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TRANSFORM INTO INDUSTRY 4.0 USING SYSTEMS ENGINEERING APPROACH

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ABSTRACT

A major change in production is aimed with Industry 4.0, which is called the industrial revolution.This concept, which aims to enable the manager to control the production line remotely, is thought to increase productivity and speed in production.Industry 4.0which aims to leave the place of human activity in production to intelligent robots (e.g.communication betweenrobots, smart transport systems) has started to spread rapidly in our country. There are many ways of transforming into the digitization process in production, and this process encompasses many areas that will affect from product design to production, transportation and even payment process. In this paper, our approach to transforming to Industry 4.0 is system engineering. It is very difficult to introduce a solution to the system without identifying all the work done or considering a system as a whole. For this purpose, system engineering approach and tools will be utilized.The system engineering is a holistic approach. System engineering evaluates all technical specifications to provide a quality product.In the process of transition to industry 4.0, the existing system should be well recognized and analyzed in all respects.User requirements have been identified for the company with the help of Structured Systems Analysis and Design Method, SSADM. Starting from the user requirements to functional, departmental and company-wide requirements have been identified. Cost breakdown structure and its requirement of digitalization have been identified in the same way. A non-parametric analysis is also done for the identifications. At the end of all identifications, a companywide readiness level for the Industry_4.0 has been stated including a breakdown structure down to the user requirements at the shop-floor level. A practical guide is also proposed for further studies. It could then be applied to different companies as well as industrial sites on the way of transformation into the Industry_4.0.

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1. INTRODUCTION

The concept of the Industrial 4.0 emerged in Germany and began to gain importance in our country. In order to keep pace with the developing technology, it is important that manufacturing companies comply with Industry 4.0. In Industry 4.0, dynamic business and engineering processes enable last-minute changes to production and deliver the ability to respond flexibly to disruptions and failures on behalf of suppliers, for example. [1] Digitally developed smart machines, warehousing systems and production facilities enable end-to-end information and communication systems-based integration across the supply chain from inbound logistics to production, marketing, outbound logistics and service [2]
As the fourth industrial revolution, it has taken on the name Industry 4.0, in keeping with the way new versions or releases of software are usually designated. [3] The Industrial Internet has now been added to agenda of the majority of companies. [4]

This work is based on two purposes. First, to determine the technology maturity level of the ABC company in the transition to the Industry 4.0 process, and secondly to digitize the system by making optimization. In the transition to Industry 4.0, the existing system needs to be analyzed first. Appropriate improvements should then be made wherever necessary in the system. For this purpose, the name of a company that made production due to commercial transparency is named as ABC. This case was worked on the real factory in Ostim and the data were collected. ABC's business management system has been examined. In the process of transformation to Industry 4.0, user requirements have been identified for The ABC Company with the help of Structured Systems Analysis and Design Method, SSADM.In this article, SSADM, which is a kind of functional flow block diagrams, is used. It has been examined to the level of the user's requirement in order to determine the points where digitalization is necessary. With SSADM, the jobs that can be optimized in the industry 4.0 transition process are identified and the level of technology maturity at each level is explained. Both the cost and the nonparametric values specific to this study were used in the system.The cost of each user's requirement is calculated. As a result, when the system is digitized, the cost exchange can be determined. Further information on the method is included in the article.

This paper is structured in seven chapters. After this introduction, chapter 2 you'll find Industry 4.0 history and basics. In chapter 3 the System and Systems Engineering is explained. Chapter 4 presents Structured System Analysis And Design Method (SSADM). In chapter 5 a brief Cost breakdown structure of company can be found . Chapter 6 presents Technology Readiness Levels (TRL). Finally, the results are discussed in chapter 7.

2. INDUSTRY 4.0

The first industrial revolution begins began at the end of the 18th century and was represented by mechanical production plants based on water and steam power; the second industrial revolution starts started at the beginning of the 20th century with the symbol of mass labor production based on electrical energy; the third industrial revolution begins began in the 1970s with the characteristic of automatic production based on electronics and internet technology; and right now, the fourth industrial revolution, namely Industry 4.0, is ongoing, with the characteristics of cyber physical systems (CPS) production, based on heterogeneous data and knowledge integration. [5]

The Industry 4.0 concept is based on developing smart chains that are based on communicating with each other means of production, products, components, plants, humans. Established in Germany, the concept of Industry 4.0, is the brainchild – its beginning reaches 2011. [6] Now, the introduction of the Internet of Things and Services into the manufacturing environment is ushering in a fourth industrial revolution. In the future, businesses will establish global networks that incorporate their machinery, warehousing systems and production facilities in the shape of Cyber-Physical Systems (CPS). [1] This is appropriate, considering that the latest industrial revolution is powered by the Internet and Web-enabled software applications capable of processing streams of manufacturing data. [3]

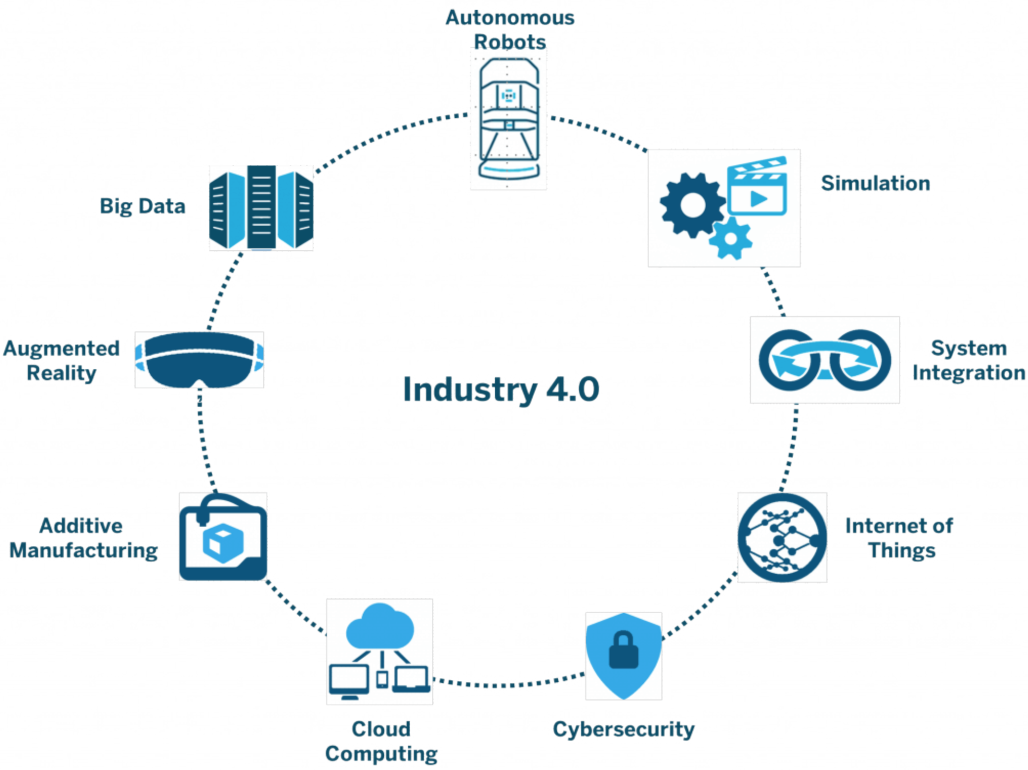
Smart industry or " INDUSTRIE 4.0" refers to the technological evolution from embedded systems to cyber-physical systems.[11] With recent developments that have resulted in higher availability and affordability of sensors, data acquisition systems and computer networks, the competitive nature of today's industry forces more factories to move toward implementing high-tech methodologies. [7]
Universality in industrial applications: Internet of Things, Internet of Services, Internet of Media, big data, communications inter-machines and cyber-physical systems using interoperability, decentralization and full virtualization certainly will affect different course of many phenomena than is apparent from past experience. [8]There are 9 pillars on which Industry 4.0 rests [12]

2.1 Autonomous Robots

Autonomous Robots reports on the theory and applications of robotic systems capable of some degree of self- sufficiency. [38] They are becoming more autonomous, flexible, and cooperative. Eventually, they will interact with one another and work safely side by side with humans and learn from them. [9]

2.2 Simulation

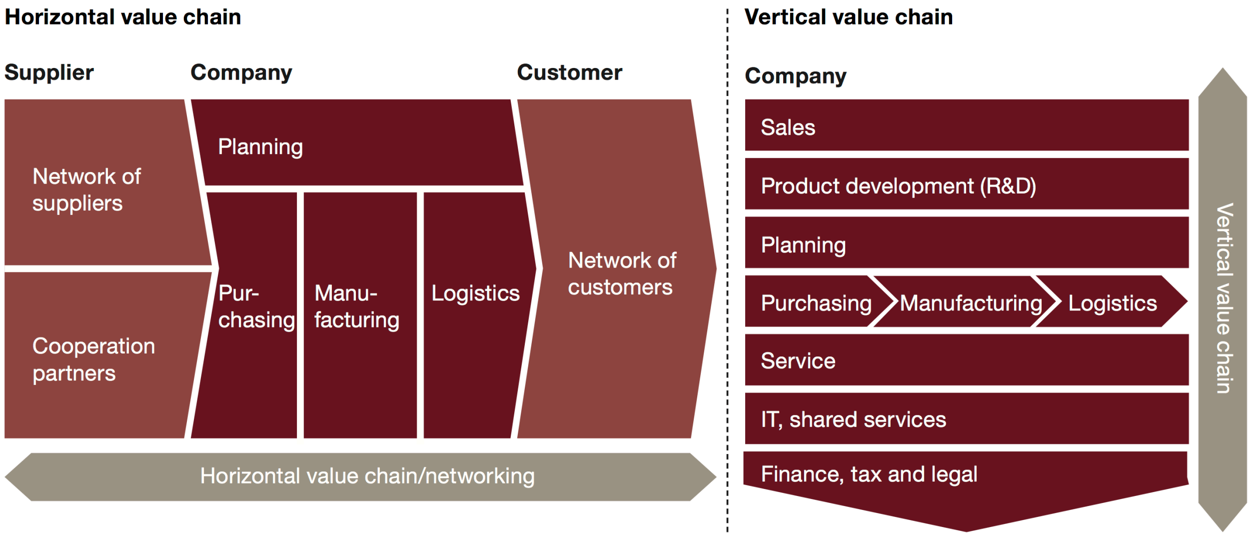
Simulations are used to mirror the physical world in virtual model, as is already used in most design processes. Through i4, future simulation will move towards smarter design to automate the "test-and-optimise" process and will be used more extensively in shipyard and ship operations. [10]



Industry 4.0 [42]

2.3 Horizontal and Vertical System Integration

Industry 4.0 would enable overall integration – companies, departments, functions etc. As the data would be on cloud, it will be real time and available for every department to access. [12]



Industry 4.0 requires comprehensive digitization of the horizontal and vertical chains [43]

2.4 The Industrial Internet of Things

The Internet of Things and Services enables to network the entire factory to form a smart environment.[13] A relatively convincing definition of IoT focuses not only on object identification and interconnection but also on the role of communication network. [14] Industry 4.0 will bring about highly connected and digitized global industry supply chain. [36] The challenges of the Industrial Internet escalate the threat of damage from cyber-attacks that manipulate processing and workflow systems [37]

2.5 The Cloud

Using shared (common) on request by computers or other devices of sets of data and computing resources (processing) on the Internet.[15] Characteristics of Cloud-based manufacturing (CBM) include networked manufacturing, scalability, agility, ubiquitous access, multi-tenancy and virtualization, big data and the IoT, everything-as-a-service (e.g., infrastructure-as-a-service, platform-as-a-service, hardware-as-a-service, and software-as-a-service), scalability, and resource pooling.[16]

2.6 Additive Manufacturing

Additive manufacturing is a suite of emerging technologies that fabricates three-dimensional objects directly from digital models through an additive process, typically by depositing and "curing in place" successive layers of polymers, ceramics, or metals.[17]
Additive manufacturing (AM) machines are increasingly being employed, due to their digitalization, automation, flexibility, and customization, which are also becoming a popular production system in the modern industry. [18]

2.7 Augmented Reality

Augmented Reality (hereafter, AR) makes reference to the real-time perception of an environmental setting that has been enhanced by means of computer-generated virtual components. (Augmented reality: An ecological blend)
AR technology has three significant contributions: (1) the real scene and virtual 3D objects are combined together, (2) the virtual 3D objects can be occurred in the real scene by registration and (3) the virtual 3D objects can be controlled in real-time.[19]

3. SYSTEM AND SYSTEMS ENGINEERING

System engineering is performed in the context of a particular organizational structure and culture, and so the discipline has always had to be attuned to and aligned with the realities of organizations and their cultures. [23]

The International Council on Systems Engineering (INCOSE) defines it as follows: [39]

Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem. Systems engineering considers both the business and technical needs of all customers with the goal of providing a quality product that meets the user needs. The system engineering approach was used in this paper and The ABC Company's business management system was analyzed as a whole.

More specifically:
The systems engineering process shall: [40]
1. Transform approved operational needs and requirements into an integrated system design solution through concurrent consideration of all life-cycle needs (i.e., development, manufacturing, test and evaluation, deployment, operations, support, training, and disposal), and
2. Ensure the interoperability and integration of all operational, functional, and physical interfaces. Ensure that system definition and design reflect the requirements for all system elements to include hardware, software, facilities, people, and data, and
3. Characterize and manage technical risks.

Systems engineering, widely used in manufacturing and aviation, is an interdisciplinary approach to analyze, design, manage, and measure a complex system in order to improve its efficiency, reliability, productivity, quality, and safety. [24] A system is developed to accomplish a specific function, or a series of functions, with the objective of responding to some identified need. Most systems are complicated series of large numbers of expensive components. [41] The various elements of a system must be directly tied to and supportive in the accomplishment of some given mission scenario or series of scenarios [20] SSADM comprises five core modules: feasibility study, requirements analysis, requirements specification, logical systems specification, and physical design module. [44]

The systems methodology incorporates methods, tools, procedures, processes, practices, and the skills and experience of practitioners who may be formed into teams, with leaders and managers; the whole then becomes the systems methodology. [21] An interdependent group of people, objectives, and procedures constituted to achieve defined objectives or some operational role by performing specified functions. [22]

4. FUNCTIONAL FLOW BLOCK DIAGRAMS (FFBDs)

According to Blanchard [20], in the development of functional-flow diagrams, some degree of standardization is necessary, for the purpose of communication, in defining the system. Thus, certain basic practices and symbols should be used, whenever possible, in the physical layout of functional diagrams. Thus, certain basic practice sand symbols should be used, whenever possible, in the physical layout of functional diagrams. The following eight guidelines should help:

1. Function block. Each separate function in a functional diagram should be presented in a single box enclosed by a solid line.

2. Function numbering. Functions identified on the functional-flow diagrams at each level should be numbered in a manner that preserves the continuity of functions and provides information with respect to function origin throughout the system.
3. Functional reference. Each functional diagram should contain a reference to its next higher functional diagram through the use of a reference block.
4. Flow connection. Lines connecting functions should indicate only the functional flow and should not represent either a lapse in time or any intermediate activity.
5. Flow direction. Functional diagrams should be laid out so that the functional flow is generally from left to right, and the reverse flow, in the case of a feedback functional loop, from right to left
6. Summing gates. A circle should be used to depict a summing gate. As in the case of functional blocks, lines should enter and/or exit the summing gate as appropriate.
7. Go and no-go paths. The symbols G and G are used to indicate go and no-go paths, respectively.
8. Numbering procedure for changes to functional diagrams. Additions of functions to existing data should be accomplished by locating a new function in its correct position without regard to sequence of numbering

In this article, SSADM, which is a kind of (FFBDs), is used. The structured system analysis and design method (SSADM), originally launched in 1981, which consists of five modules and is the official analysis method for system development in the UK. [25] It was made the mandatory standard for central government systems analysis and design in 1983, and in 1987, in the form of version 3, it was made publicly available and non-proprietary. Version 4 SSADM was launched in 1990. [26] System analysis is conducted for the purpose of studying a system or its parts in order to identify its objectives. [27] In the structured methodology well defined documentation takes place. [28]
System design methods are a discipline within the software development industry which seek to provide a framework for activity and the capture, storage, transformation and dissemination of information so as to enable the economic development of computer systems that are fit for purpose. [29]

Compared to construction, software industry is relatively a new industry, yet significant efforts have been directed towards standardisation leading to the development of several information systems methodologies supported by numerous standard techniques each addressing different aspects of the development.[45]

SSADM is based on the data flow diagrams. At the early stages of projecting at description of models (functional, informational and event-trigger) the top-down method is used.The advantages of SSADM are the precise definition and support of so-called "non functional requirements". Such requirements define the level of the quality with which the system must execute its functions. [30]

In this research SSADM was used to analyze all levels of the system. Structured Systems Analysis and Design Method consist of 3 levels. These levels are; (1) Departmental, (2) functional and (3) user requirements. The first level is the level of independent departments. At this level, information and material flows across all departments, relationships with suppliers and customers are also shown. Level 2 is flow charts at functional level. The functions owned by independent departments are shown in flow diagrams, and the names of these flow diagrams are department names. The final level is the level at which user requirements are identified and shown. At the level of the user's requirement, the information and material flows are shown in detail at the bottom of the production process.

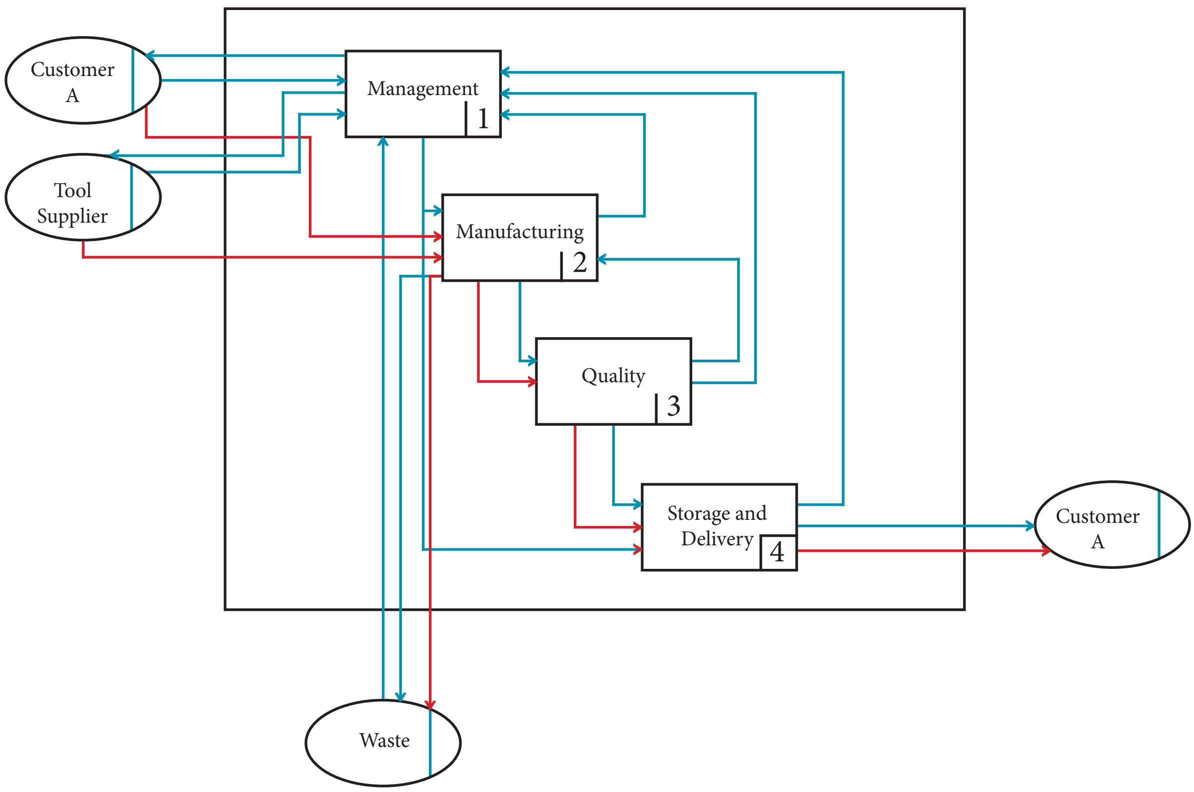
1.0 BUSINESS MANAGEMENT SYSTEM OF ABC

1.0 ABC' s Business Management System is the first level of flow charts.
There are 4 independent departments in this level. These;

- Management
- Manufacturing
- Quality
- Storage and Delivery.

This level shows information and material flows across departments, relationships with suppliers and customers.
The system begins by communicating the proposal to the customer.
If the bid remains in the firm, the contract and technical drawing are sent to company.
After the work order is created, it is sent to the Manufacturing with the technical drawing.
The products are sent to Quality for inspection.
Finally, the products come to Storage and Delivery and delivered to the Customer.

1.0 BUSINESS MANAGEMENT SYSTEM OF CETEK MAKINA



1.0 BUSINESS MANAGEMENT SYSTEM OF ABC

INPUT 2: CustomerContract(Purpose,Technical Specifications, Quality,Party Size,Delivery Date, Accounting Data)
INPUT 3: Material (Name, Code, Measure, Weight, Raw Material)
INPUT 5: SupplierContract (Purpose,Technical Specifications, Quality,Party Size,Delivery Date, Accounting Data)
INPUT 6: Material(Name, Code, Measure, Weight, Raw Material)
INPUT 12: Waste Information (Name, Code, Measure, Weight, Raw Material)

OUTPUT 1: CustomerContract (Purpose,Technical Specifications, Quality,Party Size,Delivery Date, Accounting Data)
OUTPUT 4: SupplierContract (Purpose,Technical Specifications, Quality,Party Size,Delivery Date, Accounting Data)
OUTPUT 13: Waste Information (Name, Code, Measure, Weight, Raw Material)
OUTPUT 14: Waste (Name, Code, Measure, Weight, Raw Material)
OUTPUT 19: Delivery Note (Serial Number, Type, Size And Quantity Information)
OUTPUT 20: Product

5. TECHNOLOGY READINESS LEVELS (TRL)

Technology Readiness Levels (TRL) are a type of measurement system used to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the projects progress. [35]
In this paper, non-parametric analysis was performed based on Technology Readiness Levels. In the transition to Industry 4.0, it is very important for companies to determine their technology readiness levels because they know what the current system is digital. According to this analysis, activities performed in the third level for each function are labeled with these metrics. As a result of this labeling, ABC Company's technology preparation level has been determined. Technology Readiness Level is calculated for each level by taking the arithmetic average of nonparametric values of each user requirements.The nonparametric values are as shown below.

1	Manual	The work is done by personwithout using machines.
2	Semiautomatic	The work is done by person using the machine.
3	Automatic	The work is done by the machine according to the command given by the man.
4	Fully Automatic	The work is done by the machine without people order.
5	Wi-Fi	The work is done by the machine with the command given by the other machine.

Technology Readiness Levels	
1.0 ABC' s Business Management System	2
1.1 Management	2
1.2 Manufacturing	2
1.3 Quality	2
1.4 Storage and Delivery	2

According to the results of the table ABC's technology readinesslevel is 2. This result has shown us that the system is Semiautomatic. In other words, the work done is done by the machines used by the people. In order for ABC to be ready for Industry 4.0, the TRL level must be at least 4. According to this result, it is necessary to make an improvement by considering the cost in the digitalization process.

6. COST BREAKDOWNSTRUCTURE

A cost breakdown structure constitutes a vehicle for including all costs and is broken down to the depth required to provide the appropriate level of visibility for determining the costs of various functions, processes, and/or elements of the system over time. [20]Cost breakdown is the systematic process of identifying the individual elements that comprise the total cost of a good, service or package. [31]The overall purpose of the CBS is to breakdown all the associated costs for purposes of identification and control. [32]In a way, this cost breakdown structure (CBS) links objectives and activities with resources and constitutes a logical subdivision of cost by functional activity, area, major element of a system, and/or more discrete classes of common items [33]

The manufacturing process cost of a part is dependent on factors such as necessary equipment and installation, required tools, the time for processing and the operating procedures. [34]
This paper suggests an activity-based analysis to develop a cost structure.This analysis identifies the cost elements to be considered for The ABC Company.The cost breakdown structure is started from the user requirements, which is the third level.Every kind of cost for ABC Company (such as workforce, electricity) is calculated for each activity made at this level.This calculation is done for the third level of all functions and the total cost of each function is also known as the total cost of each department.The following is an example of how to do the CBS table.

COST CATEGORY	Time (min)	Cost (TL)
1.1.3 Purchasing	607	248,87
1.1.3.1 Make Demand Verification	2	0,82
1.3.2 Create Material Requirement List	2	0,82
1.1.3.3 Request from Supplier	1	0,41
1.1.3.4 Bid Evaluation	5	123
1.1.3.5 Select Supplier	5	123
1.1.3.6 Fill up Order Form	2	0,82

7. CONCLUSIONS AND FUTURE STUDIES

Technology is rapidly changing and evolving day by day. The muscular power in production has already started to give a way to the brain and it's innovation capacity. It is very important for the national economies to follow this pace of global developments in their countries by urging large to small enterprises. New concepts such as internet of things, cloud, additive manufacturing with industry 4.0 have already entered corporate world where next step is touching our lives. In our research, ABC Company has been analyzed for Industry 4.0 readiness with system engineering approach. Firstly, ABC's business system was assessed by the technique of SSADM. Three levels of flow diagrams are drawn where on the other hand user requirements were determined and listed. Cost and nonparametric values of the identified user needs for ABC Company have been identified. During this study, the technologic level of the company versus their potential savings against automation through Industry 4.0 has been revealed. Recommendations around digitization have been introduced in accordance with the industry 4.0 concept with regards to jobs with a low level of technological maturity. After the digital suggestions are brought in, ABC's technologic readiness level and costs are recalculated. As a result of this study, prioritization of user needs to digitize and this digitalization was provided as options in front of the company management team. This analysis can be used as a role model in assessment of the level of technological readiness and also be utilized as a guide to preparation to ramp up technological levels for other companies manufacturing products.

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