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Making Factories Smarter Through Industry 4.0

Supervisors:
Prof. Benfratello Luigi

Candidate:
Ziad Hassan Mohamed Hassan Ibrahim Elkady

S251822

Abstract

The Industry 4.0 is now underway, changing traditional manufacturing into smart manufacturing and creating new opportunities, where machines learn to understand those processes, interact with environment and intelligently adapt their behavior. Big data and artificial intelligence (AI) make machines in industrial production smarter than before addressing the question of how to build computers that improve automatically through experience. The smart factories represent a new trend of industrial from more conventional computerization to a completely associated and adaptable framework one that can utilize a steady stream of information and data from associated activities and creation frameworks to learn and adjust to new demands. The main objective of this thesis is to investigate the implementation process of industry 4.0 in the future by studying a real case study of a company in Belgium, summarizes challenges and future trends of Smart applications for smart factories manufacturing and provides an overview of several that are able to give the answers to those issues and avoid the potential problems in the future.

Acknowledgement

I wish to express my gratitude to everyone who supported me throughout the process of conducting this research project. I am genuinely thankful to them for sharing their ideas, truthful views and professional opinions on the topic related to my work. I would like to thank all people at **Politecnico di Torino** and **Ghent University** of Industrial Engineering and Management department for providing me with the facilities and resources required for this study. I am deeply grateful to ***Prof. Luigi Benfratello***. This thesis would have been incomplete without his constant assistance and dedicated involvement. I also thank those who took time to participate in the survey, helping me to make the project of a better quality. Finally, I must express my gratitude to everyone involved in my personal life for listening and encouraging me throughout my studies and during the process of writing this project.

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Chapter (1): Introduction:

This thesis aims to find out, analyze and highlight the smart factories within the fourth industrial revolution. It starts with the introduction and history of Industry 4.0 in the world, tells briefly about Industry 4.0, History of Industry 4.0 and provides some information about the techniques on different sectors to understand the current situation and realize the opportunities for implementations related to Industry 4.0. It continues with highlighting the Industry 4.0, its size and related industries, and ends with the introduction of Infeed Item Sorting and its benefits in Supply chain Management (SCM).

In the third part, the research focuses on the Smart Factories and its impact on the logistics field industry. Firstly, it explains the smart factories in detail including its effect in the SCM process. Secondly explains with the case study information of Infeed Item Sorter and its importance due to the production. It is ended by the studies on different markets and industry-related statistics to give numbers and various data based on the industry potential and demands.

Finally, the research's thesis ends with the conclusion part in which the final recommendation and implications of all the previously mentioned data, information and researches are explained, and the study is summarized.

Research Aims:

In the end we will get the goals of the research will be:

- Study the automated sorter and relating this information to separation efficiency.
- Increases the production through smart factories.
- Utilizing the full Capacity of Sorting Systems with new Infeed Technology for increasing the volume of production per day.
- Suggest recommendations to achieve a better separation for our automated sorter through the study of the effect of various particle sizes and shapes at varying throughput.

History of Industry 4.0

For many centuries our societies have been constantly challenged by fundamental innovations, developments and new ideas, facilitated through visionaries, scientists and entrepreneurs. Generally, these transformations influenced certain parts of our lives like our culture, the applied sciences, the humanities, politics or our work environments. However, there have also been "revolutions", which truly formed our whole existence and turned our lives forever and as it appears today, for the better. Talking about such revolutions today, literature usually cites the "Industrial Revolutions" as essential foundations for our modern life. According to the literature, scientists and researchers, we have experienced three major Industrial Revolutions yet and together they facilitated the transformation of an, until the beginning of the 18th century, agricultural and human-work dominated life to a world in which economies and products today are crafted by automated, programmed and special-purposed machines and robots. And of course, that transformation changed the way people have been working are working together and how they have to be managed and controlled. The First Industrial Revolution happened in the 18th century and had its origin in Great Britain. Prior to the First Industrial Revolution, people predominantly lived in rural orientated societies and manufacturing was mostly done in people's homes, using hand tools or basic machines. But it was during this time that the consideration of iron and steel as resources and new input factors, the use of new energy sources, such as coal, the steam engine, electricity, petroleum or the internal-combustion engine that started the invention of new machines. The spinning jenny and the power loom for example facilitated the opportunities for an increased production with less human energy as critical input factor. But maybe the most important change happened in the organization of work itself. It was during these days that for the first-time people gathered & worked together under one roof and the "factory" was born. Furthermore, this new work organization initiated the division of labor and the specialization of functions and successively enabled mass production processes. Nevertheless, the new "factory workers" had to acquired new, innovative and more specialized skills to fulfill their tasks and their labor relations to their tasks shifted fundamentally. Instead of being a craftsman working with hand tools, they started to be machine operators and being subjects to factory discipline. This marks the first-time employees needed to be managed, organized and controlled under an all embracing "umbrella" with regulated organizational hierarchies, structures and systems. Finally, other important developments occurred in the transportation and communication sector, including the invention of steam locomotives, steamships, automobiles, airplanes, telegraphs and radio. And thanks to the First Industrial Revolution we saw the first application of science and research to industry and manufacturing. The Second Industrial Revolution is said to have happened in the late 19th, early 20th century. While the First Industrial Revolution was centered on textiles, iron and steam engine technologies, the Second Industrial Revolution evolved more around steel, railroads, petroleum, chemicals and electricity. Until the 1850s', engineering, medical technology and agriculture were understood as applied knowledge in which things just happened to work, but there was no real understanding why they worked. However, since the light start of applied sciences at the end of the First Industrial Revolution, it was during the Second Industrial Revolution when considerable feedback flows from technology to science started to be become an essential part in industry and manufacturing. Refocused scientific thinking in the light of novel inventions instead of improving already existing, new technologies creating better instruments and equipment to measure and register scientific facts and regularities, as well as to test hypotheses, were common strategies[4]. For the first time, synergies of fuels, science and technical innovations were achieved and enabled the creation of high-energy societies engaged in mass production. The Second Industrial Revolution was also the nativity for a new information age through the extensive spread of communication systems, like telegraphs, telephones and radios.

Truly, one of the greatest inventions of these days was the assembly line in the early 20th century. Henry Ford installed the first moving assembly line in his automotive manufacturing factory on December 1st, 1913 and forth on changed our production and manufacturing processes forever5. The principle of an assembly line is that each worker is assigned to one unique task within the production process that he repeats for each product and when he is finished, the product moves to the next worker who does his or her unique task until all tasks are completed and the product is finished. Was it the consolidation of workers under one factory roof during the First Industrial Revolution, the assembly line was an inevitable continued improvement during the Second Industrial Revolution that allowed to structure production processes more detailed and logical under one roof. It was the first time we had an, by electricity powered, automated production processes using conveyor belts to operate the assembly lines, which led to an increase in productivity, efficiency of labor and the opportunity for mass production. Nevertheless, the split of the production process into many specialized tasks and the implementation of automated assembly lines surely increased the complexity of managing, organizing, monitoring and controlling. And finally, the speed of the entire assembly line obviously depends of the weakest or in that case, the slowest worker in the chain.

This marks the starting point for the introduction of scientific management, or better known as "Taylorism" to factories, manufacturing operations and to management in general. In his book Principles of Scientific Management Frederick Winslow Taylor laid down the fundamental principles of large-scale manufacturing through assembly line factories and highlighted the opportunities to maximize efficiency and profits. Taylorism defines a production efficiency methodology that breaks every action, job, or task into small and simple segments that can be easily analyzed and taught. It aims to achieve maximum job fragmentation to minimize skill requirements and job learning time, separates execution of work from work-planning and management, separates direct labor from indirect labor replaces rule of thumb productivity estimates with precise measurements based on scientific studies of the tasks, introduces time and motion study for optimum job performance, cost accounting, tool and work station design and makes possible payment-by-result method of wage determination. However, Taylor was often criticized for alienating workers by (indirectly but substantially) treating them as mindless, emotionless, and easily replicable factors of production without possessing an own individuality.

Striving to increase their profits, factory owners used Taylor's principles to split production processes in even smaller and more unskilled tasks. They achieved standards that enabled them to hire people with the lowest skill sets and subsequently minimize their labor costs. However, as every single task got more unskilled and reduced, the tasks also got more unpleasant and dissatisfying. Overall, labor has turned into a simple commodity that was tradable easily and hence the competition between workers and prospect workers intensified. As results, wages have been depressed and workers were confronted with a lower level of job security as everyone could be quickly replaced if he made a mistake. Furthermore, the speed and productivity of the assembly lines had been forced, by the owners and due to the boosted economic competition, to increase and ultimately intensified the demands of work even more. However, at a certain point, the workers didn't want to accept their bad situation and started to organize in groups and unite their individual bargaining power against the owners and management. The "labor unions" were born. With their newly owned bargaining power as united groups, they have been trying to force the management and factory owners to improve the working environment, increase wages and to provide other benefits. But the growing number of labor unions, affiliated labor union members and strengthened overall power of labor unions in the mid-twentieth century also led to a push on the part of management and factory owners to accelerate the process of automation. And of course, that make sense as machines do not argue and discuss with you and don't have any demands to the work environment, except electricity. In general, the management only did what is best for business. They tried to eliminate the highest risk factor in the production process, human labor, and make the production processes more predictable, consistent & reliable and ultimately minimize interruptions. Meanwhile, behind closed military and governmental doors, the foundation for many more technological leaps was developed, the "transistor". It was introduced in 1947 and during the next two decades it paved the way for the development of advanced digital computers and finally led to the development of the "World Wide Web" in the 1990s. When computers became a more familiar machine in the 1980s, they also became a necessity for many jobs and the new computer-controlled processes further accelerated the automation of production and the de-humanization of work. We refer to this movement as the Digital Revolution, or Third Industrial Revolution. It explains the advancement and development of technology from analog electronic and mechanical devices to the digital technology available today.

Like the Second Industrial Revolution turned employees from hand crafters into machine operators, the Digital Revolution turned them from machine operators into computer operators or knowledge workers. Now, employees needed the skills to use computers and to program machines and robots, and blue color workers onsite the production floor disappeared more and more. But as those computer skills were rare and thus expensive and hard to control, management and owners had to find new strategies and practices to ease the requirements for such jobs. Instead of knowledge being "locked" into one person's head for which a wage premium can be charged, working knowledge should be made available to corporations in the form of software programs and standardized prescripts that then can be used by lower-skilled workers as well. This routinization process of production platforms and processes is called "Digital Taylorism".

Innovations can be translated into sets of routines that might require some degree of education but not the level of creativity and independence of judgment which are key skills of modern knowledge workers. Where it once seemed impossible for high-skilled work to be codified and standardized, it became clear that even highly skilled jobs could be targeted in the same manner like the crafting knowledge was captured by companies through assembly lines during the Second Industrial Revolution.

Nevertheless, knowledge workers' level of creativity and the independence of judgment did strongly depend on the amount of information they possessed and thus in the early stages of the Digital Revolution, information was a cost factor for businesses when applying the traditional economic thinking. In addition, as computers were stand-alone entities in the beginning, the information was mostly stored on single computers within the organization, sometimes connected to a network. But that was only feasible within one organization and not between more organizations. Only through the extreme development of the Internet, it became feasible to connect computers in almost limitless global public information infrastructures. Because information was now easily shareable and tradable, information changed its status from a cost factor to a factor of value creation and new technologies enabled everyone everywhere on this planet to capture, store, transfer and even manipulate information. This new competitive era is labeled as the Information Age. But still, in the manufacturing and production industries you did need persons who did feed the machines and robots in the production lines with the required information and data and who did control that they execute the programmed commands correctly.

And there we are in the present, at the edge of the Fourth Industrial Revolution, also referred as Industry, the indisputable peak of the Information Age so far. Right now, we are experiencing a world in which the real and the virtual worlds are rapidly converging. That process leads us to the concept defined as the "Internet of Things" (IoT), which describes a future where every day physical objects will be connected to the Internet and will have a digital voice, thus they will be able to identify themselves to other devices and will also be able to communicate with each other. This means that objects are not just connected to you as a single recipient anymore, but also to surrounding objects, devices or even entire databases via cloud storage. And that not only on a factory level but also in a global context. The devices develop a so called "ambient intelligence", a recent paradigm emerging from "Artificial Intelligence" (AI), where computers are used as proactive tools assisting people with their day-to-day activities, making everyone's life more comfortable". Thereby, AI is an area of computer science that emphasizes the creation of intelligent machines that work and react like humans.

Applying the ideals of the IoT and the dynamics of connected devices, machines, materials and physical objects to manufacturing enterprises lead us to the visionary concept of "Smart Factories". They are envisioned to represent context-sensitive manufacturing environments, which can handle turbulences in real-time production using decentralized information and communication structures for an optimum management of production processes. In those environments, manufacturing machines will be connected to the company's virtual network, computer systems, intranet and each other, as well as to the Internet to obtain every single bit of information and data they need for their task within the manufacturing process. Second, products will be uniquely identifiable through bar codes, chips and/ or other identifying mechanisms and may always be located via sensors and/ or other identification readers integrated in the manufacturing machines. Combined, future production systems and plants are anticipated to control themselves on their own and products should be able to autonomously control their own manufacturing processes, be able to advise the production system and related machines what services they need, how they have to be processed and forwarded, and be able to conduct their own quality control. As a goal, machinery and equipment should be able to improve processes through self-optimization and autonomous decision-making based on accessible data and information without any involvement of human workers.

In the preceding as well as most of the current industrial value chains, including product design, production planning and production engineering, production execution and services are implemented and managed through separate departments. But within Smart Factories all these production steps will be consistently connected, both, on the horizontal value chain (from inbound logistics via the manufacturing process to outbound logistics) as well as on the vertical value chain (audit and monitoring systems, planning and management tools, human resource and marketing departments). It will not matter in which company's plant they are around the globe because every single factory will be connected through the company's own IoT network and cloud.

Chapter (2): Literature review:

The Industry 4.0 lays on the increment of available data sets. Different types of available, large and complex sets of data, namely big data, cannot be processed by using existing conventional technologies. Advanced methods, technologies, algorithms and software must be used in order to collect and extract data from the manufacturing environment. Big data changes the way decisions are made inside the manufacturing environments based on different scientific areas such as computer science, mathematics and advanced statistics.

Theoretical Framework

The theoretical framework introduces the concept of Industry 4.0 which includes key technologies of Industry 4.0 and challenges of adopting Industry 4.0. Furthermore, the concept of diffusion of innovation is introduced along with the innovation process and the technology-organization-environment framework. On this basis the authors suggest a process for the adoption of technological innovation. Moreover, a maturity model for Industry 4.0 is suggested. Figure 1 shows the relationship between the research questions and the sub-chapter in the theoretical framework.

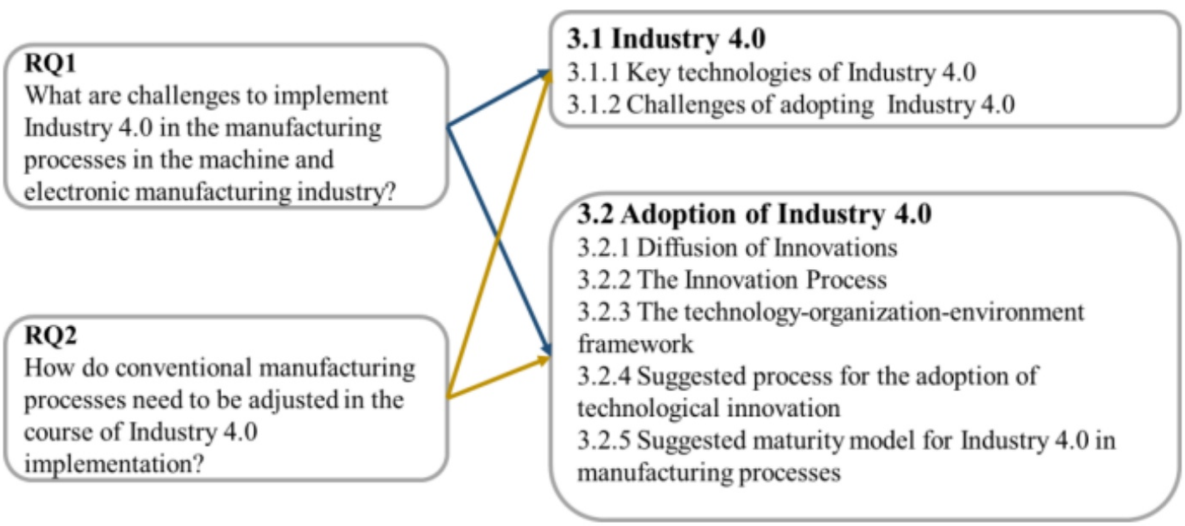


Figure 1:Relationship between the research questions and the theoretical framework

Industry 4.0

The concept of Industry 4.0 has gained large popularity and importance since it was first introduced by the German government at the Hannover Fair in November 2011. The aim and the core of each industrial revolution is to increase productivity. As can be seen in Figure 2, the first industrial revolution took place when steam power was developed which helped to increase productivity. The second industrial revolution took place when electricity was used to increase productivity.

The third industrial revolution happened when electronics and IT were used to improve productivity and efficiency.

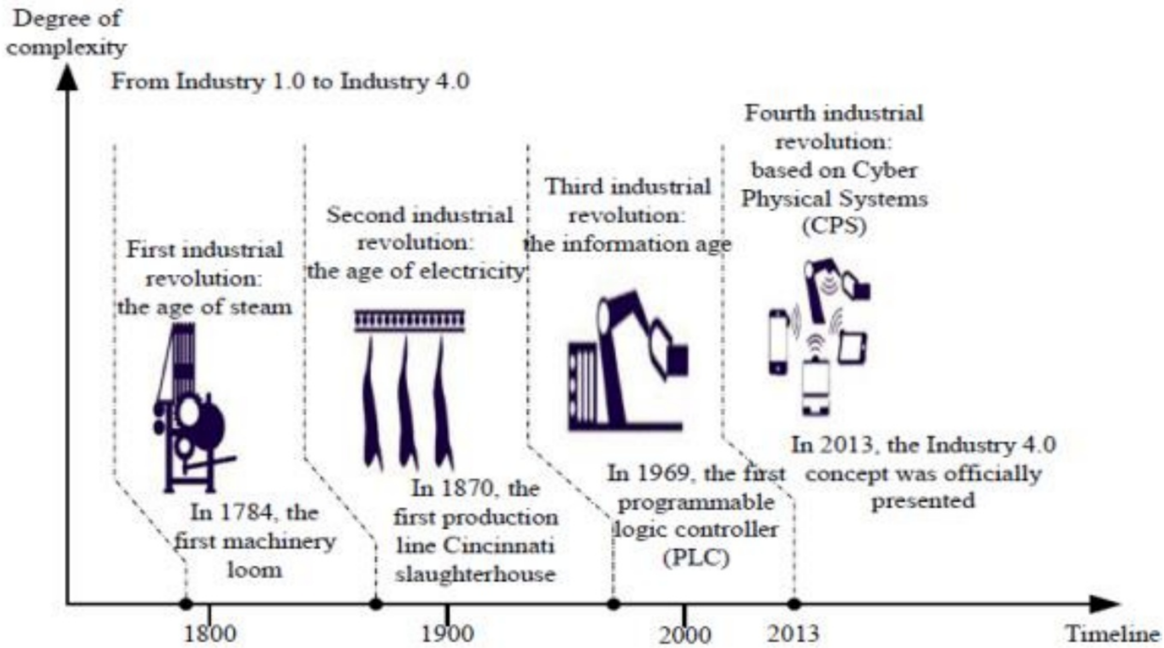


Figure 2:Concepts of Industry 4.0

Nowadays, Industry 4.0 is developing a brand-new commercial area so that it will rely upon data acquisition and sharing alongside the complete supply chain. At the equal time, Industry 4.0 is a brand-new technique to attach the virtual world with the bodily world. In addition, Oesterreich and Teuteberg (2016) stated that Industry 4.0 may be defined as "the producing environment's extended digitization and automation further to an extended communication enabled with the aid of using the advent of a virtual price chain".

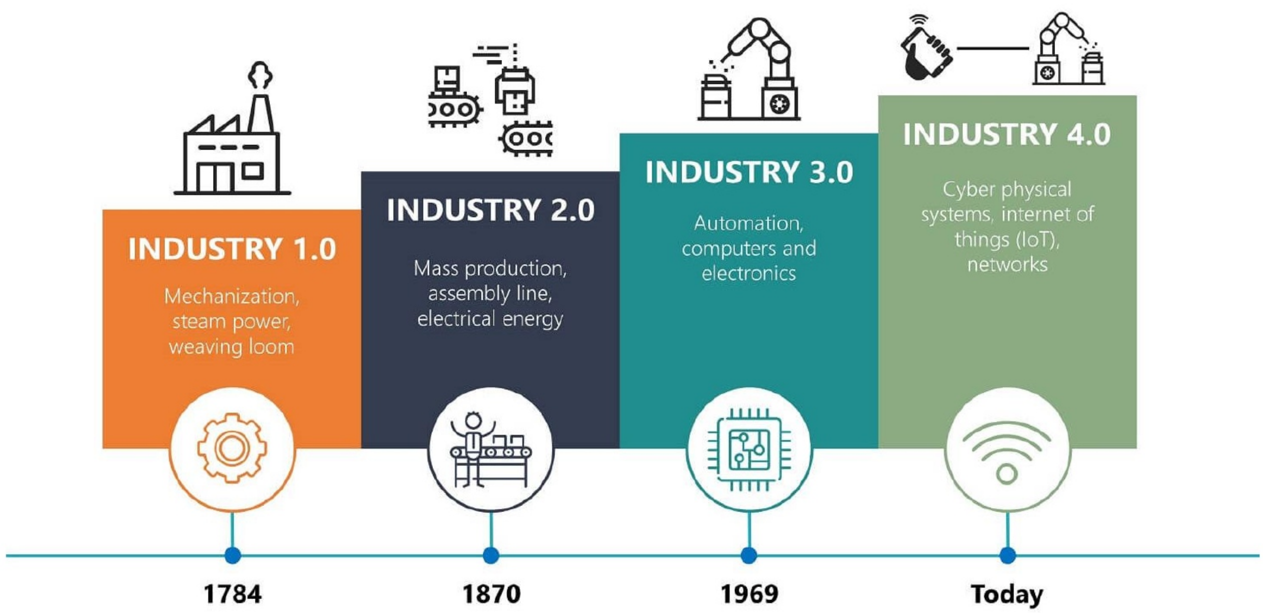


Figure 3:History of Industry 4.0

Key technologies of Industry 4.0

According to Pereira and Romero (2017), the components of Industry 4.0 is an "umbrella time period for a brand new commercial paradigm" and it include Cyber-Physical System(CPS), Internet of Things (IoT), Internet of Services (IoS), Robotics, Big Data, Cloud Manufacturing and Augmented Reality. In the subsequent parts, the important thing technology of Industry 4.0, in addition to demanding situations of adopting Industry 4.0, can be delivered as a theoretical basis.

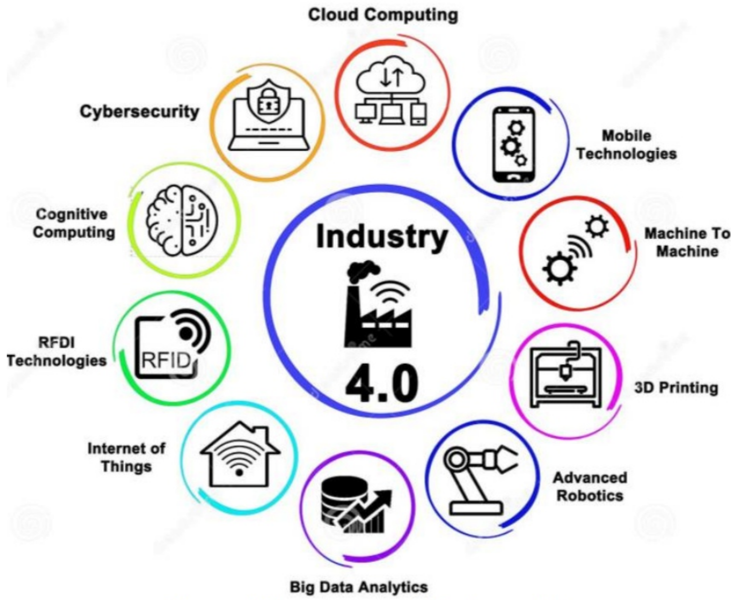


Figure 4:Components of Industry 4.0

(1) Cyber-Physical Systems (CPS)

Cyber-physical systems (CPS) are engineered systems built and dependent upon the integration of computational algorithms and physical components. Together with the internet, data, and services available online, embedded systems join to form cyber-physical systems. CPS are enabling technologies that will transform the way people interact with engineered systems. New smart CPS will bring virtual and physical worlds together and enable a networked world where intelligent objects communicate and interact. These technologies promise to revolutionize human interactions with the physical world in much the same way that the internet has transformed human interaction with information.

CPS enable interactions between high performance software-based embedded systems and dedicated user interfaces integrated into digital networks. This creates a completely new world of system functionality. CPS use shared knowledge and information from processes to independently control logistics and production systems. They are the bridge that connects IoT with higher-level services, known as the Internet of Services (IoS). Software providers, service providers, brokers and users collaborate to develop flexible applications that can be dynamically integrated with one another.

CPS also represent a paradigm break from existing business and market models, as revolutionary new applications, service providers, and value chains become possible. Industry sectors such as the automotive industry, energy, economy and healthcare, will in turn be transformed by these new value chain models. In the future, advances in CPS will enhance human security, efficiency, comfort and health. It is expected that CPS will play a central part in addressing the fundamental challenges posed by demographic change, scarcity of natural resources, sustainable mobility, and energy change.

The new generations of CPS and their emerging platforms, such as the IoT and the Industrial Internet of Things (or Industrial Internet) will influence the formation of future smart and connected environments, including smart cities. This will cut across several challenges that will need to be addressed through the creation of a sustainable Industry 4.0 governance model: ensuring control, dependability, networking, privacy, security, safety, transparency and interpretability

The importance of cyber-physical systems:

CPSs are integrations of computation, networking, and physical processes: the combination of several systems of different nature whose main purpose is to control a physical process and, through feedback, adapt itself to new conditions, in real time.

CPSs are transforming the way humans interact with engineered systems, just as the internet has transformed the way people interact with information. Humans will remain crucial in this scenario. As the most flexible and intelligent “entity” in the CPS, humans assume the role of a sort of “highest-level controlling instance”, supervising the operation of the mostly automated and self-organizing processes.

A CPS, being composed of many heterogeneous elements, requires complex models to define each sub-system and its behavior. Dynamic interactions among sub-systems are then orchestrated by an overarching model: a control entity which ensures a deterministic behavior of each sub-system. Current design tools need to be upgraded to consider the interactions between the various sub-systems, their interfaces, and abstractions

(2) Internet of Things (IoT) and Internet of Services (IoS)

As one of the latest IT developments, Internet of Things (IoT) fundamentally changed communication in SCM by providing human to things communication. The term IoT was coined in 1999 and initially referred to the possibility of using radio-frequency identification (RFID) tags for tracking objects define IoT in the context of SCM as follows: “The Internet of Things is a network of physical objects that are digitally connected to sense, monitor and interact within a company and between the company and its supply chain enabling agility, visibility, tracking and information sharing to facilitate timely planning, control and coordination of the supply chain processes”.

As said via way of means of Pereira and Romero (2017), the idea of Internet of Service (IoS) has emerged recently, it'll offer new possibilities to the carrier enterprise in view that IoS gives the commercial enterprise and technical foundation for carrier companies and clients to the carrier companies and clients via way of means of a commercial enterprise and technical foundation. Schmidt, et al. (2015) outline IoS as a brand new commercial enterprise model with a purpose to extrude how offerings are furnished and permit a better fee advent as the end result from the connection amongst deliver chain partners.

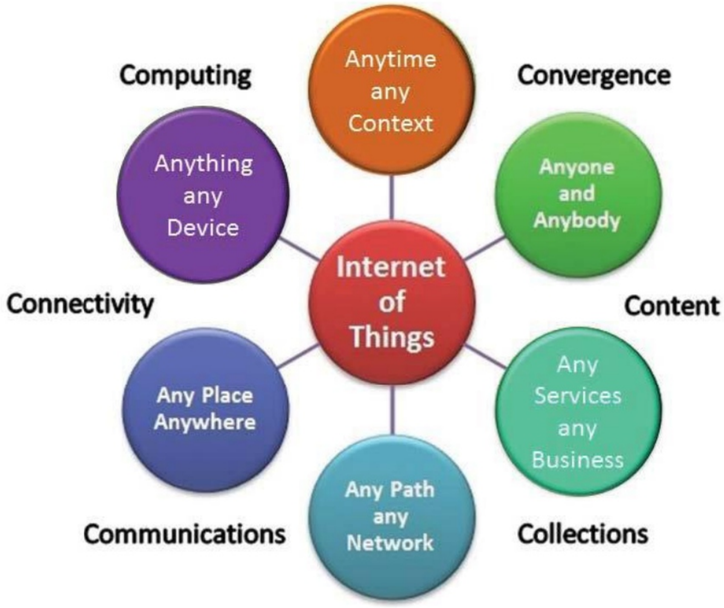


Figure 5:Internet of things

Adoption of IoT can provide new possibilities to users, producers and businesses in business environments and complete deliver chains. It has a strong affect in special fields which include automation, business manufacturing, logistics, commercial enterprise processes, method control and transportation. Furthermore, there's a brand-new time period referred to as Industrial Internet of Things (IIoT)because of this that the utility of IoT in enterprise. To enhance present day business systems, IIoT applies disruptive era which include sensors, actuators, RFIDS, software, manage-systems, machine-to-machine, records analytics and security mechanisms. Nowadays, IoT emerges within three major fields which include process optimization, optimized resource consumption and creation of complex autonomous systems.

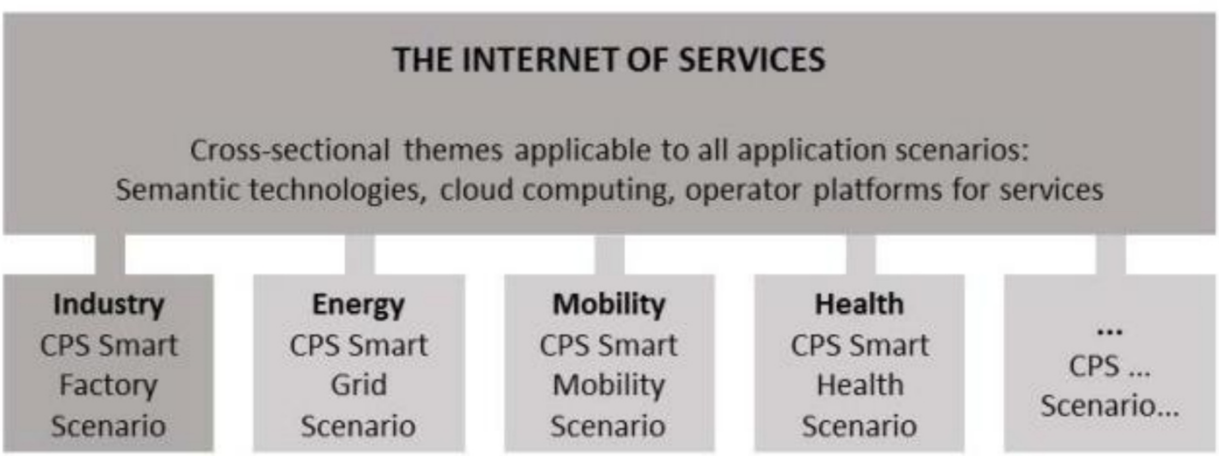


Figure 6:Internet of services

(3) Big Data (BD)

Big facts as technology has obtained increasing interest each with the aid of using researchers and the media. Bigdata refers to acquiring, storing and studying massive quantity of facts from one of a kind reasserts to boom the fee added. It can consequently be considered as a "trending new organization machine or platform" on this international technology for all varieties of industries. The time period "Big Data" may be described as a brand-new technology of technology designed for corporations to extract fee from massive facts volumes.

(Richard, 2011) states that Big facts may be described in phrases of the '3Vs', particularly volume, velocity and variety. The extent that Bigdata produces every 2d has already handed all facts saved withinside the internet two decades ago. The time period facts pace refers to the velocity of facts. Variety of facts consists of dependent and unstructured facts; maximum to be had facts is usually unstructured. (Tenkorang & Helo) said that Big Data presents possibilities in SCM as an evaluation instrument for deliver chain dangers and dimension of provider performance. The worldwide created and copied facts extent multiplied with the aid of using almost 9 instances from 2010 to 2014(Addo-Tenkorang and Helo, 2016). This can to a massive quantity be visible as a result from distinctive gadgets hired in contemporary day deliver chains, including embedded sensors, computer structures and automated gadgets (Tenkorang& Helo,2016).

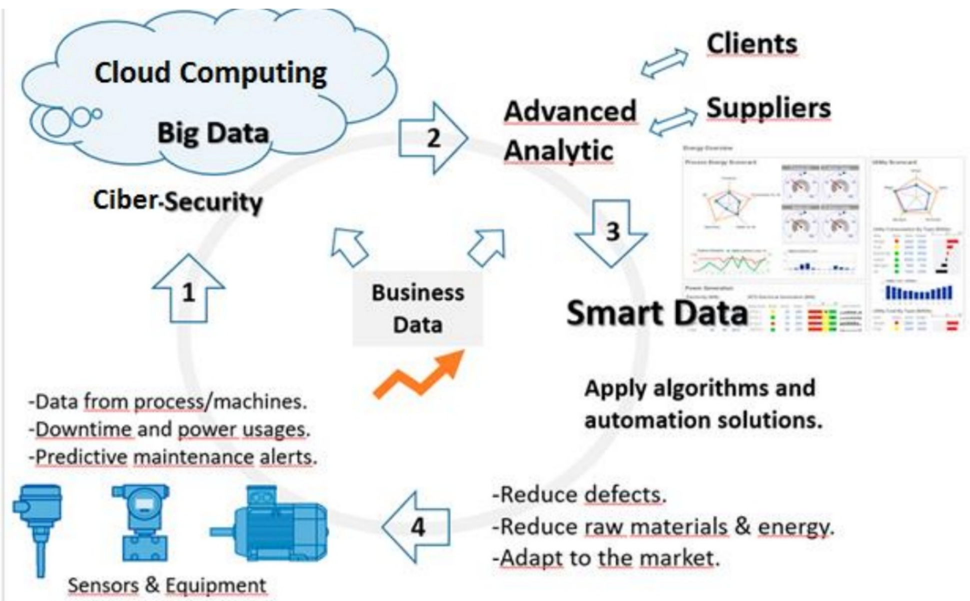


Figure 7:Big Data

(4) Cloud Manufacturing (CM)

Another new paradigm withinside the area of manufacturing is Cloud Manufacturing (CM) that has been delivered as an idea and concept by Adamson (2010). There are many definitions of CM. Most of them describe network-primarily based totally cooperation and functionality sharing as a provider amongst unique cloud users. In addition, CM is the conclusion and provisioning of all forms of production assets for the product improvement lifestyles cycle via way of means of the adoption of Cloud Computing, IoT technologies, Radio Frequency Identification (RFID), sensor networks and GPS.

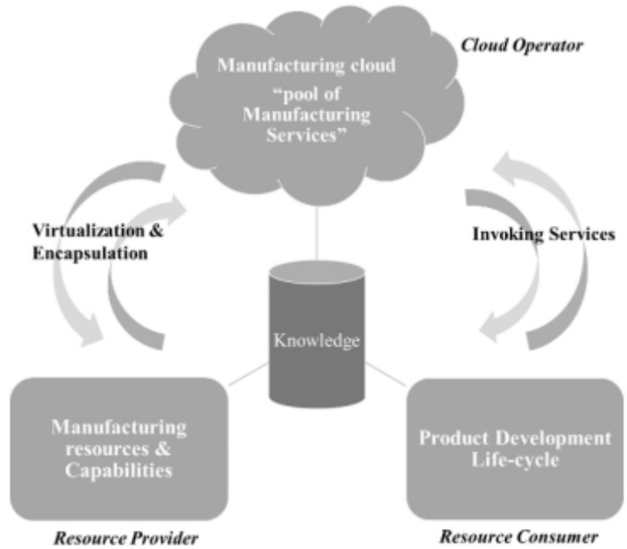


Figure 8:Cloud Manufacturing concept

Furthermore, the primary traits of CM are the "seamless and handy sharing" to reap the concept of Manufacturing-as-a-Service (MaaS) and sharing of various sorts of distributed production assets. As offered in Figure (8), the precept of CM is "for vendors to correctly prepare and encapsulate production assets and skills and lead them to be had as offerings to customers in an operator-run production Cloud" (Adamson).

(5) Augmented Reality (AR)

The goal of AR is simulation, help and development of manufacturing methods with the aid of using a progressive and powerful answer of troubles earlier than those methods may be carried out. AR packages encompass hardware and software program along with head-hooked up shows and correct trackers.

Augmented Reality (AR) tools carried out in distinctive stages of the product existence cycle and feature offered vital contributions to all stages. In precis it may be stated that the goal of AR packages is to reinforce the scene regarded with the aid of using the person with additional statistics with the aid of using combining the actual scene regarded with the aid of using the person with the virtual scene that has been generated with the aid of using a computer.

(6) Smart Factory

Smart Factories are a future form of industrial networks and are based on collaboration through cyber-physical systems. According to (PWC 2013) 50% of German Firms announce that they are building up such networks and 20% of companies have begun to implement Smart Factory. Furthermore, the aim of this smart manufacturing networking is controlling machines and products by interaction between them. Most of the new factory concepts are sharing attributes of smart networking. Furthermore, these manufacturing solutions will create an intelligent environment throughout supply chains to achieve flexible and adaptive processes (Pereira and Romero, 2017). Moreover, Smart Factories are composed of a new integrative real-time intercommunication among each manufacturing resource. This manufacturing resource has sensors, actuators, conveyors, machines, robots.

Figure (9) illustrates a Smart Factory framework that includes four tangible layers: physical resource layer, industrial network layer, cloud layer and supervision as well as control terminal layer. The physical resources are smart things and can be used for communication through industrial networks. The cloud layer can be applied in several information systems such as ERP to collect massive data based on the physical resource layer, and then, exchange the data with people by the terminals. Therefore, this tangible framework can achieve free information flow in a networked world. Simultaneously, this framework of Smart Factory as a CPS can be used for deep integration of physical artifacts and information entities.

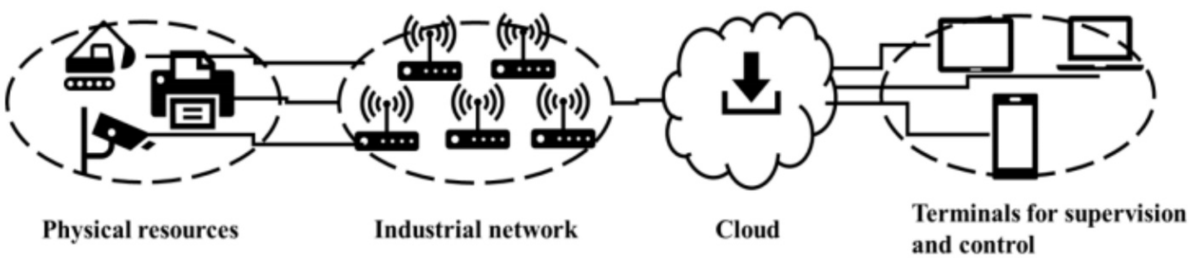


Figure 9:A brief framework of the Smart Factory of Industry 4.0

AI is a main technology for the adoption of smart factories of Industry 4.0. Tecuci defines AI as "the Science and Engineering domain concerned with the theory and practice of developing systems that exhibit the characteristics we associate with intelligence in human behavior, such as perception, natural language processing, problem solving and planning, learn and adaptation, and acting on the environment". For example, Decision support systems (DSS) are computer-based systems of AI for supply chain partners. DSS uses the required data, documents, knowledge and communication technologies for companies to solve complex problems.

Summary of Key Features of Industry 4.0

A key feature of Industry 4.0 are the three levels of integration:

(1) vertical integration,

(2) horizontal integration and

(3) end-to-end digital integration.

Vertical integration refers to the combination of IT systems, processes, sources and facts flows at some stage in all departments and hierarchy degrees in an organization. Horizontal integration refers to the combination of those factors inside an organization in addition to among the focal business enterprise and its providers and customers. The motive of those factors of integration is to acquire an end-to-end virtual integration alongside the complete deliver chain to lessen operational costs (Pereira and Romero, 2017). Since the idea of Industry 4.0 is as an alternative complex the authors of this thesis created a visible that integrates the important thing idea of Industry 4.0 with the 3 degrees of integration brought above. The visible may be visible in Figure 10 and builds a terrific foundation for a briefing report that may be used to introduce the idea of Industry 4.0 to interviewees for the duration of the facts series to acquire a not unusual place information of the idea and associated terminology.

The parent suggests a triad, which way the supplier's organization, a focal business enterprise in addition to the customer's organization. The visible suggests the 3 degrees of integration associated to Industry 4.0. Looking on the focal business enterprise, the visible suggests the computational surroundings in addition to the bodily surroundings and the carrier surroundings. By connecting the computational surroundings with the bodily surroundings, a cyber-bodily gadget is created, this gadget may be related to the internet that is then called Internet of Things. When connecting the carrier surroundings with the computational surroundings the Internet of Service is created (Pereira and Romero, 2017).

Furthermore, the visible consists of key technology of Industry 4.0, including gadget-to-gadget communication, robotics and Augmented Reality in addition to music and hint with RFID symbolized through merchandise for the duration of transportation. Big Data and Cloud Manufacturing are similarly examples for technology that combine the computational surroundings and the bodily surroundings. When all the key technology is carried out to complete extent the factory on top of that is equipped with Artificial Intelligence to make decisions based on the collected data, this can be referred to as a Smart Factory.

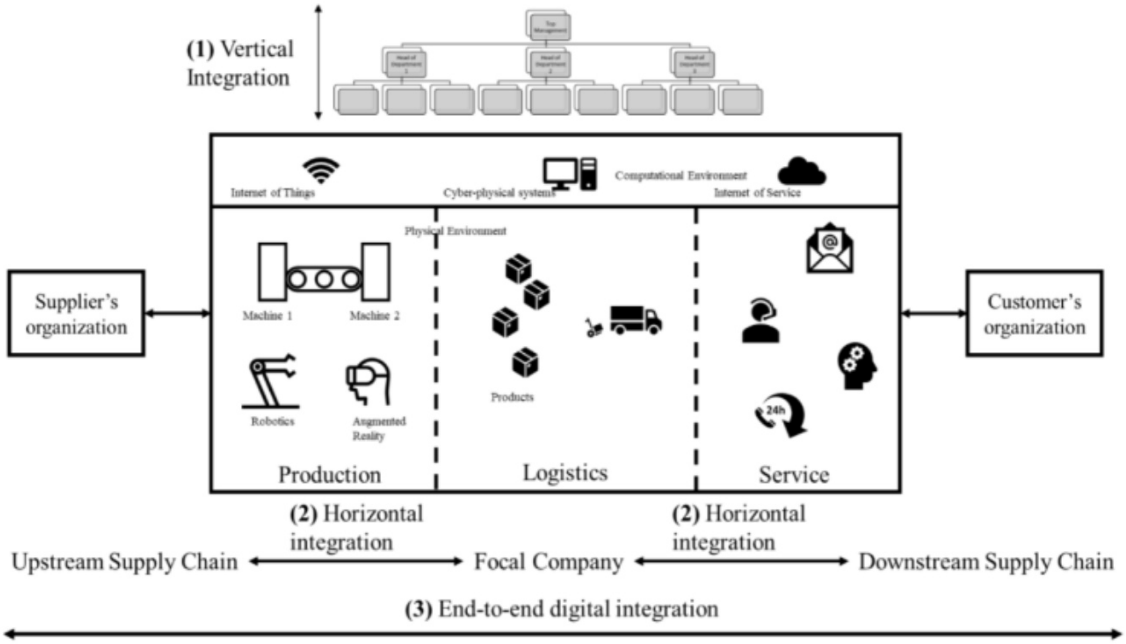


Figure 10:Key Features of Industry 4.0

Industry 4.0 refers to the convergence and application of nine digital industrial technologies:

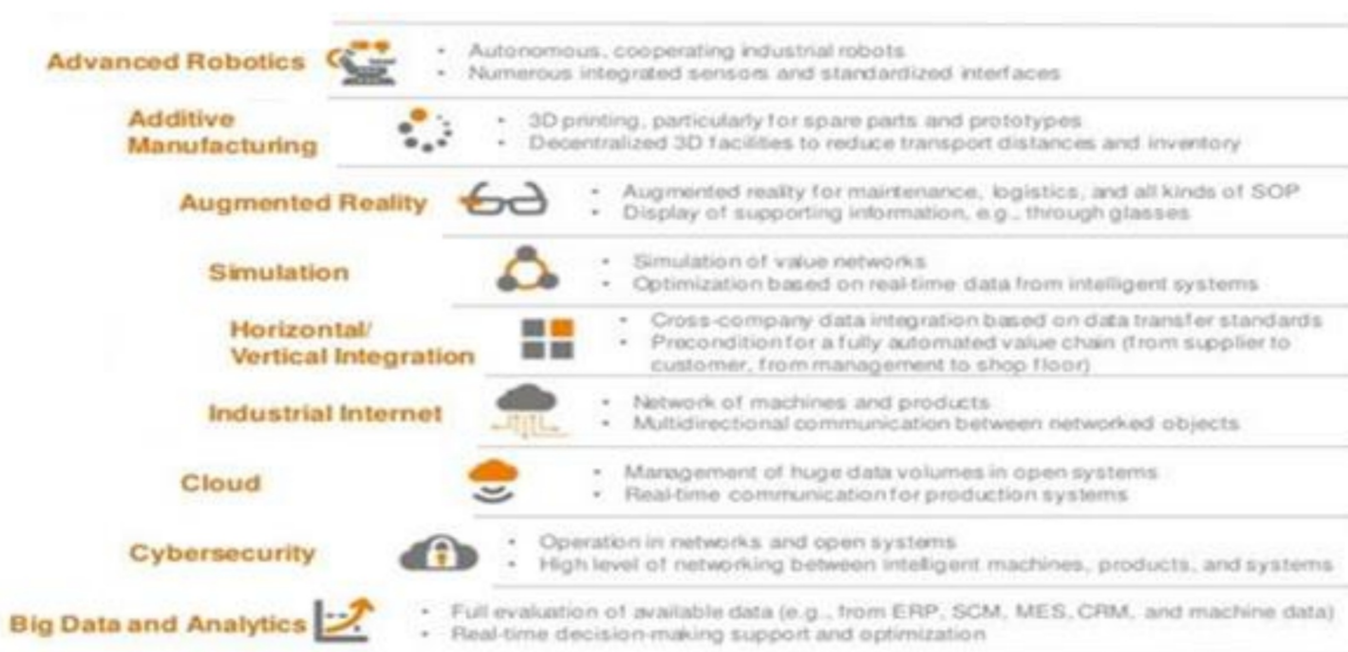
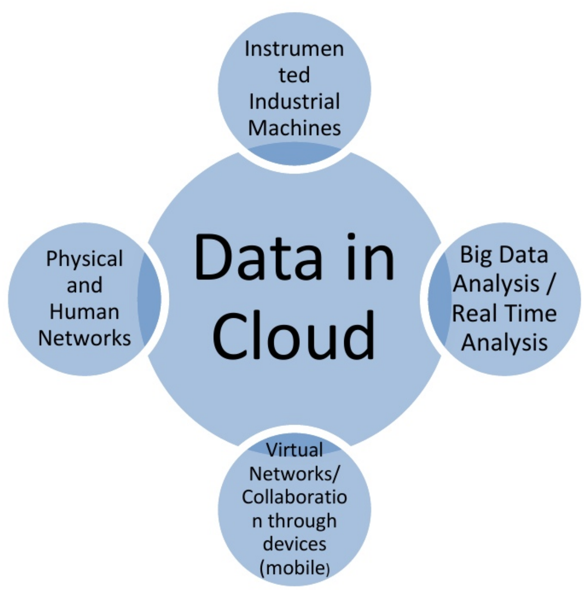


Figure 11:Applications of Industry 4.0

SWOT Analysis of Industry 4.0:

Strengths	Weaknesses
• Process efficiency leading to High Precision and Quality. • Security. • Less Human Intervention. • Customized. • Reduced usage of energy. • Lean Processes & easy monitoring.	• Data Security in a cloud. • Complex & Costlier to implement/maintain. • Not applicable for all businesses. • Less manual labor needed. • Fear of technology leads to non-implementation.
Opportunities	**Threats**
• Competitive advantage due to the process efficiency (first mover advantage). • Knowledge based industry and Hub. • Flexibility remains a key factor for the manufacturing work.	• Low acceptance level from workers. • Competition: non-trust from competitors to share datasets. • Outsourcing threat. • E-commerce "Return Rate" as a risk for environment.

Core Elements for Industry 4.0 is that increasing the efficiency by smart factory: Intelligent production systems and machines, communicating with each other "Internet of thing", integrating the physical and digital world.



Advantages of Industry 4.0:

1) **Improve OEE (Overall Equipment Effectiveness):**
    - Predict and prevent unplanned downtime.
    - Optimize equipment (effectiveness and maintenance).
2) **Reduce Costs:**
    - Real time product (monitoring and control).
    - Predictive maintenance.
    - Automation and 3D printing.
3) **Quality Control:**
    - Reduce or eliminate customer return with real time quality control.
4) **Innovate Faster:**
    - 3D printing.
    - Remote expert and collaboration technologies.

Industry Key Success Factors:

Productivity:

- Solutions to eliminate errors and wastage.
- Produce more products.
- Shortened cycle times.

Flexibility:

- Personalized products.
- Efficient production.
- Large variability in production control.

Competitiveness:

- Low manufacturing costs.
- Use of innovative solutions.
- Flexible response to fluctuations of demand.

Profitability:

- The advantage of mass production.
- Optimized processes.
- Low stock inventories.
- Production efficiencies.

Safety:

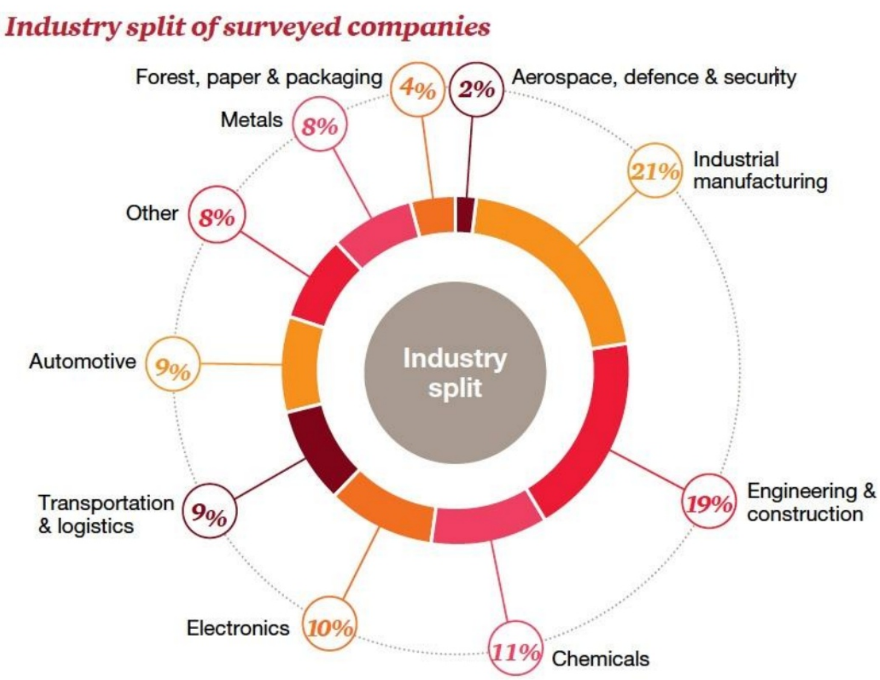
- Software prevents defects.
- Sensors are protecting worker safety.
- Immediate reaction.

Ecology:

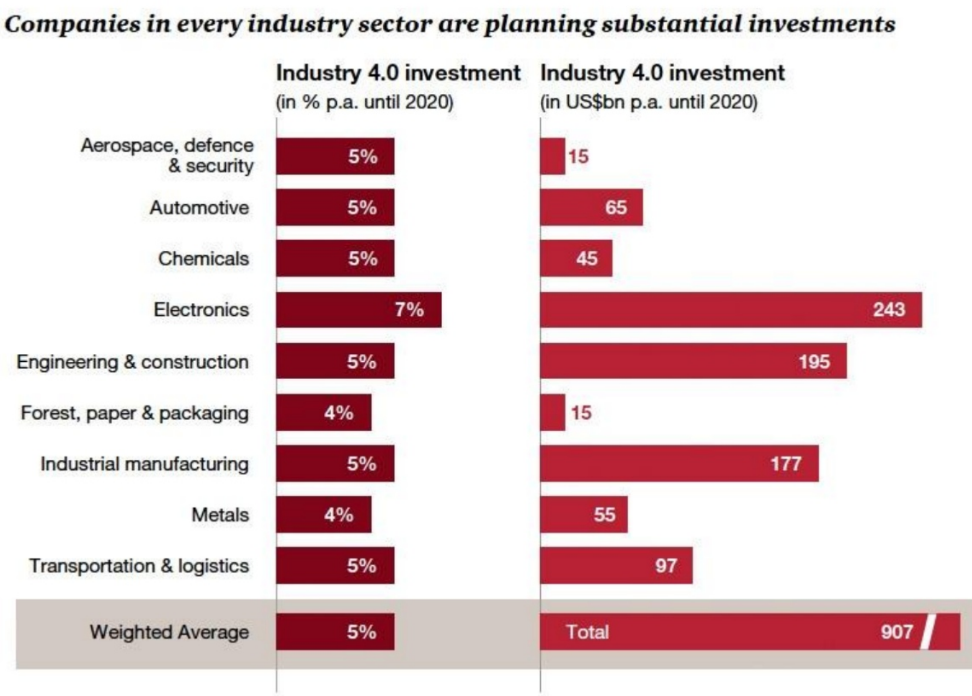
- Switching off unused objects.
- Use of green solutions.
- Renewable energy.

Industry 4.0 investments in major economies

Industry 4.0 is set to rapidly transform the competitiveness of industrial and manufacturing sectors globally, adding a forecasted $493 billion in revenue gains per annum over a five-year period. Although initial investments needed to adopt Industry 4.0 will be high a total of $4.5 trillion to 2020 the rewards are expected to be even higher. According to the new research states that the Building the digital enterprise , together with Strategy and explores the Industry 4.0 transformation taking place across 10 major industries. The research involves executives from more than 2,000 companies in 26 countries across Europe, the Americas, Asia Pacific, Middle East and Africa. Results are weighted by country GDP to provide a balanced overview of global totals. Industrial manufacturing represents the largest share of respondents, at 21%, followed by engineering & construction, at 19%.



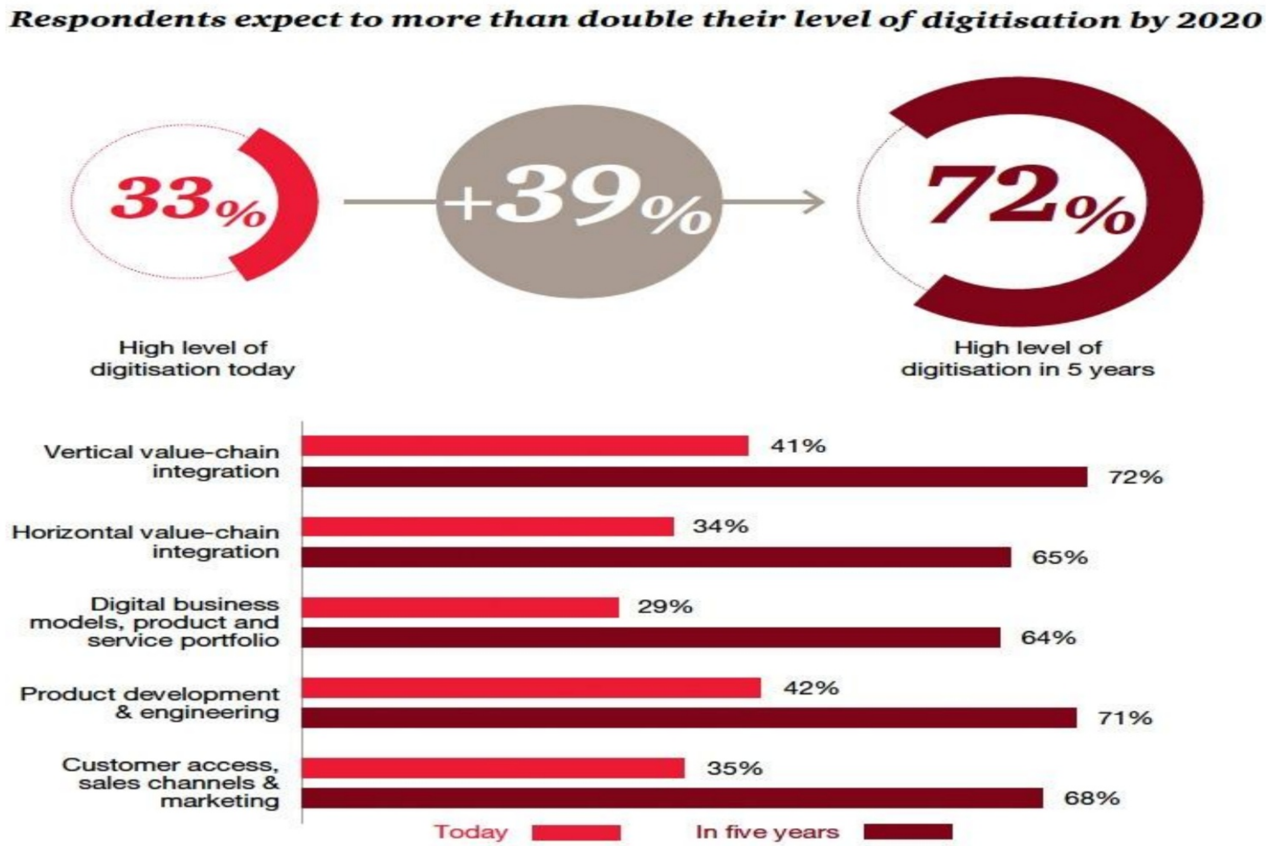
As we know 'Industry 4.0' represents the widespread deployment of an 'industrial internet', which broadly relates to the use of digitalization and automation in industrial processes. The basis of the "revolution", as it is dubbed by many, is a focus on the end-to-end digitization of all physical assets and integration into digital ecosystems with value chain partners. In the context of the industry upgrade, this means that both the vertical and the horizontal value chains become integrated, with the connection of people, things and systems creating dynamic, self-organizing, real-time optimized value-added connections within and across companies.



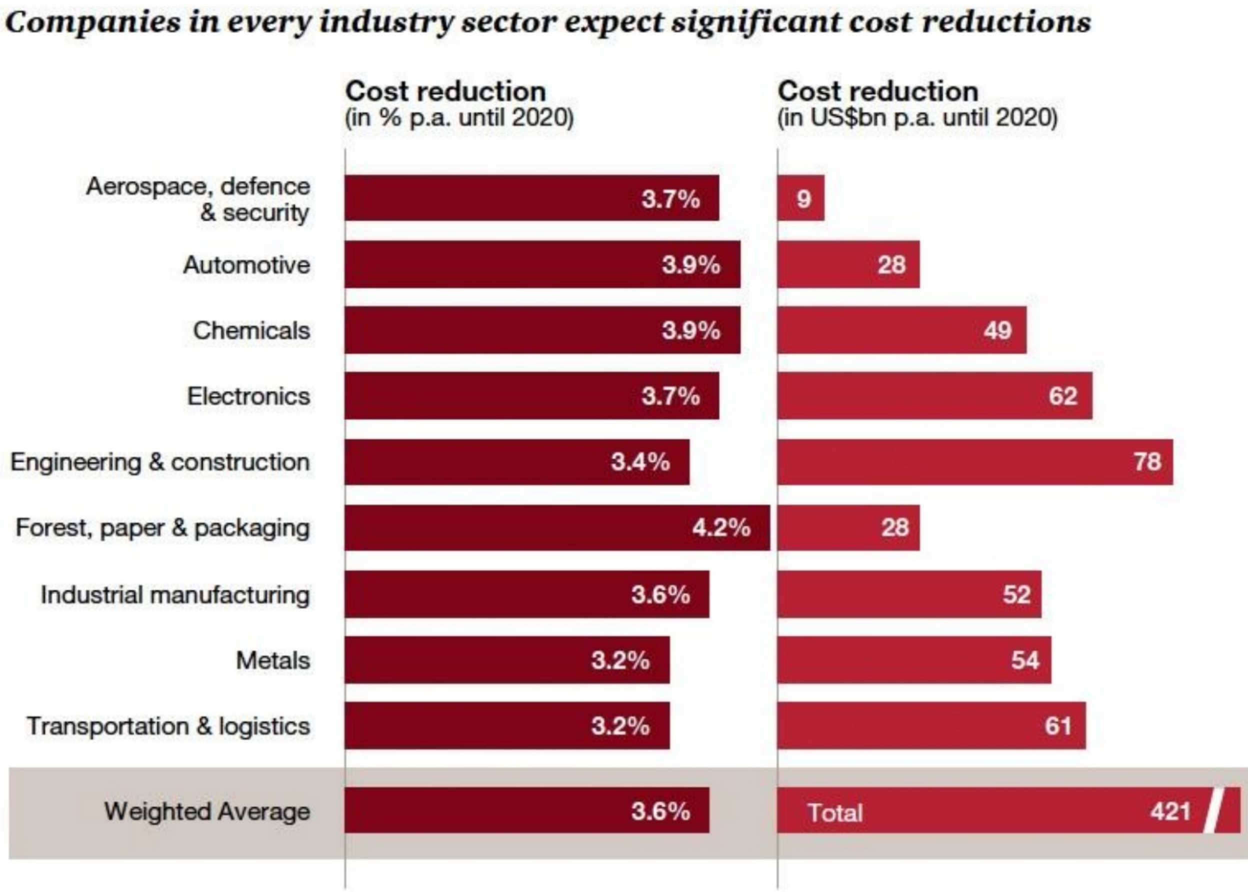
Scaling investment:

The report finds that the companies surveyed are planning substantial investments into Industry 4.0, more specifically, a total investment of $4.5 trillion over the coming years. The per annum investment will, on average, be $907 billion to 2020, equal to a 5% share of total revenues.

Investment levels in the electronics industry will take the lead, as the industry will invest $243 billion every year, or around 7% of their revenues, until 2020. Engineering and construction are the second largest investing industry by total size annually, investing $195 billion, followed by industrial manufacturing, at $177 billion.



The heavy investment is expected to result in considerably higher levels of digitalization across a range of functional areas in the years to 2020. Today, around 41% of the vertical value-chain at surveyed companies is integrated this is expected to increase to 72% in the coming five years. Horizontal value chains too are expected to see considerable integration, up from 34% today to 65% in five years. Digital business models, products and service portfolios will see increases of more than a third, up from 29% to 64%.



Improved efficiency:

One of the benefits of the new industrial process is that Industry 4.0 will help companies create efficient manufacturing processes with increased production, energy and resource efficiency. The efficiencies that may be gained through moving to integrated planning & scheduling for manufacturing are: integrated shop floor planning that can improve asset utilization and product throughput time; predictive maintenance of key assets, which uses predictive algorithms that can optimize repair and maintenance schedules; and integration within horizontal value chain partners, including suppliers and key customers, that can, according to the firm, significantly improve efficiencies and reduce inventories.

The research finds that the substantial investment by major industries is projected to result in significant cost reductions in the years to 2020. On average savings will reach 3.6% of costs annually, with a combined annual saving of $421 billion until 2020. The biggest cost reduction is set to take place in forest, paper & packaging at 4.2% annually, followed by automotive and chemical, both at 3.9% annually.

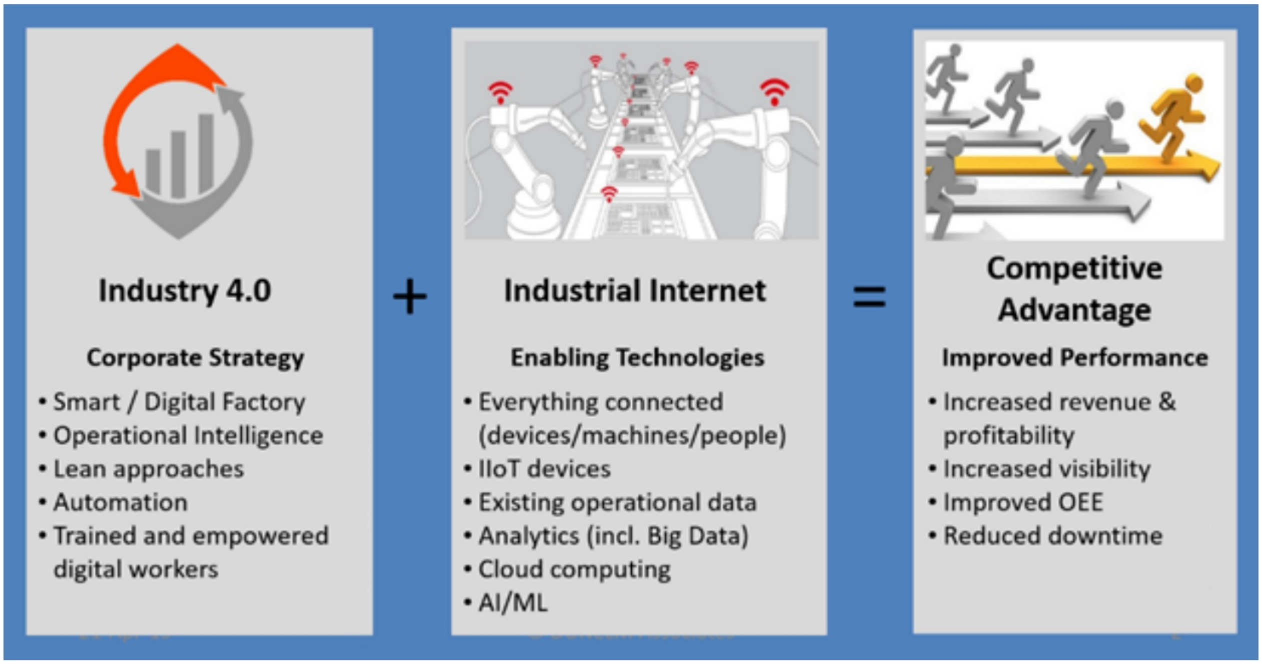
Industry 4.0 barriers

The transformation to Industry 4.0 is expected to result in significant changes within the company structure. The research results suggest that internal factors, such as culture, organization, leadership and skills, rather than external issues, will take precedence. The biggest barrier to successful transformation, for instance, has been cited as a lack of clear digital operations vision and support from leadership and top management, at 40% of respondents. The second biggest challenge for companies is a lack of clarity about the economic benefit and digital investment required, at 38% of respondents. High financial investment requirements come in third, cited by 36%.

A range of less concerning challenges include concerns around loss of control over company's intellectual property, at 14%, followed by business partners not able to collaborate around digital solutions, at 16%. Moreover, the report adds "From our interviews with industrial companies, the biggest challenges center around internal issues such as culture, organization, leadership and skills rather than external issues such as whether the right standards, infrastructure and intellectual property protection are in place or whether concerns about data security or privacy concerns can be overcome."

Industry 4.0 + Industrial Internet = Competitive Advantage

The combination of the right approaches, real-time production information plus technologies such as IIoT (Industrial internet of things) helps us build what is often referred to as "smart factories" or "digital factories".



Chapter (3) Smart Factories

The Smart Factory:

The smart factories represent a new trend of industrial from more conventional computerization to a completely associated and adaptable framework one that can utilize a steady stream of information and data from associated activities and creation frameworks to learn and adjust to new demands. A true smart factory can integrate data from system-wide physical, operational, and human assets to drive manufacturing, maintenance, inventory tracking, digitization of operations through the digital twin, and other types of activities across the entire manufacturing network. The result can be a more efficient and agile system, less production downtime, and a greater ability to predict and adjust to changes in the facility or broader network, possibly leading to better positioning in the competitive marketplace.

The recent trends such as the rise of the fourth industrial revolution and the convergence of the digital and physical worlds including information technology (IT) and operations technology have made the transformation of the supply chain increasingly possible. Shifting from linear, sequential supply chain operations to an interconnected, open system of supply operations known as the digital supply network could lay the foundation for how companies compete in the future.

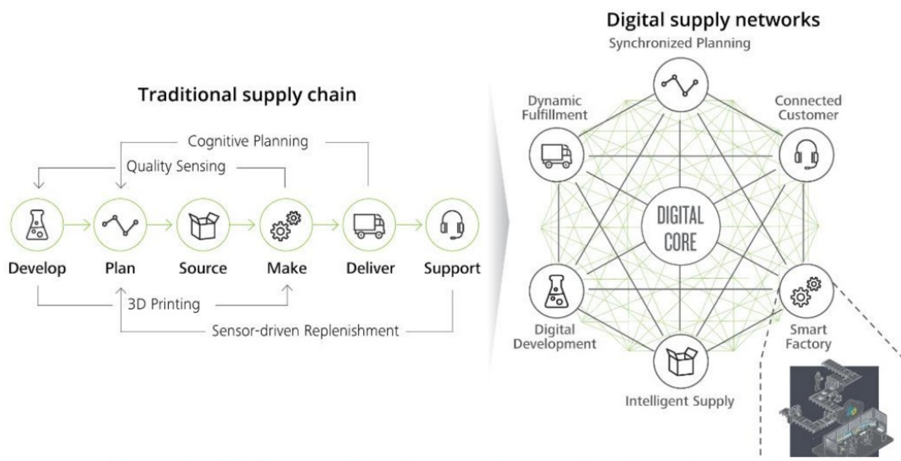


Figure 12: Shift from traditional supply chain to digital supply network

The most important feature of the smart factory, its connected nature, is also one of its most crucial sources of value. Smart factories require the underlying processes and materials to be connected to generate the data necessary to make real-time decisions. In a truly smart factory, assets are fitted with smart sensors so systems can continuously pull data sets from both new and traditional sources, ensuring data are constantly updated and reflect current conditions. Integration of data from operations and business systems, as well as from suppliers and customers, enables a holistic view of upstream and downstream supply chain processes, driving greater overall supply network efficiency.

Figure 13:The smart factory

An optimized smart factory allows operations to be executed with minimal manual intervention and high reliability. The automated workflows, synchronization of assets, improved tracking and scheduling, and optimized energy consumption inherent in the smart factory can increase yield, uptime, and quality, as well as reduce costs and waste. In the smart factory, the data captured are transparent: Real-time data visualizations can transform data captured from processes and fielded or still-in-production products and convert them into actionable insights, either for humans or autonomous decision making. A transparent network can enable greater visibility across the facility and ensure that the organization can make more accurate decisions by providing tools such as role-based views, real-time alerts and notifications, and real-time tracking and monitoring.

In a proactive system, employees and systems can anticipate and act before issues or challenges arise, rather than simply reacting to them after they occur. This feature can include identifying anomalies, restocking and replenishing inventory, identifying and predictively addressing quality issues, and monitoring safety and maintenance concerns. The ability of the smart factory to predict future outcomes based on historical and real-time data can improve uptime, yield, and quality, and prevent safety issues. Within the smart factory, manufacturers can enact processes such as the digital twin, enabling them to digitize an operation and move beyond automation and integration into predictive capabilities.

Agile flexibility allows the smart factory to adapt to schedule and product changes with minimal intervention. Advanced smart factories can also self-configure the equipment and material flows depending on the product being built and schedule changes, and then see the impact of those changes in real time. Additionally, agility can increase factory uptime and yield by minimizing changeovers due to scheduling or product changes and enable flexible scheduling. These features afford manufacturers greater visibility across their assets and systems and allow them to navigate some of the challenges faced by more traditional factory structures, ultimately leading to improved productivity and greater responsiveness to fluctuations in supplier and customer conditions. The following figures number (14) describes the key characteristics of a smart factory and the most feature that used by companies.

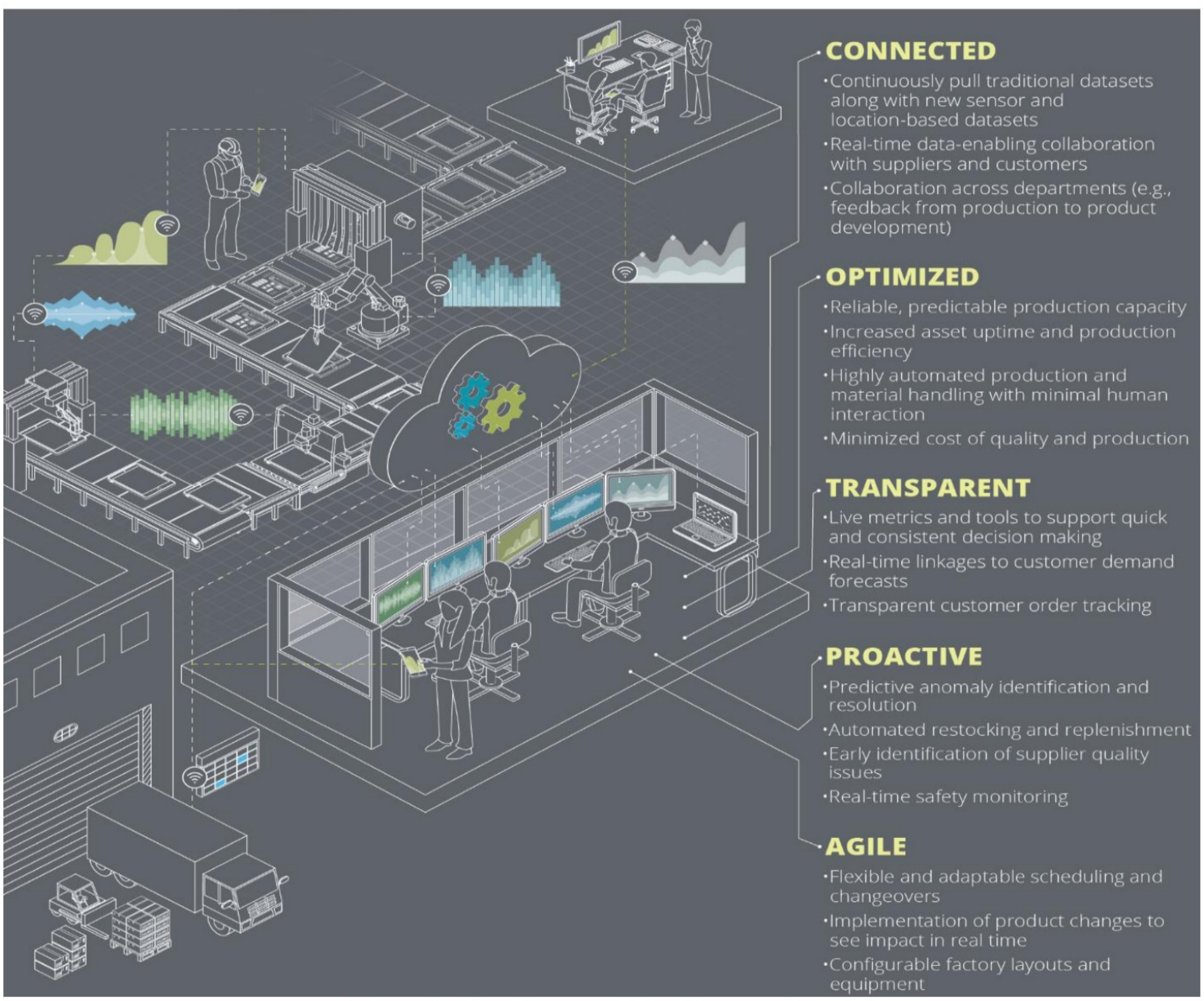


Figure 14: Five Characteristics of a smart factory

The Benefits of smart factories:

The decision on how to rise on or expand a smart factory initiative should align with the specific needs of an organization. The reasons that companies embark or expand on the smart factory journey are often varied and cannot be easily generalized. However, undertaking a smart factory journey generally addresses such broad categories as asset efficiency, quality, costs, safety, and sustainability. These categories, among others, may yield benefits that ultimately result in increased speed to market; improved ability to capture market share; and better profitability, product quality, and labor force stability. Regardless of the business drivers, the ability to demonstrate how the investment in a smart factory provides value is important to the adoption and incremental investment required to sustain the smart factory journey.

(1) Asset efficiency:

Every aspect of the smart factory generates reams of data that, through continuous analysis, reveal asset performance issues that can require some kind of corrective optimization. Indeed, such self-correction is what distinguishes the smart factory from traditional automation, which can yield greater overall asset efficiency, one of the most salient benefits of a smart factory. Asset efficiency should translate into lower asset downtime, optimized capacity, and reduced changeover time, among other potential benefits.

(2) Quality:

The self-optimization that is characteristic of the smart factory can predict and detect quality defect trends sooner and can help to identify discrete human, machine, or environmental causes of poor quality. This could lower scrap rates and lead times and increase fill rates and yield. A more optimized quality process could lead to a better-quality product with fewer defects and recalls.

(3) Lower cost:

Optimized processes traditionally lead to more cost-efficient processes those with more predictable inventory requirements, more effective hiring and staffing decisions, as well as reduced process and operations variability. A better-quality process could also mean an integrated view of the supply network with rapid, no-latency responses to sourcing needs thus lowering costs further. And because a better-quality process also may mean a better-quality product, it could also mean lowered warranty and maintenance costs.

(4) Safety and sustainability:

The smart factory can also impart real benefits around labor wellness and environmental sustainability. The types of operational efficiencies that a smart factory can provide may result in a smaller environmental footprint than a conventional manufacturing process, with greater environmental sustainability overall. Greater process autonomy may provide for less potential for human error, including industrial accidents that cause injury. The smart factory's relative self-sufficiency will likely replace certain roles that require repetitive and fatiguing activities. However, the role of the human worker in a smart factory environment may take on greater levels of judgment and on-the-spot discretion, which can lead to greater job satisfaction and a reduction in turnover.

(5) Impacts of the smart factory on manufacturing processes:

Manufacturers can implement the smart factory in many ways both inside and outside the four walls of the factory and reconfigure it to adjust as existing priorities change or new ones emerge. In fact, one of the most important features of the smart factory agility also presents manufacturers with multiple options to leverage digital and physical technologies depending on their specific needs.

The specific impacts of the smart factory on manufacturing processes will likely be different for each organization. It has identified a set of advanced technologies that typically facilitate the flows of information and movement between the physical and digital worlds. These technologies power the digital supply network and, by extension, the smart factory creating new opportunities to digitize production processes. Figure (15) states a series of core smart factory production processes along with a series of sample opportunities for digitization enabled by various digital and physical technologies.

Process	Sample digitization opportunities
Manufacturing operations	• **Additive manufacturing** to produce rapid prototypes or low-volume spare parts • **Advanced planning and scheduling** using real-time production and inventory data to minimize waste and cycle time • **Cognitive bots and autonomous robots** to effectively execute routine processes at minimal cost with high accuracy • **Digital twin** to digitize an operation and move beyond automation and integration to predictive analyses
Warehouse operations	• **Augmented reality** to assist personnel with pick-and-place tasks • **Autonomous robots** to execute warehouse operations
Inventory tracking	• **Sensors** to track real-time movements and locations of raw materials, work-in-progress and finished goods, and high-value tooling • **Analytics** to optimize inventory on hand and automatically signal for replenishment
Quality	• In-line quality testing using **optical-based analytics** • **Real-time equipment monitoring** to predict potential quality issues
Maintenance	• **Augmented reality** to assist maintenance personnel in maintaining and repairing equipment • **Sensors** on equipment to drive predictive and cognitive maintenance analytics
Environmental, health, and safety	• **Sensors** to geofence dangerous equipment from operating in close proximity to personnel • **Sensors** on personnel to monitor environmental conditions, lack of movement, or other potential threats

Figure 15: Processes within a smart factory

The smart factories are spreading nowadays due to:

- Many companies are making investments in smart factory capabilities to mitigate the risk associated with a possible labor shortage. While automation and controls have existed for decades, the fully smart factory has only recently gained traction as a viable pursuit for manufacturers.

Five overarching trends seem to be accelerating the drive toward smart factories:

- Rapidly evolving technological capabilities
- Increased supply chain complexity and global fragmentation of production and demand
- Growing competitive pressures from unexpected sources
- Organizational realignments resulting from the marriage of IT and OT
- Ongoing talent challenges

Rapidly evolving technological capabilities

Until recently, the realization of the smart factory remained elusive due to limitations in digital technology capabilities, as well as prohibitive computing, storage, and bandwidth costs. Such obstacles, however, have diminished dramatically in recent years, making it possible to do more with less cost across a broader network. Further, the capabilities of technologies themselves have grown more sophisticated: AI, cognitive computing, and machine learning have enabled systems to interpret, adjust to, and learn from the data gathered from connected machines. This ability to evolve and adapt, coupled with powerful data processing and storage capabilities, allows manufacturers to move beyond task automation toward more complex, connected processes.

Increased supply chain complexity and global fragmentation of production and demand

As manufacturing has grown increasingly global, production has fragmented, with stages of production spread among multiple facilities and suppliers across multiple geographies. These shifts, coupled with the increased demand for regional, local, and even individual customization; strong demand fluctuation; and increasingly scarce resources, among other shifts, have made supply chains more complex. Due to these changes, many manufacturers have found it important to be agile, connected, and proactive to address ever-shifting priorities.

Growing competitive pressures from unexpected sources

The rise of smart digital technologies has ushered in the threat of entirely new competitors who can leverage digitization and lower costs of entry to gain a foothold in new markets or industries in which they previously had no presence, sidestepping the legacy of aging assets and dependence on manual labor encumbering their more established competitors.

Organizational realignments resulting from the marriage of IT and OT

Factory automation decisions typically occur at the business unit or plant level, often resulting in a patchwork of disparate technologies and capability levels across the manufacturing network. As connected enterprises increasingly push beyond the four walls of the factory to the network beyond, they are beginning to have greater visibility into these disparities. The increasing marriage of IT (Information Technology) and OT (Operational technology) has made it possible for organizations to move many formerly plant-level decisions to the business-unit or enterprise level. This can illuminate where inefficiencies exist or where changes in one plant have resulted in complications in other facilities. It has also made the notion of the smart factory more of a reality than an abstract goal. While connectivity within the factory is not new, many manufacturers have long been stymied about what to do with the data they gather in other words, how to turn information into insight, and insight into action. The shift toward the connected digital and physical technologies inherent in Industry 4.0 portends solutions to this challenge: the ability to not only gather data, but to now analyze and act upon them in the physical world.

Ongoing talent challenges

Multiple talent-related challenge including an aging workforce, an increasingly competitive job market, and a dearth of younger workers interested in or trained for manufacturing roles mean that many traditional manufacturers have found themselves struggling to find both skilled and unskilled labor to keep their operations running. Many companies are making investments in smart factory capabilities to mitigate the risk associated with this possibly pervasive labor shortage. However, this move can create a new set of talent related consequences, as automated assets typically require highly skilled labors to operate and maintain the location of manufacturing facilities would need to consider factors such as this.

Sustainable manufacturing in the future:

The future of factories is small, smart and social. We've come to assume that efficiency in manufacturing is the result of economies of scale from large, centralized operations, speed and standardization. But a combination of new and existing pressures – the variability in the supply of resources, scrutiny from government on public health issues and changing consumer demands makes the mass, homogenized approach looks fragile.

A constructive way forward will be to introduce models which are service-based and personalized to deliver convenience and value moving away from mass production, and towards making personalized products to order. This will be achieved by small, local facilities that use technology to synchronize resource availability, supply and demand.

The use of sensors, big data analysis and the Internet of Things is already enabling real-time transparency across the supply chain. Methods are being developed to exploit this data be more transparent and to collaborate more with customers, suppliers and even competitors. This will help manufacturers to maintain a resilient and sustainable manufacturing business while meeting the needs of markets in general and the needs of specific individuals. Some parts of the supply chain will use data to operate autonomously. Sensing technology will, for example, monitor the quality of farmland in real-time, ensuring that problems can be fixed immediately, keeping the land operating at maximum productivity and more sustainably. Similarly. in factories sensor technology will be used as a tool for monitoring quality and supporting real-time decision-making to keep manufacturing operating efficiently, identifying oncoming bottlenecks in the process. For consumers, data will be passed on, providing more detailed information.

Industry 4.0 and Machine Learning:

The rapid development of technologies interconnected with ICT and internet of things enables the growth of manufacturing which has led to the Industry 4.0. The implementation of CPS combined with IoT can provide intelligent, flexible systems capable of self-learning which presents the core of Industry 4.0. In order to achieve intelligent and flexible systems, the big data is required. In knowledge discovery in databases of big data, machine learning plays an important role along with data mining, statistic, pattern recognition and other methods. ML, as a part of intelligent system in Industry 4.0, is broadly implemented in various fields of manufacturing where its techniques are designed to extract knowledge out of existing data. The new knowledge (information) supports the process of decision-making or making prediction of manufacturing system. But the end goal of the ML techniques is detection of the patterns among the data sets or regularities that describe the relationships and structure between those sets.

Artificial intelligence of Precision Engineering:

The supervised learning is machine learning technique, specified for large amount of input data (training sets), are applied to the systems where the correct response is provided by the knowledgeable expert.

In supervised learning, a system is trained with data that has been labelled. The labels categorize each data point into one or more groups. Then the system learns how this training data is structured and uses this to predict in which categories to classify new output data. The final goal of completed supervised learning process is that the outputs are close enough to be useful for all given input sets. The most common supervised machine learning assignments are classification and regression. In classification assignments, the program has to learn how to predict the most likely category, class or label for discrete output values from one or more input data sets. Like classification, regression problem, also requires supervised learning techniques. The difference in regression problems is that programs must foresee and predict the value of a continuous output by themselves. According to Wuest et al. as well as Jordan and Mitchell, the supervised learning is the most used ML technique, because majority of applications can provide labelled data.

Artificial Intelligence methods that can Impact Manufacturing:

1. Optimizing production processes

Artificial intelligence can assist to increase performance on the production ground by using automating guide or repetitive tasks. Robotics is a place wherein that is already in exercise, with robots being used to perform bodily duties along with assembly, lifting and packaging. using commercial robots in this manner gets rid of the need for humans to carry out ordinary, guide tasks, enabling people to recognition on greater complicated operations.

AI systems will also be able to optimize manufacturing processes by monitoring every stage of the production cycle, such as lead times and quantities used.

In the case of additive manufacturing, machine learning algorithms can be used to predict the fill rate of machine builds, thereby optimizing production planning.

Figure 16:Moving towards fully automated production

2. Safer working environments

One area of robotics that has come to the forefront in recent years is the notion of “cobots” collaborative robots designed to work safely with humans. Small and lightweight, cobots offer an entry point for companies seeking to adopt robot technologies, as they are considerably less expensive and easier to programmed than traditional industrial robots.

Cobots can help to create safer working environments by performing more dangerous and physical tasks, leaving workers free to work on more complex tasks and avoid injury. In time, machine learning algorithms will be able to improve the capabilities of factory robots so that they can better interact with and take instructions from humans.3. Demand forecasting
One great way to improve production efficiency is by accurately forecasting and predicting demand. AI-powered systems can be immensely useful for this, as they can test many different models and possible outcomes. Machine learning algorithms can use data to discover meaningful patterns and provide real-time insights. Manufacturers can use these insights to predict demand and determine which products to prioritise accordingly.

3. Product innovation

Artificial intelligence is creating new possibilities for production and generative design being a good example. Designers and engineers can then choose the outcomes that best suit their needs. In this case, artificial intelligence is able to solve key manufacturing and engineering challenges by creating new design solutions that would otherwise be impossible or inconceivable. This form of “co-creation” between humans and technology will enable manufacturers to create new, innovative products and provide services that meet customer needs with less time and at a lower cost.

4. Simplified supply chains

Companies are spending 6,500 hours per year on average on manual processes related to supply chain management activities. This includes processing paper invoices, responding to suppliers and chasing up purchase order numbers. By automating many of these routine tasks, the time spent could be slashed significantly. But artificial intelligence can take this one step further, by optimizing supply chain planning processes. Using machine learning technology, manufacturers can potentially identify patterns of demand for various products, including key variables like market behavior, political or socio-economic developments, for example. This could help forecast future market demand, having an impact on the way raw materials are sourced and help manufacturers make key financial and recruitment decisions. Optimizing the entire decision-making process along the supply chain in this way can also help to speed up delivery and balance supply and demand.

5. Predictive maintenance:

Vital to any production operation is the availability of functioning tooling equipment. Being able to predict and prevent equipment failure or malfunction is therefore highly beneficial for a smooth and efficient production process. However, the servicing of production equipment is generally based on a fixed schedule, regardless of the current operating status, wasting valuable labor time and raising the risk of unexpected equipment failures.

Manufacturers are therefore increasingly recognizing the importance of predictive maintenance solutions for example, using sensors to track the condition and performance of equipment. In time, predictive maintenance can eventually evolve into machine learning systems being able to analyses vast amounts of data to predict future malfunctions. This would significantly increase efficiency and help reduce maintenance costs related to expensive replacement parts.

6. Customized manufacturing

Much of the future of manufacturing will lie in mass customization. As consumers increasingly expect personalized products, manufacturers will need to find ways to meet this demand without affecting efficiency.

With traditional, mass production approaches, customization is neither cost-effective nor time efficient. The emergence of technologies like additive manufacturing, however, turns this on its head. Advances in artificial intelligence and additive manufacturing will help manufacturers meet demand by making products that are relevant for their customers. It will also help to share data along the value chain to create a more responsive customer service and faster deliveries.

Embracing IoT for manufacturing through logical steps of value gradation

Digitalizing manufacturing through an IIoT platform assumes that four logical steps should be covered through a timely, sequenced roadmap to ensure value.

• Data gathering: Data can come from systems such as enterprise asset management (EAM), enterprise resource planning (ERP) and MES. It can also come straight from equipment/robots/sensors.

• Pattern visualizing: This can be done through dashboards, UI and other representations to see data.

• Analytics-driven insight development: This can include predictive analytics, prescriptive analytics and industry specific analytics models.

• Cognitive: This involves new ways to process unstructured information, including imagery, video and audio, as well as machine learning algorithms.

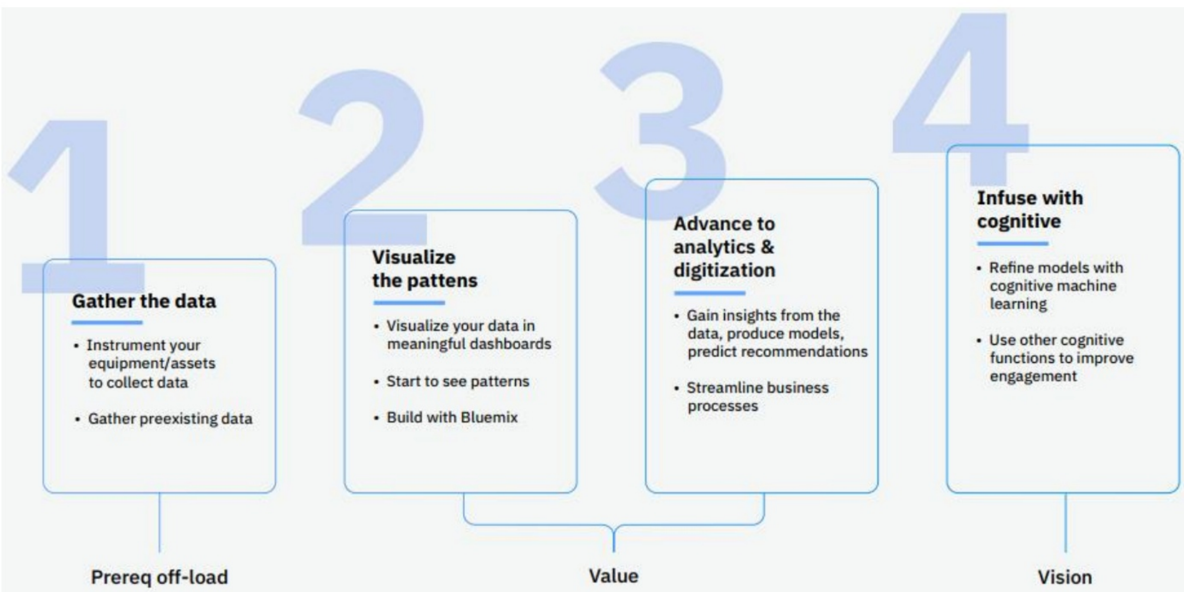


Figure 17:The four-step roadmap

The benefits expected from the four-step roadmap are the following:

• **Productivity gains:** This approach leads to higher throughput and efficiency, eliminating non value-adding-activities.

• **Failure prevention:** The roadmap also results in the highest overall equipment efficiency (OEE), avoiding rework, scrap, outages and poor product quality.

• **Flexibility:** Other benefits include hiding complexity, low configuration and reconfiguration efforts, the capacity to plug and produce, and the avoidance of technology gaps.

The field, that combines all of these sciences is machine learning (ML). ML is becoming the most important method that is used for predicting and classifying the difficulty solving problems inside the production systems. ML uses increased computing power and various software for gaining the meaningful information and knowledge from the big data, which are collected from the environment, but also, has ability to learn from those data by getting the artificial/computational intelligence. For some specific tasks, ML can achieve a higher level of requirements than human. This highlights the importance of the big data from which the information is obtained. However, the balance must be found. Too much information can lead to delay of the actions or the wrong conclusions of the certain problem and the lack of the information may not lead to problem solving. Another great issue is related to security aspect of the data. Having that issue in mind, ML must utilize the different techniques and algorithms in order to achieve maximal benefit from the data.

The most important techniques that are used for learning, classified by the available feedback, are supervised, unsupervised and reinforcement learning methods. This paper focuses on the challenges and applications that ML faces within today's manufacturing systems. Also, the accent is put on future trends of ML in manufacturing applications where the primary objective lays behind the utilization of big data in order to accomplish cost efficient, fault-free and optimal quality manufacturing process.

Chapter (4) Real Example of Smart factory:

During the writing of thesis, I did an internship in the Fashion Logistics company based in Ghent, Belgium. The internship activities allowed me to learn a lot both from a technical point of view and from organizational point of view. Enter a reality focused on teamwork by use the skills that the university has allowed me to improve in recent years and in at the same time to acquire new skills. The internship helped me a lot in this dissertation as it gives me the opportunity to see and study how the industry 4.0 will shape the future technology and how to see it in a practical real-life case study.

The internship was focusing with the following responsibilities:

1) Follow the implementation of item sorter
2) Collect and analysis the data that generated by the system
3) Proposals for optimization, improvement and efficiency.

About the Company:

The company is a leading worldwide provider of transportation, warehousing, fulfillment, global logistics, business intelligence, technology, and supply chain solutions. The company was founded more than 150 years ago. Logistics company has annual global sales of over €300M and 450 employees located in 20 countries around the world. The company is consistently recognized as one of the fastest-growing privately-owned transportation and logistics companies, a top 3PL (Third party logistics provider), a top freight brokerage and warehousing provider.

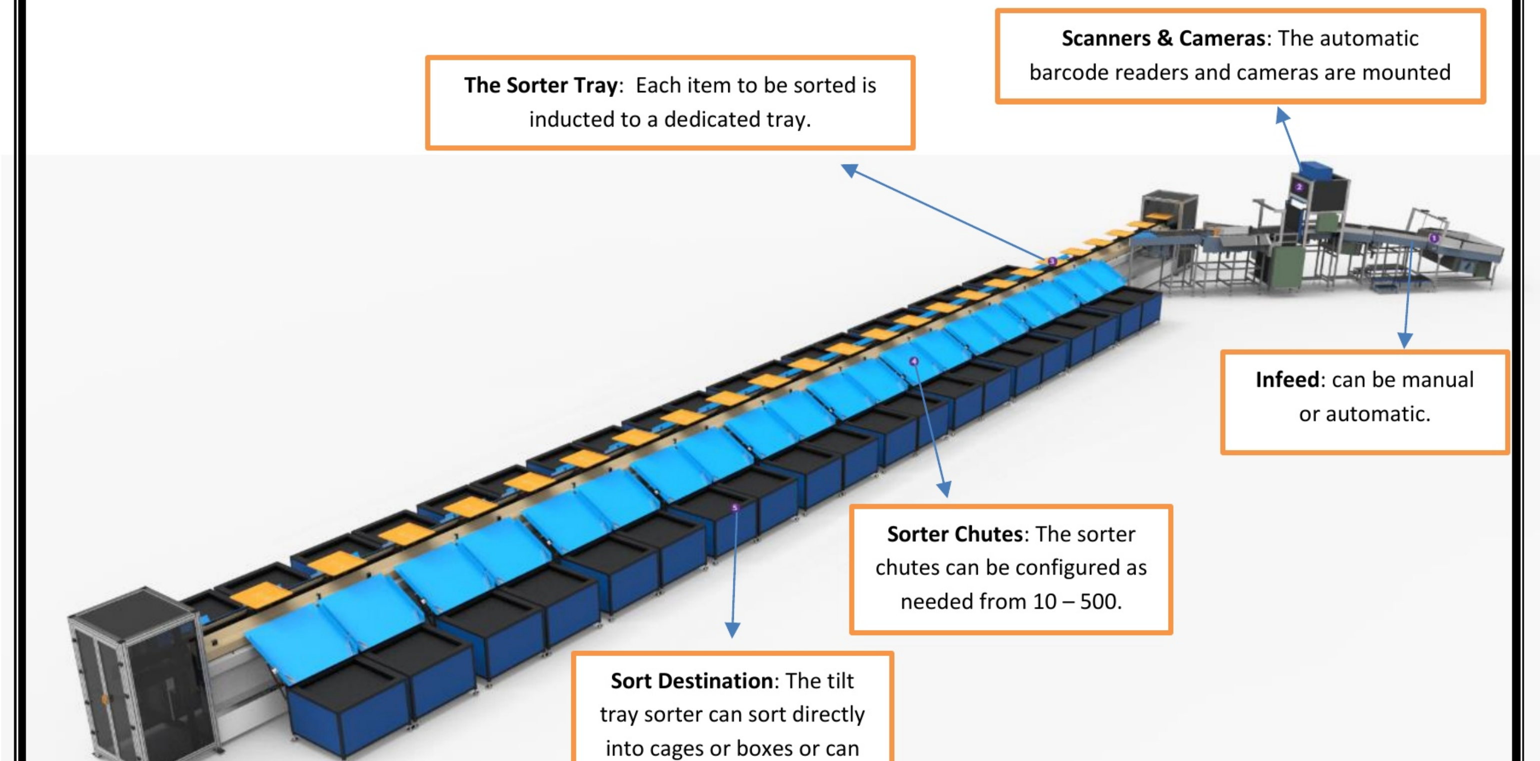
Activities of the company:

1)Warehouse& fulfillment

2) International Freight Forwarding

3) Supply Chain & Technology Solutions

Infeed Item Sorter:



Item Sorter Function:

Sortation systems are used in a wide range of applications, from post and parcel to distribution and manufacturing. To achieve high efficiency and accurate operation of the sorter host, the function of the infeed system is to automatically measure the physical parameters and identification information of items to be sorted and to ensure items are property and synchronously inducted onto the high-speed sorting vehicles.

Item Sorter Components:

1) Volume Measurement
2) Weight
3) 1D/2D Bar Code Reading

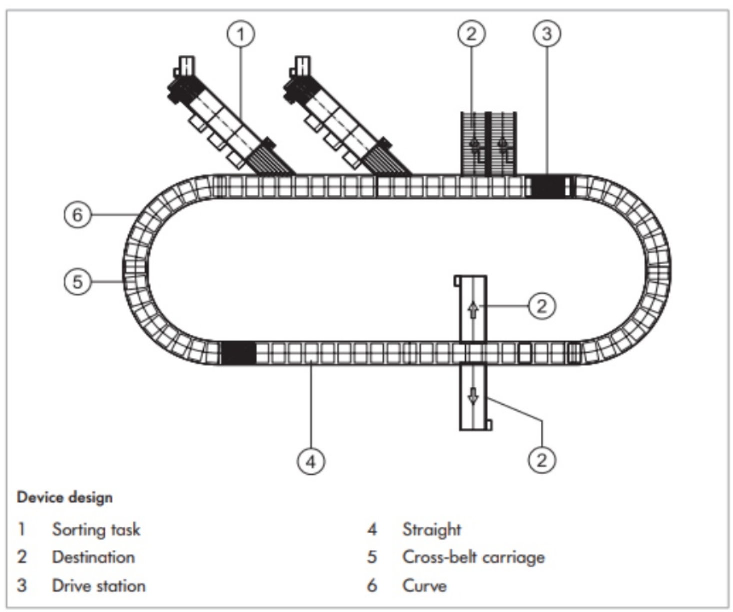
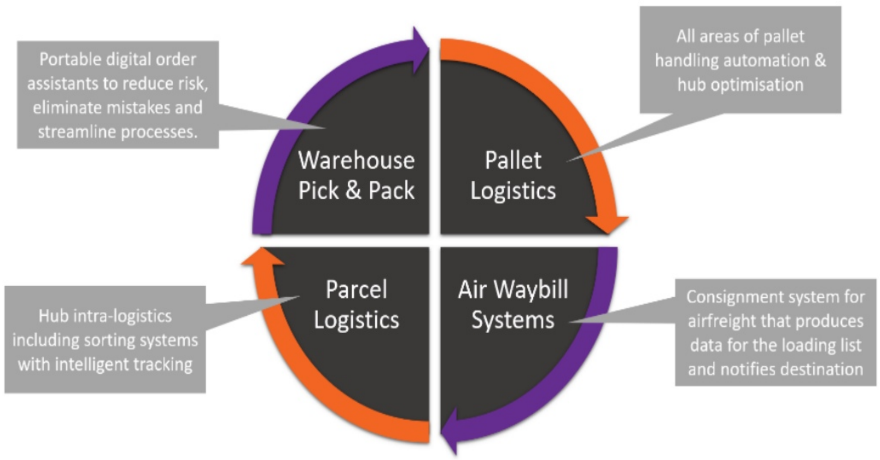


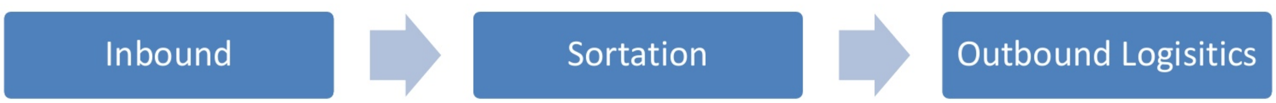
Figure 18: Item Sorter components

4) OCR (Optical Character Recognition): is the electronic conversion of images of typed, handwritten or printed text into machine-encoded text, whether from a scanned document, a photo of a document, a scene-photo or from subtitle text superimposed on an image.
5) Video Coding
6) Image Data Archiving
7) Analysis and Statics tools
8) Connection to Host System/Sorter Controller.

Figure 19:OCR



<u>The Value chain of logistics is as following phases;</u>



The focus is the sortation, so the main steps and procedures is following:

1) **Unloading/inbound**

Fast truck unloading gets the shipping process off to a good start. Manually unloading parcels from trucks, swap bodies or roll containers is no easy task it puts strain on the operators and requires considerable physical strength, endurance and time. Maybe Automatic and semi-automatic unloading aids have been around for some time now in the parcels sector.

Figure 20:Unloading and Conveying

2) Induction

The incoming three-dimensional bulk flow must be cascaded quickly and efficiently into a single layer at the start of the sorting process. The two-dimensional flow is formed by situating the parcels side by side and then transforming them into a single file. After that, the parcels are ready for further processing.

Figure 21:Singulation

3) Identification of Item by reading the bar code

Postal and parcel services require reading and recognition systems for a whole range of demands. Fast and reliable recording and interpretation of information ensure quick sorting and delivery processes for all items. The technology can decipher machine or handwritten addresses. It also recognizes linear and 2D barcodes, such as stamps, stickers, logos and labels.

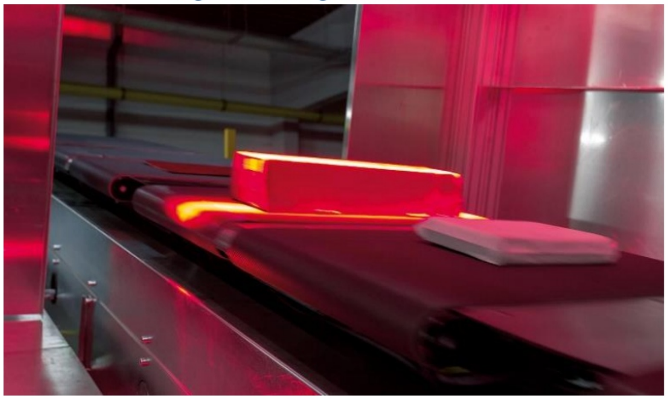


Figure 22:Reading, Coding and Tracking

Bar code: Barcode readers help distribution centers improve accuracy and traceability of shipping processes by providing a hands-free, efficient solution to verifying the correct packages are loaded onto the truck.

Figure 23:Bar code

4) Sorting

Sorting is the heart of the CEP operation. Parcels must be routed quickly, reliably and safely through the sorting center. The innovative parcel sorting systems offer great flexibility and can be easily adapted to the requirements or need. At the same time, they ensure high system throughput regardless of the parcel size, origin or destination

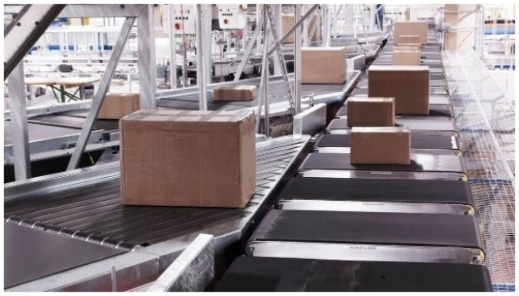


Figure 24:Sorting

5) Automated Inbound/outbound Receiving

Overhead presentation reading stations or multi-reader barcode scan tunnels decipher codes on various sides of a package, at extreme angles, and different orientations reducing rework and lowering costs.

Figure 25:Automated Inbound Receiving

6) Item Verification

The 2D or 3D Dimensioning System quickly and accurately captures volume and dimensioning data of picked items which increases order accuracy, improves inventory management, and lowers return costs. Identification of items is a core element. Load optimization is a key objective of logistics companies, resulting from dramatically rising energy costs and environmental factors. If the weight and volume of each item to be shipped are known, the service providers can use their transportation resources to their full potential.

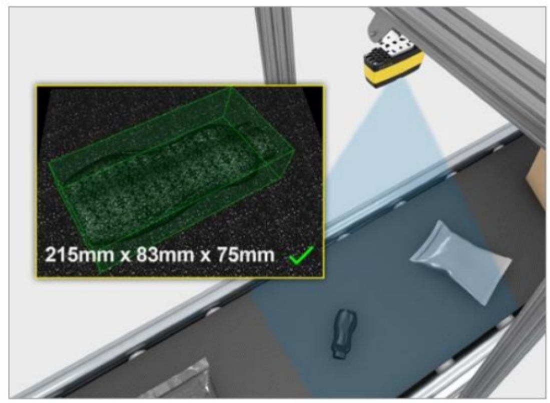


Figure 26:Item Verification

Figure 27: Item Control verification

The advantages of the system:

- Leads to cost reduction achievements
- Can increase the production output and the process quality
- Helps to better utilization of resources
- Improves various important metrics like productivity and efficiency
- Increasing operational efficiency
- The fastest innovative sorting machine
- Perfectly adapted to the sorting and preparation of rounds of objects from e-commerce.
- Outputs compatible with all types of containers (parcel, bags and boxes).
- Manual infeed/output or almost total automation thanks to robotic pick & place.

The following figures shows the Sorting from the top view, on every Cross-Belt Sorter there is an automated scanner that scan the parcel to falling out in the right place to the correct chutes.

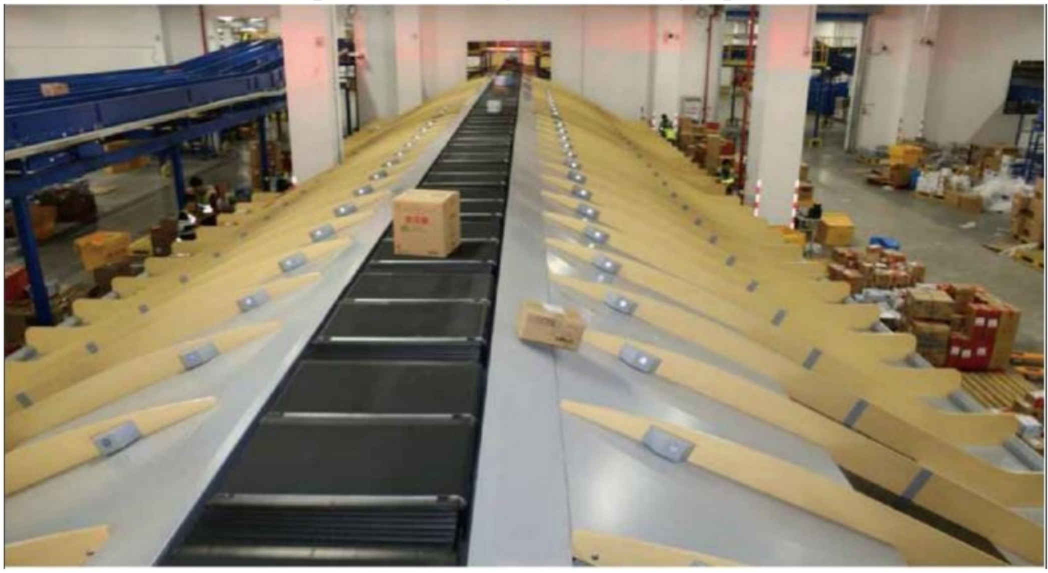


Figure 28:Site installation of Item Sorter

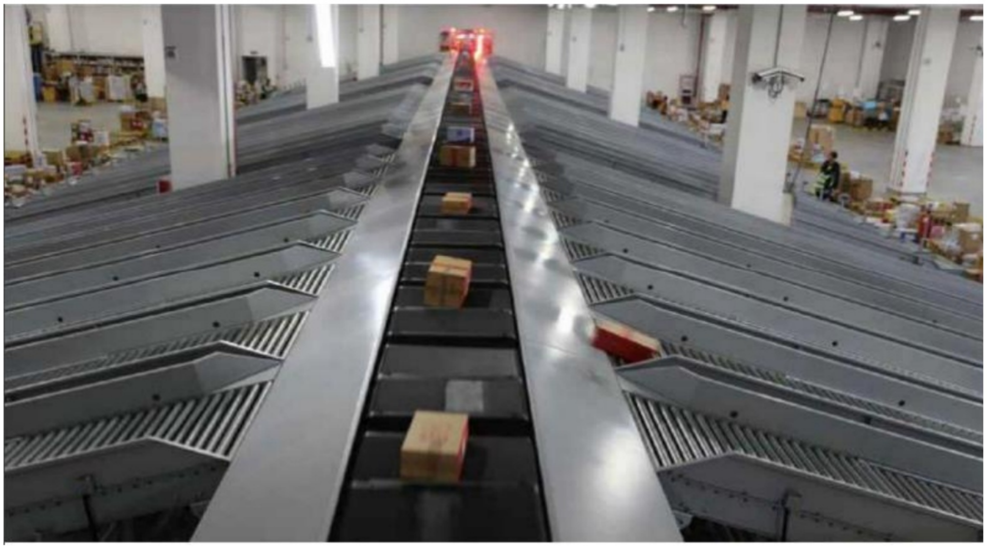


Figure 29: Installation of infeed sorter

The Features of Item Sorter:

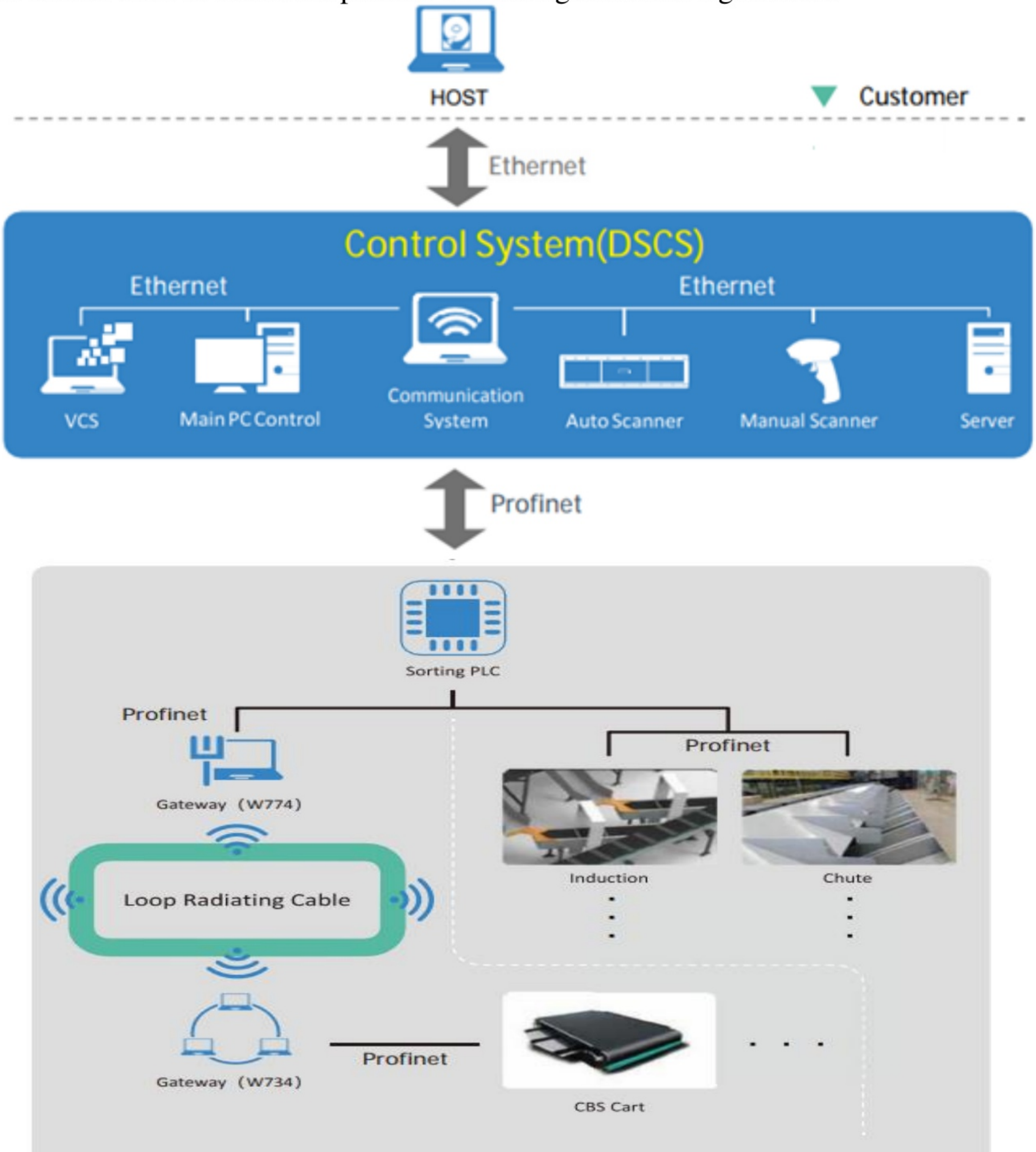
Nowadays, Due to the spreading of e-commerce buying, the logistics companies tried to figure out to an innovative system to increase the production, efficiency and decreasing time to shipping the parcel to the client so now they are using the infeed item sorting.

The following steps shows every detail from ordering until the order is exit from the warehouse. (1) the customer is ordering his/her product from the company website,

(2) The ordered was received on the system

(3) The Pickers get more than order and put the all order mixed in the pallet/ stroller.

(4) Then they put around 25 Pallets mixed on every cross-belt sorter and the system is automated scan the bar code of each item/product and falling out in the right chute.



Chapter (5) Analysis:

My main aim is to be increase the parameter of production and decreasing the time and cost by:

(1) Efficiency

Efficiency is one of the main KPI's (Key Performance Indicators) along with UOR (Utilization of Resources) and productivity monitored to show how the production is going in each of the various departments in the company. The definition of the main KPI's (Key Performance Indicators) is discussed: variables used to analyze the performance of a company, brand or product. KPIs are used to objectively measure the success of an organization in general, or to engage the success of a particular action or campaign. These units provide insight into the degree of success and the progress of the complete of long-term goals.

Examples of KPIs:

- Number of new customers;
- Sales (or sales growth);
- Average delivery time of an order;
- Unique reach of the website;
- Number of complaints;
- Spontaneous brand awareness.

$$Efficiency\ (E) = \frac{Earned\ Labor\ hours}{Direct\ Labor\ hours}$$

(2) UOR (Utilization of Resources):

It is the KPI (Key Performance Indicators) which refers to the process of making most of the resources at disposal, to achieve your target. It can be increased by better utilizing the resources of the firm. the UOR (Utilization of Resources) is equal to the productive hours divided by the presence hours. The main goal should be focusing on increasing productive hours.

$$\text{UOR} = \frac{Productive\ hours}{Presence\ hours}$$

(3) Productivity:

Productivity describes various measures of the efficiency of production. Often, a productivity measure is expressed as the ratio of an aggregate output to a single input or an aggregate input used in a production process, i.e. output per unit of input, typically over a specific period. Most common example is the (aggregate) labor productivity measure, such as GDP per worker. There are many different definitions of productivity (including those that are not defined as ratios of output to input) and the choice among them depends on the purpose of the productivity measurement or data availability. The key source of difference between various productivity measures is also usually related (directly or indirectly) to how the outputs and the inputs are aggregated into scalars to obtain such a ratio-type measure of productivity.

Productivity is a crucial factor in production performance of firms and nations. Increasing national productivity can raise living standards because more real income improves people's ability to purchase goods and services, enjoy leisure, improve housing and education and contribute to social and environmental programs. Productivity growth can also help businesses to be more profitable.

$$\text{Productivity} = UOR \times E$$

Figure 30: Efficiency report

The previous illustrate (Figure 30) extracted from the efficiency report is done by Power BI software that shows the worked hours, earned hours, efficiency by the month.

(4) Enterprise Resource Planning (ERP):

ERP system is the integrated control of major business operations, through software and technology which collects and generate real time data. The data management in this case is important because it can allow the detection of the main problems and how to formulate a solution to it. The most objective is following in lines:

- Improve business efficiency from an operational point of view, reducing costs and increasing control over the company's management,
- Risk is lowered thanks to data integrity and a greater number of financial controls,
- Increased management efficiency, in fact an increase in the availability of data makes it possible to speed up and make business processes and decision-making processes more reliable,
- Better coordination between users of data relating to business processes, in fact this shared system allows more users to access a greater number of information,
- There is a better management of human resources such as workers,

- Costs related to operational management are reduced, because as processes become shorter and more precise, time and costs are saved, thus increasing business efficiency.

Programs:

I. SAP: is the most important software in any company because every department uses the data that SAP provides, starting from the planning department which needs to allocate a plan for each machine, in order to make a complete production plan.

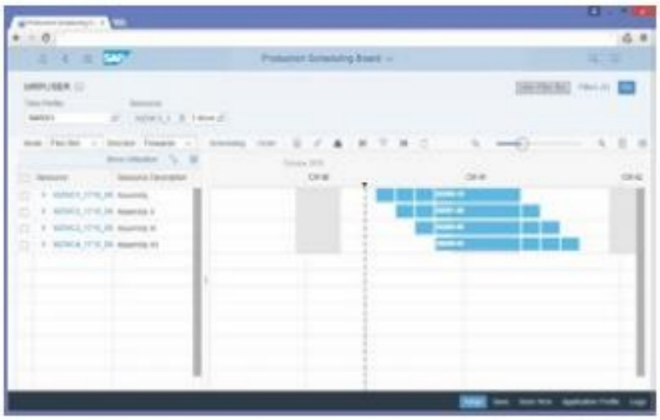


Figure 31:Production Scheduling report

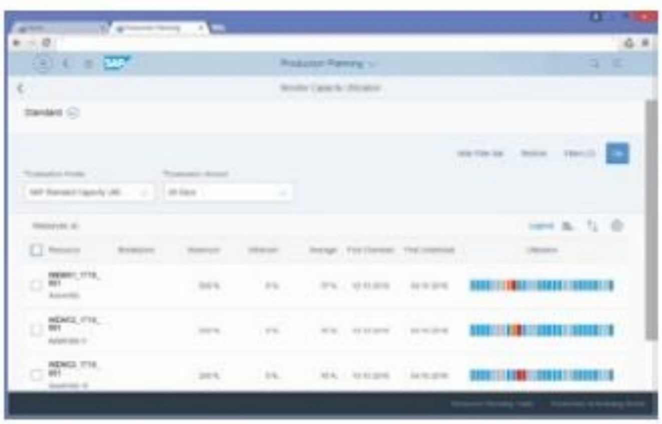


Figure 32:Production planning

It is very innovative way and effective production planning and scheduling. It predicts demand forecasting, inventory optimization, response and supply planning. It can optimize production and save costs to remain competitive.

Benefits of SAP ERP

When organizations implement SAP ERP and integrate their business processes, they can expect the following benefits:

- Connecting all parts of supply chain,
- Save money and time.
- Get instant access to real-time information.
- Make smarter and faster decisions based on data from the software's reporting tools.

II. Power BI: It provides cloud-based BI (business intelligence) services. It offers data warehouse capabilities including data preparation, data discovery and interactive dashboards. One main differentiator of the product is the ability to load custom visualizations. is the software extracting the information from the planning such as machines (in which the machine date work in, numbers of hours, numbers of produced items). Also, the best tool for business and data analytics and ad-hoc data analysis.

Figure 33:Power BI Interface

The most advantage is improving publishing efficiency and accuracy by Power BI data analysis.

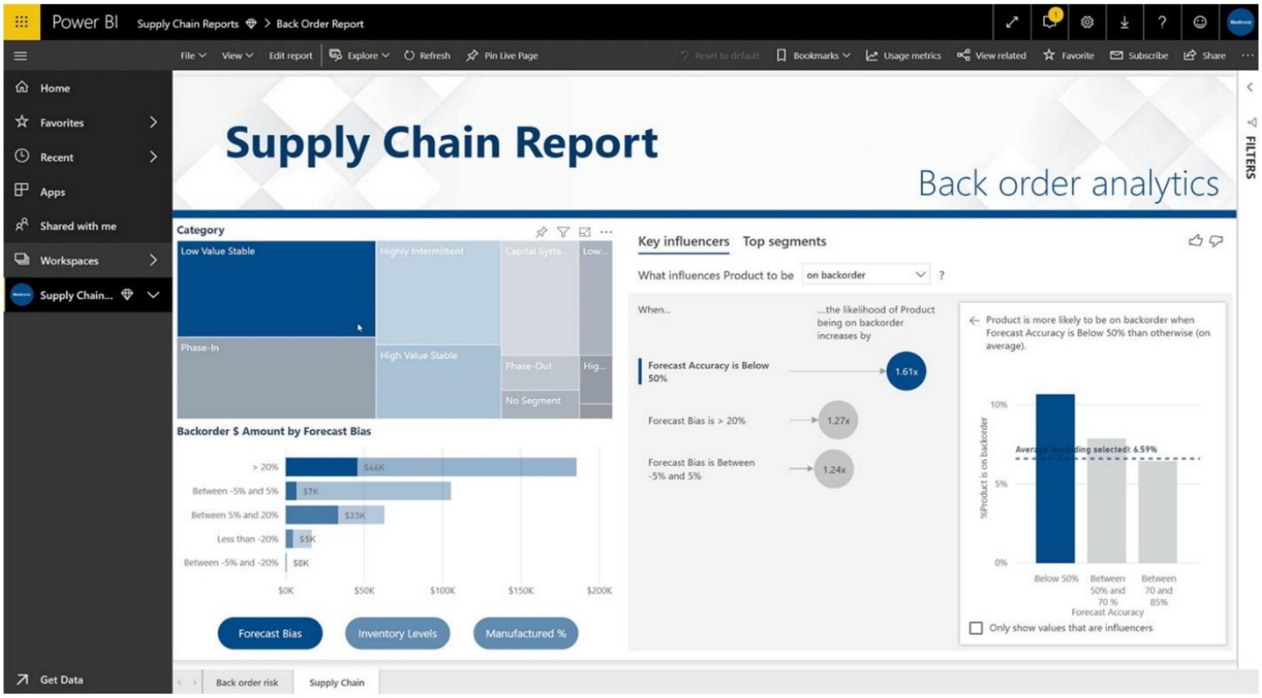


Figure 34:Supply chain report

The take advantage of the latest advances in find answer fast to input data, build machine learning models, and find insights quickly from both structured and unstructured data, including text and images to extract the analytics.

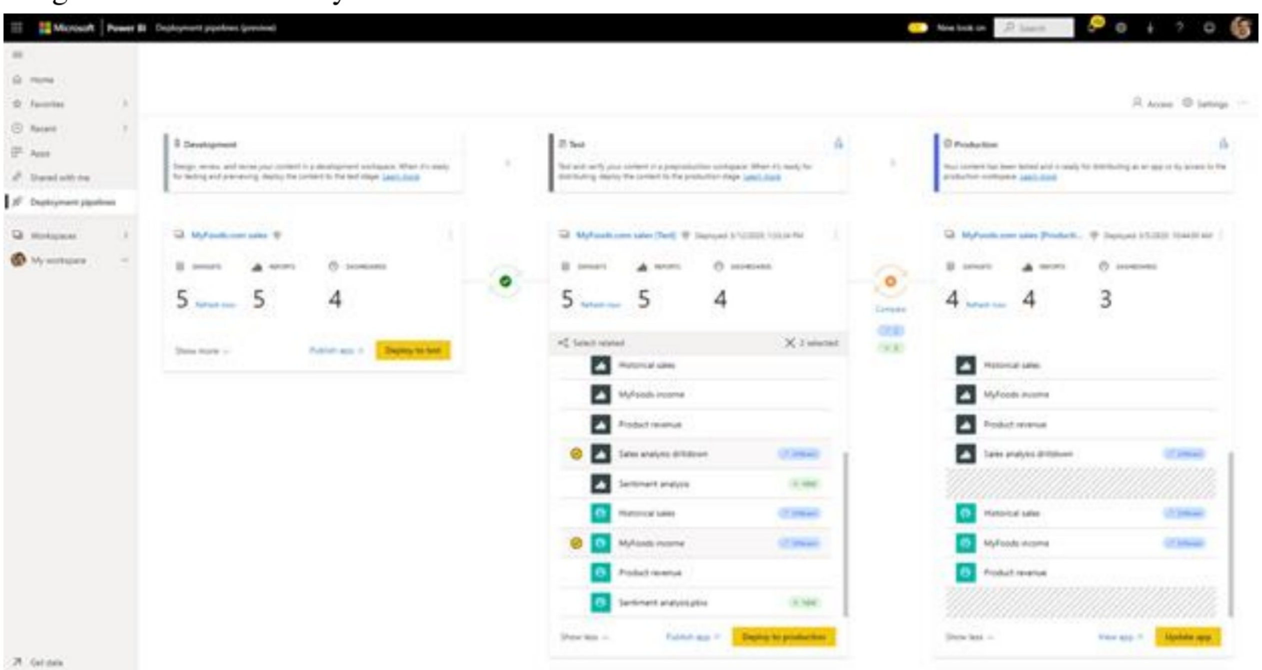


Figure 35:Production report

Improve the efficiency and accuracy of BI content quickly identify differences and move content from development and testing to production with confidence using the simple visual cues.

Chapter (6) Conclusion & Recommendations

Smart factories will be intelligent and automated factories, where machines are networked with each other, able to diagnose and solve problems by collecting and analyzing big data in real-time.

Production will become more seamless, from planning all the way to actual operations.

Supply chains will become more closely connected and efficient, delivering finished goods to warehouse for distribution through autonomous machines.

Most of all, robotic machinery handling collaborative roles in production will become smaller, more mobile, more easily programmable. They will learn and become artificially intelligent; they will become smarter, more autonomous, and able to self-optimize. Predictive maintenance will become the norm.

Smart factories are the logical, intended outcome of Industry 4.0. Smart factory automation will be driven by artificial intelligence, altering industrial production in ways we've never seen before, aided by new technologies that are now at our disposal.

It all began with the First Industrial Revolution, which introduced water-powered machines into factories and farms. The Second Industrial Revolution saw the rise of heavy industries, industrial railway transport, and the use of electricity and steam-powered industrial machinery.

The Third Industrial Revolution improved on the limitations of analog and electrical machinery by introducing computer automation. By the late 1970s, most production line machinery was first mechanically operated, becoming more and more computerized in the decades that followed. But these machineries were prone to error, heavy in maintenance requirements and could cause injury to workers.

Industry 4.0 will transform current production into smart factory production, altering business processes and reshaping the role of people in this realm, as smart machines take to sharing and complementing the roles of humans in production.

Industry 4.0 is the fulfillment of digitization as envisioned by industries across the board. We can sum up the definition of Industry 4.0 as the amalgamation of technology and business strategy. It is the key to unlocking any enterprise's maximum manufacturing potential.

In many respects, Industry 4.0 is an evolution of the previous industrial revolution. It optimizes the potential of computer automation by integrating the following:

The Internet of Things: More devices become connected to a central controller. This set-up allows manufacturers to gather more data and streamline and digitize their processes more efficiently.

Big Data: Data is crucial to Industry 4.0. because of Internet of things, data will come from many different sources, and manufacturers will need them to make sound, real-time decisions.

In the end, the highly competitive and global organizations investing and realization of Smart Factories due to:

(1) Higher quality standards in production processes and products.

(2) Reduced waste of time, human resources, materials and financials.

(3) Trimmed production lines and shortened production process flows.

(4) Accelerated manufacturing without interruptions and breakdowns. In addition, production processes should be so flexible.

(5) Allow customized products production at the speed of mass production processes.

(6) Reduce Manufacturing costs.

(7) Greater sustainability,

(8) Open opportunities for expansion.

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