach, M., Trung T. , Jung M. , Atz Willibald T., Günthner A. (2014) Warehouse and Inventory Management in decentralized Systems Journal of Business Logistics, 12(1):44-66.

Moberg, C. R., Speh, T., (2004), Third-party Warehousing Selection: A Comparision of National and Regional Firms, Mid-American Journal of Business, Vol.19, No.2, pp. 71-76.

Müsiad (2017) Endüstri 4.0 ve Geleceğin Lojistiği, Lojistik Sektör Raporu, retrieved from: http://www.musiad.org.tr/F/Root/Pdf/lojistik_raporlari_2017_12_25.PDF ,
(accessed date: 25.12.2017).

National Accademy of Science and Engineering (2013). Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative INDUSTRIE 4.0, Final Report

O'Neill, P., Scavarda, A. J., and Zhenhua, Y. (2008). Channel performance in China: a study of distribution centers in Fujian Province. Journal of Chinese Entrepreneurship, 1(1):21-39.

REFERENCES (continued)

Özkurt, C. (2016) ENDÜSTRİ 4.0 Perfpektifindeb Türkiye'de İmalat Sanayinin Durumu. (Master Thesis). Sakarya Üniversitesi, SBE, Sakarya.

Prahalad, C.K., Ramaswamy, V. (2004). Co-creation experiences: the next practice in value creation, Journal of Interactive Marketing, 18, 3, pp. 5-14.

Ramaa, A., Subramanya, K., and Rangaswamy, T. (2012). Impact of Warehouse Management System in a Supply Chain. International Journal of Computer Applications.

Rimiene, K. (2008). The design and operation of Warehouse. Economics and Management Journal.

Rogers, D. S., Daugherty, P. J., Ellinger, A. E. (1996), "The relationship between Information Technology and Warehousing Performance", Journal of Business Logistics, Vol.32, No.4, pp. 409-421.

Saetta, S., Paolini, L., Tiacci, L., and Altiok, T. (2012). A decomposition approach for the performance analysis of a serial multi-echelon supply chain. International Journal of Production Research, 50(9):2380-2395.

Think Act (2014), Industry 4.0 The new industrial revolution How Europe will succeed, retrieved from: http://www.iberglobal.com/files/Roland_Berger_Industry.pdf , (accessed date: 12.11.2017).

Voss, M. D., Calantone, R. J., and Keller, S. B. (2005) Internal service quality: Determinants of distribution center performance. International Journal of Physical Distribution & Logistics Management, 35(3):161-176.

Wang, H., Chen, S., and Xie, Y. (2010) An RFID-based digital warehouse management system in the tobacco industry: a case study. International Journal of Production Research

Xie, K., Wu, Y., Xiao, J., Hu, Q. (2016) Value co-creation between firms and customers: The role of big data-based cooperative assets, Information &Management Journal

Yang, K. K. (2000) Managing a single warehouse, multiple retailer distribution center. Journal of Business Logistics

Yang, L.-r. and Chen, J. (2012) Information Systems Utilization to Improve Distribution Center Performance : from the Perspective of Task Characteristics and Customers. Advances in Information Sciences and Service Sciences

APPENDIX

1. Pictures of Material Handling, Storage and IT Equipment:

These pictures downloaded as anonym.

Table A.1.1 Pictures of Material Handling Equipment-Conveyors

Table A.1.2 Pictures of Material Handling Equipment-Cranes and Industrial Trucks

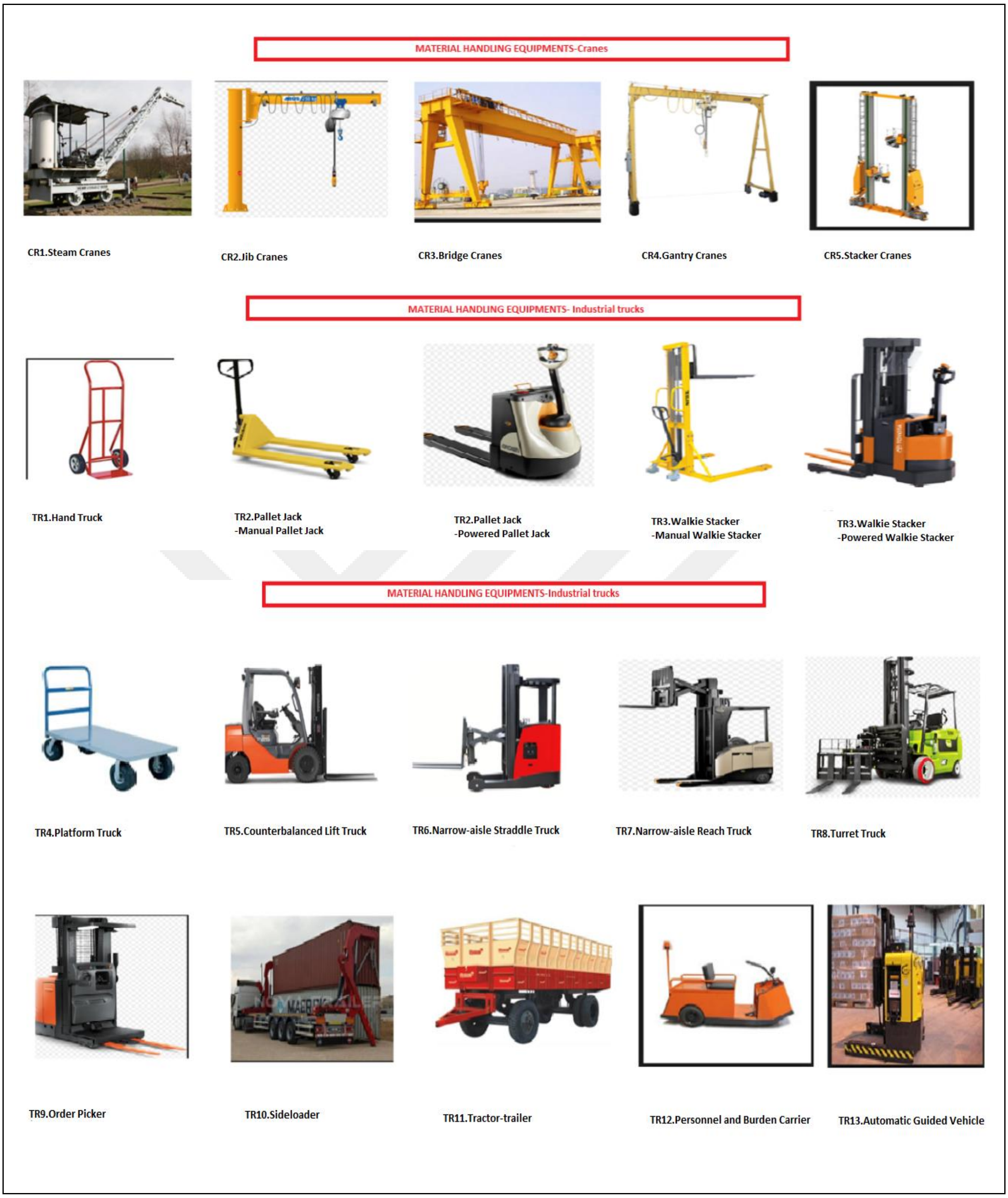


Table A.1.3 Pictures of Material Handling Equipment-Positioning Equipment and Unit Load Formation Equipment

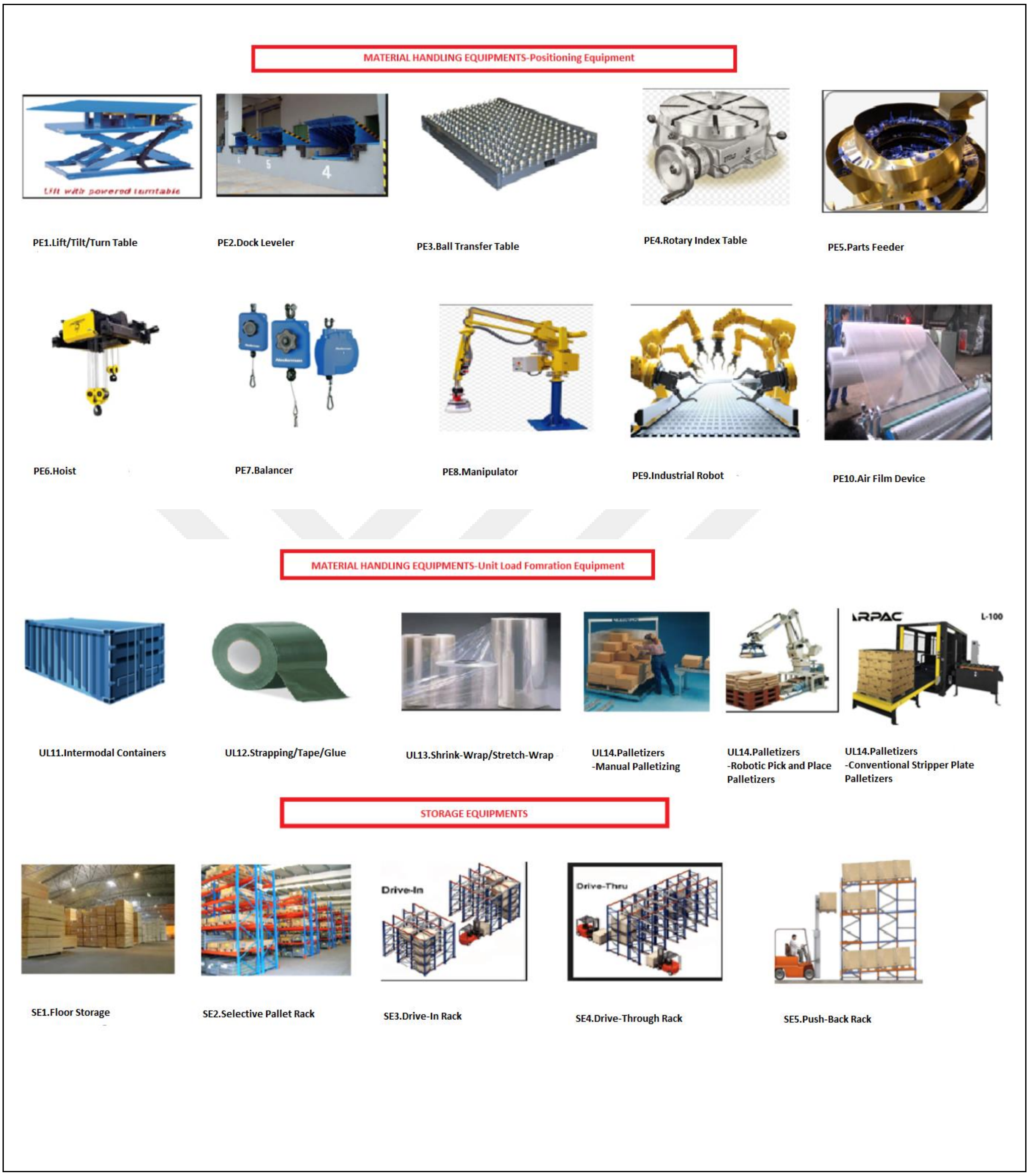
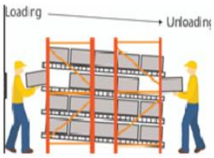


Table A.1.4 Pictures of Material Handling Equipment-Storage Eqıuipment and IT

STORAGE EQUIPMENTS



SE6.Flow-Through Rack

SE7.Sliding Rack

SE8.Cantilever Rack

SE9.Auto Store

SE10.Bin Shelving

SE11.Storage Drawers

SE12.Storage Carousel

SE13.Vertical Lift Module

SE14.A-Frame

SE15.Automatic Storage/Retrieval System

SE16.Stacking Frame

IT EQUIPMENTS

IT1.Manual

IT2.Bar Codes

IT3.Radio Frequency/Identification Tags

IT4.Voice Recognition

IT5.Magnetic Stripes

IT6.Machine Vision

IT7.Portable Data Terminals

IT8.Google Glass

IT9.VR

2. Definitions of Warehouse Equipment (Kay, 2015)

Warehouse Equipment	Definition
I.MHE	
1. Transport Equipment	These include the equipment that are employed to transfer the material or loads from a specific location to another specific location. The locations are such as; workplaces, dock and a storage area, etc. The transport equipment are subdivided as conveyors, cranes, and industrial trucks.
A. Conveyors	Conveyors move the items or materials frequently between specific locations. They are responsible moving materials over a fixed pace. When there is a sufficient flow volume to justify the fixed conveyor investment. Conveyors are categonized in different apects: Its function can change according to the type of product being handled. This means they might contain or work for unit load or bulk load. Location of the conveyor can also be used for identification. They might be in-floor, on-floor, or overhead conveyors. They can also be classified whether the loads can accumulate on the conveyor or accumation is not possible.
1. Hand Cranks and series of pullies	They might be Unit or Bulk load, On-Floor and are Accumulate types. They are generally not expensive and can link two handling devices. They also provide accumulation in shipping areas and convey items between storeys. One disadvantage with it is that it might be difficult to control position of the items.
2. Wheel conveyor	They are Unit load, On-Floor and accumulate type. It works on a series of skate wheels mounted on a shaft (or axle). Spacing of the wheels can change according to the load being transported. It is slope can be arranged for gravity movement depending on the load weight. It is more inexpensive than the roller conveyor. It is advantageous for light-duty work loads. They have genrally flexible, expandable and mobile types.
3. Roller conveyor	These conveyors are Unit loads, they work On-Floor and are accumulate types. They can be powered like alive or nonpowered like working with gravity. The materials to carry must have a firm riding surface. There should be a minimum of three rollers which should support smallest loads every time. It also consists tapered rollers on curves which maintain materials' direction.

4. Chain conveyor	These are unit load conveyors, they can be in floor or on-floor, they do not maintain any accumulation. They work on one or more endless chains on what the loads are passing directly. In their functioning the parallel chain configuration is used as chain pallet conveyor or as a pop-up device for sortation. Another function can be as vertical chain conveyor that is used for continuous and high level repeating vertical movements, where the items on horizontal places are added to the chain links.
5. Slat conveyor	They are Unit load conveyors and can be In- Floor or On-Floor conveyors. They provide no Accumulation. They make use of separately spaced slats connected to it is chain where the Unit loads are being transferred retaining its position. In this sense it is like a belt conveyor. Through its functioning direction and placement of the items are under control. They are generally taken for heavy work loads and for those which might harm a belt conveyor. In the process of Bottling and canning, factories use slat conveyors because they work well in wet conditions, where temperature and hygen requirements have been met.
6. Flat belt conveyor	They are Unit load conveyors and On-Floor, bringing no Accumulation. They work for transferring light- and medium-weight loads between operations, places and storeys. They can perform duties when there is a need for an incline or decline. They are known for providing remarkable control over the direction and placement of the materials. They are not good for smooth accumulation, merging, and sorting on the belt.
7. Magnetic belt conveyor	They are bulk load conveyor and are on-floor types. For it is functioning, a steel belt and/or a magnetic transfer bed and/or a magnetic puller is employed. They genrally transfer the metal materials in vertical directions, upside down, and around corners.
8. Troughed belt conveyor	They are Bulk load and can work on-floor which transfers bulk materials. When they are loaded, the belt takes the shape of the troughed rollers and idlers.
9. Bucket conveyor	They are Bulk load types and can work on-floor to transfer bulk materials in a vertical direction or uprising path. Buckets are positioned to a tie, chain, or belt which automatically unfold at the end of the system.
10. Vibrating conveyor	They are Bulk load conveyors and on-floor types which comprise a trough, bed or tube. They vibrate at a remarkably high frequency and on a small breadth in so that products units or bulk materials can be moved forth.

11. Screw conveyor	They are bulk load conveyors and on-floor types. They are made a tube or u-shaped stationary trough on which a shaft-mounted helix revolves to take forward the loose material with horizontal or rising orientation. It is known to be one of the most frequently used conveyors in the processing sectors and mainly used in agreeculture and chemicals sectors.
12. Pneumatic conveyor	They can be bulk load or unit conveyors and overhead types. In their functioning the air pressure is given to move the materials through vertical and horizontal tubes. In its process the product is fully enclosed and ithey are good at implementing turns and vertical moves.
13. Vertical conveyor	They are known to be Unit load conveyor, functioning On-Floor and maintaining no Accumulation. They are employed for low-frequency recurrent vertically transporting materials to different storeys. It is Differents from a freight elevator in in terms of its desing and capacity to carry people. They might be manually or automatically loaded and/or controlled and can interconncent with horizontal conveyors.
14. Cart-on-track conveyor	They are unit, in-floor and accumulate types. They are employed for transferring the carts on a track. Carts are moved thourgh a rotating tube. Drive wheel is tied to individual carts which rotate on a tube and control the speed by varying slope of link between driving wheel and rotating tube. In the process, the carts are self-reliantly controlled. At the end accumulation can be obtained by holding the drive wheel next to the tube.
15. Tow conveyor	They are unit load, in-floor and accumulate types. They employ tow lines to give force to wheeled carriers such as trucks, dollies, or carts that move on the floor. They are used for fixed-path travel of carriers. Even though, they are generally functioning in the floor, the tow line can also be positioned overhead or flushed away with the ground.
16. Trolley conveyor	They are unit, overhead and no accumulation types. They employ a series of trolleys backed from or within an overhead track. Trolleys are positioned with equal spaced and closed loop path and they are excluded from the chain. Movers are used to move multiple units of materials.
17. Power-and-free conveyor	They are known to be unit load, overhead or on-floor and accumulate types. Their functioning is similar to trolley conveyor because they make use of separately spaced carriers moved by an overhead chain. Powered and gravity conveyor types employ powered and the other non-powered carriers which can be unfastened from the power chain and accumulated or swopped onto subdivisions.

18. Monorail	They are Unit load, Overhead and Accumulate types. Their functioning rely on and nverhead single track (mono-rail) or a track network on which one or more carriers move. Carriers can be powered (meaning electrically or pneumatically working or nonpowered (meaning gravity controlled). Carrier can differ from a simple hook to a hoist which is an self controlling device.
19. Sortation conveyor	They are unit load and can be on-floor or overhead types. Sortation conveyors are employed for integration, detecting, installing, and separating products to be conveyed to specific locations. Sortation system throughput is mentioned with cartons passing per minute CPM. They can rely on merge subsystems, induct sub systems, and sort sub systems.
B. Cranes	Cranes are characterized to carry loads over fickle through horizontal or vertical directions within a limited area. Cranes are employed in the circumstances where there is not enough or recurrent flow of bulks or loads that using a conveyor cannot help. They are known to bring about more flexibility in positioning or placing than available conveyors. However, it is known that they provide more limited flexibility of replacing than industrial trucks. The loads handled by them are far more wide-ranging with regard to their profile and heaviness than those handled by a variety of conveyors. Most cranes are integrated with hoists for vertical carrying, even though manipulators are sometime employed if unique placement of the products is necessary.
1. Steam cranes	This is a kind of crane that processes steam that is backing its hoist.
2. Jib crane	This is a kind of hoist fixed crane that possesses a horizontal jib or boom that is backing its hoist.
3. Bridge crane	It is also called as an overhead crane, running a travelling bridge comprising parallel runways on which the hoist moves.
4. Gantry crane	This crane also has a bridge, which is inflexibly supported on two or more sticks moving on a permanent rail at ground level.
5. Stacker crane	This is a type of crane having a forklift like mechanism. It is employed in autonomous warehouses, automated storage and retrieval systems.
C. Industrial Trucks	
1. Hand truck	It is defined as a simple, small hand supported truck.
2. Pallet jack	It is defined as a manually operating device to up hol and move the pallets.
3. Walkie stacker	It is a type of electric lift truck (or forklift) operated by a person standing on foot called walkie.

4. Platform truck	It is a kind of a low-hung four-wheeled hand truck carrying a sideless platform. It can be powered or manual.
5.Counterbalanced lift truck	It is defined as counterbalance fork-lift truck which acts as mechanic floor conveyor. It is employed for stacking and unstacking products, loads, pallets and loading and unloading racks and trucks.
6.Narrow-aisle straddle truck	It is known to have a similar role as a counter balanced lift truck. It functions with an apparatus and method in the form of a vehicle for transferring, holding up, positioning and retrieving materials in narrow-aisle load storage racks.
7. Narrow-aisle reach truck	It is defined as a loading device working along narrow aisles and having outrigging mechanism at the front side of the truck.
8. Turret truck	It is defined as an operator supported, working on very narrow aisles to carry pallets. It is a kind of counter balanced fork truck having ability to turn 180º within the storage aisle.
9. Order picker	It is defined as a kind of equipment that pick and place the goods needed for filling orders in the storage area.
10. Sideloader	It is a kind of fork lift where the operator handles loads along the sideways. This vehicle can operate in very narrow aisles, allowing for greater storage flexibility.
11. Tractor-trailer	It is defined as a large truck holding a long trailer tied to it from the back side
12. Personnel and burden carrier	This covers all the other types of means of transporting materials and personnel other than a lift truck.
13.Automatic guided vehicle	It is defined as a system of material handling that employs autonomous vehicles such as carts, pallets or trays which are set to move between or among different manufacturing points and warehouse areas without an operator.
D.Positioning Equipment	These include all the equipment and devices that are employed to handle loads on a specific location. For instance, it might be to feed and/or manipulate loads in order to position them correctly for following handling, machining, transport, or storing activities. Not like transport equipment and vehicles, positioning stuff is generally employed for handling at a specific area. It should be noted that the loads can also be positioned by manpower without using any mechanics.
2. Lift/tilt/turn table	It is known to be used when positioning involving the actions as lifting, tilting, or turning of a load.

3.Dock level	It is defined as a mechanic apparatus for leveing or balancing for height differences between vehicles and docks in the process of loading and unloading materials.
4. Ball transfer table	It is defined as a type of conveyor styem which works in an inverted ball up position where materials are quickly transferred across an array of units.
5. Rotary index table	It can be described as a unique work positioning device that is employed in warehouses, enabling the personnel to drill or cut work at exact intervals around a stable, horizontal or vertical axis.
6. Parts feeder	It is a simple device made of leaf springs, electromagnets, vibrating feeder, hopper, sensors, a feeder stand, and is connected to a robot and a vision system.
7. Air film device	It can also be called as an air pallet device which can position heavy loads with large width sizes.
8. Hoist	It is defined as an item which can lift materials or loads by means of ropes and pulleys.
9. Balancer	It is defined as a device having the mechanism to back and control loads. In this process, an operator would only need to guide a balanced and weightless load, like a precise technic in positioning.
10. Manipulator	It is know to be employed in vertical and horizontal transferring and cycling of loads. It has a role of muscle multiplier counterbalancing the weight of a load that operator has only %1 of weight pressure.
11.Industrial Robot	It is also known as intelligent industrial robot which utilizes sensory information for complex control actions rather than simple repetitive pick and position actions.
E. Unit Load Fomration Equipment	These comprise all the equipment and items which are employed to limit loads or materials for the reason that they retain their integrity when they are handled. They are used to make a specific load during transport and storing activities.
1. No equipment	Some materials already maintain their load integrity to be considered as a single load
2.Pallet	It is defined as a platform with enough space between its bottom and top face to let a forklift to raise and move it.
3. Skids	It is defined as a platform generally made of metal with enough space under its top surface to let a lift truck to move underneath for following warehouse operations.

4.Slipsheets	It is defined as a flat material made of thick piece of paper, corrugatedfiber, or plastic where a load can be placed to be slipped away after.
5.Tote Pant	It is defined as a durable container which is used for unifying and protecting different items.
6. Pallet/skid boxes	They can be defined as durable containers to unify and protect loose items for subsequent handling.
7.Bins/baskets/rack	They can be defined as box like containers to unify or separated specific items
8. Cartons	It is defined as a one time usable container to unify and preserve specific and discrete materials or products.
9. Bags	It is defined as a one time usable container to unify and preserve bulk materials.
10. Bulk load containers	It is defined as a durable container which unifies and preserves the bulk materials.
11. Crates	It is defined as one time usable container to preserve different items. It is generally employed for distribution
12.Intermodal containers	It is defined as unit of loads to be handled as a single unit when it is transferred between means of sea and land transportation.
13.Strapping	These are materials to stabilize loads and/or to unify them.
14. Shrinkwrap	These are materials to stabilie loads and/or to unify them by covering.
15. Palletizers	It is known as the manual or automated device to form a pallet of a load.
II. STORAGE EQIPMENT	These comprise all the equipment and items which are employed to hold or buffer loads for a specific time. It should be noted that some storage elements might contain the transport of loads too. For example, the S/R machines of an AS/RS, or storage carousels are also carrying materials. It should be noted that if materials are stacked as a block straight on the floor, then no storage equipment would be needed.
1.Floor storage	It is the manual way of stacking the loads on top of each other by lines on the ground.
2. Selective pallet rack	In this type of rack, pallets are stabilized between load-supporting metal design.
3. Drive-in rack	In this type of rack, the loads are sustained by rails devoted to the upright beams. Lift trucks travel between the uprights beams.
4. Drive-through rack	It is defined as similar to drive-in rack, however it has open access at both ends, allowing access to lift trucks.

5. Push-back rack	In its process, the material units are sustained on an incline to make the gravity-sourced movement of the loads possible within the rack sytem by the roller conveyor.
6. Flow-through rack	It is designed as a FIFO process, being similar to push-back rack sytem for storage density and deepness. In its process rack is fed from the higher end and unfed at the lower end.
7. Sliding rack	It is designed to be able to change the location of the aisle by sliding rows of racks along guide rails on the ground.
8. Cantilever rack	In its process, the loads are sustained by two or more cantilevered arms on which the horizontal beams give access to trucks at the single end.
9. Stacking frame	It can be defined as a system in which interlocking units exist to make stacking of a load possible without crushing.
10. Bin shelving	It can be defined as an alternative shelve to store small, separate, and not uniform items. In its functioning, the pieces of materials placed on shelves or in bins or boxes
11. Storage drawers	It is known to be an alternative to bin shelving to store small, discrete materials.
12. Storage carousel	It is a kind of carousel that comprises a set of horizontally or vertically turning storage baskets or bins on shelves.
13. Vertical lift module	It is a system in which materials are stored on trays inside a multi-bay stockade that are transferred to the opening of a bay for handling.
14. A-frame	In its functioning the units are allotted from equivalent arrays of vertically sloped channels onto a belt conveyor that moves them into a flask.
15. Automatic storage/retrieval system	Such systems are known to involve integrated computer-controlled mechanisms, which compile storage medium, transport mechanism, and storage control with varying levels of automation for quick and correct storage of loads and items.
III. IT Equipment	These include all the equipment and items that are employed to bring together and interchange the information that is necessary for the coordination of the flows of materials and loads in a specific work place and among the warehouse, service providers, suppliers and clients. It should be noted that the identification of the work load and the related control can also be done manually without any specific equipment.

2.Bar code	A bar code contains optical and machine-directive form of data which is employed to decode the content or information of objects. A bar code lets a machine to salvage a means of information about a load of products, in the warehousing case, soon after the object or information is transferred through a specific visual code format made by drawing adjoining lines with various breadths and gaps.
3.RFID	A RFID tag can be defined as electronic tag that interchanges the data with a RFID decoder by radio waves.
4. Voice recognition	Voice recognition can be described as the ability of a machine or program to retrive and interpret human words or simply to comprehend and act accordingly to spoken out commands. Apple's SIRI can be a good example for that.
5. Magnetic stripes	Magnetic stripe technology is known to be allowing data to be stored on a conventional plastic card by magnetically defusing tiny bits within a magnetic stripe on one side of the card. Today, some credit cards have this capability.
6. Machine vision	A machine vision is a system and a new technology that allows a computing device to examine, assess and detect standing or moving images.
7. Portable data terminals	A portable data terminal is used by hand to get data from different locations and to transfer the information to a computer system.
8.Augmented reality (Google Glass)	Google Glass can be defined as a wearable, voice-controlled Android device that is made of a pair of eyeglasses and illustrates information straight on the user's eyes.
9.VR	Virtual reality can be described as a virtual space that is created with a software and shown to the operator in a way that the operator adjourns the belief and assents it as a real space.

3.Score Analysis

Table A.3.1 Conveyors Score Analysis

CONVEYORS	W	A	B	C	D	E	F	G
1. Hand Cranks and series of pullies	W1	1	0	0	0	1	0	0
2. Wheel conveyor	W1	0	0	0	0	0	0	1
3. Roller conveyor	W1	1	1	0	0	1	0	1
4. Chain conveyor	W1	0	1	0	0	0	0	0
5. Slat conveyor	W2	0	0	0	0	0	0	0
6. Flat belt conveyor	W2	2	0	0	0	0	0	0
7. Magnetic belt conveyor	W2	0	0	0	0	0	0	0
8. Troughed belt conveyor	W2	0	0	0	0	0	0	2
9. Bucket conveyor	W2	0	2	0	0	0	0	0
10. Vibrating conveyor	W2	0	0	0	0	0	0	0
11. Screw conveyor	W3	3	0	0	0	0	0	0
12. Pneumatic conveyor	W3	3	0	0	0	0	0	0
13. Vertical conveyor	W3	3	0	0	0	0	0	0
14. Cart-on-track conveyor	W3	0	0	0	0	0	0	3
15. Tow conveyor	W2	0	0	0	0	0	2	2
16. Trolley conveyor	W2	0	0	0	0	2	0	0
17. Power-and-free conveyor	W3	0	0	0	0	0	0	0
18. Monorail	W3	0	0	0	0	0	0	0
19. Sortation conveyor	W3	0	3	0	0	3	0	3
TOTAL		**13**	**7**	**0**	**0**	**7**	**2**	**12**
SCORE		**2.17**	**1.75**	**0**	**0**	**1.75**	**2.00**	**2.00**

Table A.3.2 Cranes Score Analysis

CRANES	W	A	B	C	D	E	F	G
1. Steam cranes	W1	0	0	0	0	0	0	0
2. Jib crane	W1	1	0	0	0	0	0	1
3. Bridge crane	W2	0	0	0	0	0	0	2
4. Gantry crane	W2	0	0	0	0	0	0	2
5. Stacker crane	W3	0	0	0	0	0	0	0
TOTAL		**1**	**0**	**0**	**0**	**0**	**0**	**5**
SCORE		**1.00**	**0**	**0**	**0**	**0**	**0**	**1.67**

Table A.3.3 Industrial Trucks Score Analysis

INDUSTRIAL TRUCKS	W	A	B	C	D	E	F	G
1. Hand truck	W1	1	1	0	0	1	1	1
2. Pallet jack								
(a) Manual pallet jack	W1	1	1	1	1	1	1	1
(b) Powered pallet jack	W2	0	2	2	0	0	2	2
3. Walkie stacker								
(a) Manual walkie stacker	W1	1	0	0	0	1	1	1
(b) Powered walkie stacker	W2	0	2	0	0	2	2	2
4. Platform truck	W1	1	1	1	1	1	1	1
5.Counterbalanced lift truck	W2	2	2	2	0	2	2	2
6. Narrow-aisle straddle truck	W2	0	2	0	0	0	2	2
7. Narrow-aisle reach truck	W2	0	2	0	0	0	0	2
8. Turret truck	W2	0	2	2	0	0	0	2
9. Order picker	W2	0	0	0	0	0	2	2
10. Sideloader	W2	0	0	0	0	0	2	2
11. Tractor-trailer	W2	0	0	0	0	0	0	0
12. Personnel and burden carrier	W2	0	0	0	0	0	0	0
13. Automated guided vehicle	W4	0	0	0	0	0	0	4
TOTAL		**6**	**15**	**8**	**2**	**8**	**16**	**24**
SCORE		**1.20**	**1.67**	**1.60**	**1.00**	**1.33**	**1.60**	**1.85**

Table A.3.4 Position Equipment Score Analysis

POSITION EQUIPMENT	W	A	B	C	D	E	F	G
1. Manual/ no equipment	W1	0	0	0	0	0	0	0
2. Lift/tilt/turn table	W1	0	1	1	0	0	0	1
3. Dock leveler	W2	0	2	0	0	0	2	2
4. Ball transfer table	W1	0	0	0	0	0	0	1
5. Rotary index table	W2	0	0	0	0	0	0	0
6. Parts feeder	W2	0	0	0	0	0	0	2
7. Air film device	W1	0	1	1	0	1	0	1
8. Hoist	W2	0	2	0	0	0	0	0
9. Balancer	W2	0	2	0	0	0	0	0
10. Manipulator	W3	0	0	0	0	0	0	0
11. Industrial robot	W4	0	4	0	0	0	0	4
TOTAL		**0**	**12**	**2**	**0**	**1**	**2**	**11**
SCORE		**0**	**2.00**	**1.00**	**0**	**1.00**	**2.00**	**1.83**

Table A.3.5 Unit Load Formation Equipment Score Analysis

UNIT LOAD FORMATION EQUIPMENT	W	A	B	C	D	E	F	G
1. Self-restraining/No Equipment	W1	0	0	1	0	0	0	0
2. Pallets	W1	1	1	1	1	1	1	1
3. Skids	W1	0	0	0	0	1	1	0
4. Slipsheets	W1	0	1	0	0	0	0	1
5. Tote pans	W1	0	0	0	0	0	0	0
6. Pallet/skid boxes	W1	1	1	1	0	1	1	1
7.Bins/baskets/racks	W1	0	0	0	0	0	1	0
8. Cartons	W1	0	0	0	0	1	1	1
9. Bags	W1	1	1	1	1	1	1	1
10. Bulk load containers	W1	0	1	0	0	0	1	1
11. Crates	W1	0	1	0	0	0	1	0
12. Intermodal containers	W1	0	0	0	0	0	0	1
13.Strapping/tape/glue	W1	0	1	0	0	1	0	1
14.Shrinkwrap/stretch-wrap	W1	1	1	1	1	1	0	1
15. Palletizers								
*Manual palletizing	W1	1	1	1	0	0	1	1
*Robotic pick and place palletizers	W4	0	4	0	0	0	0	4
* Conventional stripper plate palletizers	W3	0	3	0	0	0	0	3
TOTAL		**5**	**16**	**6**	**3**	**7**	**9**	**17**
SCORE		**1.00**	**1.45**	**1.00**	**1.00**	**1.00**	**1.00**	**1.42**

Table A.3.6 Srorage Equipment Score Analysis

STORAGE EQUIPMENT	W	A	B	C	D	E	F	G
1.Floor storage	W1	1	1	1	0	1	1	1
2. Selective pallet rack	W2	2	2	2	2	2	2	2
3. Drive-in rack	W2	0	0	2	0	0	2	2
4. Drive-through rack	W2	0	2	2	0	0	2	2
5. Push-back rack	W2	0	0	0	0	0	0	2
6. Flow-through rack	W2	0	0	0	0	2	0	2
7. Sliding rack	W2	0	0	0	0	0	2	0
8. Cantilever rack	W1	0	0	0	0	0	0	0
9. Stacking frame	W1	0	0	0	0	0	1	0
10. Bin shelving	W1	0	0	0	0	0	0	1
11. Storage drawers	W1	0	0	1	0	1	0	0
12. Storage carousel	W3	0	0	0	0	0	0	3
13. Vertical lift module	W3	0	0	0	0	0	0	3
14. A-frame	W1	0	0	0	0	0	0	0
15.3-D high density storage system (auto-store)	W4	0	0	0	0	0	0	0
16. Automatic storage/retrieval system	W4	0	0	0	0	0	0	4
TOTAL		**3**	**5**	**8**	**2**	**6**	**10**	**22**
SCORE		**1.50**	**1.67**	**1.60**	**2.00**	**1.50**	**1.67**	**2.20**

Table A.3.7 IT Score Analysis

IT	W	A	B	C	D	E	F	G
1. Manual	W1	1	1	1	0	1	0	0
2. Bar codes	W2	2	2	2	0	2	2	2
3. RFID	W3	0	0	0	0	0	3	3
4. Voice recognition	W2	0	0	0	0	0	2	2
5. Magnetic stripes	W1	0	0	0	0	1	1	1
6. Machine vision	W3	0	0	0	0	0	0	3
7. Portable data terminals	W2	0	0	0	0	0	2	2
8.Google Glass (Augmented reality)	W3	0	0	0	0	0	0	3
9.VR	W3	0	0	0	0	0	0	3
TOTAL		**3**	**3**	**3**	**0**	**4**	**10**	**19**
SCORE		**1.50**	**1.50**	**1.50**	**0**	**1.33**	**2.00**	**2.38**

CURRICULUM VITEA

Duygu OLCAY was born in İzmir. She is working Ocean Operations Specialist at a private company (Turkey) since November in 2015. She received her bachelor degree in International Trade and Finance from Yaşar University Faculty of Economics and Administrative Sciences in 2015 and she attended her MBA from Yaşar University. She has taken the courses about various topics, including Analytical Methods, Operations Management, Marketing Trends, Management Economics for Business etc.