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INDUSTRY 4.0: THE STAGES OF INDUSTRIAL DEVELOPMENT AND PROFIT OF CHANGE

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ABSTRACT

Industry 4.0 or digital age changes all known value propositions. Business models, processes are transforming, the rules of the past are void. There is no doubt that there is another similar form of the technological transformation that is happening now, in the near future. Trend points to this! One of the basic issues of the manufacturing industry is to integrate technology into processes and to be more productive. However, incorrect strategies can be designed and unintended results can be achieved, especially due to insufficient knowledge level. In this study, how the industrial development is formed and why, where and how the enterprises can use the technology are examined.

Keywords: Industry 4.0. Digital Transformation. Industrial Development.

1. INTRODUCTION

The Industrial Revolution (Industry 1.0), starting with generation of power from stream engine on last quarters of 18the century, is shown as the first important cornerstone of industrial history [1]. During this period when it began to be created on the basis of today's industry, humanity is learned mechanization, developed according as learned and started to satisfy more quickly and easily many of needs [1]. In the beginning of the 20th century, the effect of learning-developing process is shown with performing first mass production using assembly line through a single model by Henry Ford (Industry 2.0) [2]. This period when modern production lines firstly began to use is golden era of the producers. Products were offered to the market even there is one type and customer needs were met. These developments in the industry did impact the new players to enter the market. Releasing different model and property products to the market for social groups, which have different income and pleasure status by new player provided to freedom of choices for consumer even if it's limited and the element of cost began to come into prominence on competition [3]. Increasing competition affected to development of the production systems and industrial automation systems were started to use in production processes since 1970s (Industry 3.0). Using PLC controlled automation systems in difficult to be done by human power, long and repetitive jobs were allowed to produce products faster, higher quality, lower costs and same standards [1].

Industry focused on technology to develop and manage their processes efficiently. Due to this, Industry 4.0 tools are accepted vital competitive weapon for manufacturer. It is needed to understand the development of technology, either to use it or prepare themselves for future technological developments. In this paper, the development of technology has been studied on the basis of industry 4.0.

2. FIRST CHANGE AFTER INDUSTRY 3.0 (SMART PRODUCT)

Towards the end of the 20th century, thanks to the incredible development of technology, communication was made faster and easier. Removing borders by Internet, meeting suppliers,

customers and producers in virtual platforms did cause globalization, increasing world trade and change in socio-cultural structure [5]. Developments in the field of microelectronics paved the way for obtaining scalable & low energy consumption sensors at reasonable costs by providing to produce sensors and network technologies under the scale of economics [6]. In this way, sensors and network technologies previously used in a limited way even in high technology areas were started to use in consumers' everyday life.

To starting to use of these technology on consumer products like smart phones and tablets revealed the smart product concept and products gained sensing, interpret and communication skills. This features added new properties called private key to the products besides public key. Two keys products (private key & public key) opened the new way of income channel for producers by expanding the way of correlating the profit not only over the product but also gaining profit from after sales services by bringing new dimension to the concept of product. Smart Product: Product and Services. Smart products were not seen just a physical object anymore, at the same time they had also sensing, programming, decision making, taking action and communicating with environment properties. Manufacturers had the opportunity to be able to generating continuous income thanks to the smart products while physical products that offer to the market generated income for one time [7]. Today, consumers achieve to the information and product/service easier and faster and involve in business processes such as ordering, monitoring thanks to the individual mobile equipment. Using the data taking over the smart products effectively during the process of understanding customer's behavior and market expectations brings quite important advantages for the fast product development processes [9].

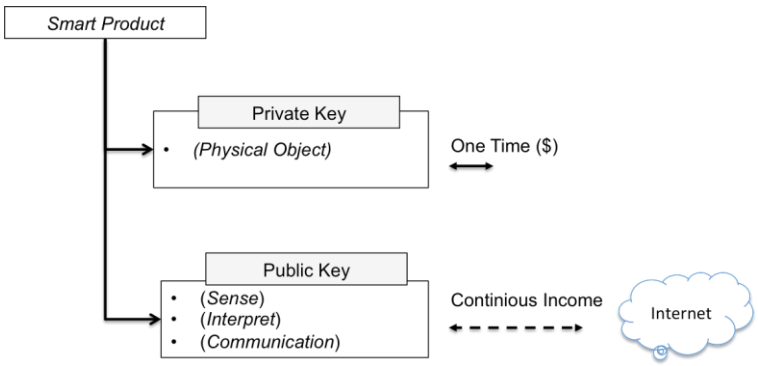

Figure 1: Smart Product (Source: Author)

3. SECOND CHANGE (SMART DEVİCE & THINGS)

Shifting competition towards smart products did have an impact on development of the production processes. Companies started to use new technologies in their operation processes on the purpose of producing more functional and special products faster and sensitive tolerance. Using sensors, network technologies and advanced software applications on business processes / equipment's provided to increase the automation skills level of production processes and as are products, also revealed smart device concept to the equipment, by bringing SIC (Sense, Interpret, Communication) property [7]. Being smart equipment a part of production processes paved the way of making communication with all direction and started to gain SIC property to objects that in production area. Gaining sensing, definition skills of objects with sensors, RFID tags, getting contact via communication protocols and technologies, behaving as decision maker with advanced level software applications provided to reveal the concept of Smart Things and with help of this concept, Smart Factory notion is revealed by gathering smart objects, smart products and smart equipment (OT: Operation Technology), working interactively over the current IT systems/technologies and integrated with digital and physical world [8].

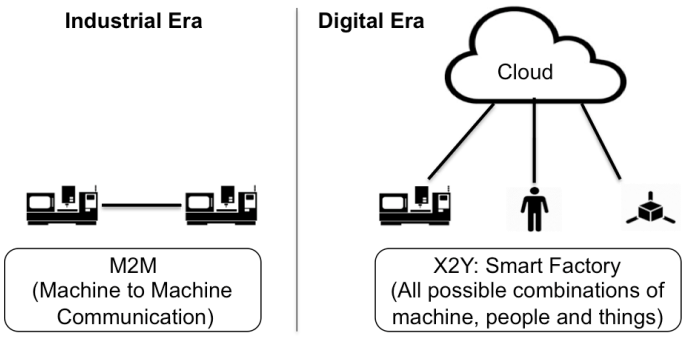

Figure 1: Industrial & Digital Era (Source: Author)

In industry today, manufacturers make use of blocks, which have sensing, interpreting and communicating skills with its environment in their production processes. Each block communicate with the object in its own network with proprietary protocols and transmit data generated through its own network to external blocks through different communication protocols. Thus, M2M concept which means previously similar type of equipment communicate locally, has left its place to communicating equipment, objects and people with each other from anywhere (X2Y→M2M, Machine to Machine; M2T, Machine to Things; M2P, Machine to People; P2T, People to Things…). Companies that started to use new technologies on production processes, equipment and objects gained important advantages in the meaning of speed, quality and cost by executing operational and supporting functions as information transfer, orientation, making decision, real-time process monitoring more effectively. Companies that use new technologies on production processes, equipment and objects; they achieved significant advantages in terms of speed, quality and cost by making operational and support functions such as information transfer, routing, decision making, real-time process monitoring more effectively. The advantage of the objects being equipped with sensor and communication modules, communicating with each other through software protocols, and getting information, has expanded the concept and included suppliers and customers. This result revealed the concept of smart chain. A growing number of objects (equipment/process, products, and objects) are equipped with these technologies in supply chain processes. According to Cisco's prediction, it is expected that 50 billion smart objects connected with Internet will make communication interactively except servers and computers in our world, which has a population 7 billion by 2020 (IoT: Internet of Things) [1].

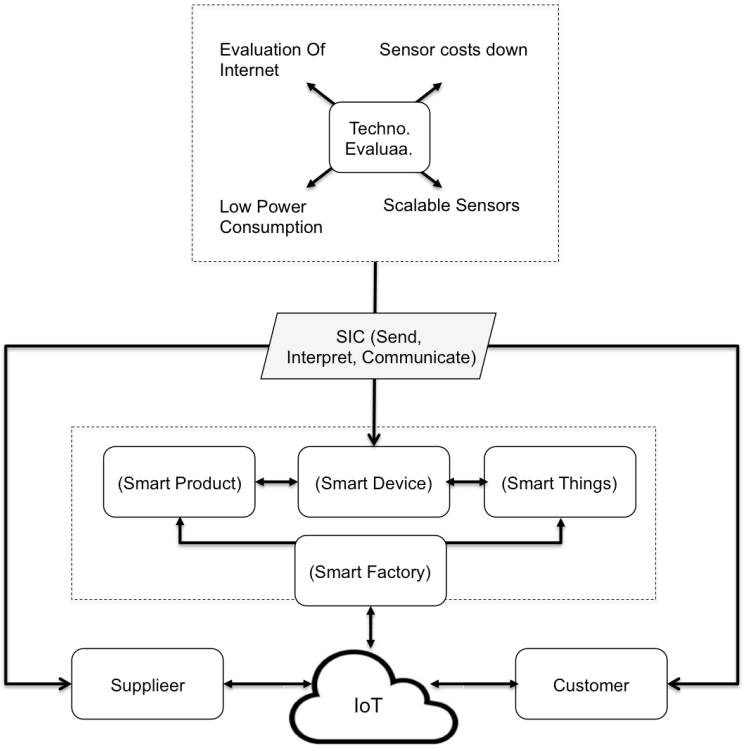

Figure 2: IoT (Source: Author)

4. THIRD CHANGE: NEW STANDARD FOR KNOWLEDGE PRODUCTION (IOT)

IoT is knowledge management standards of digital world, which carry us first smart factory then smart chain. While machines only on same platform can make communications in old days, today, objects and sensors can get in contact with each other from everywhere thanks to wireless network technologies and internet. In order to occur this situation, it is necessary that smart objects must be designed according to IoT structure and should be used standard communication protocols.

4.1 IoT Structure

IoT structure consists of three layers. Physical layer, network layer and application layer [10].

1.Physical Layer: Physical layer is smart devices and hardware which send/receive data. Sensors, RFID, actuator, network equipment's. Sensors, which based on material science and physics engineering, are the components that used for ADC (Analog to Digital Converter) technologies. Data are more Processable format due to digitalization and sensors. By this way, many process like measurement, defining position, monitoring can be managed more effectively. RFID and tags are the application examples that provide identity to objects. In a store, when the tags attached on to the product (alarm labels or small key modules) enter the coverage area of the signal emitter called transponder, it is able to produce data about energy status (stratus and identification) taken from magnetic field that is emitted from transporter through small antenna (coil) on the product.

2. Network Layer: The network layer of the IoT is Internet. Processable digital data taken from the sensors can be transmitted wirelessly between the devices thanks to development of network modules/protocols. Network layer is responsible from transferring data came from physical layer (IoT device) to other IoT equipment (connectivity). For this purpose, standard protocols are developed for different purpose in order to establish communications between smart objects and transferring data on Internet environment [12]. NFC (Near Field Communication) can communicate easily with human environment at personal distance with wearable technologies like Bluetooth. For example, two IPhone devices can perform data transfer without Bluetooth or WiFi through communication protocol that developed for Apple itself at close distance. Communications are made very easily at site scale areas like factory, business center thanks to Wi-Fi. Wi-Fi's can perform communications 40-80 m at close areas, 300 at open areas with 11 Mbytes/s. Similarly, it is often making use of LoRa-WAN (long Range Wide Area Network) within the scope of smart city and GSM/GPS technologies for issues as determining location/position in a global scale.

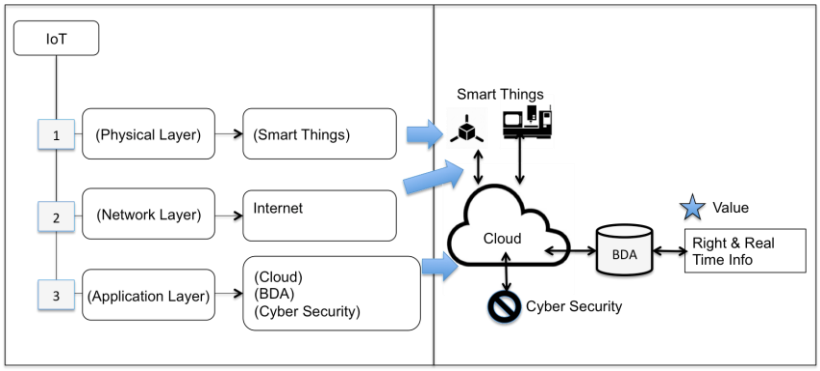

Figure 3:IoT Layers (Source: Author)

3. Application Layer: Application layer contains protocols, interfaces and software that are required for sending/receiving data of IoT objects. Data are produced in each process in smart factories/chains and data transfer is occurred between thousands of objects. This situation leads to a considerable increase in data traffic and the size.

Cloud concept (Shared Intelligence) has revealed with managing data flow, storing large data, accessing at anytime from anywhere. Big Data Analytic notion is revealed from the concept of deriving meaningful information from big data. While cloud (strategic and smart automation) provides

keeping data over high capacity virtual server on Internet, sharing with external environment and accessing mobile, at the same time, it also allows reduction of energy and investment costs due to common use of resources.

Big data analytic or data mining is quite important with regards to managing processes by obtaining perpetual structured useful information, identifying related ones with algorithms from large scale unstructured data (does not come in the standard format). Today's petroleum and the main driving force of innovation is knowledge that comes from many sources. Likewise, if recorded data are not analyzed and the actions will not be taken, there is no sense of getting under measuring and recording. IoT can be defined as a network where smart objects send/receive data through Internet [11]. IoT Device Management is becoming an important topic due to large number of objects, being found in different locations and Internet environment. Well-informed teams who are monitoring and managing this complex process is needed for coordinating of activities such as software updating/maintenance of all IoT devices associated with issues such as physical damage of IoT devices and energy needs at remote/rural location. In addition to this situation, data and mobility increase, the importance of data security and reliability increase.

Cyber Security Management concept has emerged for protection against cyber-attacks and possible losses. From "1 byte" information level generated sensors in production processes to Giga Byte level generated from ERP system, data in different size and formats are generated, sent and received. With this data, processes such as product development, document management, production planning, delivery, finance are managed. It is needed to store, operate and manage data in specific standards for working interactive, coordinated and synchronic of all system and objects placed in processes. In order to perform this process within the factory vertical integration, throughout supply chain horizontal integration are needed [6]. ERP (Enterprise Resource Planning) and MES (Manufacturing Execution System) are used in accordance with this purpose [1].

4.2 IoT Ecosystem

There are technology developer, market and standard determinants in IoT ecosystem [13]. Technology developers contribute improvement of IoT technologies (sensors, actuators, network modules, data storage and data processing etc.) by doing continuously research/development. Market (States, companies that developed innovative products, health sector, cities, universities etc.) provides to expand the IoT network by using these technologies. Standard determinants (such as IEEE) define communications, software, hardware standards and protocols need for working network conformably (Same language of protocols and standards).

Each smart object in IoT network should be defined as independent and made contact with other objects in network. For this, standard protocols must be used. However, it is not always possible that sensors, actuators and network modules that different producers produce correspond over defined standard communication protocols. Even though there are establishments, which define standards, communication standards cannot be specified transparently for all possible scenarios because of quick and continuous development of technology. The priority problem of IoT networks is compatible working of objects with each other (interoperability). In order to overcome this problem, WoT (Web of Things) concept that means communicate via standard web network protocols used currently, has revealed [13].

Knowledge management lies on the basis of IoT [1]. The most important benefit of IoT is real time decision-making, meaningful results/information taking from large sets of data comes from different formats and many places whenever wants. This benefit will be reflected us as productivity, speed and competitive advantage.

Many examples can be given to the issues of application of the ındustrial IoT.

— Productivity can be increased with monitoring all supply chain components (product, object, process) with smart chain structure and taking fast and correct decisions by obtaining real-time

information properly (IoT; Supply Chain Visibility. Product development, stock management, route planning).
- Remote and real-time management of operational processes, maintenance of equipment's can be provided. (IoT: SCADA, MES, Remote Plant Operations Management and Maintenance).
- All data collected from operational processes are evaluated and contribute to take result-oriented actions faster (Centralized Plant Data Management).
- Solutions can be found to problems faster without much education by providing technical document/information needs to share in case of breakdown maintenance/services (Smart Maintenance and Real Time Decision Support). Decrease of mistake and education costs, fast/correct problem solving, etc.
- Costs can be reduced by making energy management/planning with monitoring process energy requirements continuously and on-line (Cloud Base Energy Management).

5. FOURTH CHANGE: ADVANCED LEVEL PRODUCTION STANDARDS

Technological development is not confined with IoT. The sector is moved from mass production to customized production and speed becomes the most important competition factor. Thus it affected the development of technology in especially product development, operation management and marketing processes [14].

Products can be produced and tested in virtual platforms with simulation technologies without producing physically and launching to the market. In this way, possible problems that may arising from material or design in the market can be tested from virtual product, solved existing problems under product development and launched the physical product to the market uneventfully. With simulation technologies, all behavior of production processes contain human, product and machines can be modeled. Thus, ideal layout designs can be done effectively with process optimization, testing activities by creating digital twin of production processes in virtual platform (Simulation).

In the digital age, speed emerges as the most important competitive factor [5]. Consumers have no patience to wait. Any delay can lead companies to customer losing out to its competitors. Additive manufacturing (Additive Manufacturing / 3D Printing, digital to physical transformation) is a technology that provides to produce real three-dimensional objects from virtual models created from digital data. Making prototype in product development process or customized product manufacturing which has "1" order without costing mold design/investment, only using digital data, producing different three dimensional objects not only to gain with regards to cost but also decrease dependency of foreign resources; so it increases product development speed providing the company more reactional and agile (Agile manufacturing: Fast product development and reduce time to market time, Reduce development/operation cost) [9].

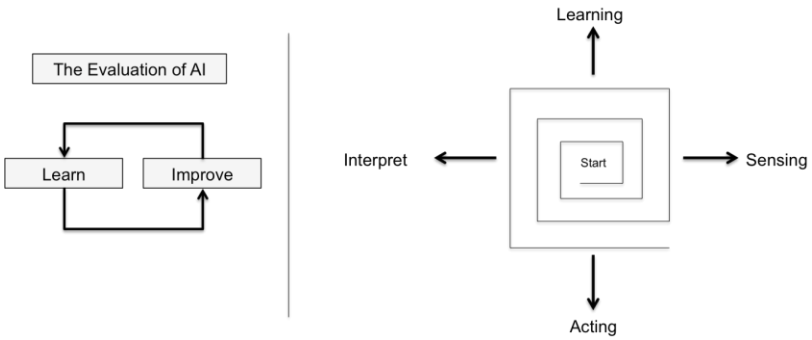

Figure 4: The Evaluation of AI (Source: Author)

Portable digital data allows to be converted physical model with 3D technology in any place from virtual models designed at different places and this provides benefits in terms of transport, storage costs and speed. In the future, many industrial products (right now as dental prosthesis, some of the

plastic parts) will be sent via e-mail to customers and the customers will be able to transform digital product to physical product through 3D printers wherever they want.

However, 3D printers do not apply to wide areas because they cannot produce at desired speed and all materials cannot be processed via them. But, with technology and material developments, 3D printers are one of the basic production processes in the near future as an indispensable element of agile manufacturing [15]. The increase in diversity makes the manufacturers very difficult in determining the characteristics and functions of the products to be developed. It is quite important understanding market expectations and accurate product [5]. Launching wrong product to the market raises the risks of further harm by not only turnover loss but also reputation loss. To avoid this risk, augmented reality application (Augmented Reality) is utilized by different variation of products are designed virtually and presented to the customers at the stage of specifying which configuration and property products will be produced physically. Similarly, speed and cost advantages can be obtained by meeting virtual products to customer in launches and introductory meetings because of sending physical products everywhere are quite expensive (Digital shadow, virtual product development).

Artificial intelligence studies provide to take place the robots in greater area during business processes. Machines were designed to work automatically, but robots are developed to learn themselves (Autonomous Robots). In ındustrial era, robots were responsible for doing the repetitive work that was thought to them, are now developed towards to mode which is able to teach themselves, make decisions and work interactively with people (Collaborative robots, hand-in-hand). Robots are getting smarter; and become smarter as they're getting smarter. It seems that, intelligent robots will do a lots of work done by people soon. In mounting bands, production cells, logistic times, call centers…

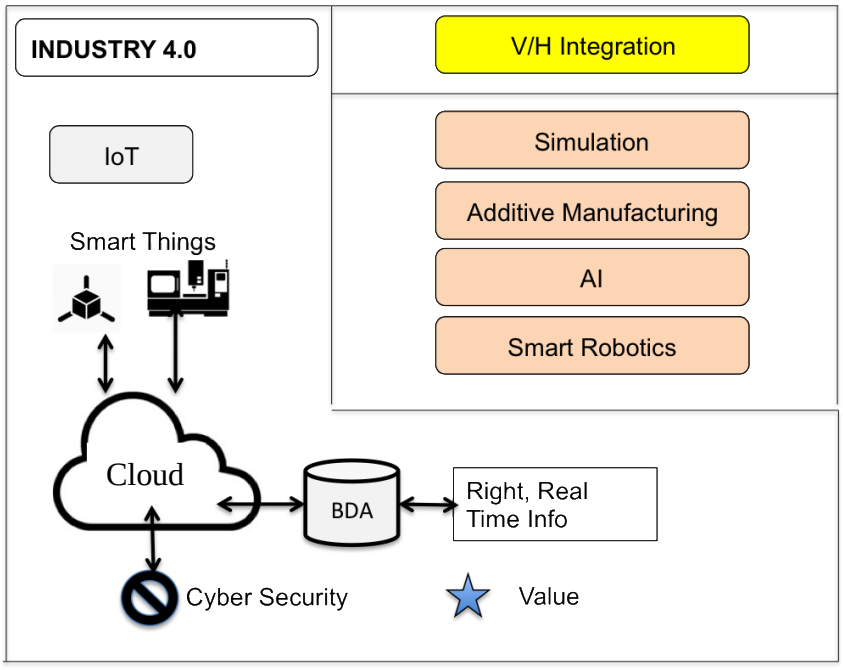

Figure 5: Industry 4.0 and its Components (Source: Author)

Adding this concepts to IoT, is increased the importance of digitization concept and as a result of all these, the concept of Industry 4.0 that we have spoken today has revealed [1]. World Class Manufacturer had passed from workplace layout (2.0) to factory level (3.0). Now, they are trying to pass from industrial era to digital era (smart factory, industry 4.0) that is a new model human – machine and other sources can work together interactively/collaboratively over complex networks in order to keep pace with the new era when competition will take a new dimension.

They are collecting data from each stages of the process with Internet of Things (IoT: Internet of Things). Now, there are thinking, decision making and information sharing objects within the processes.

- They are storing data on virtual storage (Cloud) in order to provide easy reach and operational flexibility; they are increasing their productivity by analyzing the big data and converting meaningful state (Big Data).
- They are gaining speed advantages in the market by developing prototypes and customized products in 3D printer technologies (Additive Manufacturing).
- They are capturing the maximum sensitivity with the scope of quality by using robots that can sense, learn, decide and simplify the difficult processes with regards to quality (Autonomous Robots).
- They are expanding their networks by applying vertical integration within the company and horizontal integration throughout supply chain. They are becoming more agile by obtaining information accuracy and reliability using the knowledge power effectively with process integration (Vertical & Horizontal Integration).
- They are designing processes that do not allow occurring losses by making analysis of not only product but also production processes and obtaining the most effective process in the first place with the simulation techniques (Simulation).
- They are obtaining cost advantages by sending the promotions and sharing related to product or service with augmented reality techniques more effectively and faster to intended place (Augmented Reality).

Developments show that the world class producers will produce the products of the future faster, lower tolerances, near-perfect quality, more efficiently and safely. Moreover, they will do this only for '1' product.

6. RESULTS AND DISCUSSION

Technological development, globalization and socio-cultural transformations change consumer' preferences, market dynamics and business standards, competitive environment of industrial era gives place to digital era. Manufacturers are now face-to face with new consumer base that have totally different expectations [16]. Consumers are now more informed, inquisitive and foremost they are aware of their importance. They want special product in high quality and immediately instead of standard products [17]. Diversity is gradually increasing, product life span is shortened [18] and cost / benefit factors are preferred alongside cost [19].

During the period when producers were involved in the issues such as what to produce, the features and the price of the product, limited communication was made with customers and suppliers; The existence of standard / repetitive production processes did not require competent labor, and training and development issues were raised very little. Operational performances were followed using financial criteria such as turnover, total profitability, unit cost, technology and were mainly used to enable the production of large amounts of standard products effectively. The low product range allowed the production of large quantities of standard models without frequent product / model rotation on the production lines. The most important advantage of this method, based on the mass production concept, was scale and opportunity economics. The larger the scale, the lower the unit costs, the more profit the producer made [22].

However, in the digital age, the scale is gradually shrinking and the conditions of competition change. Different expectations and tendencies of consumers lead to an increase in product variety, decrease in quantity and shortening of product life span. The displacement of consumer expectations from standard products to special, personalized products, the high quantity-low diversity concept is replaced by low-high diversity, and the scale economy loses its validity in many areas and the business processes are focused on the scope economy. The high variability and uncertainty, the increase in speed and quality expectations require new production strategies to be different. Now, it is not easy to

meet consumer expectations by means of the concept of mass production indexed to scale economy and industrial age perspective [3]. The digital age is based on the concept of making personalized-innovative products with mass production performance [1].

The demand for personalized products makes the innovation and product development process more meaningful. The most important competitiveness of the digital age is to realize the expectations of consumers before everyone and to develop the innovative products rapidly with the strategies that direct the market. Innovative product allows you to be permanent in the market and sell your product more expensive. World class manufacturers are struggling with their power to develop innovative products, devoting considerable resources to this issue.

There is no room for error in the new period! Only companies that are open to change and capable of fast learning will survive. Businesses have to be as efficient, fast and quality as ever. Moreover, they will have to do this throughout the entire supply chain, not just within their organization [5]. Not to say to the customer but to keep the stock levels low, not to be material in production but to minimize the inventory levels, to be fast in the operational sense but to use the resources at the optimum level and to decrease the carbon emission levels by taking environmental factors into consideration while doing all these, the first agenda item of the producers looking for operational excellence . All this is necessary, but the factors that seem to restrict each other are no longer able to handle any business alone. This dimension further raises the importance of supply chain management and necessitates more efficient management. The aim of a new approach "total cost" concept is not just reducing your costs, it is reducing total cost (supplier – producer - distributer) [16]. Now not firms, supply chains quality, speed and cost compete.

As a result of this situation in the digital age; 1. The product will be developed more frequently than the industrial age, and those who can do it faster will be more competitive (Fast Product Development). 2. Small lot numbers and frequent product / model return will be required in production (Leagile Manufacturing). 3. Silo-style organizations will be replaced by value chain organizations, competent and problem-solving human resources will become the norm, success / performance criteria and criteria will change (Value Stream Management). 4. The market will replace the customer networks (Network is your Customer). 5. The data concept will become a strategic asset (BDESC: Big Data Enabled Supply Chain), which is able to derive meaningful information from the data.

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