DETERMINATION OF PROBLEMS IN TRANSITION TO SMART MANUFACTURING MODEL AND SUGGESTIONS FOR ENTERPRISES

MASTER THESIS

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DEPARTMENT OF MANAGEMENT INFORMATION SYSTEMS

ANKARA, 2020
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ANKARA, 2020
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ABSTRACT

Determination of Problems in Transition to Smart Manufacturing Model and Suggestions for Enterprises

Technological developments affect human life in economic, political, cultural and social areas. These technological developments led to industrial revolutions and three major industrial revolutions took place. These are the first industrial revolution in which production systems became mechanical by using water and steam power, the second industrial revolution in which mass production was carried out by using electric power and the third industrial revolution in which automation in production was provided by the introduction of information technologies. At the point where modern industry has arrived today, there is a process called Industry 4.0, which is the fourth phase of industrialization. Industry 4.0, which came into being with the digital transformation that occurred in industrial manufacturing and was first mentioned at the Hannover Fair in 2011, contains high-tech components. An innovative manufacturing model in which these components are involved and emerging as the ultimate goal of Industry 4.0 is called Smart Manufacturing. The aim of this study is to expose the problems faced by enterprises in transition to smart manufacturing processes and to reveal how enterprises find solutions to these problems. This study is a guide for enterprises that will make the transition to smart manufacturing. In-depth interviews were conducted through a semi-structured interview form with 10 participants from four companies of Turkish origin who agreed to take part in the research. Descriptive and content analysis techniques were applied to the data obtained from the interviews. It has been observed that enterprises face organizational, technological, economic and environmental problems during the transition to smart manufacturing. As a result of the study, problems encountered in the transition to smart manufacturing and their solutions were identified and suggestions were made to the researchers for future studies.

Keywords: Industry 4.0, Smart Factory, Smart Manufacturing Model
ÖZET
İşletmelerin Akıllı Üretim Modeline Geçiş Sürecinde Karşılaştıkları Sorunların Belirlenmesi ve Çözüm Önerileri


Anahtar Kelimeler: Akıllı Fabrika, Akıllı Üretim Modeli, Endüstri 4.0
CONTENTS

ABSTRACT .......................................................................................................................... i
ÖZET ................................................................................................................................... ii
CONTENTS .......................................................................................................................... iii
INDEX OF SYMBOLS AND ABBREVIATIONS ................................................................. v
INDEX OF FIGURES ........................................................................................................... vii
INDEX OF TABLES ............................................................................................................. viii
1. INTRODUCTION ............................................................................................................. 1

2. GENERAL INFORMATION .............................................................................................. 5
   2.1. Historical Development of Industrial Revolutions .................................................... 5
   2.2. Industry 4.0 .............................................................................................................. 7
      2.2.1. Components of Industry 4.0 ............................................................................. 10
   2.3. Smart Manufacturing and Smart Factories .............................................................. 15

3. LITERATURE REVIEW ................................................................................................... 20

4. MATERIAL AND METHOD ............................................................................................ 28
   4.1. The Universe and Sample of Research ..................................................................... 28
   4.2. Research Method ..................................................................................................... 29
   4.3. Data Collection Tool ............................................................................................... 30
   4.4. Collection of Data .................................................................................................... 32
   4.5. Data Analysis ........................................................................................................... 33
   4.6. Validity and Reliability ............................................................................................ 33
   4.7. Ethical Dimension of the Research ......................................................................... 34

5. FINDINGS ......................................................................................................................... 35
   5.1. Participant Information .............................................................................................. 35
INDEX OF SYMBOLS AND ABBREVIATIONS

3D : 3 Dimensional
EU : European Union
USA : United States of America
AR : Augmented Reality
R&D : Research and Development
SM : Smart Manufacturing
IT : Information Technologies
BD : Big Data
CAFS : Compressed Air Foam System
ERP : Enterprise Resource Planning
GPS : Global Positioning System
H2H : Human to Human
H2M : Human to Machine
IEEE : Institute of Electrical and Electronics Engineers
IoT : Internet of Things
IP : Internet Protocol
IS : Internet Services
SME : Small and Medium-Sized Enterprises
LEED : Leadership in Energy and Environmental Design
MES : Manufacturing Execution System
MOM : Manufacturing Operation Management
M2M : Machine to Machine
NDA : Non-Disclosure Agreement
PLC  : Programmable Logical Controller

POC  : Proof of Concept

RFID : Radio Frequency Identification

ROI  : Return of Investment

SQL  : Structured Query Language

SWOT: Strenght, Weaknesses, Opportunities and Threats

TPM  : Total Productive Maintenance

WCM  : World Class Manufacturing
INDEX OF FIGURES

Figure 2.1. Technological components of Industry 4.0 ................................................. 10

Figure 2.2. Smart factories............................................................................................... 17

Figure 4.1. Distribution of questions to parts in the interview form ............................ 32

Figure 7.1. Problems encountered ................................................................................. 76

Figure 7.2. Solution suggestions...................................................................................... 77
INDEX OF TABLES

**Tablo 3.1.** Encountered problems in transition to smart manufacturing in the previous studies ................................................................. 27

**Tablo 4.1.** Enterprises that make up the sample ................................................................. 29

**Tablo 4.2.** Distribution of participants by enterprises .......................................................... 29

**Tablo 4.3.** Demographic information of experts ............................................................... 30

**Tablo 5.1.** Information of the participants ........................................................................... 35

**Tablo 5.2.** Problems encountered in the preparation process .......................................... 44

**Tablo 5.3.** Problems and solution suggestions arising from organizational factors .......... 50

**Tablo 5.4.** Problems and solution suggestions arising from technological factors .......... 56

**Tablo 5.5.** Problems and solution suggestions arising from environmental factors .......... 64

**Tablo 5.6.** Profession titles predicted to emerge with transformation to smart manufacturing .............................................................................. 69
1. INTRODUCTION

The development of technology has led to economic, political, cultural and social changes. Three major industrial revolutions took place in this direction. The first industrial revolution, which is called The Machine Age, is considered to be the beginning of industrialization. With the use of mechanical production machines created by using water and steam power in production, this revolution has shown itself with the taking over of machine power in the place of human power and human labor in production. With Industry 1.0, the transition from agricultural economy to industrial economy has been experienced [1, 2]. The Second Industrial Revolution, the so-called technology revolution, came about when electricity replaced steam power in production and Henry Ford discovered the first mass generation band powered by electricity. Mass production was started during this industrial period [1-4]. In the third industrial revolution which also reffered to by different names such as automation revolution, digital revolution or informatic revolution [5], gains in electronics and and programmable machines began to be used in manufacturing systems. During this period, analog systems were replaced by digital systems and production was automated. The need for human labour has decreased and the transition from industrial society to information society has been experienced [1, 2]. The three industrial revolutions that took place brought mechanization, electronics and information technology to human production. All these developments have led to the realization of the fourth industrial revolution in this period [6].

At the point where the information society has arrived today, the fourth industrial period, called Industry 4.0, is taking place. This concept was introduced for the first time in 2011 at the Hannover Fair [7-10] and over time, it have started to be referred to by different names and have been included in the strategy plans of the countries [11]. The concept of Industry 4.0 is defined as a collective term that combines the physical, digital and biological worlds, affects all disciplines, economies and industries, and contains numerous innovative automation systems [2]. Between technological components that constitute the basic building blocks of Industry 4.0; internet of things, internet services, cyber physical systems, cyber security, 3-dimensional (3D) printers, big data and data analytics, autonomous robots, simulation, horizontal and vertical system integration, cloud computing, artificial intelligence, virtual reality and augmented reality are located [12-16]. Industry 4.0 considers more flexible, lower-cost, faster, better quality and efficient production to be the ultimate
goal in new generation factories where technologies that can communicate with each other, detect the environment with sensors and recognize the needs by analyzing data. In line with this aim of Industry 4.0, a new paradigm, smart factories and the smart manufacturing model realized in these factories has emerged in which the technological elements that constitute the basic building blocks of this industrial revolution take an active role [9, 17].

Smart factories have emerged as the main feature of Industry 4.0. These factories are equipped with autonomous systems that provide automatic data exchange and connected to each other. Supported by big data-based feedback and coordination, they are able to self-organize themselves and, predict and prevent machine failures. Thus, they are defined as factories where smart, flexible and dynamic production can be achieved by containing a digital integration that manages and controls the production process [18-20]. Smart manufacturing in smart factories refers to an innovative way of manufacturing that is controlled by smart systems with automatic control, can adjust its own settings, can monitor itself and can improve itself [21]. Smart manufacturing makes it possible a coordinated and performance-oriented manufacturing attempt that respond customer demands by using real-time and high-value support systems, that minimize energy and material use and that improve sustainability, productivity, innovation and economic competitiveness in a radical way [22]. The main objectives of smart factories and smart manufacturing include reducing error rates by providing automation in production, accelerating production processes, reducing costs and increasing factory productivity and efficient use of resources [23-26].

The high quality of the products produced in smart factories and the low cost of the products are a very important competitive tool that will put enterprises ahead of their competitors in national and international markets. For this reason, it is envisaged that in the future smart factories and smart manufacturing will become a necessity and in order to respond to the demands for personalized manufacturing and changed consumer preferences, enterprises will be obliged to convert to the smart manufacturing model in their factories.

This study aims to identify the problems faced by Turkey originated enterprises in the process of transition to smart manufacturing and to reveal the solutions they have found for these problems. For this purpose; organizational, technological, economic and environmental problems faced by Turkey originated enterprises in the transition to smart manufacturing and how they overcome these problems were investigated in this study. In addition, the present situation of Turkey originated enterprises in smart manufacturing, their
activities in preparation processes and their predictions towards the future of smart manufacturing are presented in this study. A limited number of publications were available in the literature which were carried out in the same direction as the subject covered in the research. Related to the research topic, in Çakır's (2017) study smart manufacturing management system software developed in research within the scope of the implementation in the factories as a result of the installation, customization and difficulties in the development stages is demonstrated. Lee, Yoon and Kim's (2017) study examined the challenges posed by the application of the proposed big data analytics platform architecture to a foundry company's factory in South Korea. In Yuan, Qin and Zhao’s (2017) study, in order to identify the main opportunities and challenges associated with smart manufacturing in oil refinery or petrochemical plants, the difficulties encountered in providing fault detection and improved optimization for the planning and timing of refinery sites were investigated. In another study realized by Wurhofer, Meneweger, Fuchsberger and Tscheligi (2018), researchers focused on the challenges that changing business routines and practices bring to designing systems, interactions and working environments as a result of interviews with operators and maintenance engineers in automotive, logistics and electronics sectors. In the study of Petrovic and Leksell (2017), multiple case studies revealed the difficulties encountered in integrating systems into different layers and in the process of project creation. Finally, the study of Sjödin, Parida, Leksell and Petrovic (2018) revealed the difficulties faced with personnel, technology and business processes as a result of in-depth interviews with participants in the enterprises covered by research.

When the studies in the literature are examined, it is observed that there is not a comprehensive study that has investigated organizational, technological, economic and environmental problems in transition to smart manufacturing and presented solutions to these problems. Therefore, this study will contribute significantly to the literature by filling the gap in the literature in terms of comprehensively addressing the problems that may be encountered in the transition to smart manufacturing and revealing how enterprises find solutions to these problems. It is thought that this study will be a guiding work for the enterprises that will transition to smart manufacturing.

The main research question of the study is as follows:

- What are the problems Turkey originated enterprises face in transition to smart manufacturing?
The sub-research questions of the study are as follows:

- What are the problems Turkey originated enterprises face in preparation phase for the transition to smart manufacturing?

- How did Turkey originated enterprises find solutions to the problems they faced in the transition to smart manufacturing and in preparation processes?

The following sections of this study are as follows: In the “General Information” section, an overview of the historical development of the industrial revolutions, the concept of Industry 4.0 and the technological components that make up this concept is presented and the concepts of smart manufacturing and smart factories which constitute the subject of research are presented. In the” Literature Review " section, a general view of the scientific studies carried out in relation to smart manufacturing in literature and the studies carried out in the same direction with the research subject are presented and the difference of the research from these studies and its contribution to the literature is explained. In the “Materials and Methods” section, the materials and methods of the research are presented in detail. In the” Findings " section, the results of the analysis of the data are available. In the “Discussion” section, the results of the analysis are discussed by comparing them with the results of other studies in the literature. The last section is "Conclusions and Recommendations” and in this section a general evaluation of the results of the research was made and suggestions were made to the researchers for future studies.
2. GENERAL INFORMATION

In this section, an overview of the historical development of industrial revolutions is presented and then the concept and components of Industry 4.0, called the Fourth Industrial Revolution, are explained. Then, general information about the smart manufacturing method covered in the scope of the research and the smart factories where this manufacturing method is carried out are given.

2.1. Historical Development of Industrial Revolutions

In the past, nomadic societies continued their lives by hunting during the hunting-gathering period; later, they changed their way of life from nomadic life to sedentary life by raising animals and cultivating crops. This led to the start of the agrarian revolution, one of the first and most important revolutions in human history. With this development, consuming societies have become producing societies at the same time [32].

In order to make production more efficient, productive societies have started to develop various methods and make mathematical calculations. Up the year 1000 B.C., the emergence and spread of the science of philosophy had triggered the development of many new insights and ideas, and increased interest in astronomy and natural phenomena brought discovery and inventions to the fore. A.D. from the 7th Century, in addition to the developments in science, culture, art and social and economic life with the birth and spread of Islam, the invention of firearms and their accelerated efforts with the discovery of magnetic compass and gunpowder in the 11. Century, resulted with the foundation of today's science and technology. The Renaissance and Reform movements that emerged in the 15. Century were one of the most important turning points in the history of science [33]. With the invention and spread of the printing press, literacy rate increased and scientific studies began to show themselves in all fields. In the second half of the 18. Century, these developments and changes maintained their importance by increasing with the agricultural and industrial revolutions [2].

When looking at human history, it is seen that a very long process has taken place in the transition from the agricultural revolution to the Industrial Revolution. Until the present period, three major industrial revolutions were witnessed as a result of technological developments that led to economic, political, cultural and social changes and affected the
level of development of societies and countries. These revolutions not only led to increased productivity and production, but also brought about profound changes in social life [34].

The First Industrial Revolution, called The Machine Age, is regarded as the beginning of industrialisation and originated in England in 1712 with a steam machine invented by Thomas Newcomen. At the end of the same century the steam machine developed by James Watt began to be used in weaving looms. With the use of mechanical machines created by using water and steam power, production systems were mechanized in the first industrial revolution [1, 2]. Thus, the transition from agricultural economy to industrial economy was experienced in production with machine power taking over human labor and human power. The first industrial revolution spread to Western European countries and the United States (U.S.A.) immediately after England and caused significant increases in production volumes, which enabled countries' economies to grow [15].

The Second Industrial Revolution is also called the technology revolution. This revolution occurred when electricity replaced steam power in production and electric power routed assembly lines by the end of the 19. Century. During this period, also called Fordism period, Henry Ford invented the first electric-powered production line and made use of electric power to enter mass production, i.e. Fordist production [1-4]. Fordism is defined as a form of production in which industrial production is carried out significantly in the form of mass production, where product standardization brings productivity growth and increases in demand accelerate this standardization [35]. The leaders of the Second Industrial Revolution were Britain, Germany, U.S.A. and Japan.

The Third Industrial Revolution, also referred as automation revolution, digital revolution or informatic revolution [5], was manifested in the early 1970s by the gains achieved in electronics and information technologies and especially by the introduction of programmable machines in production systems. With Industry 3.0, analog systems have been replaced by digital systems. The first Programmable Logical Controller (PLC) emerged with this revolution. With the use of computers in production, production became easier by automation and the need for human labor decreased. There has been a transition from industrial society to information society. In addition, the expansion of the internet and the increase of transportation opportunities have also affected production in a positive way [1, 2].
The common feature of all three revolutions is that they aimed to increase productivity in production and, the first three industrial revolutions brought mechanization, electronics and information technology to human production. Thanks to all these developments, production has gone global. With the effect of factors such as cyber physical systems and ability of objects to communicate with each other, these revolutions led to the realization of the Fourth Industrial Revolution in this period [6].

2.2. Industry 4.0

The concept of Industry 4.0, symbolizing the Fourth Industrial Revolution, was first introduced at the Hannover Fair in Germany in 2011 [7-10]. It was stated at this fair by the experts that there was a revolution in manufacturing and that the era of information was moving the manufacturing technology to a higher level. This concept has developed by being called "Factories of The Future" in European countries, “Industrial Internet ” in USA and “Internet +” in China [19]. In October 2012, Henning Kagermann and Robert Bosch GmbH formed a working group and prepared a strategy paper for the revolution of Industry 4.0 to be presented to the German Federal Government and set out the steps to be taken under Germany. Thus, Industry 4.0 has become a strategic initiative of the German government and it has been included in the High-Tech Strategy 2020 Action Plan. The concept of Industry 4.0 has been seen as a strategy to compete in the future [11]. In 2011, with the article published by Kagerman et al. and titled as: “Industry 4.0: On The Way To The Fourth Industrial Revolution With The Internet Of Things”, Industry 4.0 has been brought up in the theoretical dimension first time [36]. This paper was the basis of the report published by the German National Academy of Science and Engineering in 2013 entitled “Recommendations for the Implementation of the Industry 4.0 Strategic Initiative” and in which new generation production methods were shared and the subject gained a formal theoretical framework [37, 38]. In addition to Germany's Industry 4.0 strategic plan, some of the other industrial states have taken strategic steps towards Industry 4.0 to improve the manufacturing industry. The United States's established organization that called “Smart Manufacturing Leadership Coalition", China's published plan that named “Made in China 2025”, also similar plans published by the United Kingdom, Japan and South Korea can be cited as examples of strategic steps. The concept of Industry 4.0 that emerged with digital transition in industrial manufacturing and represent fourth industrial revolution is based on the communication of all the units involved in the industrial production process with each other, the access of
relevant data in real time and the provision of the maximum added value possible through this data. This concept is an integration of information, communication technologies and industrial technology. Although there is no generally accepted definition in the literature [39], it can be defined as a collective term that fuses the physical, digital and biological worlds, affects all disciplines, economies and industries, contains numerous innovative automation systems, data exchange process and technology revolutions [2]. The goal of Industry 4.0 is to create a flexible manufacturing model with real-time interactions between people, products and devices throughout the manufacturing process and to provide higher levels of business efficiency and higher levels of automation in production [40].

Klaus Schwab reported that the Fourth Industrial Revolution had occurred based on three main reasons, and that this revolution was not a continuation of the third industrial revolution. These three reasons are the system effect, speed and width and depth [2].

- Speed: According to Schwab, this revolution is not proceeding linearly but at an exponential rate.
- Width and Depth: With digitisation, this revolution has gained momentum. As a result of the progress of the industrial sector with a change in which more emphasis is placed on individuality, the diversity of technology has been increased.
- System Effect: As a result of Industry 4.0; all sectors, companies and even countries are expected to experience a holistic change.

Industry 4.0 is based on 6 principles. These principles are as follows [39, 41]:

- Interoperability: Cyber Physical Systems refers to people and machines communicating and interacting with each other through the Internet of Things and the Internet of Services.
- Virtualization: This concept, also called the numerical twin, is a virtual replica of smart factories. This structure is formed by connecting sensor data with virtual facility and simulation models. With this method, all systems and subsystems can be created in a numerical analogy and all kinds of interaction, analysis and configuration changes can be tried on the digital model.
- Autonomous Administration: It is the ability of cyber physical systems's to make their own decisions within smart factories and execute the process that is defined.
- Real-Time Manufacturing: It can be defined as all processes can be executed, audited and controlled in real time.
- Service Orientation: Services are offered on the internet.
- Modularity: Refers to the increased adaptability and flexibility to changing requirements of system components.

Today, Industry 4.0 has a significant impact on the manufacturing industry within the scope of a wide range of applications, from product design to logistics and this effect is projected to continue to grow in the future [4]. Also it is expected from Industry 4.0 to have an impact in the future in areas such as service sector and business models, reliability and efficiency, information technology and machine security, product life cycle, employee training and skills, socioeconomic factors etc. [42]. Among the potential benefits of Industry 4.0; meeting individual customer needs, providing flexibility in manufacturing, optimizing decision-making mechanism, providing resource efficiency and effectiveness, providing value with new services and creating opportunities to respond to demographic change in workplaces and work-life balance are located [17]. In addition to this; facilitating system monitoring, detection of faults and errors in production, increasing self-awareness of the system and its components [43], reduction of production costs due to the efficiency of the resource [44], increasing speed of product launch to the market, providing sustainable production with environmentally friendly and resource saving behaviors [37] are among the benefits of Industry 4.0.

Beside the potential benefits of Industry 4.0, it also has some difficulties. Among these difficulties are high cost of investment requirement, need of qualified labor force, resistance against the change of traditional production method, deficiencies in international standards, inadequate laws regulating the use of competitive data, inadequate tax incentives related to investments, deficiencies of legal regulations and certification, insufficient research and development (R&D) activities incentives, need to improve the network infrastructure, and the inadequate legal regulations regarding the use of external data [45].

The concept of Industry 4.0 is seen as an important strategy for survival in the future. Today, industrial companies focus on the term Industry 4.0 to tackle challenges such as individualizing products, increasing resource efficiency and shortening time to market [46].
2.2.1. Components of Industry 4.0

The technological components that are called the heart of Industry 4.0 and constitute the basic building blocks of Industry 4.0 include internet of things, internet services, cyber physical systems, cyber security, 3D printers, big data and data analytics, autonomous robots, simulation, horizontal and vertical system integrations, cloud computing, artificial intelligence, virtual reality and augmented reality [12-16]. These components that make up Industry 4.0 are schematized in Figure 2.1.

![Figure 2.1. Technological components of Industry 4.0 [47].](image)

**Internet of Things**

Internet of Things (IoT) is defined as physical objects's ability to communication with each other by connecting to the internet via their own Internet Protocol (IP) addresses or by means of sensors embedded within them and sending and receiving data [8, 10, 43, 48]. This concept allows remote control of objects [49] and it allows communication between human and human (H2H), between human and machine (H2M), and between machine and machine (M2M) [50, 51]. The advantages of the Internet of Things include the practicalization of manufacturing and the manufacturing process, smarter order and supply chain, reduced energy, reduced infrastructure and personnel costs, and increased revenue-profit levels [43]. At the same time, objects that communicate with each other through this
structure become able to manage the works that are involved in the production process themselves [52].

**Internet Services**

Internet services (IS) are systems that allow service providers to offer their services via the internet [39, 53]. An infrastructure for service, a business model, and the service itself form the IS model [39].

**Cyber-Physical Systems**

Systems that connect the physical world and cyberspace through the internet and enable interaction between objects are called Cyber Physical Systems [15]. Cyber physical systems are supported by integrated communication, computing, control and sensor systems [54]. They collect movements in the physical world via the internet with their IP addresses, thus allowing physical productions to be modeled on computer and production processes to be seen in virtual environments [39, 55].

**Virtual Reality**

Virtual reality is a three-dimensional simulation model that allows for mutual communication in a dynamic environment created by computers and gives the feeling that it is real [56].

**Augmented Reality**

Augmented reality (AR) are animations in digital environment produced by computers with audio, video, graphics and Global Positioning System (GPS) data in a graphical environment. In other words, it can be defined as the enrichment of the physical world through digital data and images [57]. As a result of these animations, a combination of physical and real area is provided and a new perception area is created for the user. The reflection of virtual information about the environment in AR is in harmony with the real world.

AR can be seen as the continuation of virtual reality. In comparison, virtual reality and AR are not opposite each other, but the simulation of the world in virtual reality is used
instead of the existing world reality, whereas AR emerges as a result of the development of real world reality as a result of digital operations and provide graphic richness. Thus, perceptual reality was enriched and changed with AR [43].

**Three Dimensional (3-D) Printers**

3D printing, also called additive manufacturing and desktop manufacturing, refers to the processes in which various types of materials are combined or solidified under computer control to form a three-dimensional object. 3D printing is used in both rapid prototyping and physical material manufacturing [58]. 3D printers have application area in many different areas from genetics to science technologies, from medicine to industry, from jewelry to city planning with using many different materials and combinations. This groundbreaking method in science and technology is considered within the scope of the Industry 4.0 concept, as it supports flexible, low-cost and inventory-free production systems and requires little labor and human power [59].

**Autonomous Robots**

Autonomous robots are defined as autonomous, flexible and cooperative machines that can make decisions in the manufacturing process, transform their decisions into action, communicate with other robots, and exchange data, thanks to the information and hardware it contains. Since autonomous robots can also control their own systems, they provide the data needed for preventive maintenance themselves and send the necessary information to the operator or maintenance-repair unit without any malfunction. As a result, these robots with freedom of movement provide flexibility during the manufacturing phase [60, 61].

**Big Data and Data Analytics**

Big Data (BD) represents information assets that are characterized by a high volume, speed and diversity that require special technology and analytical methods for converting into value [62]. The volume used to characterize these information assets refers to the size of the data. Speed refers to how often the data changes or how often it is created. Finally, diversity includes different formats and data types, as well as ways to analyze different uses and data [63, 64]. In other words, BD refers to data obtained but not configured or processed [10]. This data includes datasets that are at terabyte, petabyte or even exabyte level [65].
practice, the BD concept covers all the transactions of user performs on the Internet [66]. For example; data collected from various sources such as social media shares, blogs, photos, videos, log files are handled among BD applications as a form transformed into a meaningful and processable form. BD, when interpreted with correct analysis methods, allows companies to make strategic decisions, manage their risks better and innovate [52].

Big Data Analytics is the analysis of the data collected in real time by means of sensors, and the use of the analysis results to improve production processes and product quality [67].

**Cloud Computing**

Cloud Information or Cloud Technology, which is also called online information distribution is where all existing applications, programs and data are stored in a virtual server, that is, in a cloud, and where any information, data or programs can be easily accessed through any device in the internet environment [52]. Thanks to Cloud Computing Systems, manufacturing facilities can have an appropriately sized storage capacity to store and analyze large amounts of data collected [41].

**Simulation**

With the simulation models prepared using real-time data, virtual reality of the physical world is created together with machines, products and people [68]. Using real-time data with this technology, simulation of virtual commissioning and cycle times, energy consumption or ergonomic aspects of a production facility can be carried out by reducing production times and reducing production failures at the start stage. Thus making the decision making process becomes easy and fast [61].

**Horizontal and Vertical Integration**

Horizontal Integration refers to a seamless flow between each step in the production and planning process. Horizontal integration establishes integrated and end-to-end systems that cover everything from raw material supply to design, production, marketing and shipping.
Vertical integration means providing uninterrupted communication and flow in the technological infrastructure used in the processes. For example; integration of sensors, valves, motors, control panels, software and applications in manufacturing are covered in this context.

Thanks to Industry 4.0, where vertical and horizontal integration is realized, it is possible to respond quickly to changes and problems in manufacturing processes, to facilitate customer-specific and personalized manufacturing, to increase resource efficiency and to achieve optimization in the global supply chain. In addition, it is possible for enterprises to have a more flexible structure and the required changes can be provided with simple interface updates [55].

**Cyber Security**

Cyber security is an increasing need for data security with the widespread use of big data and cloud computing technologies. Security measures taken in line with the concept of Cyber Security include the processes of preventing information from unauthorized use, disclosure, destruction, alteration and damage and provide protection of information [57]. Thus, it is ensured that the production tools communicate securely with each other [55].

**Artificial Intelligence**

Artificial intelligence is programs that are expected to perform cognitive functions or behaviors that are unique to humans, such as perception, learning, linking plural concepts, thinking, idea execution, problem solving, communicating, making inferences, and making decisions [69]. Artificial intelligence is used in many areas today, but it is more common in robotic areas.

All these technological components, which are at the center of Industry 4.0, try to reduce the need for human factor by acting in mutual interaction and cooperation in the production process by increasing automation. However, thanks to these technological components, it is aimed to create systems that are capable of responding to consumer needs, changing conditions and other extraordinary situations. Based on all these technological elements that make up Industry 4.0, the vision of smart manufacturing and smart factories have been emerging.
2.3. Smart Manufacturing and Smart Factories

Industry 4.0 aims to more flexible, lower cost, faster, higher quality and efficient manufacturing in the new generation factories where technologies that can communicate with each other, detect the environment with sensors, and realize the needs by analyzing data. In line with this goal, smart factories, a new paradigm in which the technological elements that make up Industry 4.0 play an active role, and the smart manufacturing model realized in these factories have emerged [9]. Smart factories and smart manufacturing are seen as the key feature and ultimate goal of Industry 4.0 [17].

In the literature, smart factories are also named as U-Factory (ubiquitous factory) [70], a factory-of-things [20], a real-time factory [71] or an intelligent factory of the future. Smart factories, which are the main feature of Industry 4.0, are equipped with sensors, actors and autonomous systems that are connected to each other and provide data exchange automatically. These factories are defined as context-aware factories where self-organizing, predicting and preventing machine malfunctions and managing and controlling the manufacturing process are supported by big data-based feedback and coordination and enables smarter, more flexible and dynamic manufacturing [18-20]. These factories include smart machines and systems that detect the business need with sensors, communicate with other remote manufacturing tools via the internet, and draw the manufacturing information they need from Big Data in cloud systems. Here, communication and interaction with the manufacturing tools are provided via the internet [15]. In addition, many manufacturing processes, such as product design and production planning, are simulated modularly, and these processes are linked by an end-to-end integration system [72]. Automation, which has been seen as a mechanization since the Industrial Revolution, has gained a new meaning with these factories. Automation is no longer just the standard movement of mass production, which machines take on the production line; it is named as the arrangements [55] of the devices and machines by communicating with each other and determining the manufacturing processes within themselves.

Considering the benefits of smart factories, the machines and equipment in smart factories can manage complex manufacturing processes more quickly and smoothly, as they have the ability to improve processes through self-healing and independent decision making [73, 74]. The products that come out are high quality, smooth and long-lasting. However, the machines in manufacturing operate in the framework of cyber security by
communicating with each other and have a feature to automatically stop manufacturing and correct the problem when a problem is encountered [75]. Smart factories make the increasing complexity of manufacturing processes manageable for the people working there, ensuring that manufacturing is also attractive, sustainable and profitable in the urban environment [76].

The most important factor that triggered the emergence of smart factories is disrupted manufacturing activities due to human error or tool errors. As a result of this situation, the development process of the smart factory understanding, which enables automation systems to move on to the next stage, has started for eliminate the existing problem [77]. The key factors that accelerate the trend towards smart factories and smart manufacturing are the rapid development of technology capability, the increase in complexity and diversity in the supply chain due to the diversification of global manufacturing and demand, unexpected competitive pressure in resource supply and the meeting of information technologies and operational technologies [78]. Mega trends that feed the formation of a new manufacturing style can be listed as demographic change, globalization and future markets, scarcity of resources, challenges caused by climate change, dynamic technology and innovation, personalization of society and sharing global responsibility [79].

Smart factories have great differences from traditional factories in subjects such as manufacturing methods, manufacturing process, decision process, routing, connection and control. The manufacturing method in traditional factories is human based; it is based on the knowledge, skills and expertise of the employee. In smart factories, the manufacturing method is internet-based, based on the interaction of objects and autonomous systems with the network connection. In traditional factories, there is a manufacturing process in which machines operate independently and are pre-configured. On the other hand in smart factories, there is a manufacturing process in which system integration is provided and the machines in the manufacturing process are connected and in communication, and they can configure themselves. The decision-making process is human-focused in traditional factories, while in smart factories it is technology-focused and carried out by robots with artificial intelligence. In traditional factories, fixed routing is available, that is, the production line is fixed. In cases where there is a need for changes in the production line, manual configuration is provided. In smart factories, routing is automatically configured. At the connection point, there is no connection between machines in traditional factories, whereas in smart factories, connection between machines, products, information systems
and people is established and interaction with the internet infrastructure is provided. At the checkpoint in the traditional factories, each machine is pre-programmed to perform the tasks assigned to it, while the smart units in the smart factories negotiate with each other to organize themselves [19, 75, 80]. An example image of smart factories where an innovative manufacturing process is carried out is given in Figure 2.2.

![Image of smart factories](image)

**Figure 2.2.** Smart factories [81].

Although smart manufacturing in smart factories does not have a common definition in the literature, it can be defined as a manufacturing model where all objects can interact with each other through the internet with advances in areas such as artificial intelligence, 3D printers and space technology [82]. By proposing a unified definition for smart manufacturing; Radziwon, Bilberg, Bogers and Madsen (2014) have defined smart manufacturing as a manufacturing solution that provides flexible and adaptable manufacturing processes that will solve problems that arise in a manufacturing facility with dynamic and rapidly changing boundary conditions in the world of increasing complexity. Sjödin, Parida, Leksell and Petrovic (2018) also pointed out that smart manufacturing is a connected and flexible manufacturing system that uses a continuous flow of data from connected operations and manufacturing systems to learn and adapt to new demands. This manufacturing model corresponds to a form of manufacturing that is self-configurable, self-monitorable, self-healable and self-controllable by automated controlled smart systems [21]. Smart manufacturing enables coordinated and performance-oriented manufacturing
initiative that responds quickly to customer demands, minimizes energy and material use, develops sustainability, productivity, innovation and economic competition radically with using real-time and high-value support systems [22]. In the factories that are fully integrated and connected to the industrial network, the machines and devices can perform smart manufacturing by acting smartly and partially autonomously with requiring minimum manual intervention [84].

The main purpose of smart factories and smart manufacturing is to reduce the error rates in manufacturing by providing the automation system, to speed up the manufacturing processes, to reduce the manufacturing costs and to increase the efficiency and effective use of resources in real time. Smart manufacturing in smart factories provides important benefits such as prototype extraction or the ability to order the original version before the product is manufactured or to make its own design. In addition, it is easier to produce tailored to customers and needs and to offering fast solutions under changing competitive conditions with smart manufacturing systems. The most important advantage of a manufacturer with a smart factory is that it can always keep the manufacturing line under control. In this way, manufacturers who have smart factory will be able to follow the 24/7 manufacturing line, anticipate any malfunctions or hardware errors that may occur and intervene immediately. With the smart manufacturing system, the process from the tracking of the raw material of the product to the storage of the manufactured product will be easily followed. However, the benefits of this system will not only remain within the factory, it will also help the supply chain network to learn more about these situations. The mentioned benefits of smart manufacturing increase the profitability and market power of companies. In addition to these advantages, companies can easily be achieved their goals such as high quality, instant access to accurate information, effective planning, integration between systems and increasing the traceability of processes by smart manufacturing [23-26].

In addition to the mentioned advantages and potential benefits, smart manufacturing also has some difficulties. Among these difficulties; need for skilled labor; sensors, embedded system designs and the need for interfaces that provide communication, and the need for serious R&D activities on current computer sciences, information and communication systems, network technologies and manufacturing automation are located. In addition, the high investment cost required for smart factories, the reliability and stability of wireless connections in factory automation and process control environments, and the higher complexity of both hardware and software are among the challenges encountered in
smart factories [85]. In addition, the demand for labor will decrease and the advantage provided by the cheap labor will end, and the muscle strength will be replaced by intellectual accumulation. Therefore, the qualities of the demand for labor will change [86]. This situation can be listed among the difficulties that can be encountered with smart factories.

In addition to all these, it is predicted that with the transformation to smart manufacturing model, new professional titles will emerge in the future and some of the existing professional titles will increase in popularity. Occupational titles that are expected to will emerge include occupations such as industrial data science, robot coordination, information technology (IT) solution architecture, industrial solution architecture, cloud computing expertise, data security expertise, network engineering, 3D printer engineering, wearable technology designer. It is thought that recruitment will increase in professions such as software and analyst and nano technologies will develop and serious employment will be created in these fields. Today, these occupational titles are gradually emerging especially in Germany [87].

The fact that the products produced in smart factories are both of high quality and low cost, show themselves as a very important competitive tool that will put the companies ahead of their competitors in the national and international markets. For this reason, smart factories and smart manufacturing will become imperative in the future and due to changing consumer preferences and in order respond to demands for personalized manufacturing, enterprises will be obliged to transform in their factories.
3. LITERATURE REVIEW

There are several studies in the literature on Industry 4.0, smart factories and smart manufacturing and many of which are new studies. Within the scope of this research, scientific studies conducted since 2010 have been scrutinized and analyzed. Databases were used for literature review including ScienceDirect, Institute of Electrical and Electronics Engineers (IEEE) Explore, SpringerLink, and the Taylor and Francis Library. While performing the search, the terms that are most frequently cited in the related literature such as “Smart Factory”, “Intelligent Factory”, “Digital Factory”, “Ubiquitous Manufacturing”, “Smart Manufacturing” and “Intelligent Manufacturing” have been used.

Keywords "Lights Out Factory" and "Lights Out Manufacturing" are not included in the literature review. When the literature is examined, although the term lights out factory can be used interchangeably the concept of smart factory; while it is seen that smart factory refers to production facilities that incorporate Industry 4.0 technologies and cooperate with robots and humans, it is seen that the concept of lights out factory differentiates from smart factories because it refers to an autonomous production system that does not require human interaction [88]. Therefore, the terms of lights out factories and lights out manufacturing are excluded from the literature review due to the scope of the research subject.

The references obtained as a result of the literature review were refined taking into account the relevance of the research subjects and 54 references were included in the scope of the research. These references are classified in seven different categories (a general assessment of smart manufacturing, a literature review, a conceptual framework, an approach to smart manufacturing or an architectural proposal, handling smart manufacturing from a technological perspective, application scenarios of smart manufacturing systems and studies carried out in line with the purpose of this research) to represent one category in each paragraph according to research topics. While the first six categories included in the literature review presented offer a general view of the studies and research topics related to smart factories and smart manufacturing; in the seventh category, there are studies conducted in line with the subject of this research and examining the problems faced by enterprises in the process of transition to smart manufacturing and the solutions to these problems.
When studies that evaluate an smart manufacturing vision are examined, in the study of Yıldız (2018), it is seen that there is a general evaluation including the steps taken by the countries regarding Industry 4.0 applications and the foreseen effects of Industry 4.0 in the future. Lee et al. (2018) addressed the contribution of smart factories to health and maintenance management practices and emphasized the contribution of advanced network technologies, the internet of things, cloud computing and big data analysis management to the development of machine health management. In the study of Calp, Bahçekapılı and Berigel (2018), the process of evolving smart factories from traditional factories, smart factory architecture, basic features, life cycle, duties, usage areas and the technologies required to create these factories analyzed with detail. Radziwon, Bilberg, Bogers and Madsen (2014) proposed a unified definition for smart factories in their study, since the common understanding of smart factories is not a consensus. In another study, Pîrvu and Zamfirescu (2017) provided an overview of social and key technological requirements for smart factories and revealed global and specific to the country of Romania challenges that hinder smart factory vision. Among the global challenges that hinder smart factory vision, the lack of a clear vision for a real revolution and the lack of a national Industry 4.0 strategy for Romania stands out. In their study; Zhong, Xua, Klotz and Newmanc (2017) reviewed key technologies that allowed smart manufacturing to take place. In addition, they provided an overview of the countries’ strategic plans for smart manufacturing with the steps taken worldwide in smart manufacturing and present current challenges for smart manufacturing. Among the current difficulties related to the smart manufacturing that they present in their studies, the difficulties caused by the complexity of CPS applications, the difficulties caused by cloud computing technologies in terms of privacy and security stand out. Hermann (2018) examined the organizational and financial risks of smart factories and structured these risks. Tuptuk and Hailes (2018) discussed the security of smart manufacturing systems, current vulnerabilities, cyber awareness and future security issues in their study. The study of Lu, Morris and Frechette (2015) includes a review of the relevant standards on which smart manufacturing systems will be based. Also they discussed opportunities and challenges for new standards in their study. Robert, Daniel and Bilal (2016) analyzed what skills are needed for future smart factory systems engineering. Prinz et al. (2016) have presented learning modules for smart factories. They have identified new profession profiles that will emerge with the Industry 4.0 transformation and discussed their presented learning modules with individual learning goals and mapped scenarios. Wiktorsson et al. (2018) studied South Korean and Swedish small and medium-sized enterprises (SMEs) and large companies to
embody the concept of smart manufacturing in their study. Cimini, Pinto and Cavalieri (2017) provided an overview of reference models that describe the characteristics of smart factories.

When studies revealing a literature review for smart manufacturing are examined; Şekkeli and Bakan (2018) examined many international publications in their study and they theoretically explained the technological components of the smart factory concept such as IoT, cyber physical systems, cloud computing, cyber security etc and also they explained what benefits this concept has. High competitiveness, low cost, quality, flexibility, high productivity and security stand out among the benefits of smart factories. In their study, Jerman, Bach and Bertoncelj (2018) conducted a bibliometric analysis and compiled the competencies needed in smart factories in the future. Strozzi, Colicchia, Creazza and Noè (2017) have depicted a view of the scientific literature on the concept of smart factory by applying a dynamic methodology. In the study of Kang et al. (2016), they determined the technologies related to the past and present levels of smart manufacturing by analyzing various articles and predicted the future of smart manufacturing with their development aspects. De Felice, Petrillo and Zomparelli (2018b) analyzed studies published between 2011 and 2018 on smart manufacturing using bibliometric analysis and multi-criteria decision making model in their studies. The study of Lu and Weng (2018) has revealed the background of the development of smart manufacturing and the industry development policies of various countries through a research and analysis of the current literature. In addition, their study proposes market maturity in smart manufacturing as well as an estimate of emerging technology development trends.

When studies that offer a conceptual framework for smart manufacturing are examined; Mabkhot, Al-Ahmari, Salah and Alkhalefah (2018) analyzed and categorized existing research on smart factories and proposed a framework for highlighting the perspectives that shape smart factories for realizing these perspectives. Among the perspectives that have shaped smart factories, the most notable have been standard communications and cyber physical systems, modular and decentralized control architecture, and service orientation. Taoa, Qi, Liub and Kusiak (2018) discussed the role of BD and data analytics in smart manufacturing. In their articles, they proposed a conceptual framework for the big data perspective and summarized the typical implementation scenarios of the framework they proposed. In their study, Lee, Jun, Chang, and Park (2017) proposed a smartness assessment framework for smart factories. In Lee's (2015) study, possible
technologies for smart factories are explained and a general technological framework and advantages of smart factories are presented.

When the studies suggesting an approach and architecture for smart manufacturing systems are examined; Shariatzadeha, Lundholma, Lindberga and Sivarda (2016) tried to identify approaches and principles in integrating smart factories based on IOT in production and proposed an approach when and how information should be integrated. Kannengiesser et al. (2015) explained their approach based on a meta-process idea for a continuous improvement aimed at developing processes in smart factories in cooperation with stakeholders. Chen et al. (2017) proposed a hierarchical architecture for smart factories and analyzed key technologies in smart manufacturing. In their study, they discussed important problems and potential solutions for key technologies in smart manufacturing through some application cases. Among the important problems for smart manufacturing, the necessity of improving the level of smartness of the manufacturing equipment stands out. They proposed a configurable controller and self-reconfiguring robots as a solution. In addition, a combination of optimized programs has been proposed for the difficulty of increasing workshop efficiency. The fact that manufacturing data cannot be used directly for reasons such as high dimensions, variable metrics and the need to define data semantics are another challenge that stated in the study and domain ontology has been proposed as a solution for providing data semantics. Jung, Choi, Kulvatunyou, Cho and Morris (2016) introduced a design and development model for smart factories. They put forward a case study on the activity model they proposed. In their studies; Ivanov, Dolgui, Sokolov, Werner and Ivanova (2016) presented a dynamic model and algorithm for short-term supply chain planning in smart factories. Jiang (2018) proposed a new architecture to create cyber physical systems in smart factories. Tang et al. (2018) introduced a cloud-supported, self-organizing smart manufacturing system architecture. Wan, Yang, Wang and Hua (2018) proposed a four-layer Compressed Air Foam System (CAFS) architecture for smart factories. Another study that demonstrates smart factory architecture is the study where Hu, Miao, Wu, Hassan and Humar (2019) proposed system architecture for the iRobot factory and they provided solutions for important functions in smart factories. Kannengiesser and Müller (2013) proposed subject-oriented modeling as a technology that enables the use of agent systems in smart factories. In their study; Jung, Morris, Lyons, Leong, and Cho (2015) proposed a method to determine which aspects of a manufacturing system should be addressed to respond to changing strategic goals. Their proposed method is shown in the study through
the scenario. Shrouf, Ordieres and Miragliotta (2014) presented a reference architecture for smart factories based on IoT and proposed an approach for energy management in smart factories based on the IoT paradigm.

When studies dealing with smart manufacturing systems from a technological perspective are examined; Wang, Wan, Li, and Zhang (2016) focused on vertical integration in the implementation of smart factory systems and presented their application display and main configurations through their smart factory prototypes with the design scheme they developed. Zawadzki and Żywicki (2016) presented a general concept of smart design and manufacturing control in their study and focused on the integration of additive manufacturing technologies and virtual reality techniques. Pu, Jiang, Yue, and Tsaptsinos (2018) discussed using agent technology and developing dynamic location planning capability to optimize supply chain management. Reinfurt, Falkenthal, Breitenbücher and Leymann (2017) presented IoT molds in their study and showed that these molds can be applied to smart factory systems. Nagorny, Lima-Monteiro, Barata and Colombo (2017) presented a comprehensive list of innovations and improvements, subsequent challenges, potential use cases and potential exploitation possibilities by reviewing big data analysis in smart manufacturing systems. Among the challenges related to big data analysis, how to deal with the challenges of increasing volume, diversity and speed of the data, how to measure the quality of the data, difficulties such as the integrating heterogeneous data into suitable databases, challenges in implementing privacy, security and governance requirements are stand out. Syberfeldt, Ayani, Holm, Wang, and Lindgren (2016) provided a comprehensive overview of current techniques and state-of-the-art systems for indoor localization in smart factories, and compared their advantages and disadvantages. Cheng, Chen, Sun, Zhang, and Tao (2018) reviewed the development of data mining techniques in their study and discussed the applications of data mining techniques in production management in smart factories. Hrustek and Furjan (2019) explained the basic approaches to the transformation of traditional factories into smart factories and examined the application of digital technologies in smart factory processes.

When studies revealing smart manufacturing systems with application scenarios are examined; Thoben, Wiesner and Wuest (2017) discussed the smart manufacturing systems from the technological and economic perspective with their presented application scenarios in their study. Zheng et al. (2018) presented demonstration scenarios in relation to smart manufacturing. They reviewed possible applications to key technologies and smart
manufacturing systems based on these demonstration scenarios. Wang, Wan, Imran, Li, and Zhang (2016) used the personalized candy packaging application as a showcase to show smart factory designs in their study. They presented experimental results by a scheme for layered interaction. Kayar, Ayvaz and Öztürk (2018) discussed the basic concepts of the implementation processes of the Industry 4.0 concept through a sample application. The advantages provided with the transition to smart manufacturing through the sample application include increase in productivity at the field level, achieving 40% faster production in the production process, a significant decrease in the raw material costs of the company, ensuring traceability in production and detecting faults in a short time, and ensuring that the system operates for a long time. Gőkalp, Gőkalp and Eren (2019) have proposed a smart apparel factory. They analyzed the benefits and challenges of the smart apparel factory, they proposed phased implementation plan for the transition from the current situation to the smart apparel factory and included the proposed plan. Among the benefits of the smart apparel factory, they listed the increased efficiency, decreased operating costs, increased quality, transparency, decreased order delivery time and increased customer satisfaction. Among the difficulties of the smart apparel factory, they listed difficulties such as initial investment cost, data privacy and security, lack of global standards and technical difficulties.

In the literature, the number of studies examining the problems faced by enterprises during the transition to smart manufacturing and suggesting solutions to these problems through a real case analysis is in limited number. The existing studies differ on the subject and scope of this research. In the study of Çakır (2017), the Smart Production Management System software was developed and implemented in seven different factories in the Aegean Region and its surroundings. As a result of the study, it was seen that common difficulties were encountered in the establishment, adaptation and development stages of the enterprises. The difficulties in the installation phase include the insufficiency of the factories in technological factors such as hardware, software, internet connection and access point. The fact that the system requires investment other than itself has made it difficult to put the project into operation. Among the difficulties encountered during the implementation phase, the insufficiency of local enterprises in data and information management is at the forefront. In the study of Lee, Yoon and Kim (2017), big data analytics platform architecture and system modules are proposed to be applied in smart factories place in SMEs. This platform was applied to the factory of a foundry company in South Korea for evaluation purposes.
Thus, difficulties in implementing big data analytics in SMEs have been exposed. In the study of Yuan, Qin and Zhao (2017), a Chinese company was included in the scope of the study in order to reveal the opportunities and challenges related to smart manufacturing in oil refinery or petrochemical plants. Difficulties and opportunities for fault detection and planning and timing of oil refinery areas for a catalytic cracking unit working with big data are presented as a result of the study. Another research was carried out by Wurhofer, Meneweger, Fuchsberger and Tscheligi (2018), and interviews with operators and maintenance engineers from three different industrial contexts shed light on their roles in smart factories and their experience in automated and digitalized factories. As a result of the study, based on the experiences conveyed by the participants, it has been understood that the automation and digitalization increasing with the conversion to smart manufacturing in the factories have both advantages and disadvantages. Among the difficulties arising in the study, it has been determined that changing business routines and applications poses difficulties for the design of systems, interactions and work environments. In the study of Petrovic and Leksell (2017), in which multiple case studies were carried out to guide industrial automotive manufacturers in smart factory transformation, many success factors, difficulties and application results were revealed. Among the challenges posed are what kind of difficulties encountered in integrating the systems into different layers and in the process of creating the project. Finally, in the study of Sjödin, Parida, Leksell and Petrovic (2018); in-depth interviews were held with participants from five factories in two leading automotive manufacturers to analyze the difficulties faced by enterprises in implementing smart factories and to determine the basic steps required to implement the smart factory concept. As a result of the study, a preliminary maturity model for difficulties related to personnel, technology, business processes and smart factory application has been introduced.

Summarize of the problems encountered in transition to smart manufacturing in the previous studies is given in Table 3.1.
Tablo 3.1. Encountered problems in transition to smart manufacturing in the previous studies

<table>
<thead>
<tr>
<th>Author</th>
<th>Publication Year</th>
<th>Encountered Problem in transition to smart manufacturing</th>
</tr>
</thead>
</table>
| Çakır K. [27] | 2017 | • Difficulties in the installation phase are inadequateness of factories in technological factors  
• Difficulties in the implementation phase are insufficiency of local enterprises in data and information management |
| Lee JY, Yoon JS & Kim BH. [28] | 2017 | • Technical problems due to outdated machines  
• Economical problems due to limited budget of SMEs |
| Yuan Z, Qin W & Zhao J. [22] | 2017 | • The ability to quickly obtain the right set points for control systems  
• Accuracy of the knowledge-driven approach  
• Difficulties in fault detection and diagnosis |
| Wurhofer D, Meneweger T, Fuchsberger V & Tscheligi M. [29] | 2018 | • Difficulties for the design of systems, interactions and work environments arose from changing business routines and applications |
| Petrovic A & Leksell M. [30] | 2017 | • Technological barriers  
• Paradoxes anchoring managers  
• Personnel-related problems  
• Insufficient knowledge about business process and investment of technology |
| Sjödin DR, Parida V, Leksell M & Petrovic A. [31] | 2018 | • Difficulties based on employee  
• Uncertainty in the business case based on technological complexity  
• Difficulties in adapting traditional routines and work processes to digital transformation |

When the studies in the literature are analyzed, it is seen that there is no existing study that examines the problems faced by the enterprises in the transition to smart manufacturing in a wide range based on organizational, technological, economic and environmental factors and revealing how solutions are found for these problems. Current studies address the problems encountered in the transition to smart manufacturing in limited scope. In addition, there is no study in the literature that explains how to find solutions to the problems encountered in the transformation into smart manufacturing based on the experiences of the staff who have experienced this process. With this study, it is aimed to fill the gap in the literature. It is anticipated that the study will be a guiding study for the enterprises that will switch to smart manufacturing in the future. It is the main motivation for this study to help enterprises to know the difficulties they will face in advance and to take precautions.
4. MATERIAL AND METHOD

In this section, the research method, the universe and the sample of the research, the data collection tool, the process of data collection, the analysis of the data, the validity and reliability of the research and the ethical dimension of the research are included.

4.1. The Universe and Sample of Research

The universe of this research consists of Turkey originated enterprises that are in the process of transitioning to smart manufacturing model and have started to perform smart manufacturing activities in part. The reason why enterprises are determined as Turkey origin as a criteria for the selection of the universe is that the researcher is resident in Turkey and will be able to conduct interviews with the enterprises in the country where the researcher resides during the data collection process. These enterprises have been identified by gathering information from internet research, from consulting firms and enterprises that perform smart manufacturing or are in the process of transition to smart manufacturing. As a result, it is determined that 11 Turkey originated enterprises carried out smart manufacturing operations in their manufacturing plants partially and it is determined that their transition process to smart manufacturing continuing. The 11 enterprises identified constitute the sample of the research.

Invitation electronic mails (e-mail) were sent to these enterprises, which constitute the sample of the research, to take part in the thesis study. Later, these enterprises were contacted by phone. Detailed information was provided about the study and a request for an interview was made to these enterprises. In addition to this, the ethics committee approval (13.11.2019 / 04) obtained from the Ankara Yıldırım Beyazıt University Social and Humanities Ethics Committee and permission letters obtained from the Institute of Social Sciences were shared with the enterprises. Four of the 11 enterprises accepted the interview request, and the rest of the enterprises rejected the request for the interview by stating different reasons such as their desire to protect their confidentiality regarding their smart manufacturing activities and they could not spare time due to their work intensity. For this reason, the sample of this study is limited to four enterprises that accepted the interview request and were included in the study. Interviews were conducted with a total of 10 participants who agreed to conduct interviews from four enterprises in the sample of the study.
Since enterprises and participants want their names to remain private; enterprises are symbolized as A, B, C and D and participants are symbolized as Participant 1, Participant 2… Participant 10. The activity sectors of enterprises that included in the working group are presented in Table 4.1. Within the scope of the study, interviews were held with three participants from Enterprise A, two participants from Enterprise B, one participant in Enterprise C and four participants from Enterprise D. The distribution of the participants, which are symbolized by number in the study, according to the enterprises they work in is given in Table 4.2.

**Table 4.1. Enterprises that make up the sample**

<table>
<thead>
<tr>
<th>Enterprises</th>
<th>Industry Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>White Appliances and Electronics</td>
</tr>
<tr>
<td>B</td>
<td>Automotive Sector</td>
</tr>
<tr>
<td>C</td>
<td>Automotive Sector</td>
</tr>
<tr>
<td>D</td>
<td>White Appliances and Electronics</td>
</tr>
</tbody>
</table>

**Table 4.2. Distribution of participants by enterprises**

<table>
<thead>
<tr>
<th>Participants</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterprises A</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td></td>
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<tr>
<td>Enterprises B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Enterprises C</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td>X</td>
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<tr>
<td>Enterprises D</td>
<td></td>
<td></td>
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<td>X</td>
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</tbody>
</table>

**4.2. Research Method**

Qualitative research method was used in this study, which aims to identify the problems faced by enterprises during the transition to the smart manufacturing model and offer solutions to them, as it provides an opportunity to convey the experiences of the participants in the interviewed companies and provide in-depth information. Qualitative research is a research method in which perceptions and events are obtained by following a qualitative process through a realistic and holistic structure and qualitative data acquisition methods such as observation, interview and document analysis. One of the most important goals of qualitative research is to reveal the perceptions and experiences of the individuals participating in the research [132].

In addition, the study is a case study, which is one of the qualitative research models and allows for an in-depth analysis and understanding of a situation. Case study model is
named in the literature as case analysis, case study and case study method [133] and it is a systematic pattern types including steps such as gathering information, organizing, interpreting and accessing research findings [134].

4.3. Data Collection Tool

In the study, a semi-structured interview form was prepared as a data collection tool. The reason for choosing the semi-structured interview form as the data collection tool is that it facilitates receiving in-depth information and provides the opportunity to ask questions at the end. The questions in the interview form were prepared by the researcher after the literature review. The opinions of 11 experts were taken in order to ensure the validity, understandability and suitability of the sections and questions placed in the interview form created by the researcher. The information of the experts who gave opinions to the data collection tool is presented in Table 4.3.

<table>
<thead>
<tr>
<th>Expert</th>
<th>Age</th>
<th>Education Level</th>
<th>Major</th>
<th>Institution</th>
<th>Profession</th>
<th>Title</th>
<th>Working Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>39</td>
<td>Master</td>
<td>Business Administration</td>
<td>State Agency</td>
<td>Administrator</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>45</td>
<td>Undergraduate</td>
<td>Engineering</td>
<td>State Agency</td>
<td>Administrator</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>42</td>
<td>Undergraduate</td>
<td>Engineering</td>
<td>State Agency</td>
<td>Engineer</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>29</td>
<td>Undergraduate</td>
<td>Engineering</td>
<td>State Agency</td>
<td>Project Engineer</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>49</td>
<td>Master</td>
<td>Engineering</td>
<td>State Agency</td>
<td>Expert</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>46</td>
<td>Master</td>
<td>Business Administration</td>
<td>State Agency</td>
<td>Expert</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>31</td>
<td>Undergraduate</td>
<td>Engineering</td>
<td>State Agency</td>
<td>Administrator</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>43</td>
<td>Master</td>
<td>Economy</td>
<td>State Agency</td>
<td>Administrator</td>
<td>22</td>
<td></td>
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<tr>
<td>9</td>
<td>39</td>
<td>Master</td>
<td>Business Administration</td>
<td>State Agency</td>
<td>Project Engineer</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>31</td>
<td>Undergraduate</td>
<td>Engineering</td>
<td>State Agency</td>
<td>Expert</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>53</td>
<td>Master</td>
<td>Engineering</td>
<td>Consulting Firm</td>
<td>Digital Transformation Consultant</td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

In accordance with the opinions of the experts, spelling errors in the questions in the interview form were corrected. In order to clarify the purpose and scope of the interviews, the definition of smart factories and the purpose of the research have been added to the interview form. Some parts were removed from the interview form for be spoken verbally.
In addition, four questions were removed from the interview form in line with expert opinions and two new questions were added to the interview form. Some appropriate changes have also been made above the existing questions. The comprehensiveness, fluency and compliance of the questions in the interview form were checked by two experts in the field of Turkish Language and Literature. As a result, the final form of the semi-structured interview form was created using the opinions received from the experts.

There are eight sub-sections in the interview form, respectively. These are: participant information, present state, preparation process, organizational factors, technological factors, economic factors, environmental factors and predictions. In the first part, the age of the participants, the level of education, the field of education, their profession, the department they work for, how long they have worked in the institution they have been working, and what are their duties and responsibilities in smart manufacturing are asked. In the second part, the questions about determining the present state of the enterprises regarding smart manufacturing activities are included. In the third part, there are questions about the preparation process of enterprises before the transition to smart manufacturing. In the fourth section that called “Organizational Factors”, there are questions about staff in the processes before the enterprises start to smart manufacturing and in the process in which they currently perform smart manufacturing. In the fifth part, there are questions to identify the problems faced by enterprises regarding smart manufacturing processes and technological factors in the pre-process. In the sixth section, questions related to costs are included in the transition to smart manufacturing. The seventh section includes questions on the determination of factors that affect smart manufacturing environmentally. In the last section, the questions about determining the predictions of the enterprises in their own enterprises and globally with the transition to smart manufacturing are included.

In the interview form, there are 47 open-ended questions under eight sections. The distribution of the number of questions in the interview form to the parts of the interview form is presented in Figure 4.1. The interview form is given in Appendix-2.
4.4. Collection of Data

In this study, the data were collected through interviews with using a semi-structured interview form. The semi-structured interview form is neither as limited as fully structured interview forms nor as flexible as unstructured interview forms [135]. This technique is a data collection technique that covers all the dimensions of the subject, provides more open-ended questions, provides more detailed answers and allows for face-to-face and one-on-one information collection [136]. In addition, before the interviews were conducted, the interview form was printed and a voice recorder was prepared.

Data collection was carried out by the researcher between October 14, 2019 and February 7, 2020. During the data collection process, face-to-face interviews were conducted with three of the four different companies by making an appointment in advance and by going to the location of the enterprise by the researcher. The interviews were held in the work offices in line with the requests of the participants. Each interview lasted an average of two hours. Negotiation were held with the other enterprise as online via the Skype application at the request of the enterprise. During the interviews, first of all, the participants were informed about the purpose of the study, its scope and the concepts related to the research topic. During the interviews, the answers given to the questions were recorded with the voice recorder within the permission of the participants, and the answers were also noted. After the interview, transcripts were prepared for each interview. While creating the transcripts, care was taken to write the answers of the participants one-to-one. In order to
confirm the accuracy and validity of the transcripts, transcripts were sent to the participants via e-mail and their approval was obtained. Eight out of 10 respondents stated that interview transcripts are appropriate. The two participants gave feedback on interview transcripts. In line with the feedback received, minor adjustments were made to the data of these two interviews.

4.5. Data Analysis

In this research, the data obtained from the interviews were analyzed by using descriptive analysis and content analysis techniques. In descriptive analysis; the data obtained are summarized according to the themes determined previously and supported by direct quotations. In content analysis, the conceptual framework formed as a result of the literature review was used. The answers were grouped within the conceptual framework, and themes and categories were reached. As a result, data similar to each other were combined in certain concepts and interpreted.

4.6. Validity and Reliability

To ensure the validity of this study, expert opinion was received for the questions in the interview form. The interviews were held face to face and the data collected were presented to the participants for confirmation. In addition, direct quotations are included in the descriptive analysis of the data. After the qualitative data in this study was converted into a transcript, the audio recording was checked by the researcher once and then by the supervisor researcher, by listening to the audio recording. The researcher and the supervisor researcher analyzed and coded the same texts independently of each other, and the findings were finalized by comparing the findings obtained.

For the reliability of the study, the researcher firstly clarified and defined his own position in the research process. Detailed information about the participants was given and the environment and processes in which the interviews took place were explained. The conceptual framework used in data analysis is explained and data collection and analysis methods are detailed. In addition, all the data obtained (sound recordings and notes) were stored to be submitted for review when necessary.
4.7. Ethical Dimension of the Research

Following the acceptance of the thesis proposal submitted by the researcher to Ankara Yıldırım Beyazıt University Institute of Social Sciences, Ethics Committee Approval was obtained from the Ethics Committee of the relevant Institute in order to conduct the research. Related ethical approval is given in Appendix-1. In addition, a permit was obtained from the relevant Institute in order to conduct interviews with the participants within the scope of the thesis study and the permit documents were sent to the participants via e-mail before the interviews were conducted.

Participants in the study were given detailed informations about the identity of the researcher, purpose of the research, where and how to use the information received, knowledge that participation in the study is voluntary and participant can leave the study at any stage. After explanation why participants were chosen, interviews started after obtaining participants' verbal consent to record interviews with a voice recorder.
5. FINDINGS

In this section, evaluations regarding the interviews with 10 participants from four
Turkey originated enterprises that are in the process of transition to smart manufacturing and
and partly perform smart manufacturing and agree to be included in the research are
included. Descriptive analysis and content analysis techniques were applied to the data. The
descriptive analysis and content analysis results of each section in the interview form in
Appendix-2 are presented below.

5.1. Participant Information

In the section entitled “Participant Information”, which constitutes the first part of
the semi-structured interview form, age, education level, profession, department and
working time information of the participants were collected. These data of 10 participants
participating in the research are given in Table 5.1 below.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age</th>
<th>Education Level</th>
<th>Profession</th>
<th>Department</th>
<th>Working Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36-45</td>
<td>Undergraduate</td>
<td>Digital Transformation Manager</td>
<td>Digital Transformation</td>
<td>More than 7 years</td>
</tr>
<tr>
<td>2</td>
<td>36-45</td>
<td>Undergraduate</td>
<td>Supply Chain Manager</td>
<td>Supply chain management</td>
<td>More than 7 years</td>
</tr>
<tr>
<td>3</td>
<td>36-45</td>
<td>Undergraduate</td>
<td>Test Systems Engineer</td>
<td>Production</td>
<td>5-7 years</td>
</tr>
<tr>
<td>4</td>
<td>46-55</td>
<td>Undergraduate</td>
<td>R&amp;D Manager</td>
<td>R &amp; D</td>
<td>More than 7 years</td>
</tr>
<tr>
<td>5</td>
<td>26-35</td>
<td>Master</td>
<td>Mechanical Engineer</td>
<td>R &amp; D</td>
<td>More than 7 years</td>
</tr>
<tr>
<td>6</td>
<td>26-35</td>
<td>Doctorate</td>
<td>Smart Production Technologies Manager</td>
<td>Production</td>
<td>More than 7 years</td>
</tr>
<tr>
<td>7</td>
<td>46-55</td>
<td>Master</td>
<td>Factory Director</td>
<td>Digital Production Technologies</td>
<td>More than 7 years</td>
</tr>
<tr>
<td>8</td>
<td>36-45</td>
<td>Undergraduate</td>
<td>Digital Production Manager</td>
<td>Digital Production Technologies</td>
<td>More than 7 years</td>
</tr>
<tr>
<td>9</td>
<td>36-45</td>
<td>Undergraduate</td>
<td>Quality Assurance Manager</td>
<td>Quality assurance</td>
<td>More than 7 years</td>
</tr>
<tr>
<td>10</td>
<td>36-45</td>
<td>Master</td>
<td>Production and Production Engineering Manager</td>
<td>Production and Production Engineering</td>
<td>More than 7 years</td>
</tr>
</tbody>
</table>
When the data of the participants in Table 5.1 are analyzed, it is seen that the vast majority of the participants are in the 36-45 age group, they have been working for more than 7 years in the enterprise they are in and the majority of them are in the managerial positions in the enterprises they work for.

In the “Participant Information” section, which constitutes the first part of the interview form, additionally the participants were asked what their duties and responsibilities were in the smart manufacturing system. Participant 1 [137] answered this question as: “We have five factories within our enterprise and we are carrying out activities towards digitizing the production processes of these five factories. Actually, we are managing the process of implementing Industry 4.0 in these factories and expanding the project that we have implemented and yielded in one of these factories. One of our main duties is to find technology suppliers, to ensure coordination between technology suppliers and the production unit, and to put this process into a project and try to provide project management. Apart from this, it is among our duties to ensure coordination between the production facilities of five different factories. I can say that I am mostly in the administrative part of the production process.” Participant 2 [138] who is the Supply Chain Manager in the company where he worked, expressed his duties and responsibilities in the smart manufacturing system as follows: “If we look with wide scale within the scope of the smart manufacturing system, we are responsible for planning all the functions including production from the supplier of the factories that started production with the smart manufacturing system, to the customer who is the end user. We are trying to digitize our functions in our own supply section with these systems.” While Participant 3 [139], who worked in the production department of the enterprise where he work as a test systems engineer, stated that he is involved in the installation of full automatic systems in the tests of telephone and television units; Participant 4 [140] stated that he work as project manager within the scope of smart manufacturing system and Participant 5 [141] stated that he is responsible for the realization of R&D studies within the scope of smart manufacturing activities, and Participant 6 [142] stated that he work in smart manufacturing systems as a smart manufacturing technologies manager. Participant 7 [143] expressed his duties and responsibilities in smart manufacturing systems as follows: “I have been in the management section since the establishment of the smart manufacturing factory, and now I am working as the factory director responsible for the operation of the factory processes and I am part of the team that leads the digital transformation process in the production technologies of
our enterprise.” While Participant 8 [144] state that he is responsible for the realization of all functions such as the installation, development, operation of smart manufacturing systems and responsible for IT systems, Participant 9 [145] answered this question as follows: “I have been involved in the execution of the project from the very beginning of the process of transformation into smart manufacturing systems and I was interested in quality assurance processes. I took part in the creation of relevant processes and the realization of investments. Apart from that, I had duties and responsibilities in terms of what kind of data we should collect on the digital side, what kind of studies can be done with the data collected.” Finally, Participant 10 [146] stated that he was responsible together with his team in all processes in the design, installation, commissioning and operation of smart manufacturing systems.

In line with the answers given to the second question of this section, the diversity of the departments in which the participants take part in their enterprises and diversity of their duties and responsibilities in smart manufacturing systems also facilitated to receiving more accurate, comprehensive and complete answers to the problems encountered in the transition to smart manufacturing and receiving solutions to these problems. Based on these data, it can be concluded that interviews were held with the participants who have the necessary knowledge and experience in the research.

5.2. Present State

In the section titled “Present State”, which constitutes the second part of the semi-structured interview form, four questions were asked to the participants in order to express their present state of the smart manufacturing activities of their enterprises.

In the first question of this section, the participants were asked how long they had been doing smart manufacturing in their factory/factories. It is seen that Enterprise A has been engaged in smart manufacturing for three or five years. It is observed that B and C enterprises have been engaged in smart manufacturing for five or seven years. It is seen that only enterprise D has been in this transformation for a short time. Considering that the smart manufacturing model that emerged in line with the vision of Industry 4.0 and this revolution came to the fore for the first time in 2011 [7-9], it can be said that some of the enterprises in our country trying to adapt to the innovations in a short time in order to not stay behind this competition.
In the second question in this section, the participants were asked in which units of the factories in their enterprises or in which part of the manufacturing process are the smart manufacturing activities taking place. With this question, learning that whether smart manufacturing activities take place in all or in a certain part of the manufacturing processes in participants' enterprises was wanted. Participant 1 [137] answered this question as: “Currently, we have carried out smart manufacturing activities in two of our five different production facilities, and we still working on the realization of other two of them. We hope that we will complete the transition to smart manufacturing activities in these two factories in 2020. In the assembly plant, which is our last remaining factory, we have a goal of starting the transformation to smart manufacturing at the end of 2020 and completing this transformation in 2021. Our factories that we have transformed and are in the process of transformation are our factories that produce television, which is the sub-industry of the electronics industry, and provides plastic and metal parts. Our first factories where we started smart manufacturing are our plastic injection or metal press factories. The reason for this is that there are places with less human factor and more machine tracks. The transformation into smart manufacturing in the assembly plant which contains the human factor is left to last stage because it contains more human factor.” The answer of Participant 4 [140] to this question is as follows: “We have been in the process of transformation into smart manufacturing for five years. Although we have not been able to fully complete transition to smart manufacturing, some of our applications have been in operation for the last two years now. For example, robotic manufacturings that do not require outside manpower intervention that we carry out with robots communicating with each other are currently available in our manufacturing units.” Considering the responses given to in which unit of the factories or which part of manufacturing processes the smart manufacturing activities in their enterprises are taking place, it is concluded that the enterprises participating in the research have not yet made a complete transformation. Yet it is seen that adapted their manufacturing processes and factories to this manufacturing system partially.

In the third question, the participants were asked the number of people responsible for the smart manufacturing system in their factories where they perform smart manufacturing. Participant 1 [137] answered this question as follows: “Our automation team currently has six engineers and around 30 technicians working in blue collar. There are eight engineers in the Smart Systems Department working on software issues and also as two people in the digital transformation unit, we support the smart manufacturing process.
There are five people in the management section. Looking at the total, 50 people can be said to be responsible for the smart manufacturing system.” Also Participant 4 [140] answered this question as follows: “We can say that on average 30 people are the number of people responsible for the smart manufacturing system. These 30 people include maintenance personnel, production personnel, project management team etc. That is, all of these personnel involved in commissioning the system and its functioning and maintenance after commissioning are involved in their process.” Participant 7 [143] stated that a total of 47-month paid and 60-hour paid employees are responsible for the smart manufacturing system.

In the last question of this section, the participants were asked to explain the selection criteria of location of the factory/factories where smart manufacturing was carried out considering the geographical features. Participant 1 [137] stated that they have built their factories in which they realized smart manufacturing in the area where other production facilities are located, that all factories and production facilities are located in the same area therefore they do not consider any geographical features or selection criteria in the establishment of their smart manufacturing facilities. Participant 4 [140] likewise stated that all the manufacturing units are located in the same region as the region where their enterprise first located, and that the smart manufacturing units are built within the same region as other manufacturing units, so any criteria in the geographical location of the smart manufacturing units are not considered. In addition, Participant 4 [140] stated that the only criterion they consider geographically in the establishment of their plants at the location of their first and subsequently established factories is proximity to other automotive factories that are their customers, and therefore they have built units that they realized smart manufacturing in the same location. He emphasized that there is no important factor to consider in the selection of the geographical location of the smart manufacturing factories as follows: “While establishing a factory, proximity to customers and suppliers, proximity to ports and crossroads, selection of the region that will not be affected by any natural disaster if the region located on the earthquake zone, selection of an area where wastes can be easily disposed of without harming the environment in setting up a factory such as textile factories that produce waste that can damage the environment are such criterias can be considered in general terms. However, there are no specific criteria to be considered in factories where smart manufacturing realized.” Participant 6 [142] answered this question as follows: “With considering the proximity factors to logistics and supply channels, we have determined the geographical location of our factory.” Also Participant 7 [143] responded this question as:
"Our company established its factory where it realizes smart manufacturing in Romania in order to create a manufacturing center in Europe, other than that, there is no other factor that we consider in determining the geographical location."

When the answers given in this section are evaluated, it is seen that at least 30 people responsible for the smart manufacturing system. Consideration the criteria such as proximity to ports and junction points, proximity to suppliers and customer firms, not being in an earthquake zone, and being in an area that will not be affected by natural disasters. Also it is seen that they have positioned their smart factories in the same region as their existing factories. Apart from the specified criteria, it is noticeable that there is no geographical criterion that they especially consider in determining the location of the factory/factories where they realize smart manufacturing.

5.3. Preparation Process

The third part of the semi-structured interview form is “Preparation Process” and five questions were asked to the participants in this part.

In the first question of this section, the participants were asked what kind of studies they carried out in the preparatory processes before switching to smart manufacturing. For the purpose of clarifying the question, examples are given as feasibility study and simulation software. In response to this question, Participant 1 [137] stated that they carried out all of the exemplary works except for strenght, weaknesses, opportunities and threats (SWOT) analysis and simulation software, in addition, he continued his explanation as follows: “We took out the feasibility, extracted the cost-benefit analysis, started with the pilot application before the system was installed, then carried out dissemination activities and organized benchmarking trips to factories realizing smart manufacturing. In this way, we have determined the stages of the system that we will establish by discussing how the things we see in those factories can be applied to our own factories and by producing scenarios.” Participant 4 [140] stated the works they carried out during the preparation process as follows: “We have carried out feasibility studies in order to find answers to questions such as what this project will bring us, how much it will cost, how much it will be used from which sources, in which production units we will be able to implement this project, whether we will be able to implement it throughout the factory or whether it will remain in the form of a pilot application. We carried out the simulation software studies in the implementation process
after the project started. We did not perform a SWOT analysis. We conducted the cost benefit analysis within the feasibility studies. We also had pilot implementation studies. We applied our first pilot application in the section on making spot welds. Previously, operators were making punto sources in our company. In this case, this process is now performed by robots, not by operators. Apart from that, we had pilot applications in many areas of the production process and we are currently implementing many of them in the production process. Apart from these, we also carried out benchmarking activities through our negotiations with other companies. We also had meetings with universities for the purpose of know-how.” 

Participant 6 [142] answered this question as follows: “We carried out feasibility study, simulation software, SWOT analysis, cost / benefit analysis, pilot application and benchmarking studies in our preparation process before moving to the smart manufacturing system.” Finally, Participant 7 [143] stated the works they carried out during the preparatory processes as follows: “We have carried out all the studies that placed in options such as feasibility study, simulation software, SWOT analysis, cost / benefit analysis, pilot application, benchmarking in our preparation process. Apart from this, we have collaborated with institutes, academicians and consultants, and we have also developed collaborations with leading companies in the field.” 

When the findings obtained from the responses of the participants to the questions in the “Preparation Process” section of the interview form are examined, it is seen that enterprises pay particular attention to the careful realization of the feasibility study among the studies carried out by the enterprises during the smart manufacturing preparation process. In addition, it is seen that the companies carry out cost-benefit analysis, pilot application studies, benchmarking, simulation software applications, know-how studies, SWOT analysis and collaborations with institutes, academicians and consultants within the scope of feasibility studies. These findings are important for the literature in terms of revealing what kind of studies the companies are doing in the pre-transition to smart manufacturing processes and it is thought that these findings will guide other companies in the transition to smart manufacturing. 

In the second question of the part, the participants were asked why they needed to switch to the smart manufacturing model and the reasons that pushed their enterprises to implement this model. Participant 1 [137] answered this question as follows: “One of the main reasons that pushed us to apply this model is our desire to follow these technological trends in the global world and to apply these technological trends in our own production
factories, thereby not to be left behind in the competition in the global world and to maintain our prestige and leadership by continuing our existence in the competition. In addition to this, our desire to reduce costs in production, to reach instant data, and to be informed about this situation quickly when a problem occurs in production, and to be able to evaluate and intervene may be among other reasons. ” Participant 4 [140] stated the reasons that led their enterprises to implement this model as follows: “Increasing the safety of operators, reducing costs, increasing the level of product quality and reducing the error rates in production are a few of our main reasons. Especially in the automotive industry, production errors are undesirable and production has to take place as it should be. In order to eliminate them, we felt the need to install some automated systems and decided to switch to the smart manufacturing model.” While Participant 6 [142] responds to this question as follows: “We needed to switch to a smart manufacturing model to create efficiency”, Participant 7 [143] answered this question as follows: “The main motivation was the adaptation of the company's manufacturing systems to smart manufacturing systems. Creating added value, creating efficiency, reducing production costs, being able to perform digital transformation in factory totally, increasing quality and benefiting from technological developments were among the main reasons for this transition.” When the responses given to why enterprises need to switch to smart manufacturing model and what causes their enterprise to apply this model are evaluated; it is seen that prominent reasons include the desire of enterprises not to lag behind in the global competition and desire to survive in competition, desire to reduce costs, desire to access instant data and gain the ability to quickly respond to production errors, desire to increase the safety of operators involved in production, desire to increase product quality and reduce error rates, desire to increase efficiency and create added value.

In the third question of this part, the participants were asked whether there were enterprises and countries that they identified as a role model that encouraged them to this manufacturing model before transition to the smart manufacturing model, and in response to this question Participant 1 [137] has listed Siemens, which has announced Industry 4.0 to the world, Bosch and Harley-Davidson as among the companies that they have determined as role models, and he listed Germany and the USA as country. Participant 4 [140] answered this question as follows: “In fact, we cannot say that there is a enterprises that we see as a role model. The idea of transition to smart manufacturing emerged as a spontaneous need within the company. In this context, we have not determined an enterprise or a country as a role model.” In addition, Participant 7 [143] answered this question as follows: “We have
done a lot of benchmarking study before moving on to this model and as a country, I can say that Germany is a role model for us in this regard. We have carried out benchmarking study with many companies and institutions in Germany, the USA and the Far East.”

In the fourth question, participants were asked whether there were institutions or individuals with whom they received support or cooperation in the scope of project during the transition to smart manufacturing. Consulting firms, universities, consultants, leaders, mentors and academics are listed as an example in this question. Participant 1 [137] answered this question as follows: “We did not meet with a mentor or a consultant, but we can say that we have received consultancy service from the managers of the company we supply the Enterprise Resource Planning (ERP) system we use. Our study with universities has always been and our study is still ongoing. However, our meetings with universities have never been to answer questions such as ‘What should we do?’ By discussing with universities, we bring out some cases from academics’ scientific publications such as thesis and we do additional studies on our own system.” Participant 4 [140] stated that they have cooperated with universities and academicians and received support from them and that they did not receive support from any consulting firm or consultant. Participant 6 [142] stated that they made many research and external field visits during the transition to the smart manufacturing system and that they did not have the institutions and people they received support from, and that they achieved this transformation with their own internal resources. Also Participant 7 [143] answered this question as follows: “We cooperated with consulting firms, universities and academics, and we received support from them during this process, as well as we had strategic partnerships with companies.”

In the last question of the part, the participants were asked to explain what the problems they faced during the preparation process which expresses the process previous moving to smart manufacturing. Participant 1 [137] answered this question as follows: “One of the most important problems we encountered was the different standards, languages and protocols of the machines. Translating them into the language we will understand was one of the biggest problems we encountered. Second, old machines were our biggest problem. Some machines, for example, were unable to provide internet connectivity, and their modification and adaptation was one of the most common problems for us. In addition, the lack of know-how and the small number of companies that we can get support in this country was one of the biggest problems. The process of providing support for the investment we will make due to the fact that there are problems related to infrastructure in ourselves and that
our company is a family company were the other obstacles we encountered. We tried to overcome these problems by attaching sensors to old machines, overcoming different machine protocols with software and hardware solutions, tried to overcome the companies that we could not find for know-how in Turkey by turning abroad.” Participant 3 [139] stated that they faced resistance in fulfilling new demands in the R&D department. Participant 4 [140] answered this question as follows: “The cost part of the work is at the top of the problems we encounter. Building smart systems in manufacturing units rather costly process, especially in Turkey. In addition, finding qualified personnel on the subject was another problem we encountered.” Also Participant 6 [142] expressed the problems they faced with this answer: “We encountered problems regarding the insufficiency of our infrastructure for data collection and the processing, modeling and interpretation of the collected data.” Participant 7 [143] answered this question as follows: “Identifying and choosing which manufacturing system model will create the most value for us was the biggest challenge we encountered. Other than that, there was no problem we encountered.”

According to the data obtained as a result of the interviews, the problems faced by the enterprises in the preparation processes of transition to smart manufacturing can be seen in Table 5.2.

**Table 5.2. Problems encountered in the preparation process**

<table>
<thead>
<tr>
<th>Problems encountered in the preparation process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different standards, languages and protocols of machines</td>
</tr>
<tr>
<td>The lack of internet connection in old machines, the need for modification and adaptation</td>
</tr>
<tr>
<td>Lack of know-how and very little number of firms that can be taken support on this subject in Turkey</td>
</tr>
<tr>
<td>Difficulties in finding trained and qualified personnel</td>
</tr>
<tr>
<td>Problems encountered in the processing, modeling and interpretation of the collected data</td>
</tr>
<tr>
<td>High cost of transition to smart manufacturing</td>
</tr>
<tr>
<td>Resistance to meet new demands in the R&amp;D department</td>
</tr>
<tr>
<td>Infrastructure related problems</td>
</tr>
</tbody>
</table>

As can be seen in Table 5.2, enterprises faced various problems in the preparation processes that formed the transition to smart manufacturing. It is seen that these problems
are mostly caused by computer technologies and personnel. As a solution to these problems, enterprises overcome the problem of the standards, languages and protocols of the machines with software and hardware solutions, attach sensors to old machines, modify the machines and adapt them to the new production process, seek the companies they cannot find for know-how at home and seek support from abroad. In addition, some of the enterprises within the scope of the research have worked with consultancy firms and leading companies in their fields, and they received services both for their problems and for the purpose of receive guidance in the transition to smart manufacturing. In addition, they also have worked in collaboration with academics and universities. However, despite all these, it is seen that enterprises do not have a solution for every problem they face.

5.4. Questions About Organizational Factors

In the fourth part of the semi-structured interview form, there are six questions regarding organizational factors.

In the first question of the part, the participants were asked whether personnel needs planning was carried out during the transition of their enterprises to the smart manufacturing system. In response to the question, Participant 1 [137] stated that they have been doing a need planning study and when they first set up such a system, they have tried to set up the issue of how to manage it, so they first draw up personnel needs planning at the establishment stage of these systems. In addition, he continued his explanations for this question as follows: “We have identified one engineer from each factory on this subject. When they attained to this job, their gaps were filled in other ways. We started to manage this issue centrally, we were in the management. Personnel recruitment was carried out for respond to our needs in parts such as automation and software, which would not affect the flow period of normal production. Apart from this, after the installation of the system, we have determined the positions of the personnel who will work in both central units and departments to solve the problems so that the system can walk. We also realized manpower planning for the positions we will need in the future.” Participant 4 [140] answered this question as follows: “Almost 98% of the personnel working in our company are mechanical engineers. After we started this project, we realized that we needed personnel trained in other fields. At this point, we made personnel needs planning and, as I mentioned, we also employed personnel who are specialized in other fields to work in the relevant project within the company. Currently, our search for and recruitment process continues, especially for the software part of the project.”
Also Participant 6 [142] and Participant 7 [143] stated that they carried out personnel needs planning in a similar way.

In the second question of this section, the participants were asked whether the employees in their enterprises were informed about this transition and whether a transparent communication was established with the employees before moving to the smart manufacturing system. Participant 1 [137] stated that they informed the employees, that they provided information to the employees prior to installing the systems in this regard, and that they provided training for the employees starting from the installation phase. He completed his answer to the question as follows: “We tried to be transparent whenever we could in the information we give to our employees. In this informational process, we provided information by making speeches in small groups, not with crowded groups. In the informing process, we aimed to breaking our staff’s resistance to this new manufacturing model by talking about the purpose of our desire to switch to the smart manufacturing system, by inform them about what it will benefit us and by talking about that our aim is not to dismiss anyone but to reduce the recurring works that do not have added value. Both our blue-collar and white-collar staff took part in our informational process.” Also Participant 4 [140] gave the following answer to this question: “Our company has been implementing the Word Class Manufacturing (WCM) system for 6 years. In this context, our employees are always aware of the innovations developed within our company and we have informed all our staff about these systems and processes and we established a transparent communication with them before moving to the smart manufacturing system.” Participant 6 [142] stated that they informed the employees and provided transparent information sharing in this process. Participant 7 [143] answered this question as follows: “We have informed all our staff in this process, regardless of whether they are hourly wage or monthly wage staff. As the information method, we made announcements throughout the company, and provided information on the online platform with the participation of the general manager and assistant general managers. We provided weekly, biweekly, monthly, quarterly and yearly status information about the process. In the content of these informations, when the smart manufacturing will be put into operation, what are our goals by switching to this system, how this system will provide us with added value etc. informations was included.”

In the third question of the part, the participants were asked whether there was any need for new personnel during the transition to the smart manufacturing system, if need is was, in which field of the smart manufacturing process was and how they met the needs of
adequately trained personnel. Participant 1 [137] answered this question as follows: “Yes, of course, we needed new personnel because the manufacturing in our factories continues uninterruptedly and you have to continue without stopping, you also have to install new systems at the factory. For the new system we will set up, we allocated one engineer from each production unit and when we employed that engineer in this transition to the new manufacturing process project, we recruited new personnel to fill the personnel gap in that manufacturing unit. In addition to this, we have tried to find experienced personnel who have been involved in similar processes in order to work in automation and software departments in the smart manufacturing process and we have provided internally and externally provided trainings to make them suitable for our needs...” Participant 3 [139] expressed his explanations for this question as follows: “In this process, we have procured the competent staff that we need from our experienced staff within our own production units. We commissioned some of our own staff in collecting data in the field, commissioned some of them in process of developing user interfaces and reporting interfaces, etc. We have also used some of our staff alternately in these parts.” While Participant 4 [140] answered this question as follows: “We needed staff trained in different fields. In this context, we have recruited new staff in our company. Staffing needs occurred especially in the software and robotics parts of the project”; Participant 6 [142] stated that they experienced need for new personnel in the process of transition to smart manufacturing system, they met the new personnel needs by training the personnel with leveraging their own resources and that they did not recruit new personnel. Also Participant 7 [143] answered this question as follows: “We have newly recruited all the staff in this factory we established in Romania. Initially, only six employees working in our factories in Turkey were assigned to this newly established factory, we hired all the remaining staff for this factory newly. Among the staff positions we hired were digital operators, data engineers, data analysts. We provided trainings to the staff we hired using company resources to achieve the competence we need.”

In the fourth question of the part, the participants were asked what kind of problems they encountered in their process of transition to the smart manufacturing system or performing smart manufacturing activities. Participant 1 [137] answered this question as follows: “The biggest problem we encountered in people who will use these systems was their resistance to the new manufacturing system, or rather to all kinds of innovations. Breaking this resistance was challenging for us, because it was difficult to discourage staff from the way they used to. This was the problem we encountered with the personnel who will
use the technology. In addition to this, the biggest problem for the personnel who will adapt the technology to the manufacturing system, in other words our biggest problem, was the lack of knowledge and experience.” Participant 3 [139] stated that they faced resistance in fulfilling new demands in the R&D department. Participant 4 [140] gave the following answer to this question: “As part of the smart manufacturing project, we had problems with the lack of specialized staff in the areas needed such as artificial intelligence, 3D printing, robotic software etc and as we mentioned before, we have recruited new personnel to solve this problem. In addition, our company now develops projects in connection with abroad and provides product imports, at this point we encountered some difficulties regarding the foreign language knowledge of the staff.” Participant 6 [142] stated that the problems they faced regarding the personnel were their lack of awareness about smart manufacturing and their training needs related to the subject. Also Participant 7 [143] answered this question as follows: “It was a big problem for us to find competent people and attract them to our factory in these processes. The number of people who wanted to work in manufacturing was very low in Romania because manufacturing lost its appeal and because we employ personnel from Romania, the differences in the working culture we encountered in the staff due to being a different country was also a problem for us…”

In the fifth question, the participants were asked what kind of personnel policy they followed for the personnel resources that would not be needed after the robots took over the place of human power in manufacturing in transition of their enterprises to smart manufacturing. Participant 1 [137] answered this question as follows: “One of our biggest geographical advantages is that our manufacturing factories, which realize very different productions, are located in the same location. Here we know how difficult it is to find manpower from outside, so we direct any staff power to that will be wasted in any manufacturing unit and will not be needed and we evaluate the staff power there. Therefore, in this process, we did not pursue any layoff policy, but instead evaluated them in other parts of manufacturing that were needed. Whether a blue collar or a white collar, we always have need for personnel power and so recruitments are constantly taking place in our enterprise. By providing a circulation in this way, we directed the personnel power that is no longer needed in one unit to another unit that needs personnel power.” Participant 4 [140] gave the following answer to this question: “We followed a personnel policy in the form of employing our unnecessary personnel resources in different manufacturing units needed. We didn't fire anyone.” Participant 6 [142] stated in similar way that they utilize personnel resources that
are not needed together with smart manufacturing in other processes that will provide added value. Also Participant 7 [143] gave the following answer to this question: “Didn’t happen such thing with the conversion to the smart manufacturing system in our factory, we did not dismiss anyone. Because, as I mentioned before, we established this factory from the ground up for smart manufacturing only and all personnel were initially hired for this purpose. In other words, instead of firing the staff, we have provided staff employment.”

In the last question of the part, the participants were asked about the attitudes that would recommend to top managers to follow during the transition to the smart manufacturing system. Participant 1 [137] stated his recommendations in the following way: “The attitudes that I can recommend to top managers are not afraid to take risks and invest, so that not lag behind technology and trends, continue to exist in the competition at all times, not to be afraid of technology, to always follow technology and to be visionary, to determine their company's strategies well and to direct their employees in line with these strategies.” Participant 4 [140] gave the following answer to this question: “I suggest them having an attitude that supports such technological developments, but in this process, I recommend that they should conduct detailed research on feasibility studies (the benefit of this business, the cost, the time of return on investments, etc.) and they should be very meticulous.” Participant 6 [142] stated that among the attitudes recommended to top executives in this process are to lead the process, strengthen the team, support and adopt the new system. Participant 7 [143] stated his recommendations as follows: “In this process, a dedicated sponsorship is necessary. Before deciding which technologies to use, I definitely recommend make their teams to do proof of concept (POC) studies and choose the most appropriate technologies that will create the most added value in company dynamics, and I recommend that make their investments accordingly.”

When the data obtained as a result of the interviews were evaluated, it was seen that the enterprises faced with problems arising from organizational factors in the transition to smart manufacturing. These problems and solution suggestions are presented in Table 5.3.
Table 5.3. Problems and solution suggestions arising from organizational factors

<table>
<thead>
<tr>
<th>Problems</th>
<th>Solution Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competent personnel need</td>
<td>Employment and training of personnel with the enterprise's internal and external resources</td>
</tr>
<tr>
<td>Personnel resistance</td>
<td>With the trainings organized in-house, meeting the training needs of the staff and raising the awareness of them about the new innovative manufacturing model</td>
</tr>
<tr>
<td>Lack of awareness</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
</tr>
<tr>
<td>Staff resource that are not needed with smart manufacturing</td>
<td>Evaluation of personnel resources in different manufacturing units and other processes that will provide added value</td>
</tr>
<tr>
<td>Corporate communications</td>
<td>Transparent communication</td>
</tr>
</tbody>
</table>

When Table 5.3 is evaluated, it is seen that the problems encountered due to organizational factors are mostly based on personnel, senior management and institutional problems.

5.5. Questions About Technological Factors

In the fifth part of the semi-structured interview form, there are eight questions related to technological factors.

In the first question of the part, the participants were asked where they obtained the technology assets included in the smart manufacturing system in their enterprises. Participant 1 [137] gave the following answer to this question: “We can divide this into two, including acquisition from internal and external sources. Since our technology was not enough at the beginning and this was not our main business, we provided many technologies from outside. But procuring the technology from outside brings you very serious costs, so we started to supply only the main components of the technology from the outside, not the turnkey technology and at the point we arrived, as a result of increasing our knowledge and know-how, we are trying to produce both the software parts and the mechanical parts of our technology. Thus, at this point, we started to provide very serious cost gains. Currently, in the acquisition of technology assets, our company is intertwined in outsourcing and R&D.”

Participant 3 [139] stated that they are trying to develop and purchase software that makes automatic decisions within the scope of smart manufacturing process, continues the manufacturing process, learns as much as possible and can apply what it has learned. Participant 4 [140] stated that they procured robots and robot software from distributors in Turkey by means of purchasing technology, carried out smart manufacturing projects in the
form of international project partnership within the European Union (EU) project, and for this reason some of the software used within the scope of the project are developed by the project partners through their R&D studies. While Participant 6 [142] gave the following answer to this question: “We provided our technology assets within the scope of the smart manufacturing system with our own internal resources. We did not purchase technology from the outside, we provided the necessary software and hardware technology resources with our R&D studies within the company”, Participant 7 [143] stated that they developed their technology assets within their enterprises through R&D studies. Also Participant 8 [144] stated that they have technology assets that they purchase from outside, as well as developing complementary applications and technologies with their own internal resources.

In the second question, the participants were asked whether there are systems that they use or transform from existing technology assets in the process of transition to smart manufacturing system. Participant 1 [137] gave the following answer to this question: “We had technology assets that we transformed. We adapted and converted old production machines from our technology assets to this process with methods such as adding sensors so that they can receive data. We did not have any technology assets that we dispose of, but we tried to transform them all to adapt to the new manufacturing process. We tried to change the operation of the robots we have and turn them into collaborative robots.” Participant 4 [140] answered the same question as: “It is already very difficult to dispose of an existing technology due to no longer working and also it is difficult to replace it with a new one, too. Therefore, we made our existing technology assets revised and renewed as much as possible. Our primary goal has always been revision rather than purchase.” While Participant 6 [142] gave the following answer to this question: “After necessary adaptations, we used our existing IT systems within the smart manufacturing system”; Participant 7 [143] stated similar to other participants that there are technology assets they transformed. Participant 8 [144], taking part in the same enterprise with Participant 7 [143], detailed the answer to this question as follows: “We actually transformed the relevant modules of our current technologies, adapted certain functions to our new technology assets.”

In the third question, the participants were asked which criteria they consider when choosing the technology assets included in the smart manufacturing system in their enterprises, and whether they carried out works such as benchmarking. Participant 1 [137] gave the following answer to this question: “We did benchmarking studies. In addition, we are a company that has been implementing total productive maintenance activities (TPM)
since 2010. Our aim here is to try to destroy our losses in the factory. As a result of these studies, in manufacturing we can find out we have lost in which factories, so we can give our TPM activities as an example when we choose technology assets since we have chosen the technology assets to eliminate these losses.” Participant 4 [140] answered this question as follows: “At first we searched for technology suppliers, who could provide us with technology assets. After that, we had meetings with each of our suppliers with a team consisting of manufacturing, quality and technical units. We received information about the features of their products, their prices and their ability to meet our needs. Afterwards, we chose the best for us with the benchmarking works we did.” In response to the same question, Participant 7 [143] said that they carried out benchmarking studies in the selection of technology assets and that the impact on productivity and quality was one of the important criteria for them during the selection. Participant 8 [144] answered this question as follows: “It would be more accurate to divide the selection of our technology assets into tool selection and implementation selection. We performed benchmarking studies in tool selection, we looked at the sustainability of the tool. These were our main criteria in choosing the tool. In the choice of implementation, the fact that implementation was global was the most important factor, the fact that it could be given on-site support in every country was the criterion we considered.”

In the fourth question of the part, the participants were asked which technical difficulties they encountered during the transition to the smart manufacturing system and how they resolved these problems. Participant 1 [137] answered this question as follows: “Due to the different languages and protocols of the machines, we encountered technical difficulties in the data acquisition section and in order to eliminate them, we contacted the companies that we supplied these machines to perform modernizing our existing machines instead of buying new ones. In addition, our existing factory infrastructure was not very suitable for the systems and servers that we had to record the technologically produced data in this process. In other words, we had an infrastructural problem and we have solved this problem with increasing the infrastructural requirement we need with each system. Besides this, we are the company in Turkey that first use the some of the production system modules received from abroad, and these modules had not a patch that are unique to Turkey. For this reason, we tried to solve the national factors at many points in these modules, the simplest of which was that there was no patch that did not detect Summer Time-Winter Time application in Turkey due to the removal of Summer Time-Winter Time application in our
country. We wanted a separate patch specific to this country about the clocks.” Participant 3 [139] expressed the problems they faced as follows: “Among the difficulties we experienced here, the most important was the difficulties we had in communication. Like communication between the phone and the computer and communication between the robot and the computer. We overcome these problems with some layers, protocols and software that we put together.” Participant 4 [140] answered this question as follows: “We had problems with the adaptation of the machines, we had to create a new layout plan in the manufacturing facilities and we had to rebuild. These were all costly transactions, but none were unexpected troubles, they were anticipated before starting the project, and their costs were included in the budget before start of the project.” Participant 5 [141], who is in the same enterprise with Participant 4 [140], stated that they faced some technical problems in the software and hardware departments and that they overcomed technical problems they faced by getting support from the experts, academicians and companies in the field during the transition to the smart manufacturing system in their enterprises. Participant 7 [143] stated that the continuous change and development of the technology is the biggest problem they face and therefore they face the difficulty of constantly adapting to new technologies. He also stated that they do not encounter any technical problems. Participant 8 [144] answered this question as follows: “The biggest problem we encountered was the fact that the vendors had to adapt to digital transformation and adapt their systems and software. Ultimately, we somehow achieved this adaptation and solved this problem. In addition to this, the lack of a systematic expert in our own resources was among our technical difficulties, we solved this problem by getting consultancy service.”

In the fifth question, the participants were asked which technologies they used in the transition to the smart manufacturing system. Participant 1 [137] gave the following answer to this question: “We have implemented almost all of the factors that trigger Industry 4.0. Collaborative robots, IoT systems, additive manufacturing, 3D printing, cloud solutions, cyber security technologies, big data and analysis technologies, horizontal-vertical integration technologies are among the elements we use. Simulation and AR technologies are among the technologies we have just started using.” Participant 4 [140] stated that they have already used cloud solutions and continue to use them in the smart manufacturing process, and that they are also working on image processing. He stated that they have no previous studies on artificial intelligence and that they will start using artificial intelligence technologies newly. Participant 5 [141] supported the response of Participant 4 [140] with
the following response: “As part of the internet and communication of the machines, we used machine learning and three-dimensional printers during the transition to smart manufacturing. Artificial intelligence will be used in new projects developed for smart manufacturing. We did not use image processing.” Participant 6 [142] stated that they used robotics, cloud solutions, artificial intelligence, machine learning and image processing technologies during the transition to smart manufacturing. While Participant 7 [143] gave the following answer to this question: “Cloud solutions, artificial intelligence, image processing, 3D printing, collaborative robots, cyber systems, simulation techniques and machine learning were the technologies we used in this process.” Participant 8 [144] stated their explanations about this question as follows: “We used cloud solutions, artificial intelligence, image processing technologies. In addition collaborative robots, full automated systems, data prediction and analytics were among the technologies we used.”

In the sixth question, the participants were asked whether different software (package software, decision support systems, expert systems) were used in their enterprises during the transition to the smart manufacturing model. In response to this question, Participant 1 [137] stated that in their enterprises, there are ERP systems, supply chain software, and separate softwares they use for manufacturing planning and warehousing. Participant 4 [140] and Participant 5 [141], who worked in the same enterprise, stated that they use both the software they purchase from the outside and the software developed by the project partners by their own R&D activities. Participant 6 [142] also stated that they used different software developed by themselves, similar to the answers given by other participants. Finally, Participant 7 [143] and Participant 8 [144], who work in the same enterprise, stated that they used all of the package software, decision support systems and expert system softwares presented in the example of the question. Additionally, they stated that they use Manufacturing Execution System (MES) platforms as a different software.

In the seventh question of the part, the participants were asked whether they received expert assistance or consultancy service on the technical operation of the smart manufacturing activities in their enterprises. Participant 1 [137] stated that they received consultancy and expert assistance in response to this question and continued to receive this service. Participant 4 [140] stated that they receive specialist assistance when they encounter technical problems from suppliers that provide them technologies they have acquired within the scope of the smart manufacturing system. Participant 6 [142] stated that they had not received expert assistance or consultancy service before. Participant 7 [143] answered this
question as follows: “We received counseling during the transition process, but we no longer receive counseling during the process, we currently manage it with our own internal resources.” Also Participant 8 [144] answered this question as follows: “With the completion of the implementation phase this month, the contract of our consultancy service that we received has ended. Not for now, but if we need to receive consultancy service again in the future, we are considering consultancy service.”

In the last question that formed this section, in addition to the questions in the section, the participants were asked if they had any other opinions and suggestions about technological factors. In response to this question, from the participants only Participant 5 [141] made comments and suggestions and he expressed his opinions and suggestions as follows: “Occupational safety can also be considered in the smart manufacturing process. I can declare as an opinion that all accident scenarios that may occur during the integration and operation of such systems, all the factors that can disrupt the system or disrupt the working process should be considered within the scope of smart manufacturing. Also that emergency scenarios that could be taken as a precaution should be planned in advance. We have carried out a detailed study on what can happen to us on this issue in future, and what measures we will take in a situation that happens to us, before moving on to smart manufacturing activities. Failure to consider them in advance can have serious consequences. In addition, the wireless communication of the systems is a very important factor and provides very serious support in the scope of smart manufacturing. In wireless communication, communication speed is a very important factor and there are external factors that can reduce the communication speed, and these should be evaluated well and measures should be taken. Security problems may also arise as disadvantages of wireless communication, and threats that may be faced related with security must be well evaluated and taken precautions.” As a result of the content analysis applied to the responses given by the participants, it was observed that the enterprises faced problems due to technological factors during the transition to smart manufacturing. These problems and solution suggestions are summarized in Table 5.4.
Table 5.4. Problems and solution suggestions arising from technological factors

<table>
<thead>
<tr>
<th>Problems</th>
<th>Solution Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Due to the different languages and protocols of the machines, technical</td>
<td>Contacting enterprises that supply machines and modernizing</td>
</tr>
<tr>
<td>difficulties encountered in the data acquisition section</td>
<td>and adapting existing machines</td>
</tr>
<tr>
<td>Incompatibility of existing factory infrastructure in terms of systems</td>
<td>Increasing the need for infrastructure needed</td>
</tr>
<tr>
<td>and servers required to record the generated data</td>
<td></td>
</tr>
<tr>
<td>Absence of specific patch to Turkey in some of the manufacturing system</td>
<td>A country-specific development and patch request</td>
</tr>
<tr>
<td>modules purchased from abroad</td>
<td>from the product supplier</td>
</tr>
<tr>
<td>Technical problems in software and hardware parts</td>
<td>Getting support from relevant field experts, academicians</td>
</tr>
<tr>
<td></td>
<td>and companies</td>
</tr>
<tr>
<td>The necessity of vendors to keep up with digital transformation and adapt</td>
<td>Adaptation of vendors</td>
</tr>
<tr>
<td>their systems</td>
<td></td>
</tr>
<tr>
<td>Lack of expert systematics in the company’s internal resources</td>
<td>Getting consultancy service</td>
</tr>
</tbody>
</table>

As seen in Table 5.4, it is seen that problems arising from technological factors are mostly caused by problems with software, hardware and suppliers.

5.6. Questions About Economic Factors

The sixth part of the semi-structured interview form consists of five questions related to economic factors.

In the first question that formed this section, the participants were asked whether they faced unexpected costs such as technical device costs and supplier costs that occurred during the transition to the smart manufacturing system. Participant 1 [137] answered this question as follows: “We had unexpected costs relevant to suppliers. To give an example, we had to adapt some of our machines to the smart manufacturing system, here we faced unexpected costs, because these are expensive services. In addition to this, although we thought that our infrastructure was sufficient at the beginning of the transition to smart manufacturing, we later noticed that our infrastructure was insufficient and the infrastructure had to be changed. This was one of our unexpected costs.” Participant 4 [140] answered this question as follows: “We encountered unexpected costs from time to time. As an example, in the transition to smart manufacturing, due to the old machines, we encountered higher costs than expected in the budget within the scope of machine revision. In addition, our software needs have emerged, which can be evaluated within our unexpected costs.” Participant 6 [142] stated that there were unexpected costs for unsuccessful pilot studies. Participant 7
expressed the unexpected costs they encountered as follows: “20% to 25% unexpected costs revealed for both hardware and software.” Participant 10 [146] answered this question as follows: “Unexpected costs of course happened. You start each project with a certain scope, content and expectation, but these factors may change or additional needs may arise, so you can develop and change your proposed solution. Specifications, costs and investment amounts can vary. All of this can happen in the pre-project period, or at the project stage. In our enterprise, unexpected costs occurred in terms of technical device costs and construction costs at the point of planning the project budget, but the deviation from the first budget determined was much lower than 8%.”

In the second question of this section, the participants were asked whether they dismissed staff during the transition to the smart manufacturing system and, if staff dismissed, whether additional costs revealed related to the layoffs such as return to work costs, unexpected compensation payments, court costs. Participant 1 [137], Participant 5 [141], Participant 6 [142], Participant 7 [143] and Participant 10 [146] stated that they did not dismiss anyone in response to this question. In addition, Participant 5 [141] detailed his answer to this question as follows: “...we evaluated our unnecessary manpower arised from smart manufacturing in our other manufacturing units needed.” Also Participant 10 [146] detailed his statement as follows: “In case of converting an existing manufacturing system, personnel dismissal may be valid, but we have established a new factory realizing smart manufacturing from zero point and hence we have hired all staff from scratch for this factory. Therefore, we did not dismiss anyone and we did not have unexpected staff dismissal costs, but we had a hard time finding competent personnel, and then we had employees who left the job voluntarily with the idea that I could not run a business at this level. It is generally possible that such a situation will occur, it is a very natural situation.”

In the third question, the participants were asked to explain what they expect from their smart manufacturing system in the short, medium and long term, and what advantages they have provided to their enterprises with the transition to this manufacturing system. Participant 1 [137] answered this question as follows: “In the short term, our expectations are to get instant data and to intervene as soon as possible in case of any problems in manufacturing with this instant data. In the medium and long term, it is among our expectations to be able to predict which problems may occur by help of machine learning and data analysis, predictive analysis, and to ensure that the smart manufacturing predicts these, and thus to make the decision support mechanisms work better. In addition to these,
the reduction of costs in the medium and long term (such as minimizing energy consumption, reducing raw material usage) is among our expectations.” Participant 2 [138] expressed the advantages of the smart manufacturing system to their enterprises as follows: “We now provide our suppliers with notification of our needs from digital platforms, we receive our confirmations from digital platforms, and we also perform material orders through digital platforms. Thanks to smart manufacturing, we have been able to digitally monitor the loading of our products on transportation vehicles, track of our products on the road and logistics process until the factory. This provides us with instant data accuracy and helps to realize the manufacturing plans correctly, in addition, we plan the manufacturing lines with the help of smart systems to provide maximum benefit.. Along with this, we have ability to calculate our costs and profitability more accurately with smart manufacturing, we have increased our profitability in a great extent.” The Participant 3 [139], who carried out the telephone and television unit tests with his team in his enterprises, stated that they aimed to eliminate operator errors and save time in product tests with smart manufacturing systems. In addition to the programs they have established within the framework of the smart manufacturing system, they expressed the benefits they provided to their enterprises by stating that these programs provide getting to know the product and informations related the product from structured query language (SQL) database and thus these programs provide the necessary program settings and communication settings itself, and that the data obtained as a result of the tests are reported to the SQL database by program’s itself. While Participant 4 [140] gives the following answer in response to this question: “Realizing a manufacturing that minimizes operator intervention, optimizing manufacturing, increasing the quality level in manufacturing, increasing job security are among our expectations in the medium and long term.”; Participant 6 [142] stated that productivity increase in manufacturing, reduction of breakdowns and shortening of the cycle time are among the advantages of this system. To the same question, Participant 7 [143] expressed their advantages they provide and what they aimed by giving the following answer: “Efficiency and quality are among the advantages we provide. Compared to our other factories, this factory’s, which perform smart manufacturing, field performance is high than others in terms of 30% on efficiency and 50% on quality. In the short term, our goals include improving quality and efficiency. In the medium term, our goals include learn, analyze and realize that what we can do other than the data we obtain and use, how we can provide more added value. In the long term, being able to guide the other 22 factories of our enterprises and to gradually switch them to the smart manufacturing system are take part in our goals.” Finally, Participant 10 [146]
answered this question as follows: “Basically among the goals, we expect smart manufacturing to give us vision and enable us to move towards change to maintain our presence in competition. In the further term, we expect the system to reduce operating costs and manufacturing costs, and to ensure that we obtain a higher quality product after the investment costs are amortized. Among the advantages of this system, thanks to the infrastructure we have established, we can instantly access data on productivity regarding manufacturing lines, which saves us time. In the long term, we aim to implement the smart manufacturing system, which we have installed and experienced in our factory in Romania, to other factories. Currently, this transformation is present in some of our other factories. We are unable to fully provide these expectations and advantages that I mentioned in response to this question right now, but I can say that we are close to providing. We aim to reach our financial targets after the amortization of the investment and aim to achieve the expectation in 1-2 years on the quality side.”

In the fourth question of the part, the participants were asked whether financial support such as government support and credit support was received during the transition to the smart manufacturing system in their enterprises. Participant 1 [137] stated that they did not receive credit, but they received grant support within the scope of R&D projects from government in transition to smart manufacturing. Participant 4 [140] answered this question as follows: “We have received state support and we have received financial support from Technological Research Council of Turkey (TUBITAK) within the scope of project support with code 1509. We did not receive support from another place.” Participant 6 [142] expressed their financial supports they received as follows: “Yes. We received supports such as Horizon 2020, EUREKA, ITEA, Tubitak projects etc.” Finally, while Participant 7 [143] gave the following response: “We benefited from the European Union's incentive funds to Romania.”; Participant 10 [146] supported the response of Participant 7 [143] with the following response: “We received both state support and credit support from banks in Romania.”

In the last question, the participants were asked if they had any other opinions and suggestions about economic factors. Participant 10 [146] expressed his opinions and suggestions as follows: “In this regard, I can state that the state supports on additional incentives, financial supports and supports in finding competent personnel should be increased a little more.” Also Participant 10 [146] continued his statements on this issue as follows: “Due to the importance of feasibility activities, it should not be overlooked before
projecting. I can state this as a comment.” Other participants did not make comments and suggestions.

In the process of transition to smart manufacturing, enterprises encountered problems arising from economic factors. The most prominent of these problems are unexpected costs arising from suppliers, higher than expected machine revision, lack of infrastructure, unsuccessful pilot studies, additional software needs and construction costs. As a solution of unexpected costs, the participants have suggested meticulous budget planning.

5.7. Questions About Environmental Factors

The seventh part of the semi-structured interview form consists of six questions related to environmental factors.

In the first question of the part, the participants were asked what are the legal problems they encountered during the transition to smart manufacturing system and how they solved these problems. Participant 1 [137] gave the following answer to this question: “..to track employee productivity, we cannot track information that creates personal data such as when operators leave work, where they go. We cannot apply this because it is not legal, we could not find a solution to this problem. We keep customer information in the cloud in relation to the smart manufacturing process, but since the servers of the enterprises that provide this cloud environment are abroad, the protection of this data is not the responsibility of our country, there is no legislation regarding it. This may be among the legal problems we have encountered and we could not find a solution to this.” Participant 4 [140] stated the problems they encountered legally as follows: “Some of the legal regulations related to customs are among the problems we encounter. As an example, we are carrying out this project as part of the EU project, as we said and when we bring back a product that we took it to Germany for promotion, this product may be appear as goods brought from abroad at the customs. These kinds of legal regulations can be shown among the problems we face.” Also Participant 7 [143] gave the following answer to this question: “Because we established our factory in Romania, we had to spend more than budget expenses on investment costs due to fire and environmental regulations in Romania. This was the only legal issue we encountered.”

In the second question, participants were asked to answer how they legally protect their technology assets placed within the scope of smart manufacturing systems. Participant
1 [137] gave the following answer to this question: “We protect the technologies that we have developed within our enterprise through the patent applications. We also sign a contract called Non-Disclosure Agreement (NDA) that prevent data from being given to third parties with the companies we work with.” While Participant 4 [140] stated that they protect their technology assets with mutual contracts and patent applications, Participant 6 [142] stated that they protect their technology assets with patents and various legal procedures. Also Participant 7 [143] gave the following answer to this question: “We carry out necessary insuring operations and take preventive measures with risk analyzes made by independent companies. We legally protect our assets with patent applications and NDA activities we carry out.”

In the third question of the part, the participants were asked whether they encountered problems related to industry standards in the smart manufacturing model in their enterprises. Participant 1 [137] gave the following answer to this question: “The fact that not all of the machines meet the same standards was actually a problem we encountered with industry standards. We solved this problem with interlayer applications, softwares, and the support of the companies we supply the machines. The conversation of the systems with the systems takes place at a certain standard and we overcome this problem with the support we received from the experts in this field.” Participant 4 [140] stated that they did not encounter an obstacle because they already routinely carry out industry standards and quality standards within the scope of smart manufacturing. Participant 6 [142] answered this question as follows: “We had problems in stages such as equipment, design, and data collection. We have updated some standards.” Also Participant 7 [143] gave the following answer to this question: “There is not yet a single common communication language and way of doing business related to smart manufacturing, so the lack of an industry standard is a problem we face, but within a few years an industry standard will be created for this model.”

In the fourth question of the part, the participants were asked to explain the problems they faced related to their suppliers during their transition to the smart manufacturing system in their enterprises. Participant 1 [137] gave the following answer to this question: “We need to divide the concept of supplier into technology supplier and material supplier. Problems we encounter with material suppliers include the resistance to this new system, just like our staff. Because with the smart manufacturing system, the data you receive from the suppliers become transparent, so you can see the effort and costs they actually spend. Suppliers do not want this transparency. For this reason, we encountered resistance with suppliers on
this matter. We encountered problems related to the know-how of technology suppliers, and you cannot agree with suppliers in a common language. Either they do not fully understand what you want, or you can not explain what you want, but they focus on what they can give to you rather than what you want. Because technology suppliers know their talent, capacity and what they can give. When they realize that the other party's requests exceed them, they go to convince the other party by the technology they can give. At this point we had really big problems. In addition, technology suppliers become inaccessible in the process after selling the product. You need support after purchasing the product, but you cannot find the supplier from whom you supplied the product. We solved this problem by getting support from other companies.” Participant 2 [138] explained the problems they faced with their suppliers in their enterprises and how they found solutions to these problems as follows: “In the digital collaboration platforms you established with your suppliers, we had some difficulties in data accuracy and digital provision of data when their level of digitality was not as good as yours. At this point, we have found solutions by trying to develop and use platforms that will contribute to the digitalization of our stakeholders, which can be carried out more easily, and do not require very high level of expertise that everyone can perceive. Also we have provided online training to suppliers with some training packages on how to use those screens correctly.” Participant 2 [138] stated that they digitalized their communication with their suppliers in this way, provided their suppliers with the notification of needs through digital platforms and received the necessary confirmations from them through digital platforms. In addition, he added that they also perform material orders via digital platforms, and that they are able to track transportation vehicles, products on the road and logistic process digitally until the factory, thanks to smart manufacturing. Participant 6 [142] also stated that they faced problems about their suppliers on their awareness, technology maturity level and integration. Also Participant 7 [143] gave the following answer to this question: “With this system, we had some problems in terms of communication and coordination with our suppliers. We established an end-to-end system from the supplier to the customer, and we opened this infrastructure to both suppliers and customers, and we solved this problem in this way, they can see our system through user interfaces.”

In the fifth question, the participants were asked how they manage the processes with the local community and local administrations in the region they are in the process of transition to smart manufacturing. While Participant 1 [137] answers this question as follows: “Since smart manufacturing is not a form of manufacturing that harms the
environment and has a high risk of occupational accidents, it was not a process we should manage with the local community and local administrations.”; Participant 4 [140] similarly answered this question as follows: “Since we did not produce environmentally harmful manufacturing and we do not have such an activity and waste within the scope of smart manufacturing, we haven’t had a process that we should manage with the local community and local administrations. We have an environment document and how to dispose of each waste is already determined by legal regulations and it is a process we manage.” Also Participant 7 [143] answered the same question as follows: “We haven’t had a process that we need to manage with the local community and local governments in the region. Because our factory has investments in environment in a pioneering way and we do not produce environmentally harmful manufacturing. I can say that we are an ecologic factory. We have making this known officially with the Leadership in Energy and Environmental Design (LEED) Platinum award that we received.”

In the last question of the part, the participants were asked whether they have any opinions and suggestions they would like to add to the problems they face due to environmental factors during their transition to the smart manufacturing system. None of the participants made comments and suggestions in response to this question.

In the process of transition to smart manufacturing, enterprises encountered problems arising from environmental factors. These problems and solution suggestions are shown in Table 5.5 as a result of applied content analysis to the findings obtained from participants.
Table 5.5. Problems and solution suggestions arising from environmental factors

<table>
<thead>
<tr>
<th>Problems and solution suggestions arising from environmental factors</th>
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<tbody>
<tr>
<td>Problems</td>
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<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>Lack of legislation related to cloud computing</td>
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<td>Legal regulations related to customs</td>
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<tr>
<td>Unexpected costs as a result of legal regulations</td>
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<tr>
<td>Protection of technology assets</td>
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<tr>
<td>Lack of industry standards</td>
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<tr>
<td>Insufficiency and lack of awareness of suppliers' digitality levels</td>
</tr>
<tr>
<td>Lack of support from technology suppliers in the process after the product is purchased</td>
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</table>

When Table 5.5, which includes the problems encountered due to environmental factors, is examined, deficiencies on legislation and standard in the field of informatics draw attention. In addition, there are also problems with suppliers.

5.8. Predictions

In the eighth part of the semi-structured interview form, the participants were asked six questions that aimed to determine their predictions about the future effects of smart manufacturing in their enterprises and the future of smart manufacturing in general.

In the first question of the part, the participants were asked how they think their profitability will change in their enterprises after switching to smart manufacturing systems. Participant 1 [137] gave the following answer to this question: “While we are trying to integrate a system, we perform ROI (Return of Investment) analysis and try to avoid investments with high ROI value. The shorter the return on investment, the better for us. There is an positive improvement in our profitability with the transition to smart manufacturing systems.” Participant 2 [138] also stated that with the transition to smart manufacturing, they increased their profitability to a great extent. Participant 4 [140] gave the following answer to this question: “Although I cannot say anything about how much our profitability has changed, I can say that it has changed positively. Because smart manufacturing activities are reflected on the quality of our products, reflected on the manufacturing time and therefore on customer satisfaction. Consequently, when we look at our customer performance evaluations, we saw a positive increase, so our profitability
Participant 6 [142] stated that their profitability will change proportionally. Also Participant 7 [143] answered this question as follows: “In this factory, which performs smart manufacturing, the productivity in production is 30% higher than and the quality is 50% high than our other factories. We are 2.5 times better at delivery to the customer. We are in the depreciation phase now. We hope that we will start making profits after 3 years.”

In the second question, the participants were asked in how many years they think the cost of transition to smart manufacturing will return to their enterprises. While Participant 1 [137] gives this question to the following answer: “Smart manufacturing system contains many components and you make new additions while installing the smart manufacturing system in your manufacturing facilities, so it is impossible to say something clear about in how much time the cost will be amortized. But we can say that the costs we have made for the smart manufacturing system vary for the manufacturing units, and amortized within an average of 1 or 2 years.” Participant 4 [140] answered this question as follows: “The ROI made within an average of 2 years is expected, the investments that will return in a longer time are not considered as positive anyway. We have provided the ROI within the scope of SM for now.” Participant 6 [142] gave the following answer for the same question: “It varies according to the spread rate. If recycling is more than 5 years, it would not be appropriate to invest. We foresee that it will be back in 5 years.” Participant 7 [143] stated that they plan to amortize the transition cost in 6 years.

In the third question, the participants were asked which new departments and occupational titles they would expect to appear in their enterprises and in other enterprises, with the transition to the smart manufacturing system. Participant 1 [137] gave the following answer to this question: “Digital Transformation Units, Manufacturing Operation Management (MOM) Productivity Tracking Unit, new professional titles for the staff working in these units, Robot Developer, IoT Architect working on sensors, Cloud Developer, R&D Worker, Data Scientist, 3D Printer Operators etc. departments and profession titles have occurred in us and new departments and profession titles continuing to occur.” Participant 4 [140] stated his thoughts on this issue as follows: “I anticipate that new professions related to the software section will emerge. In general, there is a great need in the software section in all companies. At the same time, new departments may emerge for the protection and management of intellectual and industrial property rights, our enterprises also has such a department.” Participant 6 [142] also stated the professional titles that he thinks would emerge with the following response: “Occupational titles will appear in the
future such as Robotics Specialist, Data Analysis Specialist, Data Processing Specialist, IoT Specialist, Advanced Automation Software Specialist, Virtual Reality Specialist, Wearable Technologies Specialist, Cloud Information Systems Specialist etc.” Participant 7 [143] predicted that many titles and departments would emerge that starts with the word 'digital' such as Digital Production Management Unit, Digital Operator etc. Finally, Participant 9 [145] gave the following answer to this question: “Data analysts and experts who will be able to analyze and process the data will emerge as occupational titles in order for the collected data to be useful and benefit from this data. Data analysis departments, where staff with this title work, may also appear in the future. We can see the need for this profession title and department in our enterprise, where we realize smart manufacturing. Apart from this; Automation Engineer, Production Specialist etc may arise together with smart manufacturing as a new profession group and they are the positions we currently hold in our staff.”

In the fourth question of this section, the participants were asked about their views on how the unemployment rate will change in the world with the manufacturing factories in the enterprises switch to the smart manufacturing system. In response to this question, Participant 1 [137] stated that they did not dismiss anyone with the transition to smart manufacturing, because it is impossible to render each stage of manufacturing unmanned, and processes that require manpower still exist and will continue to be available. In addition, he continued his explanations with the following response: “With the transition to smart manufacturing, we transferred our personnel and operators, who are involved in the manufacturing processes where robots take over their duties, to other manufacturing units that still require manpower. At the same time, as we said in our answer to the previous question, we also hired new personnel within the scope of Industry 4.0 and new professional titles that emerged with the transition to smart manufacturing. In the future, I mean at least 20-30 years later from now, there will be no need for blue collar people who are currently performing their current job routine, but blue collar people who perform other business routines will always be available. For example, a blue collar screwing a product at the moment will not be in the distant future, maybe robots will undertake this work, but the blue-collar people that realize maintaining the robots, which emerged with a new job definition, will always exist. But blue-collar and white-collar, which will emerge with new job descriptions, will consist of trained and skilled personnel in the future. So, what will happen to uneducated and unskilled staff? At this point, we anticipate that these personnel will move
to jobs that do not require any qualifications such as agriculture in line with state policy. Therefore, I foresee that the unemployment rate will not increase in the future, or even more employment areas will be created and the unemployment rate will decrease.” Participant 4 [140] expressed his thoughts on this question with the following answer: “I do not think that the unemployment rate will increase, the personnel power that will not be needed within the scope of smart manufacturing will definitely be directed to other areas where human power is needed. We have applied the same strategy in our company and we continue to apply it. Since we started the process of transformation into smart manufacturing and partially implemented smart manufacturing in some manufacturing processes, we did not dismiss anyone in our company. The firing of staff from a company in this context will also create a negative image for the company.” Participant 6 [142] stated that they think that the current balance will be maintained with the emergence of new professions. Participant 7 [143] gave the following answer in response to this question: “This is actually a very controversial issue. In the future, classic business areas will shrink, more creative and innovative new business areas will be created, the unemployment rate will probably remain the same, it will not show an increase or decrease.” Also Participant 9 [145] gave the following answer to this question: “.every industrial revolution, technological developments create new employment areas, differentiate employment areas, so I don’t think the unemployment rate will change in the long term. In the short term, unemployment rates may decrease, especially in routine repetitive jobs, however, it is important for countries to analyze the smart manufacturing needs and to develop training and skills in areas related to technology and creativity in terms of how quickly this period will be over. This is true for those who working at every point of manufacturing as engineers and direct workers with hourly wages and monthly wages. In addition, employment will be provided in new professional titles that will be needed in the long term. This situation will be the same not only for white-collar but also for blue-collar, because the manufacturing model which we call smart manufacturing has a human factor, and human factor will continue to exists because of points that cannot be automated in manufacturing. In this manufacturing model, the personnel in the manufacturing areas where full automation is provided and where no manpower is needed will be directed to other areas of the manufacturing that require manpower.”

In the fifth question, the participants were asked about their opinions about at what rate smart manufacturing will increase and become widespread in the future. Participant 1 [137] answered this question with this answer: “I do not think there will be a enterprises that
will not perform smart manufacturing in the future. In the future, every enterprise will switch to smart manufacturing, they need to switch. Therefore, I think that smart manufacturing will become widespread and increase in the future, but it is not possible for me to give a clear rate regarding this, but eventually every enterprise will have to switch to smart manufacturing.” Also Participant 4 [140] answered this question with the following answer: “I predict that smart manufacturing will increase in the future. Firms are now in the process of transformation into the smart manufacturing and other firms will be involved in this transformation in the future. No one can fall behind this transformation in order to maintain a competitive environment.” Participant 6 [142] expressed his thoughts on this issue as follows: “We anticipate that this process will increase exponentially with the rapid development of technology.” While Participant 7 [143] stated that smart manufacturing will probably become widespread in the future and the transition to smart manufacturing will increase, but added that this will not be fast; Participant 9 [145] stated that it is inevitable for enterprises to switch to smart manufacturing in the future, but of course there will be enterprises that cannot easily achieve this transformation in the future. In addition, he stated that those who act fast in this inevitable process will be at the forefront of competition, while those who act slowly will be left behind in the competitive environment.

In the last question of this part and of the semi-structured interview form, the participants were asked if they had any other opinions and suggestions they would like to express on this matter. None of the participants made comments and suggestions in response to this question.

When the findings obtained from the responses of the participants to the questions in the “Predictions” section of the interview form are analyzed, it is seen that the participants stated that there is a positive improvement in their profitability after switching to smart manufacturing systems in their enterprises, and this increase was attributed to the increase in product quality and efficiency, production time, shortening delivery time and customer satisfaction. Some of the participants stated that they could not predict in how long the transition costs to smart manufacturing would be amortized as the transition processes are ongoing and the installation is not fully completed, but that their investment to date had been amortized in an average of 2 years. Some of the participants stated that the entire cost of switching to smart manufacturing will be amortized in 5 years, and some in 6 years. Additionally, when the responses given were examined, it is seen that some participants stated that the investments to be returned over a period of 2 years would not be evaluated
positively, while some participants stated that this period of more than 5 years would not be evaluated positively. Although there is no common consensus in the data obtained, when the findings are evaluated, it is concluded that the costs of transition to smart manufacturing cannot be amortized in less than 2 years.

As a result of the content analysis applied to the findings obtained, among the departments that the participants foresee that they will emerge in the future with transition to smart manufacturing are Digital Analysis Department, Digital Production Department, Manufacturing Operation Management Department and Protection and Management of Intellectual and Industrial Property Rights Department are located. Forecasts of participants related to new profession titles that will emerge with the conversion to smart manufacturing in the future are presented in Table 5.6.

**Table 5.6.** Profession titles predicted to emerge with transformation to smart manufacturing

<table>
<thead>
<tr>
<th>Profession titles</th>
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<tr>
<td>Robot Developer</td>
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<td>IoT Architect</td>
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<tr>
<td>Cloud Developer</td>
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<tr>
<td>Data Scientist</td>
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<tr>
<td>3D Printer Operator</td>
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<tr>
<td>Robotic Expert</td>
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<tr>
<td>Data Analyst</td>
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<tr>
<td>Data Processing Specialist</td>
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<tr>
<td>Advanced Automation Software Specialist</td>
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<tr>
<td>Virtual Reality Specialist</td>
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<tr>
<td>Wearable Technologies Specialist</td>
</tr>
<tr>
<td>Cloud Information Systems Specialist</td>
</tr>
<tr>
<td>Digital Operator</td>
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<tr>
<td>Automation Engineer</td>
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<tr>
<td>Production Specialist</td>
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6. DISCUSSION

In this section, the findings of the research are compared with the results of similar studies in the literature and discussed critically.

When looking at the goals of smart manufacturing in the literature, it is seen that the responses given to the reasons why enterprises need to switch to smart manufacturing model and what causes the implementation of this model in their enterprises support the literature. In the studies carried out, it is seen that among the objectives include energy saving, sustainability, agility / flexibility, quality and efficiency, long-term competitiveness, and an increase in the effective use of resources in real time [19, 39, 127, 147, 148, 149].

When the literature is examined, it is emphasized that with the transition to smart manufacturing, the need for professions that require software, communication and analytical skills will increase [12]. It is envisaged in the literature that this industrial revolution will reveal new professions such as Algorithm Technician, Interactive Interface Designer, Universal Service Consultancy, Digital Process Engineering, Industrial Data Science, Robot Coordinator, IT / IOT Solution Architecture, Cloud Computing Expert, Data Security Expert, 3D Printer Engineering, Wearable Technology Designer, Business Therapist [150], Industrial Software Programming, Information Systems and Internet of Things Solution Manufacturer, Industrial Data Analysis Specialist, Robot Coordinator-Programmer-Repairer, Production Technologies Specialist, Smart Cities Planners and Product Designers [151]. In addition to these, Benešová and Tupa (2017) listed the professions such as Software Engineer, IT Specialist, PLC Programmer, Cyber Security Specialist among the future professions. No predictions have been made in the literature for the departments that will emerge. Within the scope of this research, the answers given by the participants have provided diversity to literature in terms of professional titles that are predicted to appear in the future. In addition, participants’ answers have revealed departments likely to appear in enterprises in the future.

As a result of this study, the participants stated that it is not possible to automate each stage of manufacturing by making it unmanned. In addition, they emphasized that manufacturing processes involving the human factor will always exist. Enterprises included in the study did not dismiss their staff but also recruited new staff with professional titles which were predicted to emerge with the transition to smart manufacturing. In the literature,
it is pointed out that in some studies, there will be employment problems due to the decrease in demand for uneducated and unskilled staffs and need for more skilled staffs with the transformation to smart manufacturing [153]. It is predicted in the literature that the Industry 4.0 revolution will cause five million people to dismissal from their jobs in 15 developed economies in the next five years [86]. At this point, it is recommended to improve the national workforce capacity in this direction by examining the social effects of the transformation to smart manufacturing [131]. Another view in the literature is that in the light of increased automation and digitalization, it is uncertain whether or not people will still be needed in smart factories. As a common opinion, it is stated that people will still be required but their job and duties will change [154]. When the studies in the literature are examined, there is no common opinion on this subject.

6.1. Evaluation and Discussion of Findings Related to Organizational Factors

In the literature, the difficulties and problems related to the organizational factors that may be encountered during the implementation of Industry 4.0 are listed as follows: personnel resistance and reluctance against to changing the existing traditional system [16, 31, 153], lack of personnel awareness [155], corporate culture, lack of systematic approach of enterprises to adopt modern project models [31], the need to preserve the integrity of production processes, the possibility of increasing unemployment result from replacing existing workforce by robots [156], insufficient expert human capacity for the technologies specified under smart factories, data security [86, 155] and managing and raising people [157]. The answers given by the participants within the scope of the research also support the problems and difficulties caused by the organizational factors in the literature. Employing internal and external personnel to meet the need for competition and training these personnel to acquire the necessary competencies, breaking the resistance of the personnel against innovation, organizing in-house trainings at certain intervals to raise awareness and meet the training needs of the staff are among the solution suggestions that the participants find against these problems. In the trainings they organized, they provided a transparent flow of information to all staff and explained the purpose and benefits of the transition to the smart manufacturing system. The fact that they evaluated the unnecessary personnel resources in different manufacturing units and in other processes that will provide added value and that they did not dismiss anyone is important solution suggestion in response to the problem of personnel resources that will not be needed together with the smart
manufacturing which is emphasized in the literature. Also, the enterprises within the scope of the research carried out personnel needs planning and determined the personnel positions to be needed along with smart manufacturing in this process.

6.2. Evaluation and Discussion of Findings Related to Technological Factors

In the literature, technical difficulties arising from the fact that the technologies in smart manufacturing are new technologies and technical difficulties resulting from the scarcity of application examples, reference models, hardware and software architectures are reported among the difficulties and problems related to the technological factors that can be encountered in transition to smart manufacturing [2, 28]. In addition, difficulties in creating a cyber physical system as a tightly integrated smart network system [158], difficulties in providing end-to-end digital integration [154], arising situations where tools or machines do not provide the right quality level for the process [155] are included in the literature as other difficulties. Also, as another difficulty, smart factory technologies and highly complex nature of their systems make it difficult to measure potential benefits and creates an uncertain business situation for implementation [31].

Among the difficulties encountered due to the technological factors that are not included in the literature but revealed as a result of this study are modeling and interpretation of the collected data, communication difficulties between the robots and the computer, encountered technical difficulties in the data retrieval section, lack of appropriate infrastructure in current plants for the system, lack of appropriate servers that need to record the data generated, the absence of Turkey-specific patch of some of the manufacturing system module that bought from abroad, some technical difficulties encountered in the software and hardware parts, necessity to vendors to keep pace with digital transformation and to adapt their systems and software, lack of expert systematists in the company's internal resources.

Technological components used in the literature to realize smart manufacturing are wireless sensor network, cyber physical systems, IoT, IS, radio frequency identification (RFID), BD and data analytics, robot technology, automation technologies, virtual reality, AR, cloud computing, kinect technology, image processing, machine learning, artificial intelligence, 3D printing, holograms and cyber security [19, 128, 131, 159, 160, 161, 162, 163]. These technological components help to make smart decision making. In this study,
enterprises stated that they have implemented almost all of the factors that trigger Industry 4.0 in the process of transformation into smart manufacturing model in their factories in the same direction and they stated that among these elements, collaborative robots, IOT systems, additive production, 3D printers, cloud solutions, cyber security technologies, big data and analysis technologies and horizontal - vertical integration technologies are involved. Some of the enterprises stated that simulation and AR technologies are among the technologies they have just started using. Technologies used by enterprises in transition to smart manufacturing are compatible with the literature.

6.3. Evaluation and Discussion of Findings Related to Economic Factors

In literature, among the difficulties and problems related to economic factors that may be encountered in the process of implementing Industry 4.0 include high cost of initial investment, high cost of problems, reluctance of enterprises’ to invest smart factories due to the high investment cost, lack of economic added value transparency [2, 155, 156]. Also high cost of smart factory implementation will accrue in an uncertain time in the future especially in the first years because of the intensification of uncertainty [31]. Another economic difficulties that can be encountered in the transition to smart manufacturing and expected to contribute to the literature as a result of this study are unexpected costs may arise due to the renewal of the machines, technical devices, additional software requirements, construction costs, infrastructure changes, unsuccessful pilot applications and problems arising from the suppliers.

In addition, it has been revealed that the companies involved in the research have benefited from grant support in the context of R&D projects from Horizon 2020, UREKA, ITEA and they received project support and incentive funds from TUBITAK in transition to smart manufacturing. Also companies have received loan support from banks. Regarding the given supports in transition to smart manufacturing: state supports, additional incentives, financial supports and supports in finding competent personnel should be increased.

In literature, the advantages of enterprises provided with transition to smart manufacturing model are providing competitive advantage, the reduction of production, logistics and management costs [164] and the provision of customer-oriented small batch manufacturing [165]. In addition to this, with the 7/24 manufacturing of machines to provide faster manufacturing and products to be introduced to the market faster to allow [22, 166]
are also among the highlighted advantages. By enabling instant monitoring of manufacturing with the help of the sensors used and thus allowing immediate intervention to possible manufacturing errors and reducing manufacturing errors, increasing quality in manufacturing, increasing flexibility and efficiency in manufacturing, and increasing sustainability [12, 15, 23, 31, 52, 55, 131, 150, 155] are another benefits of transition to smart manufacturing that seen in some study results. In addition, smart factories significantly reduce storage, shorten the personalized product delivery cycle and provide a radical reduction in stocking throughout the supply chain compared to existing factories [26]. In this study, the expectations of enterprises from smart manufacturing are in line with the literature and support the literature.

6.4. Evaluation and Discussion of Findings Related to Environmental Factors

In the literature, the difficulties and problems associated with the environmental factors that may be encountered during the implementation of Industry 4.0 are: disagreements between companies and their stakeholders who do not want to risk, [156], necessity of ensuring the confidentiality and security of digital data fully, the absence of a global standard developed under Industry 4.0 [2, 167], the risks [93] that can be encountered with smart manufacturing in terms of standardization, information security, the availability of information technology (IT) infrastructure and the availability of fast internet. In the literature about the security of smart factories, it is stated that cyber attacks are very frequent and dangerous in today and the security of the data is particularly important, the lack of capacity to ensure correct data security is very risky and recent examples show that this can lead to large pauses and long failures in production centers [155]. In the literature, it is stated that the complexity of systems, the move towards increased autonomy, insufficiency of security experts and intense trust in vendors affect the effective security of manufacturing systems, and it is emphasized that the potential consequences of security attacks on smart manufacturing systems should not be ignored and risk assessments should be made. Among the proposed solutions at the security point, it has been proposed to work with research and industry communities to develop effective security solutions, to focus on efficient, robust, reliable, low-cost security solutions for the security of current and future manufacturing systems, and to start training the trainers of the next generation of security experts and manufacturing control engineers [94]. In these planned trainings, the focus should be on developing technical skills, methodological skills, social skills and personal skills [168]. It
is also emphasized that communication with various protocols is required to ensure security, thus protecting data [2].

In the context of this study, some problems were encountered as different to the problems encountered due to environmental factors in the literature. Among these problems, due to the fact that the servers of companies that provide cloud environments are abroad, absence of legislation in our country related to the protection of this data; encountered legal regulations regarding customs, lack of awareness in suppliers and insufficiency in suppliers' digitalness levels, and difficulties related to supplier support are included. Some of these problems could not solved by the enterprises involved in the research. They emphasized that these risks and problems should be considered and that measures should be taken against them.

It has been observed that some of the problems encountered due to organizational, technological, economic and environmental factors in the transition to smart manufacturing are in line with the literature and have similarities. In addition, some research findings related to the problems encountered due to organizational, technological, economic and environmental factors in the transition to smart manufacturing contributed to the literature since it was not previously included in the literature. Besides, revealing the solutions found by the enterprises to the problems encountered in the research has contributed greatly to the literature, and the research findings have guiding qualification for enterprises that will switch to smart manufacturing.
7. CONCLUSION AND SUGGESTIONS

In this study, 10 participants from four companies of Turkish origin were interviewed and the problems faced by the enterprises in the transition to smart manufacturing and how they found solutions to these problems were determined. Qualitative research method was used in the research. The research model is case study. As a result of the study, it was observed that Turkey originated enterprises faced technological, economic, environmental and organizational problems during the transition to smart manufacturing. In addition, how they find solutions to these problems has been revealed. Problems encountered in the transition to smart manufacturing process summarized in Figure 7.1 and the solution suggestions for these problems are summarized in Figure 7.2.

Figure 7.1. Problems encountered
As it can be seen in Figure 7.1, it is clearly seen that the basis of the problems of the enterprises due to organizational factors is personnel. The need for competent personnel, the unnecessary personnel resources arising in the parts where robots take over manufacturing and the need for training arising due to the lack of personnel awareness are the primary problems. Enterprises can overcome these problems by periodically organizing trainings for the personnel and directing their unnecessary personnel to other manufacturing units. Among the problems faced by enterprises arising from technological factors; technical problems caused by the different protocols, software and hardware problems, and the inability of the machines to comply with the new manufacturing method stand out. It has been observed that these problems can be solved by modernizing and adapting the machines, and putting together some layers, protocols and software and with the support of experts, academics and companies. It is seen in Figure 7.1 that the main problem that arises due to economic factors is unexpected costs. Due to environmental factors, it is observed that enterprises experience various difficulties in transition to smart manufacturing due to legal regulations, lack of industry standards and suppliers. As seen in Figure 7.2, enterprises solved these problems with the platforms they developed for the suppliers and the trainings they organized, with the middleware applications, software and expert support at the point of industry standards.

Enterprises that will switch to smart manufacturing may be advised to attach importance to feasibility and benchmarking before the transition process. In addition,
enterprises must be prepared for all kinds of situations with taking into account the unexpected costs before the transition period and realize their investment planning meticulously, taking into account the difficulties they may encounter. In the transition process, based on the experience of the companies within the scope of the research, it is recommended to enterprises not to hesitate getting support from individuals or institutions such as consultant, leader, mentor, academician and recommended to think in multi-criteria when choosing technology assets. It is among the other issues that have great importance and recommended to the enterprises to carry out the personnel needs planning in detail during the transition period and to adapt their stakeholders to this transformation without delay. In addition, senior managers play an important role in the transition to smart manufacturing system. As a result of this study, the following suggestions can be given to the senior managers of the companies that will switch to smart manufacturing:

- Should not be afraid to take risks and invest,
- Always follow and support technology,
- Determine the company strategies well and direct the personnel in line with these strategies,
- Perform feasibility studies with great care before transitioning to smart manufacturing,
- In the transition to smart manufacturing, before deciding which technologies to use, have your team do the POC work and thus choose the most appropriate technologies that will create the most added value in the company's dynamics,
- Lead the process and support their teams in the transition to smart manufacturing

The fact that Turkey originated enterprises have encountered various problems based on organizational, technological, economic and environmental origin and determination of how they have overcome these problems in this study clearly shows that each research question has been answered within the scope of the study and the purpose of the research has been fully reached.

The results of the study are critical for enterprises planning to switch to smart manufacturing since this study presents what problems can be encountered in transition to smart manufacturing and how to solve the problems encountered. In addition, this study is a guide for enterprises that intend to switch to smart manufacturing.
This study has some limitations. Problems encountered and solution suggestions were obtained as a result of interviews conducted. In future studies, a questionnaire may be applied and information may be gathered from more companies and employees about the problems they face in transition to smart manufacturing. Using a semi-structured interview form as a data collection tool is another limitation of the study. There are also some limitations in collecting data. Only one participant from each enterprise in the study answered all of the questions in the interview form. These participants are managers who manage the process of transformation into smart manufacturing in their enterprises. Other participants answered the questions in which they have information in the interview form considering their profession and the departments they worked for. So the study results are limited to the views of the 10 participants interviewed. In addition, only the preparation and transition process of smart manufacturing is within the scope of this research. In future studies, problems and solutions encountered in the smart manufacturing process can be investigated by using the mixed research method with companies that have completed the process.
8. REFERENCES


[146] Participant 10. Interview. Interview Date: 07.02.2020, Interview Hour: 17.10-17.45.


9. APPENDIX

APPENDIX-1. ETHICS COMMITTEE APPROVAL

ANKARA YILDIRIM BEYZAT UNIVERSITY (AYBU)
ETIK KURULU
PROJE ONAY BELGESI


Proje etik açısından uygun bulunmuştur.
Proje etik açılarından geliştirilmesi gerekmedir.
Proje etik açısından uygun bulunmamıştır.

AYBÜ ETİK KURULU KARARI
(Etik Kurul tarafından doldurulacaktır)

Araştırma kodu (Yıl – Araştırma sıra no) 2019 – 435
Başvuru formunun Etik Kurula ulaştırıldığı tarih 16.10.2019
Etik Kurul Karar toplantısı tarihi ve karar no 13.11.2019 – 04
Yer Yıldırım Beyazıt Üniversitesi, Esenboğa Külüybesi

Katılımcılar Formda imzası bulunan üyelerimiz toplantıya katılmıştır.

KURUL Başkanı, BASKAN YARDIMCISI VE ÜYELER:

Prof. Dr. Cem Şafak ÇUKUR
Prof. Dr. Tekin AKDEMİR
Prof. Dr. Muharrem KILIÇ
Doç. Dr. Özge GÖKBULUT ÖZDEMİR
Doç. Dr. Behlül TOKUR
Doç. Dr. Birgül ÖZKAN
Dr. Ögr. Üyesi Şule KAYA
Dr. Ögr. Üyesi Ertuğrul DEMİRDEL
Dr. Ögr. Üyesi Nimet YILDIRIM TİRGİL
APPENDIX-2. INTERVIEW FORM

This interview form was prepared within the scope of a research on “Determination of Problems in Transition to Smart Manufacturing Model and Suggestions for Enterprises”. Smart manufacturing which is accepted as an important result of Industry 4.0 expresses a smarter, dynamic, flexible and technology oriented manufacturing model and contains a connected combination of information and communication technologies and smart manufacturing technologies unlike traditional manufacturing standards in order to optimize the manufacturing process and increase productivity. With this research, it is aimed to present a study that guides the enterprises whose demands for transition to smart manufacturing model are increasing.

The information obtained through the interview form will only be used for academic purposes and the names of the enterprises interviewed will not be included in the research report. Only researchers will know what is spoken in the interview. In addition, no names will be included in the research report.

Merve Öncül  
Ankara Yıldırım Beyazıt University
Institute of Social Sciences
Department of Management Information Systems
Master Student with Thesis

Asst. Prof. Dr. Vildan Ateş

Place of the interview: ___________________________________

Date:__/__/__  Time (Start / End):_______/________

Participant Information

Your Age: 18-25( ) 26-35( ) 36-45( ) 46-55( ) 56 and over ( )
Your Education Level:  Elementary Education ( )  High School ( )  Undergraduate ( )  Master ( )  Doctorate ( )
Your Education Branch: ____________________________
Your Profession: ________________________________

Department You Work for in Your Enterprise:____________________

How long have you been working in this enterprise?
Less than 1 year ( ) 1-3 years ( ) 3-5 years ( ) 5-7 years ( ) More than 7 years ( )

What are your duties and responsibilities in the smart manufacturing system?

__________________________________________________________________________

Present State

1. How long have you been continuing smart manufacturing in your factory/factories where you are realizing smart manufacturing?

Less than 1 year ( ) 1-3 years ( ) 3-5 years ( ) 5-7 years ( ) More than 7 years ( )

2. What is the number of people responsible for the smart manufacturing system in your factory where you realized smart manufacturing?

3. Can you briefly explain what factors you have taken into account in determining geographical location of your smart manufacturing factory/factories?

Preparation Process

1. What kind of studies did you perform in your preparation process before moving to the smart manufacturing system? Can you explain briefly?
   - Feasibility study
   - Simulation software
   - SWOT analysis
   - Cost / benefit analysis
   - Pilot practice
   - Benchmarking
   - Others____________________________________.

2. Why did you need to switch to the smart manufacturing model? Could you briefly explain the reasons that led you to apply this model?

3. Are there enterprises and countries that you designate as role models and encourage you to switch to this manufacturing model prior to your transition to smart manufacturing model?

4. During your transition to the smart manufacturing system, were there any institutions or people you cooperate with and get support within the project scope? (Consulting firm, university, consultant, leader, mentor, academician, etc.)
5. Could you briefly explain the problems you encountered in your preparation process before moving to the smart manufacturing system?

Questions About Organizational Factors
1. Did you perform personnel requirement planning in your transition process to smart manufacturing system?

2. Did you inform your employees about this process before moving to the smart manufacturing system? Did you establish transparent communication with your employees in this process?

3. Did you need new personnel in transition to the smart manufacturing system? If so, in which area of the smart manufacturing process did you need new personnel and how did you meet your adequately trained personnel needs?

4. What kind of problems did you encounter regarding the transition to the smart manufacturing system or in the working process?

5. What kind of personnel policy did you follow for your personnel resource that would not be needed after the robots took over the place of production after the transition to the smart manufacturing system?

6. What attitudes do you suggest that top managers to follow in transition to smart manufacturing system?

Questions About Technological Factors
1. Where did you obtain your technology assets within the scope of the smart manufacturing system?

2. Are there any systems you use / transform from your existing technology assets during the transition to smart manufacturing system?

3. What criteria did you consider when choosing your technology assets within the scope of the smart manufacturing system? Did you perform studies such as benchmarking?
4. What technical difficulties did you encounter during the transition to the smart manufacturing system? How did you solve these difficulties?

5. Which technologies did you use during the transition to the smart manufacturing system? (Cloud solutions, artificial intelligence, image processing etc.)

6. Did you use different software during the transition to smart manufacturing model? (Package software, decision support systems, expert systems etc.)

7. Do you get expert support on the technical operation of your smart manufacturing model?

8. Do you have any other comments and suggestions you would like to add regarding technological factors?

**Questions About Economic Factors**

1. Have you had any unexpected costs during the transition to the smart manufacturing system? Can you explain briefly? (Such as technical device costs, supplier costs etc)

2. Have you had any personnel you lay off during the transition to the smart manufacturing system? Have you had any additional costs for your dismissed staff? (Such as return to work costs, unexpected compensation payments, court costs)

3. What are your expectations from the smart manufacturing system in the short, medium and long term? Could you briefly explain what kind of advantages you provide to your enterprise with the transition to this manufacturing system?

4. Have you received financial support in the transition to smart manufacturing process? (Such as government support, credit)

5. Do you have any other comments and suggestions you would like to add regarding economic factors?

**Questions About Environmental Factors**

1. What were the legal problems you encountered in your transition to smart manufacturing system? How did you solve these problems?
2. How do you legally protect your technology assets within the scope of your smart manufacturing model?

3. Have you encountered problems related to industry standards in the smart manufacturing model? Can you explain briefly?

4. Could you briefly explain the problems you encounter with your suppliers during your transition to smart manufacturing system?

5. How did you manage the processes with the local community and local administrations in your region in your transition to smart manufacturing?

6. Do you have anything to add to the problems you encounter due to environmental factors during your transition to the smart manufacturing system?

**Predictions**

1. How do you think your profitability will change after switching to smart manufacturing systems?

2. How many years do you think the cost of transition to smart manufacturing will return to your enterprise?

3. With the transition to smart manufacturing system, what new departments and professional titles do you foresee to emerge in your enterprise and other enterprises?

4. How and in what direction do you think the unemployment rate will change in the world with the transition of factories to the smart manufacturing system?

5. To what extent do you think smart manufacturing will increase and become widespread in the future?

6. Do you have any other comments and suggestions that you would like to say about this?
# CURRICULUM VITAE

## PERSONAL INFORMATION

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## WORK EXPERIENCE:

- Growth Hacker / 3Y Teknology (February 2019-March 2019)
- Project Assistant / Presidency of The Republic of Turkey Presidency of Defence Industries (May 2019- Present)

## FOREIGN LANGUAGES:

- English (Advanced Level)

## AWARDS:

- Top 5 Entrepreneurial Idea Honors - Ankara Entrepreneurship Project “Young Entrepreneurship Development Project-YEDP”
- High Honor Student Award - Ankara Yıldırım Beyazıt University (2018-Spring Semester)

## PUBLICATIONS: