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Effective managing your organization involves many aspects, from day-to-day to large-scale events or maintenance, while managerial duties are often never ending. Solid leadership skills and an understanding of the industry are a great start, but these alone will not create solid management in your organization. **Industry 4.0** is a disruptive paradigm, challenging the ways manufacturers think about knowledge intensive industrial processes, making manufacturing more flexible, smarter and more effective. What is needed? You need to study **Enterprise & Business Management**. Studying **Management** help you to understand theory and develop the skills to put it into practice but modern business is too complex to be covered by a single subject; modern managers need to have a broad outlook. It is needed to develop an awareness of academic and practitioner perspectives and apply them in real life settings. Studying **Enterprise and Business Management** you should gain an understanding of entrepreneurship, by focusing on the examination of entrepreneurial processes, and its ability to change organizations, markets and whole societies. You have to focus on the concept of management processes and practices in global context, develop an understanding of the management theory and its relevance to practice and get an idea on which challenges managers face in today’s ever-changing business environment.

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In the current volume of our **Enterprise & Business Management series** we focus on **Industry 4.0**. Each ‘lesson ticker’ focuses on one of these fundamentals in detail and gives you a comprehensive overview on what is important to know. Each **chapter** focuses on specific aspects of the five fundamentals, including review questions, exercises and literature for further studies. Because of the international board of authors and their knowledge, the contributions reflect the internation-
al views on business as well as enterprise management topics. This provides the publication with specific international foresight in the area of business and enterprise management and a significant place to combine theory and practical research.

The editor wishes the reader a most informative and enjoyable reading.

Alptekin Erkollar
August 2019
Integration of Industry 4.0 Principles into Reverse Logistics Operations for Improved Value Creation: A Case Study of a Mattress Recycling Company

Learning Objectives

The objectives of this chapter are to highlight the importance of shifting traditional business operations towards the digital era and to provide a comprehensive understanding of Industry 4.0 principles together with the value-adding role of these principles in reverse supply chain operations. Once you have mastered the materials in this chapter, you will be able to:

- Understand the goal of supply chain management and the significance of reverse logistics in supply network flow.
- Discuss the role of environmentally, economically, socially, and technologically sustainable value creation tasks in long-term corporate strategies.
- Describe value creation modules of Industry 4.0 and their functions in the digital era.
- Identify Supply Chain 4.0 and its major deliverables in the context of the sustainable value chain.
- Comprehend the utilization of Industry 4.0 principles into business operations through a real-life case study.

Chapter Outline

This chapter introduces the vision of future-oriented supply chain technologies in the area of Industry 4.0. Growing trends towards digitalization and globalization significantly trigger the ever-increasing customer demand for personalized products and the rapidly-expand-
ing complexity in managerial and operational layers of value chains. As a result, companies today are required to realign their long-term corporate strategies to adopt to state-of-the-art technologies. Industry 4.0 is signified as the paradigm shift in business processes since it facilitates the transition of traditional industrial operations to a highly intelligent digital platform. Focusing on these, the chapter first provides a conceptual understanding of supply chain operations and the distinctive role of reverse logistics in sustainable development to reach a steady state in competitive value creation. Then, Industry 4.0 principles and the utilization of these principles in sustainable reverse distribution are examined through an in-depth analysis in order to discuss their impacts on the overall value-adding capability of organizations. As an illustration, a case study of a mattress recycling company is presented so as to support a coherent insight of this topic. The proposed results aim at delivering a new perception to the traditional value chain in terms of economically, environmentally, socially, and technologically adaptable infrastructures.

Keywords

Industry 4.0, Supply Chain Management, Reverse Logistics, Sustainability, Value Creation, Qualitative Research

1 Introduction

Today, manufacturing companies are forced to a disruptive change caused by various ongoing trends such as globalization, individualization, and virtualization. As a result of such trends, the complexity in manufacturing networks is steadily growing along with the ever-increasing market requirements. Specifically, fast-growing demand for newer and customized products results in shortened product life cycles, which reveals the need for firms to have faster and more reliable production technologies. In addition, the growth in global business activities compels firms to build advanced communication channels via far-reaching networks. Moreover, growing environmental concerns and regulations obligate companies to carefully assess the sustainable impact of their products and services considering environmental, econo-
mic, and social aspects at all stages of a product life cycle (Efendigil et al. 2008). These challenging requirements force corporations to adapt using state-of-the-art technologies in their business operations in order to maintain their competitiveness in today’s highly complex market environment. However, traditional production and supply chain technologies have become insufficient to simultaneously overcome the ever-increasing complexity and ensure sustainable development in their manufacturing functions (Stock and Seliger 2016). As a result of insufficient capability of traditional technologies on value creation, the need for intelligent technologies emerges in order to enable companies to enhance total value added in terms of cost efficiency, productivity, modularity, flexibility, adaptability, stability, and sustainability along their supply chains (Hofmann and Rüsch 2017). With this motivation, the term Industry 4.0, also referred to as the Fourth Industrial revolution, was developed so as to shape a concept of integrated industry to achieve effective management of production and supply chain and value creation in the product recovery towards sustainability (Lasi et al. 2014). In the subsequent sections, the basics of supply chain management along with the role of reverse logistics in sustainable supply chain operations are presented. Following this, the context of Industry 4.0 and its deliverables to the long-term operational strategies are elaborated through an in-depth discussion. Consequently, a case study mattress recycling company is introduced in order to investigate reverse logistics activities in the Industry 4.0 era so as to provide a coherent understanding of this topic.

2 The Basics of Supply Chain Management

The concept of supply chain management (SCM) first emerged in the early 1980s, however, received a growing interest from both academics and practitioners upon the mid-1990s. This topic originated from the theory of binding logistics operations with various business functions including planning, sourcing, production, and distribution in an effort to develop a dynamic flow of information, materials, services, and funds. One of the basic but very common definitions of SCM was provided by Handfield and Nichols (1999) as “the supply chain encom-
passes all activities associated with the flow and transformation of goods from the raw materials (extraction), through the end user, as well as associated information flows. Material and information flow both up and down the supply chain. “By its very nature, SCM integrates all parties within a network including suppliers, manufacturers, wholesalers/distributors, retailers, and customers while enabling them for collaboration and coordination within and between organizations. To this end, SCM is undoubtedly a preeminent task that companies must pursue in order to have a successful competitive advantage since it examines entire business operations as well as responding to the needs of stakeholders. Figure 1 depicts a generic supply network flow model adapted from Chopra and Meindl (2007). Keeping in mind the network flow across the players presented in this figure, the pertinent chain design may vary according to customers’ needs and organizations’ workstream to increase the overall value of supply chain. To illustrate an example, some companies may fulfil consumers’ orders directly without employing intermediaries such as retailers and/or wholesalers/distributors, whereas some others may engage with each channel of supply network in their business processes.

Fig. 1 A generic supply chain network flow model (Chopra and Meindl 2007)

An optimum chain design is positively correlated with the value of the network which is signified as the difference between the revenue generated from the sales and the total cost incurred throughout the network (Chopra and Meindl 2007). Inferring this fact, a desirable material stream notably triggers value creation, efficiency, and therefore, the overall performance of businesses (Ahi and Searcy 2013). Such outcomes are characterized as value-creating activities within a supply chain, which also refers to the value chain. According to Porter (1985),
value chain distinguishes the primary internal and support activities that organizations are engaged in an effort to transform inputs to outputs, in other words, raw material acquisition to sales to end-users. In conventional supply chains, core internal activities comprise the features of inbound logistics, operations, outbound logistics, marketing and sales, and service, whereas support activities include firm infrastructure, human resource management, technology, and procurement. These functional components as a whole practice solely economically accountable operation. Yet today, due to increasing demand for personalized products and environmental regulations mandated by government agencies in addition to expanding operational layers in supply chains, companies encounter major challenges to secure their strategic position in the market. Adopting to new technologies alone becomes insufficient to achieve a sustainable competitive advantage. The companies are now under pressure to also fulfil one or more of the requirements of competitiveness such as cost and energy efficiency, productivity, product differentiation, flexibility, adaptability, stability, resource conservation, and waste reduction (Bartodziej 2016, Hofmann and Rüsch 2017). To accomplish such major qualifications, corporates are expected to evolve their traditional economically-driven supply chains towards an advanced environmentally and socially friendly network designs. Hereby, the conception of the sustainable supply chain derives as a necessity resulted from this issue. Sustainability embedded supply chain management embraces economically viable activities while ensuring environmental and social circumstances and enables corporates to maintain a tenable competitive strategy in the market environment. Specifically, sustainable supply chains assemble the perception of reverse logistics (RL) in typical internal business applications, where the stages of product end-of-life and product recovery processes at end-of-life are appended to the last stage of the value chain (Tozanli et al. 2017). RL is latterly acknowledged as part of sustainable supply chain management by both academia and industry. A detailed description of RL and its role in sustainable value chains are provided in the next section.
2.1 The Role of Reverse Logistics in Sustainable Supply Chain Operations

Logistics is a part of supply chain management which governs an effective and efficient point-to-point flow of products, services, and related information to match customers’ requirements (Bartodziej 2016). Sustainable logistics facilitates two types of material flows: downstream and upstream. While the management of downstream flow is known as forward logistics, the management of upstream flow is defined as reverse logistics. Here, forward logistics refers to traditional product delivery routes addressing the optimization of long-term financial return of supply network. Unlike such typical distribution approach, reverse logistics is a relatively new concept which was initiated by manufacturers as part of their supply chain strategy over the last decade. The RL concept emerged from the idea of developing environmentally friendly operational business strategies. With regards to this approach, RL aims at regaining the value embedded in discarded products in an efficient and effective way and ultimately utilizing acquired output as an input in the forward system. Not for long, reverse logistics rapidly became a mandatory task that must be aligned in corporations’ long-term business practices due to shortened product life cycles and growing environmental concerns and regulations imposed by governments. In its working discipline, RL incorporates the reverse distribution of products and materials between channel members, and it concentrates on identifying environmentally, economically, and socially viable solutions through the transparency of information flow (Tozanli et al. 2017). Specifically, RL primarily encompasses the processes of the collection of used products, inspection and sorting, remanufacturing, recycling, reuse, and/or disposal, distribution, and integration to the forward logistics channel. In this regard, upstream management briefly is summarized as retrieving the value added from scrap or reusable products and inserting them into the downstream route to be used as raw material in the production line of new products. A basic presentation of forward and reverse logistics flows is shown in Figure 2.
A basic presentation of forward and reverse logistics flow (Agrawal et al. 2015)

The integral of forward and reverse transportation fosters the growth of closed-loop product life cycles where the products move from facilities to end-users and back to facilities for product recovery on a continuous basis. As indicated in Tozanli et al. (2017), the closed-loop supply chain is one of the distinctive scopes in the sustainable value chain, and its proper handling constitutes a vital role to endorse sustainable competitiveness. With this motivation, it can be declared that only corporations which have the competency to harmonize these two channels within their value chain are capable of achieving sustainable material flows for their products throughout their life cycles. Beyond this fact, the utilization of Industry 4.0 can only be legitimate with adequate employment of logistics practices which cater the desired input factors to the production systems in the right quantity, with the right quality, at the right costs, at the right time, and at the right place (Bar-todziej 2016, Hofmann and Rüsch 2017).
3 Industry 4.0: A Disruptive Industrial Movement

Ever since the beginning of the Industrial Revolution in the late eighteenth century, industries have been influenced by ongoing developments. The past three industrial revolutions emerged by technical innovations has led to radical changes in industry. Specifically, the first industrial revolution was in the field of mechanization by the use of water- and steam-powered manufacturing; the second industrial revolution was the evolution to mass production and assembly lines by the intensive use of electricity; and the third revolution was the transition to the digitalization in conjunction with computer aided manufacturing and automation systems.

As mentioned in the previous sections, companies are challenged by dramatically expanding complexity and market needs. Among these, demand for high product variety at high quality levels and low costs, capital for maintaining global corporate activities, and capability of achieving developments towards sustainability constitute some of the major needs. To address these challenges, industries seek faster and more reliable business technologies to be utilized in their manufacturing and logistic processes throughout their supply chain in order to attain sustainable competitive advantage. Due to this, the German government established an initiative under the name “Industrie 4.0” in order to not only secure the future production requirements of German manufacturing industries but also to stimulate the industrial sector as a forerunner ensuring German market competitiveness in the world (Bartodziej 2016, Hofmann and Rusch 2017). The utilization of Industry 4.0 significantly consolidates the German manufacturing industry since it elevates the efficiency of domestic production and the volume of export significantly contributing to their GDP. Industry 4.0 represents the developments towards the fourth stage of industrialization. The background of this concept relies on the year 2011 when it was first presented at the Hannover Messe Trade Fair and published by Kagermann et al. (2011) in a German-speaking manuscript. The idea here was introduced as the establishment of autonomous, knowledge-based, sensor-embedded, self-organized and decentralized IT-driven production systems. Therefore, the Fourth Industrial revolution was simply described as the future production systems that run modular
and efficient manufacturing operations where the products control their own manufacturing processes. Endorsing its importance, Kagermann et al. (2012) stated that the active participation in the Industry 4.0 is vital for companies to overcome possible challenges and opportunities in future production systems in terms of industrial value creation. Industry 4.0 was not common outside of German-speaking areas until the Industrial Internet Consortium in the US promoted it in 2015. Subsequently, it was listed as a main topic on the 2016 World Economic Forum’s (WEF) agenda (Hofmann and Rüsch 2017, Stock and Seliger 2016). Since then, this promising concept has received attention from both academia and industry due to its ability to cope with the complexity of the market dynamics by putting forward the vision of future-oriented manufacturing and logistics processes. Industry 4.0 is considered as the transition from current industrial technologies to a new fully digitalized industrial age. This evolution can basically be signified as the convergence of disruptive technologies such as Cyber Physical Systems (CPS), Internet-of-Things (IoT), cloud computing, big data analytics, artificial intelligence, advanced robotics and autonomous systems, augmented reality, and additive manufacturing (WEF 2017). Undoubtedly, CPS and IoT here can be remarked as the most powerful core enablers which form the basis of the fourth stage of industrialization. In particular, IoT provides manufacturers the ability to keep track of individual products throughout the value chain on a continuous basis via embedded devices such as high-quality sensors, actuators, RFID tags, and microprocessors (Brettel et al. 2014). CPS decodes the ongoing digital-to-physical and physical-to-digital cycles; therefore, it maintains the communication between these intelligent structures and humans. To emphasize its power, Hofmann and Rüsch (2017) described the CPS platform as an unprecedented degree of end-to-end control, surveillance, transparency, and efficiency in the value chain. Furthermore, big data analytics and cloud computing serve as data enablers. In this regard, big data analytics transforms large volumes of data obtained from intelligent IoT processors into valuable real-time information with the help of a machine learning software. Bartodziej (2016) delineated this structure as a self-optimizing intelligent system which stimulates the reduction of lead time and energy consumption as well as the increase of quality. Additionally, cloud comput-
ing demonstrates a user-friendly interface of advanced digital platform which delivers a rapid real-time network connection. With regards to its working discipline, data gathered from intelligent objects are sent to a server, processed via big data analytics, and sent back to the designated location. Through all enablers, companies can reduce the complexity and uncertainty in their business processes by governing end-to-end real-time information flow. The fourth stage of industrialization hence introduces an embedded system where current advanced manufacturing technologies are integrated into CPS in manufacturing and supply chain operations as well as IoT in industrial processes (Bar- todziej 2016). Specifically, this concept aims at fully integrating industrial technologies to establish smart objects including smart factories, smart logistics, smart products and services embedded in CPS and IoT in order to optimize overall industrial value added (Stock and Seliger 2016). Industry 4.0 also facilitates a paradigm shift in corporate strategies by extending business functions beyond an advanced and highly flexible platform. To this end, the new business environment accommodates a decentralized, modular, self-organizing, flexible, innovative, and sustainable structure. High flexibility together with increasing innovation capability decreases the product development periods while concurrently performing mass production. Decentralized organizational structures notably accelerate the decision-making processes while modularity allows for individualization on demand and removes strict production hierarchies. In addition, Industry 4.0 paves the way to a remarkable level of resource- and eco-efficiency in terms of sustainability. Illustrated in Figure 3, the prominent value creation modules of Industry 4.0 embrace an interplay of the intelligent technologies in association with up-to-date corporate strategies. With the help of these key modules, the benefits of Industry 4.0 can be compiled as an advanced mechanization and automation, simultaneous information flow and real-time coordination with a communication technology infrastructure, reduction of complexity costs, and the emergence of new services and innovative business models while expediting eco-efficiency, adaptation of human needs into the system, and corporate social responsibility.
In general, the oncoming industrial age revolutionizes conventional ways of value creation by transforming all point-to-point steps in production and supply chain models, and therefore constructs a bridge between human needs and advanced technologies (Bartodziej 2016, WEF 2017). This novel system as a whole build the term called Smart Factory which allows for the base components of industry such as machine, product, human, and organization to communicate with one another using ubiquitous flow of smart data in an integrated network. Moreover, the intelligent infrastructure reinforces the capability of the value chain including inbound and outbound logistics, manufacturing, production and service operations (Lasi et al. 2014, Stock and Seliger 2016).

Fig. 3 Value creation modules of Industry 4.0 (Brettel et al. 2014)
3.1 Impacts of Industry 4.0 on Supply Chain Operations towards Sustainability

Industry 4.0 conveys a noteworthy perception to the future of supply chain management which can also be called Supply Chain 4.0. A successful aggregation of compatible technologies leads to a concrete value-creating capability throughout the sustainable supply chain. Utilization of such intelligent systems prompts a unique, secure, agile, dynamic, responsive, knowledge-based, and customer-oriented constellations which help to succeed in long-term competitiveness. Similar to technological developments, sustainable and secure flow of materials is another fundamental surroundings for corporations to be capable of utilizing their resources effectively, therefore, becoming more competitive in industry (Bartodziej 2016). The intersection of intelligent and operative systems in the digital era yields more sustainable value creation and delivers superior benefits to firms against their competitors. Through the Supply Chain 4.0 setting, organizations become more responsive to the rapidly-changing market environment, more flexible to settle new technological functions in their existing systems, and more interactive by binding all parties in a network throughout their forward and reverse logistics operations. Additionally, this interdisciplinary cornerstone avoids firms from wasting their time and resources by using the help of autonomous IT-based platform. Smart supply chain management can be examined under the umbrella of three overarching strategic pillars for actions such as horizontal integration, end-to-end digital integration in product life cycle, and vertical integration (Stock and Seliger 2016). In this regard, horizontal integration addresses the same level value-adding activities along supply chain of a firm or between multiple firms. This integration puts forward a collaborative digital value network of multiple companies including an exchange of materials, energy, and information (Bartodziej 2016). This network constitutes greater significance for Small Medium Enterprises (SME) due to its capability of expanding resource channels conjointly with reducing the complexity of manufacturing processes and business layers (Brettel et al. 2014). End-to-end digital integration supports the concatenation of IT-driven systems into entire product life cycle steps beginning from raw material acquisition to end-of-life...
product (Stock & Seliger, 2016). Consequently, vertical integration arranges the intelligent end-to-end solutions between different hierarchical levels from production management and manufacturing stations to sales and marketing in supply chain of a smart factory (Bartodziej 2016, Stock and Seliger 2016). Contrary to the horizontal merger, vertical aggregation gives firms the opportunity to reduce their operational costs and increase effectiveness and efficiency by acquiring varying levels of managerial capabilities. The 2017 WEF’s report “Impact of the Fourth Industrial Revolution on Supply Chains” endorses its economic potential by indicating that the majority of companies who achieved altering their digital transformation appears in the manufacturing sector (79.9%) and the logistics sector (85.5%). Here, the manufacturing industry has achieved having a positive impact on the cost reduction plus additional revenues by 20.1% while the logistics sector has increased by 17.8%. In the technical standpoint, Supply Chain 4.0 authorizes manufacturers to unify people, objects, and operating systems in an integrated network and uplifts business models towards a new degree of value creation. Hereby, Fourth Industrial revolution in sustainable supply chain can be concisely presented as the union of physical and digital value chain. Physical value chain analyzes the impacts of advanced models on organizational and strategic structures allied with economic, environmental, and social perspectives, while a digital value chain evaluates the long-term value-adding pattern from the technological viewpoint. The implications of such modern interconnected value chain can be examined in different characteristics such as digitalization, localization, customization, and collaboration (WEF 2017). Focusing on these, digitalization facilitates an unprecedented degree of surveillance and quality control along the point-to-point value chain from product design to end-of-life product recovery. The integration of key technologies such as CPS, IoT, big data, and cloud computing intelligently links all primary objects within a factory such as human, machine, and product as well as all partners within a supply chain such as supplier, manufacturer, logistics provider, and consumer to each other. In particular, as outlined previously, IoT pertains to small, widely distributed, and virtually connected ubiquitous devices which read, collect, and store continuous real-time data in a cloud. CPS transforms these collected data into real-time information.
via the cloud using the help of big data analytics. This system generates the emergence of environmentally friendly smart grids where the need for energy generation of advanced factories is met by renewable energies or short-term energy storages (Bartodziej 2016, Stock and Seliger 2016). This profound progress as a whole develops the intelligent logistics system. The workflow of the Supply Chain 4.0 setting is exhibited in Figure 4.

Fig. 4 The workflow of the Supply Chain 4.0 setting

Through this setting, firms are capable of monitoring an online material flow, and hence reducing errors on forecast analysis through the stream of smart data. Therefore, digitalization helps organizations im-
prove a transportation system by eliminating the uncertainty in both their forward and reverse logistics flows. Moreover, localization and customization imply decentralized organizational structures accompanied with flexible and agile production logistics. Based on these features, manufacturers obtain individualization on demand in high quantities and mass customization. Collaboration eventually stimulates the involvement of all actors along the end-to-end value chain, and therefore, provokes transparency in the logistics network. As a consequence, the characteristics of corporation's substitute with highly flexible, adaptable, innovative, digital, and responsive features through advanced communication channels. The following section presents a case study on mattress recycling network in order provide better understanding of Industry 4.0 in practice.

4 Reverse Logistics Network Design for Mattress Recyclers: A Case Study

Without a doubt, mattresses fulfil one of the most basic needs of individuals, and therefore appeal to an extensive range of consumer profile. Mattresses today have a large variety available in the market place in response to the varying needs of customers. Beddings are classified as memory foam, gel, innerspring, crib, fiber, latex, airbed, temporary air, waterbed, organic eco-friendly, pillowtop, smart, and hybrid mattresses (Tuck 2018). A typical mattress contains various recyclable content such as metal, polyurethane foam, wood, fibrefill, cotton batting, paper, and other miscellaneous textiles (DEEP 2018). More specifically, these components by weights can be distributed as 48% of metal, 26% of polyurethane foam, %5 of wood, %16 of cotton and fibrefill, and %5 of non-recyclables, which is also graphically demonstrated in Figure 5.
Mattresses at the end-of-life (EOL) stage are one of the major contributors to the growing waste with an estimated range of 20 million units disposed of each year in the US (CascadeAlliance 2017). Despite the fact that more than 80% of the materials in a typical mattress or box spring are recyclable, the vast majority inevitably are sent to landfill or incineration. Recycling is the primary product recovery method which aims at regaining the value embedded in EOL products by transforming waste components into reusable materials. Recycling significantly improves waste reduction, energy efficiency, and resource conservation. In addition to environmental hazards, EOL mattresses, if not handled properly, may lead to severe health issues by creating an avenue for parasites, bed bugs, and other contagious diseases to be transmitted into community (DEEP 2018). As a solution, energy recovery is another commonly used EOL mattress recovery option where polyurethanes and other plastics are combusted to generate energy. For every EOL mattress recovery, the estimated CO2 saving reaches up to 1.5 tons and the saved landmass rises 23 m³ of landfill space (CascadeAlliance, 2017). To this end, a proper reverse logistics management becomes a vital importance in order not only to regain the maximum value but to also maintain an environmentally, economically, and socially viable value chain. However, EOL mattress recovery program requisitely turns out to be on a non-profit basis since the revenue gained from the sales of material yield is not appealing for a business venture. With this motivation, three states, Connecticut, California,
and Rhode Island, in the US enacted a legislation requiring manufacturers to establish a statewide mattress recycling program, whereas Connecticut was the first state to adopt the comprehensive mattress stewardship law in 2013 (CascadeAlliance 2017, GBCE 2018). The recycling program is conducted through Bye Bye Mattress project launched by Mattress Recycling Council (MRC) – a non-profit organization which was formed by mattress industry to develop and implement the statewide mattress stewardship program (DEEP 2018). According to the Bye Bye Mattress program, each state funds its activities through a unit recycling fee collected from consumers per sale of bedding or box spring (CascadeAlliance 2017), and thereby the states can afford the labour, recycling, and transportation costs.

This case study investigates business operations of a non-profit mattress recycling organization in Connecticut from various standpoints. This organization is the only mattress deconstruction and materials recycling business of its kind in the Northeastern United States. The vision of the company is to reduce the cost of mattress disposal and increase the volume of recycling rate while ensuring green and clean neighborhoods (GBCE 2018). Therefore, the aim of this study is to explore the ways to increase operational efficiency of the organization in addition to finding alternative markets for its raw materials via in-depth analysis. Reverse logistics network of the business starts with the collection of used mattresses, followed by recycling operations and the sale of materials back to the manufacturing industries. The organization has several suppliers including various transfer stations, hospitals, universities, prisons, hotels, and retailers. With regards to the workflow, the hauler delivers the used bedding products which are received by individuals and collected at transfer stations, or EOL mattresses can be directly brought to the recycling facility by other suppliers. Following this, the facility unloads, inspects, and segregates the collected mattresses. Here, unhygienic products are immediately sent back or taken aside to be sent to incineration. The Connecticut Department of Energy and Environmental Protection (DEEP) imposes the facility to recycle at least 85% of the materials in each mattress taken for recovery (CascadeAlliance 2017). Therefore, incineration is not accepted as an option for used mattresses in good condition. Mattress recycling is a complex process that involves the stages of separation
and dismantling that require capital investment to carry out safely. To encourage recyclers, the law in Connecticut cuts the cost of mattress recycling by imposing an echo-fee of $9 on all new mattress purchases, which is pooled to support the mattress deconstruction programs. Mattress retailers transfer the total echo-fee to the recycler, who uses this amount for transportation and recycling of unwanted mattresses. Therefore, the non-profit organization meets the capital needs to recycle around 40 thousand EOL mattresses annually with no additional cost to the used mattress providers. Recycling operations performed in the facility is labor-intensive, where materials are taken apart, sorted, and baled manually. The valuable materials extracted from the mattresses are arranged as metal, foams, woods, and cotton and fibre. After the reprocessing, these components are sold back to various manufacturing industries to fulfil their production line requirements. To increase the sales, the company purchased a metal baler to crush the metal, which increased the net income up to $4K/month. Despite the fact that metal and wood are the two most profitable materials, foam is the most challenging material due to the difficulties in economies of scale. Hence, insufficient demand for foam results in a mismatch between its supply and demand in the recycler’s supply chain. As a result of the decline in this demand, the fluctuating revenue from the resale of components causes insufficient capital to sustain recycling operations and cover labour costs. With this motivation, the steps of EOL mattress recovery in the organization starting from delivery of beddings to the resale of the extracted material have been monitored and recorded through several site visits and personal communications. Based on the data and information collected, the main objectives of this study are designated as follows:

- Finding additional markets for recycled foam that utilize foam for the business.
- Determining the best suitable recycling method for foam, viz. mechanical or chemical recycling.
- Creating a more appealing material/product market for the consumers.

Additionally, the utilization of future technologies into the existing business functions is assessed from different perspectives such as po-
ential for IT-oriented developments and expected limitations for future technologies.

4.1 A Qualitative Research Approach

A qualitative research methodology is determined as the most suitable technique for this real-life case study since it addresses “why” questions to comprehend issues and “how” questions to explore process behaviours (Bartodziej 2016). As a part of qualitative analysis, in-depth individual interviews, open-ended questions, participant observations, group discussions, and systematic data collection and analysis are conducted. In this regard, a limited number of respondents who noticeably have in-depth insights of this related topic has been identified, which constitutes a sample of 7 people including one manager, three faculty, and three graduate students. Based on these, the manager has been intermittently interviewed face-to-face with a series of open-ended questions in order to fully examine the business processes and evaluate the complex issues. Similarly, group discussions have been periodically implemented among the manager and researchers in order to explore the spectrum of opinions and associated solutions to the relevant questions. Some examples of these questions are listed as follows:

- Can you think of any alternatives where foam can be used as a raw material?
- Can you think of other nearby institutions in addition to existing providers where the mattresses can be supplied from?
- Can you think of any value-added operations similar to metal crushing which now pays for more jobs?
- Can you think of online channels for material sales? If yes, what would be the setting? Who would be the customers? What would be the platform and why?
- Can you think of alternative products that can be made via the recycled materials?
- Can foam be used for carpet padding/packaging? What would be the minimum amount required to make it profitable (the breakeven point)?
- How many bales can you produce per day with the vertical baler?
Can you think of chemical recycling of foam to increase the profitability in the long-term period?

How to contain flammable materials so that they are stacked together to save space?

At the next stage, business environment has been monitored on site to verify that the information provided by the informants and to gain further insight regarding the business. As a part of participant observations, photographs, video-recordings, and artefacts have systematically been collected from the facility. Consequently, the final stage of data analysis has been applied. In this regard, information collected through interviews and observations have been carefully analysed in order to reduce vast amount of information and obtain meaningful insights. With regards to the market pattern and business structure, emerging subjects have been clustered under different labels such as the development of a smart transportation model, establishment of online channels, identification of alternative products, and assessment of the environmental and economic feasibility of mechanical and chemical recycling of foam based on the market patterns. Accordingly, the relevant findings are elaborated under each label in order to accomplish each main objective of the study in the context of Industry 4.0:

Development of a smart transportation model: This proposed solution focuses on the establishment of a smart logistics model. Accordingly, a geographic information grid system is utilized to accurately obtain key places to look for customers and suppliers within 100-mile radius of the recycler’s location. This system is an aggregation of advanced information technologies and geographical grid system, which provides users the ability to reach a variety of potential customers through online services with no additional cost. With the help of such system, the recycler can achieve a cost-effective shipping of supplies to the destination points.

Establishment of online channels: Online marketing services help the organization to create new customer profiles from individuals to wholesalers. By the virtue of web services, the recycler is required to pay either no or slightly a small amount of additional cost to operate business activities in online channels. Identification of alternative products: Foam can be utilized for various purposes in the market place such as insulation, packaging, sports mats, cushioning, pet hous-
es, architectural models, clown nose, and decorative purposes. At this step, the company should pursue a strategy to explore new customers who utilize such products in their production line by using the above-mentioned solutions, and therefore adding new consumers to its value chain. Assessment of the environmental and economic feasibility of mechanical and chemical recycling of foam: Polyurethane foam is recycled in two primary ways: mechanical or chemical. Mechanical recycling is a method where foams are regained in polymer form. The most common mechanical recycling method is rebond which is made up of pieces of chopped foam that are bond in one slab (ACC, 2018). Rebond is primarily used by carpet underlay market, followed by sports mats and cushioning industry. On the other side, chemical recycling is a method where foams are decomposed to their chemical constituents. Alcoholysis is the most respected chemical recycling method due to its mild reaction condition and the good performance of regained components (Yang et al., 2012). The polyols obtained from alcoholysis can be used in myriad applications from furniture to packaging (ACC, 2018). Building one of the recycling techniques is crucial for the organization in order to realign its business to adopt changes in an autonomous manner and optimize foam value added in the long term. To determine the best appropriate recycling process, technological evaluation of these two methods can be assessed through several methods such as cost-benefit ratio analysis, Delphi method, and risk analysis (Bartodziej, 2016). Due to this fact, an in-depth discussion on market dynamics is carried out to evaluate pros and cons of two processes. Compared to chemical recycling, mechanical recycling is an economically and environmentally viable option, and it is commonly applicable in the market. Mechanically reprocessed materials are more appealing for wider range of consumers using online sales channels. However, the rebond market now goes down, and it is expected to be no longer an option in a decade. Even though chemical recycling appears to be a costly choice in comparison to the traditional reprocessing, the unit sale price of materials is significantly higher than the rebond. Therefore, it is a fact that such setting can pay for itself in the long term. On the other side, this alternative implies negative environmental impacts which have to be inspected before its establishment. In addition, the type and age of foams also constitute an important place since they...
may necessarily affect the quality of output materials. Regarding to these, environmental regulations and restrictions posed by local governments, the convenience of the facility location, and type and quality of foams to be recycled are signified as the primary parameters to assess the outcomes of this method. Eventually, chemical recycling presents as an ultimate and effective alternative in the long term.

5 Conclusions

This chapter introduced the utilization of Industry 4.0 in supply chain activities towards sustainability. With this motivation, the chapter comprehensively interpreted the context of Industry 4.0. Following this, its potential impacts on reverse logistics operations examined through a qualitative analysis in order to find viable solutions to increase the overall value added in business operations. Then, a case study of a mattress recycling company is presented so as to provide a better understanding of this topic. The proposed results here aimed at delivering a novel perception to the traditional value chain in terms of not only economic levels but also environmentally, socially, and technologically adaptable infrastructures. With the development of Industry 4.0, companies are subject to a movement from conventional industrial technologies to a fully digitalized era. This novel concept provides the industry with the opportunity to keep track of end-to-end real-time information and material flow through state-of-the-art intelligent systems. With the help of the ubiquitous flow of smart data generated via such digital technologies, corporates become capable of communicating with each of their partners in the supply chain network. This state culminates in a high degree of collaboration and coordination skills in organizations’ value chain. Smart infrastructures not only vitalize the formation of an efficient and effective future manufacturing architecture but also remarkably influence a unique, secure, agile, dynamic, responsive, knowledge-based, customer-oriented, transparent, and sustainable supply chain constitution. The industrial transformation towards the fourth stage of automation can legitimately be endorsed as a keystone of operational and organizational structures, and
therefore, its adoption becomes a vital essence for companies who desire to be sustainable in the vision of future business environment.

6 References


7 Key Terms

<table>
<thead>
<tr>
<th>Supply chain management</th>
<th>Reverse logistics</th>
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<td>Supply Chain 4.0</td>
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8 Questions for Further Study

**Why** do companies today realign their supply chain strategies towards sustainability to remain competitive in the market? What are the major deliverables of embedding sustainability into the supply chain strategy? **Why** are organizations forced to a disruptive change? What are the major factors that trigger organizations adapting to this change? **Compare** and contrast traditional industrial technologies with fully digitalized industrial technologies. What are the distinguished functions of the digitalized setting? **Classify** value creation modules of Industry 4.0 and describe their working discipline as a whole. **Compare** and contrast three overarching pillars of smart supply chain management.
What are the primary outcomes of utilizing Supply Chain 4.0 in the context of physical and digital value chain?

9 Exercises

Suppose you are a supply chain manager who is in charge of the management of economically-driven forward channels in an electronics company. Your directors have decided to adopt to sustainable supply chain strategies due to its positive outcomes in long-term business operations. What would the methodology that you would follow look like? Develop a network design which incorporates forward and reverse supply flows of your company (similar to Figure 2). Could you list any potential improvements compared to the prior strategy?

Suppose you are an analyst developing a new information system compatible with Supply Chain 4.0 infrastructure in collaboration with production engineers, IT engineers, supply chain specialists, and other technical and managerial departments. What changes could you expect from this transition? What could your role and responsibilities be during this changeover in order to be capable of creating a fully-fledged smart information system as an analyst?

The key components of Industry 4.0 and their functions discussed in this chapter can be integrated into a supply chain network to build an intelligent hybrid business model. How could this advanced model affect the organizational structure? Is it a worthwhile model to perform? Think about the impacts of this model to the customer relations and company’s profitability in the long period.

10 Further Reading


Learning Objectives

The objectives of this chapter are to understand safety stock strategies for highly promoted items; learn the impact of these strategies on inventory, stock outs, and fill rate; and build a simulation to help management conceptualize the impacts of different decisions. Once you have mastered the materials in this chapter, you will be able to:

- Explain different methods to set safety stock levels
- Build a model to simulate the effects of different inventory management policies
- Apply these techniques to a variety of products in several different industries
- Determine which inventory policy is correct for your specific assortment
- Structure a continual review of inventory levels

Chapter Outline

This chapter reviews inventory management techniques for fast moving, highly promoted items. Retail companies struggle to maintain the appropriate levels of inventory on promotional and seasonal items due to management pressure to never be out of stock. Dynamically changing desired service levels during promotions or seasonal periods will ensure accurate safety stock levels and reduce manual interventions. We simulate inventory policies introducing dynamic changes in desired service levels to determine the impact on inventory, stock outs,
and fill rate. We show that dynamic service levels can reduce inventory and stock outs while maintaining the same fill rate as fixed policies. Having different service levels throughout the year contingent on business needs ensures that companies will have the right inventory at the right time.

Keywords
High-low pricing, Dynamic safety stock, Simulation

1. Introduction

1.1 Problem Statement and Company Background

Retail Business Service's (RBS) high-low pricing strategy requires strategic safety stock investments to ensure inventory levels are adequately controlled. RBS' current inventory policy does not address the need to dynamically manage the safety stock of items as business needs evolve throughout the year. RBS is one of the largest food retailers in the world. In the United States they operate nine different retail banners, each with a different go-to-market strategy. RBS' largest US banner is located in the southeastern US and operates over 1,100 stores selling over 10,000 unique center store products. Supporting these stores are five full case distribution centers (DCs) and one break-pack DC. Annually, this banner generates sales of over $11 billion while moving close to 500 million cases through their DCs. RBS uses different pricing strategies to support their banners. One of the northern banners uses an everyday low-price strategy. This strategy advertises consistent prices throughout the year and does not typically offer discounts through promotions. This differs from the high-low strategy used at their southern banner. Through weekly advertisements and in-store signs, they promote key items at lower than market prices. In a sample week at one DC, promoted products represented 22% of the stock keeping units (SKUs) shipped and 32.4% of the total cases shipped. To compensate for the margin loss on these items, non-promoted items
are often priced slightly above market. This strategy, according to RBS, allows them to generate excitement and return visits as promotions change weekly. Additionally, this creates a customer perception of low prices. However, from an inventory management perspective, a high-low retailer's weekly promotional changes create additional volatility in demand and difficulties in forecasting. As RBS' average vendor lead time is 10 days, if the right amount of product is not purchased prior to a promotion, it is difficult to rebound. Conversely, if too much product is purchased, selling through excess inventory is equally challenging. To buffer against demand and forecast volatility, RBS must use an inventory policy that increases safety stock on these critical items.

1.2 Motivation

Holidays and promotions are when retailers can differentiate themselves, attract new customers, and create a lasting price impression. To meet these goals, retailers put immense pressure on the supply chain to maintain high on shelf availability. In response, demand management teams and retail stores often disregard normal inventory policies in favor of a "don't be out of stock" mentality. This emotionally driven inventory policy leads to large manual orders by both retail stores and distribution centers. These orders cause a bullwhip effect which results in excess inventory or high fees to expedite deliveries. Promotions and holidays require active supply chain management on the "important few" products that are constantly changing. Canned pumpkin is a top item during Thanksgiving, but is quickly relegated to the bottom of the list in June. A slow-moving shampoo, when displayed and promoted, can become a retailer's top selling item. On the other hand, paper towels sell around the same amount every week. Given the range and variability of products carried by food retailers, it is difficult to find a one-size-fits-all inventory policy. This research will develop a method to alleviate emotional responses to promotions and holidays by creating dynamic cycle service levels.
2 Literature Review

2.1 Retail Applications

A multi-criteria item classification system aims not only to reduce inventory costs, but also to improve customer satisfaction by offering greater in stocks on key items such as those on promotion. Improving in stock conditions, according to Dubelaar et al. (2001), will cause an increase in the square root of sales. Retailers struggle to maintain high in stock numbers, especially for items on promotion. Taylor (2001) found that in the grocery industry, advertised items are not available in their normal shelf location 11.5% of the time. When items are not available on the shelf, according the Emmelhainz et al. (1991), 39% of customers will go to another store to find what they’re looking for. The potential financial ramifications of these lost sales can have a lasting impact on a retailer. Service levels have a direct impact on the company’s revenue and profit (Millstein et al., 2014). If they are too high, substantial capital is tied up in inventory. However, if they’re too low, they can lead to stock outs which can cause the loss of the customer goodwill; this in particular makes it difficult to measure the cost of stock outs. Therefore, management should make inventory decisions taking into consideration the service performance perceived by the customers (Bijvank, 2014). Promotional research has focused on creating strong promotional forecasts to ensure high product availability (Thompson, 2015; Koottatep and Li, 2006). Little research has been done on incorporating promotional importance into a segmentation strategy. This research seeks to reduce the lost sales caused by promotional product unavailability and improve customer satisfaction by maintaining high in stock rates. In the next section, we review existing SKU segmentation policies and different business strategies addressed.

2.2 SKU Segmentation

As companies continue to add more diversity to product assortments, it is necessary to define methods for grouping and managing these dif-
ferent items. According to Mohammaditabar et al. (2011), managing thousands of items can cause companies to unnecessarily focus on unimportant items while not paying adequate attention to key items. The traditional approach to segmentation is the ABC analysis in which management groups items into three classes as A, B and C based on some predetermined criteria (Armstrong, 1985). According to Teunter et al. (2009), the most common method for classification is to use demand value, namely annual goods movement multiplied by unit cost. This principle is based on Pareto’s principle that 80% of sales typically come from the top 20% of SKUs (Armstrong, 1985). According to Zhang et al. (2001), there are several drawbacks to the demand value classification system. First, this system will put a large amount of capital investment into the most expensive items. Second, this segmentation still requires "optimization of stocking parameters within each group" (Zhang et al., 2001). Consequently, considerable research has been done in the field of multi-criteria inventory classification using different factors in ABC classification. The general premise of ABC classification is to manage the "significant few" A items closely and spend less time on the "trivial many" or C items (Flores, 1992). Zhang et al. (2001) proposes ranking items based on the ratio of annual demand divided by lead time times the square of item cost. The problem is solved using linear optimization with fixed service levels and order frequency. The authors demonstrate a 30–35% lower inventory investment as compared to traditional demand value segmentation. Teunter et al. (2009) also solves this problem using a single criterion and clearly defines how to set cycle service levels (CSLs). The criterion used for classification is:

\[
\frac{hQ}{bD} \quad (2.1)
\]

Where \( h \) = holding cost, \( Q \) = order quantity, \( b \) = criticality defined as shortage cost and \( D \) = annual demand. CSL can correspondingly be defined using:
There is a clear tradeoff between the management cost of multiple classes and the safety stock cost. Millstein et al. (2013) assigns a fixed management cost per class and uses this in an optimization model to maximize profitability rather than reduce inventory cost. This model, however, is limited by a fixed planning horizon and is built around a one-time run. Yang (2016), attempts to address the limitation of Millstein's (2013) research and expand to include non-stationary demand. A majority of the research into SKU segmentation has been conducted in the spare parts industry (Teunter et al., 2009; Zhang et al., 2001; Molenaers et al., 2011; Millstein et al., 2013). This research will expand on previous research by defining retail-specific classification criteria such as promotional importance and seasonal relevance. Additionally, it will look at future demand patterns and optimize service levels continually based on business needs. The results will be extended to the food retail business, where little, if any research, has been done.

\[ CSL = 1 - \frac{hQ}{bD} \]  

(2.2)

2.3 Inventory Management

Once a firm classifies an item using one of the techniques mentioned above, it must decide which inventory policy to assign to that class of items. Firms should assign an inventory policy that reflects the nature of the items as well as their relative importance. According to Silver et al. (2017), there are two main categories of inventory policies: continuous review and periodic review. In a continuous review system, a firm’s inventory position (on hand inventory + pipeline inventory) is evaluated continuously. In a periodic review, inventory is only evaluated every \( R \) days where \( R \) is the review interval. When certain conditions are met, an order is created. There are tradeoffs with each policy. A periodic review policy can create synchronization across a large family of items. Because items are being ordered on a coordinated schedule, multiple items from the same supplier can be ordered together. Additionally, a periodic review creates stability, as a firm can plan order days for each supplier. However, periodic reviews require higher levels
of safety stock because the time between replenishment periods is longer. A continuous review reduces the amount of safety stock because items can be ordered whenever they are demanded (Silver et al., 2017). However, constantly reviewing items can eliminate coordination between SKUs and cause higher labor costs. There are two main forms of a continuous review policy: the \((s,S)\) system and the \((s,Q)\) system. The \((s,S)\) system, also known as order-point, order-up-to-level states that when inventory position falls below the reorder point \(s\), the firm should order up to the maximum desired inventory \(S\). An \((s,Q)\) policy is similar except that the order quantity \(Q\) is fixed. In this system, when the inventory position falls below the reorder point \(s\), the firm orders a fixed quantity \(Q\). Typically, \(Q\) is the economic order quantity or specific lot size (Silver et al., 2017). Two popular periodic review policies are the \((R,S)\) system and the \((R,s,S)\) system. The \((R,S)\) policy states every \(R\) units of time order enough inventory to raise the inventory position to the desired level \(S\). The \((R,s,S)\) policy goes one step further and states that every \(R\) units of time if the inventory position is below the reorder point \(s\), order up to the desired level \(S\) (Silver, 2017). A third type of inventory policy common in enterprise software is the MRP policy. This is essentially a modified version of the \((R,s,S)\) policy. In this policy, the firm sets a desired level of safety stock, \(s\). Every \(R\) days, they examine their inventory and order enough so that inventory does not fall below \(s\) at the end of that replenishment cycle. For example, assume a firm reviews inventory every Monday and the product is delivered the following Monday. On the first Monday, a replenishment is created such that the inventory will not fall below \(s\) during the period when that product arrives (the second Monday) until the next delivery arrives (the third Monday). In all the policies mentioned above, it is necessary to define the appropriate levels of safety stock. As with inventory policies there are a variety of ways to determine a firm's desired level of safety stock. To name a few, safety stock levels can be set to minimize the backorder costs, minimize the stock out costs, satisfy a minimum amount of demand, or ensure a certain probability of no stock outs (Silver et. al, 2017). Several of these methods require hard-to-measure numbers such as the fixed cost of stock outs or backorders. As mentioned above, the goal of our research is to show the value of changing the levels of safety stock as business needs
change. Therefore, we will calculate safety stock in the same way as RBS by using the cycle service level. A CSL is the probability that no stock out will occur during lead time (Silver et al., 2017). Assuming that demand is normally distributed, safety stock (SS) is set using the equation 2.3.

\[ SS = k \times \sigma_l \]  

(2.3)

Where \( SS \) is safety stock level, \( k \) is the safety stock factor which is calculated from the desired CSL, and \( \sigma_l \) is the standard deviation of demand over lead time. We will show in later sections other methods of calculating \( \sigma_l \) such as standard deviation of forecast error.

3 Methodology

In this section, we discuss our procedure for calculating the effectiveness of dynamic cycle service levels as shown in Figure 3.1. The research is centered on CSL changes for promotional and seasonal periods. To set the business context, we begin with an operational overview of the current inventory system and discuss shortcomings and backdoor solutions. We evaluate the motivation for these backdoor solutions from interviews with management and current inventory analysts. We apply the results of these interviews to construct a decision frame used to set dynamic CSLs. We then show how this decision frame can be incorporated into the inventory policy to set safety stock levels. To evaluate the effectiveness of the decision frame, we simulate the inventory policy using two different simulations. The first simulation uses a system dynamics model created in VenSim software package and the second runs in RBS’ demand planning software (DPS).
Figure 3.1: Methodology to calculate the effectiveness of dynamic cycle service levels in an inventory policy.

### 3.1 Operational Context

To systematically manage the inventory for thousands of items, an inventory system must be able to cope with large variability in demand. Seasonal dependency and frequent promotions drive large spikes in demand and lead to inventory management outside the traditional bounds of the models discussed in Section 2.3. An example of the impact of this variability is shown in Figure 3.2. A majority of the annual demand for this item (shown in orange) occurs in the last two months of the year (highlighted in yellow). The demand in these time periods is up to 8 times higher than the average demand during the rest of the year. To anticipate the increase in demand, inventory managers begin stock piling inventory prior to the season (shown in blue). On hand inventory numbers reach a maximum immediately before the large seasonal spikes begin. Aggressive manual ordering in reaction to an out of stock can lead to twice the average inventory for two months after the...
seasonal/promotional event occurred. This sporadic and manual inventory management is a result of the RBS's current system design.

![Graph showing demand, inventory, and promotional periods for a seasonal item](image)

**Figure 3.2:** Demand, inventory and promotional periods for a seasonal item

### 3.1.1 Current System Design

RBS' inventory management group is responsible for inventory at both retail stores and distribution centers. In this two-echelon system, RBS manages safety stock levels using the following methodology; if retail stores are heavy on inventory, then less safety stock is needed in the DCs. The CSL target for each item at each DC is calculated weekly using the following formula:

\[
CSL = 1 - \frac{1}{365} * (\text{Store Days Extra})
\]  

(3.1)
The following variables are easily measurable at a weekly level: last week’s movement, number of deliveries, minimum shelf presentation, and ending inventory. Combining the above formulas and reducing to only measurable variables gives the following equation for CSL:

\[
CSL = 1 - \frac{\text{Week Ending Inventory} - \text{Minimum Presentation} + \frac{\text{Last Week’s Movement}}{\text{Number of Deliveries}}}{365 \times \text{Last Week’s Movement}}
\]  

(3.7)

While this method can be used to calculate the desired CSL each week using readily available numbers, the results are generally not as desired. Namely, the CSL is based entirely on the prior week’s movement. It
does not address any future fluctuation in demand that may be brought on by holidays or promotions. In practice, the demand management team at RBS sets a floor and ceiling for the CSL. During weekly runs, most items end up at either end of the spectrum (Figure 3.3). This sub optimal policy leads to many manual workarounds.

![Service Level Distribution](image)

Figure 3.3: Current service level distribution of SKUs at RBS' DCs

To have the right products to satisfy customer demand for promotions and holidays, RBS employs manual practices outside of the service level policy outlined above. A typical example is the following policy; if a promotion is one week long, then order the forecasted demand for the week prior to the promo, the promo week, and the week after the promo. Plan to have demand for all three forecasted weeks in the ware-
house nine days prior to a promotion beginning. This policy requires substantial manual intervention and removes any systematic calculation of safety stock. As these items are defined as the "most important," the desired CSLs should reflect this business need.

3.1.2 Interviews and Business Context

We conducted interviews with current purchasing staff and the management team at RBS to gain insight into the classification criteria that should influence CSLs. According to Armstrong (1985), CSLs are typically set by management. Therefore, it was necessary to have business input to ensure compliance and accuracy. The first insight was the criteria that led buyers to deviate from the traditional inventory policy. As expected, promotion and seasonality were the top criteria leading to deviations. The service level agreement between the demand management and category management team requires 99% product availability on all promoted items. Therefore, a backdoor process called a "gap report" is used to meet these requirements. These gap reports use the backdoor inventory policy described above (order X weeks of forecasted demand) and measure the "gap" between current inventory position (on hand + pipeline) and desired inventory (X weeks). Buyers are instructed to "close the gap" prior to promotions beginning. The inventory group presented two additional criteria that led to operating outside of the traditional inventory policy. First, is a criterion that we will call Key Item that meets at least one of the following conditions: The product is displayed in a secondary location, the product must have a high service level due to business or brand purposes. Examples include baby formula or private label cheese.

The second criterion we will call Vendor Dependability which is the vendor's ability to fulfill a spike in demand. Vendor dependability is calculated annually based on promotional fill rates. Vendors are then segmented regarding their historical fill rate performance and assigned a “1” or “0” for dependable or not. In the next section, we show how the classification criteria identified in the interviews can be used to define CSLs.
3.2 Decision Frame

Using the classification criteria from the management interviews (Table 3.1) described in the previous section, we constructed a decision frame to assign discrete desired CSLs to different classes as seen in Figure 3.4. Throughout the year, items will follow different paths in the decision frame depending on their binary values in each of the four classification criteria.

Table 3.1: Overview of the classification criteria used in determining CSL

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
<th>Value</th>
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| Promo (P)         | An item is on promotion resulting in a price reduction| 1 = yes  
                    |                                                      | 0 = no |
| Seasonal (S)      | An item is defined as being “in season”               | 1 = yes  
                    |                                                      | 0 = no |
| Key Item (KI)     | 1. Product is in a secondary location                 | 1 = yes  
                    | 2. Brand or business requirements                     | 0 = no |
| Vendor Dependability (VD) | Vendor consistently delivers critical product (promo, seasonal, KY) in full. | 1 = yes  
                               |                                                      | 0 = no |

For example, an item that is on promotion, in season, a key item, and sourced from a dependable vendor would trace the leftmost path in the decision frame arriving at the leftmost class with a desired CSL of 95%. The CSL is then used to calculate the $k$ factor used to set the safety stock levels.

Figure 3.4: Decision frame for 16 possible outcome classes
The CSL values in Figure 3.4 were set by the current management group and can be adjusted as business needs change. In the next section we show how this decision frame is incorporated into the inventory policy.

### 3.3 Inventory policy

The inventory policy that we use in our simulations is the MRP policy presented in Section 2.3. We define inter-delivery time as the time between two subsequent deliveries. This policy states that every $R$ days an order should be placed such that the inventory levels during the inter-delivery time do not fall below a desired level of safety stock. In this section we will walk through the ordering flow of this inventory policy and show how the decision frame is used to impact the safety stock levels.

#### 3.3.1 Ordering Flow

In the MRP inventory policy, inventory flows from an order to pipeline inventory and then to on hand inventory after a specified lead time. When stores demand an item from DC, either inventory flows out as sales or demand is lost if it is greater than the on-hand inventory as seen in Figure 3.5. The flow begins with the setting of a purchase order (Order). Then suppliers initiate their shipment process, and the amount in the order enters the pipeline inventory, remaining in that status until the order is received (Lead Time). For consistency in simulations, the model assumes that all orders arrive on time and in full. The inventory levels are affected by the number of orders received, and outbound sales are represented below by demand filled. Demand in this policy is store orders and sales are the shipments from the warehouse to the stores.
Figure 3.5: Ordering flow from supplier to store

Figure 3.6 shows the ordering flow, which is based on the calculations using the MRP policy. The flow is as follows:

The first step in the MRP policy is to determine whether or not each day is an order day. This is set by the $R$ value or review time.

If it is an order day, we first calculate what our inventory will be when the delivery arrives ($Inventory$ at $Lead Time$). This is the difference between our inventory position ($Pipeline + On Hand Inventory$) and the forecast between now and when the delivery arrives ($Forecast over Lead Time$).

We then calculate how much inventory is needed between when this order arrives and when the next order arrives ($Product Needed$). This is the sum of the safety stock and the forecast values for that period ($Forecast at Lead Time between Replenishment Time$).

If the quantity needed ($Product Needed$) is greater than the inventory at lead time, we order the difference. If not, then no order is created.
For the safety stock calculation, we can either use Standard Deviation of Demand or of Forecast error. After choosing which to use, a measure for standard deviation over review time is calculated by multiplying the square root of the days between review time by either the standard deviation of demand or the standard deviation of forecast error (Figure 3.7). This result is then multiplied by the k factor to set the safety stock level.

\[
\text{Standard Deviation over Review Time} = \text{Standard Deviations} \times \sqrt{\text{Days Between Review Time}} \tag{3.1}
\]
Recall from Equation 2.3 that safety stock is equal to the safety stock factor $k$ multiplied by the standard deviation over lead time. The $k$ value is defined according to the desired CSL. For the desired CSL we can choose from a fixed service value used in the current company policy or the CSL assigned to an item's class in the decision frame as seen in Figure 3.3. The intention behind using the frame is to dynamically change the service level according to the item class during each order cycle (Figure 3.8). Namely, when an item is promoted and in season, it will have a different desired CSL than when it is not.

### 3.3.2 Decision Frame in Safety Stock Calculation

Figure 3.7: Calculation of the standard deviation used to set safety stock.
Flow to assign desired service levels

Based on the item position in the decision frame shown in Figure 3.4, it is assigned to a service level class. At each review time, the item’s classification criteria are reviewed and it is assigned to a specific service level class that sets the $k$ factor. Items can also be assigned to a fixed service level.

The $k$ value calculation uses the maximum CSL value during the order cycle time, or, if it is fixed, the predetermined value. The CSL is then used to set the $k$ factor (Figure 3.9). The $k$ value is then multiplied by the standard deviation over lead time to set the desired level of safety stock.

Figure 3.8: Flow to assign desired service levels

Figure 3.9: Calculation of the $k$ factor used to set the safety stock.
This inventory policy has dynamic safety stock levels determined by the desired CSLs set through the decision frame. In the next section we describe the simulations used to test the impact of this inventory policy.

3.4 Simulation

To evaluate the impact of dynamic CSLs, we use two types of simulations as a system dynamics model and a simulation through RBS’ forecast and replenishment software DPS. The system dynamics model uses the exact flows outlined in the previous section. This model allows a user to easily adjust service levels throughout the year and see immediate impacts on product availability and inventory. However, the system dynamics model is limited in that it is only a model and cannot be used to create actual replenishment orders. DPS allows for a wide variety of simulations using production data and results can be used directly in production. Each simulation used actual historical data for starting inventory position, forecasted demand, store orders, lead time, review time, and standard deviation. The models then simulated the inventory levels through different CSL settings. Both simulations first model the results of the inventory policy when using fixed CSLs throughout the year. We then vary the method of calculating standard deviation between demand and forecast error. Next, we simulate the impact of using dynamic CSLs according to the decision frame. Finally, we simulate the impacts of using dynamic CSLs that are different from the decision frame. In the following sections we present the parameters used in the system dynamics and DPS simulations.

3.4.1 System Dynamics Model Parameters

We selected five items for our initial simulation using the system dynamics model. Throughout the simulated time period, items needed to have frequent changes in importance that would merit service level changes. We also selected items based on their seasonal variability and dramatic changes in importance throughout the year. Finally, as RBS stores forecast data for two years, we considered the items with com-
plete records. Figure 3.10 shows a plot of the coefficient of variation (CoV) versus the weekly demand for the selected items shown as yellow stars. A list of demand attributes for the simulated items is shown in Table 3.2.

**Figure 3.10: Coefficient of variation vs. weekly demand for system dynamics simulation**
We ran each simulation for the maximum amount of time for which data was available. The goal was to understand the long-term implications of the dynamic policy, so more data was advantageous. For each item, we tested the impact of using the standard deviation of demand versus the standard deviation of forecast error when calculating the safety stock levels. Following DPS’ policy, we calculated the standard deviation of each of these parameters using the last 180 days of data. In each simulation we used a lead time of 7 days and a review time of 7 days. These variables can be manipulated in the simulation if agreements with vendors change. In reality, vendor lead times can vary and, when under pressure, orders can be placed whenever they are needed. However, in order to isolate the impact of dynamic CSLs, it was necessary to fix both of these variables throughout the simulation. The final parameter was that demand that cannot be fulfilled directly from inventory is lost and not backordered. This assumption follows what RBS does in practice.

### 3.4.2 DPS Simulation Parameters

Due to constraints on available data in the DPS system, we selected different items for these simulations than those used in the system dynamics model. However, our criteria for item selection remained the same. Namely, items needed complete records, needed to be fast and slow movers, and needed to have varying levels of importance.
throughout the year. Using two years of historical sales data, we exam-
ined items with respect to their CoV and the total movement for two 
years (Figure 3.11). We extracted two years of data because that is the 
amount of historical data that RBS uses for forecasting activities. Any 
items that did not have at least 60 weeks of movement were removed 
from the selection process. Demand attributes for the selected items 
are shown is Table 3.3.

Table 3.3: Demand attributes for items in DPS simulations

<table>
<thead>
<tr>
<th>Demand Pattern</th>
<th>Average</th>
<th>Standard Deviation</th>
<th>CoV</th>
<th>Service Level</th>
<th>Standard Deviation Method</th>
<th>Days on Promotion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast mover</td>
<td>2667</td>
<td>900</td>
<td>0.33</td>
<td>A – 0.95</td>
<td>Forecast Error</td>
<td>68</td>
</tr>
<tr>
<td>Highly Variable – Slow</td>
<td>162</td>
<td>133</td>
<td>0.82</td>
<td>B – 0.90</td>
<td>Demand</td>
<td>18</td>
</tr>
<tr>
<td>Highly Variable – Slow</td>
<td>1232</td>
<td>334</td>
<td>0.27</td>
<td>A – 0.95</td>
<td>Forecast Error</td>
<td>75</td>
</tr>
<tr>
<td>Slow Mover</td>
<td>5</td>
<td>1</td>
<td>0.18</td>
<td>C – 0.85</td>
<td>Demand</td>
<td>0</td>
</tr>
<tr>
<td>Steady – Slow</td>
<td>174</td>
<td>25</td>
<td>0.14</td>
<td>A – 0.95</td>
<td>Forecast Error</td>
<td>90</td>
</tr>
<tr>
<td>Steady – Fast</td>
<td>255</td>
<td>40</td>
<td>0.15</td>
<td>A – 0.95</td>
<td>Forecast Error</td>
<td>90</td>
</tr>
</tbody>
</table>
In the system dynamics model, the CSL for the base case was fixed at a predetermined value. However, in the DPS simulations we used the actual desired service levels from ABC segmentation. This method of segmentation follows the Pareto model of demand volume as discussed in Section 2.2. In our simulation, all items in this product category are organized based on their sales quantity. Items are partitioned into the following groups based on demand: top 75%, middle 15%, and bottom 10% as A, B, C respectively. Corresponding service levels are assigned to each group \{A, B, C\} = \{95, 90, 85\}. As we discussed in the previous section, we simulate two different methods to calculate the standard deviation used in the safety stock calculation: demand and

---

**Figure 3.11**: Coefficient of variation vs. average weekly shipments for DPS simulation

In the system dynamics model, the CSL for the base case was fixed at a predetermined value. However, in the DPS simulations we used the actual desired service levels from ABC segmentation. This method of segmentation follows the Pareto model of demand volume as discussed in Section 2.2. In our simulation, all items in this product category are organized based on their sales quantity. Items are partitioned into the following groups based on demand: top 75%, middle 15%, and bottom 10% as A, B, C respectively. Corresponding service levels are assigned to each group \{A, B, C\} = \{95, 90, 85\}. As we discussed in the previous section, we simulate two different methods to calculate the standard deviation used in the safety stock calculation: demand and
forecast error. Based on business requirements, RBS has configured the
DPS system such that items that have been on promotion for more
than 108 out of the last 180 days use the standard deviation of forecast
error to set safety stock. Forecast error is calculated daily at the item-
location level and 180 days are used to calculate standard deviation.
For items that are not highly promoted, the safety stock calculation us-
es the standard deviation of demand for the last 180 days. The ration-
ale is that highly promoted items are more difficult to forecast and
therefore require additional safety stock. In the DPS system, we ran 16
different simulations. For each simulation we ran it for three different
120-day time periods (Table 3.8). Simulations were broken into three
different groups as following; base case, dynamic, and extreme. The
base case used all items and current system settings. Using the base
case service levels, we also ran simulations with the two different stan-
dard deviation calculations to understand the impacts of each. In the
dynamic simulations, we evaluate the impact of having a higher de-
sired service level during promotional time periods and ABC segmen-
tation when not promoted. Finally, in the extreme simulations, we ig-
nore the ABC values and set all non-promoted items at a base service
level of 80%. Using the values from the decision frame, we change ser-
vice level to 96% when items are on promotion. After each simulation
we measure the inventory levels, item fill rate, and lost sales. These
are standard metrics used by RBS to evaluate performance. We compare
these results across the different methods of calculating standard devi-
ation and the fixed and dynamic CSLs.

1. Fill Rate = Total Sales / Total Orders
2. Average Week Ending Inventory: The average inventory value on the
   last day of the financial week (Saturday)
3. Lost Sales: If demand is less than inventory then sales are lost

4 Results

In this section we examine the results of the simulations using the sys-
tem dynamics and DPS models. We first present the differences be-
tween the two standard deviation calculations. Next, we look at the
impact of using a dynamic service level from the decision frame. Final-
ly, we show the impact of using dynamic CSLs with values different from the decision frame.

4.1 Standard Deviation of Demand or Forecast Error

The first test using the simulations was to look at the results of using the standard deviation of demand versus using the standard deviation of forecast error. As stated earlier, DPS uses the standard deviation of forecast error to set safety stock levels for highly promoted items. Items that are promoted are typically more difficult to forecast and, therefore, should require higher levels of safety stock to maintain high fill rates. Regarding the average inventory position, setting safety stock levels using the standard deviation of demand led to an average inventory reduction of 5% for 4 out of the 5 items in the system dynamics simulation (Table 4.1). Item 6180 showed a 1% increase in inventory levels using the standard deviation of demand. This result follows from the item selection in that, of all the items selected, the forecast accuracy for item 6180 was the highest. The fill rate followed in that 4 out of the 5 items experienced a lower fill rate using the standard deviation of demand. On average across all items and tests, the fill rate was 1% lower using the demand calculation. Again, item 6180 experienced the opposite due to the relative accuracy of the forecast and higher inventory position. The fill rate improvement for item 6180 was less than 1%.

Table 4.1 - % Difference between the standard deviation of demand and the standard deviation of forecast error using the system dynamics simulation

<table>
<thead>
<tr>
<th>Item</th>
<th>Inventory Change</th>
<th>Fill Rate Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>6180</td>
<td>1.73%</td>
<td>0.10%</td>
</tr>
<tr>
<td>80760</td>
<td>-5.90%</td>
<td>-2.14%</td>
</tr>
<tr>
<td>355440</td>
<td>-4.28%</td>
<td>-0.27%</td>
</tr>
<tr>
<td>598640</td>
<td>-4.68%</td>
<td>-0.34%</td>
</tr>
<tr>
<td>698260</td>
<td>-4.74%</td>
<td>-0.35%</td>
</tr>
</tbody>
</table>
In the DPS simulation, the top moving item had a significant inventory reduction when using the standard deviation of demand instead of forecast error. However, this inventory reduction resulted in a 14% reduction in product availability. In this case, the additional safety stock matches the importance of the item. On the two steady moving items, using the standard deviation of demand instead of forecast error led to an inventory reduction while still maintaining the same product availability. From these simulations, items with high velocity or high variability benefited the most from using the standard deviation of forecast error.

Table 4.2: % Difference between the standard deviation of demand and the standard deviation of forecast error using the DPS simulation

<table>
<thead>
<tr>
<th>Demand Pattern</th>
<th>Default Setting</th>
<th>Inventory Change</th>
<th>Fill Rate Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast mover</td>
<td>Forecast Error</td>
<td>-36%</td>
<td>-14%</td>
</tr>
<tr>
<td>Highly Variable – Slow</td>
<td>Demand</td>
<td>-13%</td>
<td>-1%</td>
</tr>
<tr>
<td>Highly Variable – Slow</td>
<td>Forecast Error</td>
<td>-37%</td>
<td>-4%</td>
</tr>
<tr>
<td>Slow Mover</td>
<td>Demand</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Steady – Slow</td>
<td>Forecast Error</td>
<td>-10%</td>
<td>0%</td>
</tr>
<tr>
<td>Steady – Fast</td>
<td>Forecast Error</td>
<td>-7%</td>
<td>0%</td>
</tr>
</tbody>
</table>

4.2 Fixed vs. Dynamic Cycle Service Levels

We tested adjusting service levels at key times of the year to see the impact on inventory and product availability. First, using the system dynamics model, we demonstrated that using dynamic CSLs can reduce the average amount of inventory while still maintaining a high fill rate. For each item, the highest fill rate and also highest level of inventory came through fixing the service level at 99%. In the case of item 6180, where the forecasts were relatively accurate, the dynamic model produced a 24% reduction in inventory over fixing the service level at 99% while still fulfilling 97% of the demand filled by the 99% service level (Figure 4.1)
On average, the dynamic CSLs allowed the items to achieve a fill rate above the fixed 90% simulation while carrying less inventory (Table 4.3). Further adjusting the service levels in the decision matrix could improve fill rates even more, but at the expense of extra inventory.

Table 4.3: The average inventory positions and fill rates for all items in the system dynamics model.

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Average Inventory</th>
<th>Average Fill Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Demand</td>
<td>424.5</td>
<td>86.57%</td>
</tr>
<tr>
<td>Fixed 80 Demand</td>
<td>394.5</td>
<td>84.49%</td>
</tr>
<tr>
<td>Fixed 85 Demand</td>
<td>409.2</td>
<td>85.26%</td>
</tr>
<tr>
<td>Fixed 90 Demand</td>
<td>428.5</td>
<td>86.15%</td>
</tr>
<tr>
<td>Fixed 95 Demand</td>
<td>457.5</td>
<td>87.32%</td>
</tr>
<tr>
<td>Fixed 99 Demand</td>
<td>512.8</td>
<td>89.24%</td>
</tr>
</tbody>
</table>

In the DPS simulation, we tested the dynamic model against the current system configuration. The dynamic model used service levels of ABC items, if the item was not promoted and a 98% service level when the item was on promotion. As expected, there was not a dramatic
change in the highly promoted items as the ABC service level was already 95%. Across all items, the dynamic model raised product availability 0.6%, inventory 3.1%, and reduced lost sales by 2.9% (Table 4.4).

Table 4.4: Change in availability, inventory, and lost sales between the dynamic model and the baseline model in DPS.

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Days on Promotion</th>
<th>Service Level</th>
<th>Demand Pattern</th>
<th>Availability Change</th>
<th>Inventory Change</th>
<th>Lost Sales Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>3582609097</td>
<td>79</td>
<td>0.95</td>
<td>Fast mover</td>
<td>2.8%</td>
<td>3.1%</td>
<td>-3.6%</td>
</tr>
<tr>
<td>4154803485</td>
<td>27</td>
<td>0.90</td>
<td>Highly Variable – Slow</td>
<td>0.3%</td>
<td>0.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>3582608913</td>
<td>110</td>
<td>0.95</td>
<td>Highly Variable – Fast</td>
<td>0.6%</td>
<td>6.3%</td>
<td>-1.6%</td>
</tr>
<tr>
<td>7524320345</td>
<td>0</td>
<td>0.85</td>
<td>Slow Mover</td>
<td>0.0%</td>
<td>0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>8793260155</td>
<td>130</td>
<td>0.95</td>
<td>Steady – Slow</td>
<td>0.0%</td>
<td>5.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>8793200257</td>
<td>130</td>
<td>0.95</td>
<td>Steady – Fast</td>
<td>0.6%</td>
<td>4.0%</td>
<td>-4.9%</td>
</tr>
<tr>
<td>Total Change</td>
<td></td>
<td></td>
<td></td>
<td>0.6%</td>
<td>3.1%</td>
<td>-2.9%</td>
</tr>
</tbody>
</table>

4.3 Improvements on Dynamic Cycle Service Levels

Our initial dynamic CSLs used the decision frame inputs from inventory managers and buyers at RBS. In our next set of simulations, we sought to adjust those dynamic levels to see if we could maintain the same service while decreasing the overall inventory levels. For each item, we ran a baseline model using the current service level set by the RBS replenishment system. Next, we changed the service level from fixed to dynamic and adjusted the levels in the decision framework. The goal of these simulations was to produce the lowest level of inventory, while maintaining a service level that was the same or better than the baseline simulation.
Table 4.5: Inventory reductions using dynamic CSLs in the system dynamics simulation

<table>
<thead>
<tr>
<th>Item</th>
<th>System Determined Fixed Service Level</th>
<th>Simulated Average Inventory with Fixed Service Level (Cases)</th>
<th>Simulated Average Inventory with Dynamic Service Level</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>6180</td>
<td>0.97</td>
<td>476</td>
<td>391</td>
<td>-18%</td>
</tr>
<tr>
<td>80760</td>
<td>0.97</td>
<td>172</td>
<td>170</td>
<td>-2%</td>
</tr>
<tr>
<td>355440</td>
<td>0.83</td>
<td>723</td>
<td>663</td>
<td>-8%</td>
</tr>
<tr>
<td>598640</td>
<td>0.935</td>
<td>336</td>
<td>310</td>
<td>-8%</td>
</tr>
<tr>
<td>698260</td>
<td>0.873</td>
<td>232</td>
<td>218</td>
<td>-6%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1940</td>
<td>1752</td>
<td>-10%</td>
</tr>
</tbody>
</table>

Through adjustments in the decision frame, we were able to reduce overall inventory while maintaining the same service levels as the fixed policy. In the original decision frame presented in Figure 3.4, the class in which an item was not promoted, critical, or in season had a desired cycle service level of 80%. This class was representative of items that did not have any special importance to the business and, therefore, presented an opportunity to lower inventory. We found that in many cases this number could be reduced substantially with little impact on the product fill rate. The fixed policy forced items to carry high levels of safety stock when the business did not necessitate it. Adjusting the service levels to reduce inventory and maintain fill rates led to higher inventory during the important promotional times and lower overall inventory in the non-promoted times. In the DPS simulations, we were not able to actively adjust service levels to find the best tradeoff between service and inventory. The service level frame needed to be set before running each simulation. Therefore, based on the results of the system dynamics model, we tested an extreme scenario in which desired promotional CSLs were 96% and CSLs at all other times were 80%. We found that on items with many promotions, the service level decreased slightly (0.3% and 0.6%) while the overall inventory reduced by 5.3% and 5.1%, respectively (Table 4.6). However, this reduction led to a 50% increase in the number of lost sales throughout the different simulations. For the fast-moving item, this policy led to a significant
reduction in inventory (19.1%) with a 3.1% reduction in product availability. Depending on the importance of the item, the decrease in inventory could justify the increase in lost sales. In the next section we present a strategy for how to think about these tradeoffs in practice.

Table 4.6: Comparison between extreme dynamic model and the base case in DPS

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Days on Promo</th>
<th>Service Level</th>
<th>Demand Pattern</th>
<th>Availability Change</th>
<th>Inventory Change</th>
<th>Lost Sales Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>3582609097</td>
<td>79</td>
<td>0.95</td>
<td>Fast mover</td>
<td>-3.1%</td>
<td>-19.1%</td>
<td>11.1%</td>
</tr>
<tr>
<td>4154803485</td>
<td>27</td>
<td>0.90</td>
<td>Highly Variable – Slow</td>
<td>1.1%</td>
<td>0.3%</td>
<td>3.3%</td>
</tr>
<tr>
<td>3582608913</td>
<td>110</td>
<td>0.95</td>
<td>Highly Variable – Fast</td>
<td>0.7%</td>
<td>-11.0%</td>
<td>9.9%</td>
</tr>
<tr>
<td>7524320345</td>
<td>0</td>
<td>0.85</td>
<td>Slow Mover</td>
<td>-9.9%</td>
<td>0%</td>
<td>50.0%</td>
</tr>
<tr>
<td>8793260155</td>
<td>130</td>
<td>0.95</td>
<td>Steady – Slow</td>
<td>-0.3%</td>
<td>-5.3%</td>
<td>50.9%</td>
</tr>
<tr>
<td>8793200257</td>
<td>130</td>
<td>0.95</td>
<td>Steady – Fast</td>
<td>-0.6%</td>
<td>-5.1%</td>
<td>50.1%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>-0.4%</td>
<td>-9.4%</td>
<td>9.9%</td>
</tr>
</tbody>
</table>

5 Discussion

Through simulation, we showed that dynamic CSLs could reduce inventory levels while still delivering a high level of service. However, inventory reductions often result in some tradeoff of service or increase in lost sales. In this section, we show how to use the system dynamics model to minimize these tradeoffs. We then comment on the types of items that benefit from using a dynamic CSL.

5.1 System Dynamics Model in Practice

The system dynamics model creates value by providing immediate feedback on management decisions. Additionally, due the model visu-
ally represents the dynamics of a firm's inventory policy. Therefore, it is easy to understand how different variables in the model interact. The data necessary to run these simulations (historical forecasts, store orders, and item classifications) should be readily available from most companies. Therefore, management can quickly simulate results for different items to understand the tradeoffs between service and inventory. This model provides insights into where inventories can be lowered while still maintaining desired CSLs. Below is a four-step methodology to set and modify CSLs.

1. Define classes and set desired CSLs. As a first step, determine, with the key stakeholders, which classification criteria are most important in setting CSLs. Using these classification criteria, build a decision frame as shown in Figure 3.4. Leveraging management’s expertise, assign service levels to the different classes in the decision frame.

2. Collect data on items and their classification criteria. Collecting some types of data in an optimal quantity and quality can be challenging. Therefore, it is important that the classification criteria defined in the previous step are easy to record and trace.

3. Select representative SKUs for testing. Representative SKU’s fall in several different desired CSLs classes throughout a given time window. Some important demand attributes in selecting items are coefficient of variation, promotional frequency, and frequency of manual orders.

4. Run simulations and adjust the initial values in the decision frame to achieve the desired results.

**5.1.1 Operations of System Dynamics Model**

The model can be used to give the company a better understanding of the dynamics of the purchase orders and inventory levels, and to help the decision maker define the best policies for the purchase order process. First, we present the operational dashboard for the model and then explain how to run simulations. Figure 5.1 shows the operational dashboard of the system dynamics model. The model includes a decision frame, output graphs, and a series of different switches. The switches can be used to adjust CSLs for different classes, switch from a
fixed to a dynamic inventory policy, and determine which standard deviation measure to use. The decision frame is at the top and is originally set with the default values defined by management. However, during simulations, these values can be adjusted using the sliders for each class. The output graphs will help with the understanding of the dynamics of the simulation and to make the adjustment to the variables. The graphs that we included in the model are:

1. **Inventory Levels (total, regular and promotional):** Average inventory level segmented by total, regular and promotional.
2. **Stock outs:** Number of days with an inventory level of 0 units.
3. **Service level (fill rate):** Percentage of sales compared with total demand along all the simulations.
4. **Item status & fill rate:** Fill rates of the different item classes during simulation.
5. **Demand vs. forecast:** Levels of demand and forecast demand along all days in the simulation.
6. **Service level (fill rate over time):** Fill rate levels at each point of time in the simulation.
7. **Sales, lost sales and inventory:** Levels of sales, lost sales and inventory at each point of time in the simulation.

Using the switches below each class in the decision frame we can adjust the variables to improve the results in the inventory performance namely, fill rate and inventory levels. The switches give us the option to make the next changes:

1. Choose from a fixed CSL to dynamic.
2. Set the value for the fixed CSL.
3. Choose from standard deviation of demand to standard deviation of forecast error.
4. Adjust the values for each dynamic CSL class.

To run the simulations, we follow the procedure used in Section 4.3 and recommend using the following steps to find the best policy for the simulated item.

*Step 1:* Run a simulation with a fixed desired CSL.
*Step 2:* Adjust the fixed desired CSL and switch for standard deviation to achieve a desired fill rate and inventory.
Step 3: Run a simulation with the dynamic CSL frame and the standard deviation used in the previous simulation (Step 2).

Step 4: Adjust the CSLs for each class in the decision frame until fill rate meets the values in Step 2.

Step 5: Continue to adjust the CSL for each class to minimize the amount of inventory carried while maintaining the same fill rate from Step 2. The previous steps will give the insights to set a new policy for CSLs.

5.2 Benefits of Using Dynamic Cycle Service Levels

Setting dynamic CSLs makes sense in situations when demand management groups disregard inventory policies due to fear of running out of stock. These situations can include seasonal transitions or critical promotions. A dynamic policy accounts for the important factors that lead to manual orders. Given that the management teams provided the factors used to set the dynamic CSLs, this policy creates additional trust in the system and, ideally, reduces the need for manual interventions. As business priorities change and buyer groups feel the need to deviate from a system, it is important to understand the underlying causes for these changes. Reexamining the decision frame and incorporating these new classification criteria can help realign the buying practices with the business priorities. As shown through the simulations, a dynamic frame increases safety stock based on the importance of the item and reduces it when the item is less important. This was shown to reduce overall inventory and thus free up working capital that could be reinvested into other parts of the business. Using dynamic CSL does not necessarily make sense in every business context. For example, there are certain external opportunities such as forward buys or limited product availability that may require a firm to deviate from this model. Finally, as with all inventory policies, it is important to remember that strong inputs lead to strong outputs. Therefore, forecast accuracy is also critical in maintaining high service levels. While a dynamic policy provides extra safety against demand variability, inaccurate forecasts will also lead to out of stocks. In the simulations in which a 99% CSL was desired, out of stocks still occurred due to forecast in-
accuracies. When there is high variability in forecasts, it makes sense to use the standard deviation of forecast error as an additional buffer in safety stock.

6 Conclusion

This research demonstrates the advantages that a firm can achieve by using dynamic CSLs. Inventory management is a constant balancing act. If a firm carries too much inventory, working capital is tied up and cannot be invested into other areas of the business. By carrying too little inventory, a firm risk missing sales and losing customer goodwill. Traditionally, safety stock levels have been fixed throughout the year depending on a single criterion, demand volume. This often leads to manual intervention and correspondingly high levels of inventory. Our research demonstrates the value of catering safety stock levels to the underlying needs of the inventory managers. By establishing a safety stock framework that meets the priorities of the business, a firm can lower their inventory levels and reduce manual intervention while maintaining a high level of service. This framework can be applied to any business that carries inventory of variable importance throughout a year. The current framework is limited in that it handles service level variations for only one item at a time and the optimal tradeoffs between inventory and service are up to the user. An obvious area for future research would be applying these dynamic techniques across entire segments of items. Instead of fixing service levels by segment, as is typically done, a dynamic framework could be assigned to each segment. The service levels for each segment could be assigned through an optimization in which the highest service level is achieved given a predefined budget for inventory. This could be shown as a preferred technique to the traditional ABC methods. The dynamic model provides unique value in that it takes input from the key decision makers to come up with the best levels of safety stock. Through our research we found that trust in an inventory management system is essential to ensuring that rules are followed and inventory levels are correct. Dynamically setting service levels that can adapt to changing business needs ensure that a firm has the right inventory at the right time.
7 References


8 Key Terms

<table>
<thead>
<tr>
<th>Cycle Service Level</th>
<th>Safety Stock</th>
<th>Lead Time</th>
<th>Inventory Management</th>
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<td>Decision Frame</td>
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<td>Dynamic Policy</td>
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<td>ABC Classification</td>
<td>SKU Segmentation</td>
<td>K factor</td>
<td>MRP Policy</td>
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9 Questions for Further Study

Supposed a firm could improve their forecast accuracy on promoted items. How would this affect the levels of safety stock needed?
Discuss the relative benefits of the two types of simulations. Which is better at representing reality? Which would you recommend for decision making?
What additional exogenous factors would lead a firm to want to carry more safety stock?
Given the average tenure of your procurement team is 20+ years, describe an approach to effectively implement this type of policy change. How would you approach these discussions? What could you do to limit manual ordering?

10 Exercises

Using equation 3.7 calculate the desired CSL for an item with 3 units of inventory, a minimum presentation of 2, last week’s sales of 10 and 1 delivery per week. Try varying each factor one at a time. What shortfalls can you identify with this system?
Suppose you are running a first-time promotion on a new to market product. Describe how you would determine the appropriate level of safety stock. Would you allow manual ordering? How would you determine the right strategy for this item?
What effect does lead time have on the levels of safety stock? Does a 50% increase in lead time effect safety stock the same as a 50% decrease in forecast accuracy?

Discuss the classification criteria in Table 3.1. Provide an operational overview of how these criteria could be determined and with what frequency. Would you recommend using all of these criteria? Are there criteria that are missing?

11 Further Reading


Serpil Erol, Gül Didem Batur Sir

Industry 4.0: Is Your Country Ready?

“God, grant me the serenity to accept
the things I cannot change,
the courage to change the things I can,
and the wisdom to know the difference.”
Reinhold Niebuhr

Learning Objectives

The objectives of this chapter are to define the main preconditions and to give a roadmap for the implementation of Industry 4.0. Once you have mastered the materials in this chapter, you will be able to:

– Discuss the readiness of countries for the 4th industrial revolution.
– Explain the challenging tasks to be met in order to implement the concept.
– Identify the necessary preconditions and predispositions for being ready for Industry 4.0.
– Apply the evaluation steps to any country taking action plans.
– Analyze the countries and/or economies according to their readiness for Industry 4.0.

Chapter Outline

Industry 4.0 is the contemporary phenomenon of today’s world. Many of the leading economies make researches over the subject and prepare strategies in order to have a successful transition to this new era. Together with rapid technological developments, digitalization and mass customization, applications of Industry 4.0 get more attention in industrialized countries, especially in the last decade. Many industrialized countries have adapted their strategies according to Industry 4.0 in order to increase their competitive skills and to be efficient across the global production environments. There are challenging tasks that
have to be met as regards in order to implement this concept accurately. The Industry, Report and Energy Report which was requested by the European Parliament’s Committee on Industry, Research and Energy defines these tasks as standards, work processes and organization, availability of products, new business models, security and IP protection, availability of workers, research, training and professional development and the legal framework. Within the scope of this chapter, the readiness to this process, which is a strategic decision, is taken under consideration. The subject is evaluated, considering the necessary preconditions and predispositions of Turkey and any other country as well.

**Keywords**

Industry 4.0, Readiness for Industry 4.0, Roadmap, Preconditions, Industrial revolution, Digitalization.

**1 Introduction**

Industry 4.0 is a concept that emerged in Germany in 2011 and is considered as a rising trend all over the world because of the economic and social benefits it will provide and will directly affect the level of development of countries. The fourth industrial revolution has become one of the most popular topics the past few years, with governments and industries around the world realizing the rise in research on the Internet of Things (IoT) and Cyber-Physical Systems (CPS) and taking action to benefit from the advantages of this new wave of the industrial revolution. One of the most persuasive arguments in the emergence of Industry 4.0 lies in its ability to shift global production, which is directed at countries with low labor and other resource costs, especially in the Far East, due to production costs, to the developed western countries. Looking at the last 20 years, it can be seen that due to the low costs, the productions made in the west are transferred to countries where cheap labor is abundant. Depending on this situation, it is observed that western countries are experiencing global market share losses of around 10% due to low-cost economic transfers from some other sources. How can global production be possible again in the west, where the costs are quite high? Industry 4.0 is the term used for a digi-
tal revolution in which a highly qualified human resource plays a central role. At this point, one of the unique tricks of the battle is the presence of qualified human resources. Analyzes demonstrate that unit production costs can be inferior in productions made with highly qualified labor, intelligent robots, and autonomous systems and can be equalized, as is the case in countries where labor costs are low. In 2018, 2.3 million units of robots were expected to be used in the industry. It is stated that the developments in the field of robotics in particular trigger the formation of intelligent production systems in the production sector. With intelligent production systems, it is aimed to provide customized, intelligent production, improved production quality, less error production, less waste, more localized manufacturing processes, faster innovation processes and fewer resources that respond more and more quickly to customer preferences and needs. It is estimated that in 2020, approximately 50 billion devices will be in communication with each other. The network of intelligent manufacturing systems, intelligent cities, homes, logistics, networking, networking of device elements with social networks and e-commerce networks will result in a network of ecosystems that will use the internet environment of services, objects, and individuals, which is expected to affect about 46 percent of the global trade volume in the next quarter century. The European Union adopts the goal of 2020 to move the industry’s gross domestic product share from 15 percent of the current situation to 20 percent. The European Commission is investigating how the Fourth Industrial Revolution in industries transforms production, logistics, and consumption models. The prepared action plan includes the strategy that Europe will set on digitalization, cyber-physical systems, cloud computing, artificial intelligence, internet of things, and robotic systems. The European Union, which supports the digital transformation of the industry, has many initiatives to compete locally and nationally. The European Commission is developing the most appropriate strategy to bring these initiatives to the next level. Under the heading of digitalizing the European industry, the focus is on the action plan related to the following subjects: Facilitate access of all industrial companies to digital technology, to prepare the basis for the creation of digital industry platforms in Europe, to keep the workforce ready to
benefit from digital transformation to provide appropriate solutions for the widespread adoption of intelligent industry.

Countries should decide how best to use national strategies and production capacity as a capability in this new production paradigm. To this end, countries should consider the factors and conditions that are most influential in the transformation of production systems and assess whether they are ready for the future or not. After that, governments can work together with industry, academia, and civil society to implement appropriate actions. This chapter focuses on the factors that determine countries' readiness for the Industry 4.0 process. In Section 2, the issue is assessed, considering the prerequisites and trends related to this subject. In Section 3, an assessment is presented for Turkey. It is also possible that the evaluation can be applied to any other country. Section 4 is devoted to the final remarks and suggestions.

2 Readiness for Industry 4.0

Although Industry 4.0 has entered our lives as a concept, the existence of serious uncertainties surrounding the development and adoption of new technologies means that we do not yet know how transformations driven by this new industrial revolution will evolve. While there is a vast network of communication, numerous information and data, internet of things that is rapidly continuing to shape our whole life and the access to the big data that is obtained thanks to these developments; those who do not know how to use all of them will, unfortunately, be out of the system in the future. Mueller et al. argue that although there is no doubt about the probable advantages of Industry 4.0, there must be answers to questions such as "What are the application areas of the Industry 4.0", "How should the Industry 4.0 be implemented?" and "Which perspectives should be considered". When considered as a revolution, they argue that the concept of Industry 4.0 has been criticized for "inadequacy of details". Furthermore, another critical shortcoming is that; although joint research has been carried out, the conclusions of the Industry 4.0 surveys have stated that a reference architecture with a detailed view of the practical application is very generic. (Mueller et al., 2017). Gentner (2016) stated that even though

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many countries have an action plan for Industry 4.0, the vast majority of ideas are still unclear. He discussed what is real, what ideas are likely to be real in the future, and what ideas will remain to be defined as science fiction. (Gentner, 2016). The final report of the Industry 4.0 Working Group, "Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0" is now the most cited and accepted reference study to Industry 4.0. Kagermann et al. discussed the three integration features required for Industry 4.0 (horizontal integration through value networks, end-to-end digital integration of engineering across the entire value chain, and vertical integration and networked manufacturing systems), and put forward eight priority business plans for these integrations to be realized. These areas are given as follows (Kagerman et al., 2013): Standardization and open standards for a reference architecture, managing complex systems, delivering a comprehensive broadband infrastructure for industry, safety and security as critical factors for the success of Industrie 4.0, work organization and work design in the digital industrial age, training and continuing professional development for Industrie 4.0, regulatory framework, resource efficiency. In recent years, governments and industries around the world are aware of this trend and are actively taking advantage of this new wave of the industrial revolution (Ridgway et al., 2013; Siemieniuch et al., 2015). In this framework, many countries have prepared action plans (Liao et al., 2017): From the government plans perspective, since 2011, the United States government has begun national-level discussions, actions, and recommendations to ensure that they are ready for the next generation of production (Rafael et al., 2014). In 2012, the government of Germany adopted an action plan, which sets a billion-euro budget each year for the development of the most advanced technologies (Kagermann et al., 2013). In 2013, the French government initiated a strategic review process called “La Nouvelle France Industrielle”, in which 34 sectoral enterprises defined as the industrial policy priorities of France (Foresight, 2013). In 2013, the government of the United Kingdom offered a long-term picture for the manufacturing sector, which is called “The Future of Manufacturing”, until 2050 (European Commission, 2016). In 2014, the European Commission published a new Public-Private Partnership (PPP) agreement on “Factories of the Future” (FoF). Under the “Horizon 2020”
program, it plans to raise about 80 billion euros for seven years (2014–2020) (Kang et al., 2016). In 2014, the government of South Korea announced “Innovation in Production 3.0”, highlighting new strategies and assignments for Korean production (Li, 2015). The government of China published the “Made in China 2025” strategy as well as the “Internet Plus” plan in 2015, prioritizing the manufacturing sectors to accelerate information and industrialization (Cabinet Office, 2015). In 2015, the government of Japan adopted a new plan, in which special attention was paid to the manufacturing sector to realize the world’s leading “Super Smart Society” (National Research Foundation, 2016).

In 2016, the government of Singapore allocated 19 billion dollars to the RIE 2020 Plan (Research, Innovation, and Initiative) (Evans and Annunziata, 2012). From the industrial plans perspectives, in 2014, AT&T, Cisco, General Electric, IBM, and Intel set up the Industrial Internet Consortium (IIC) to catalyze and coordinate the priorities and opportunities of Industrial Internet (https://www.statista.com/statistics/667634/leading-countires-industry-40-worldwide). Meanwhile, other big firms such as Siemens, Hitachi, Bosch, Panasonic, Honeywell, Mitsubishi Electric, ABB, Schneider Electric and Emerson Electric have made significant investments in projects related to the Internet of Things and Cyber-Physical Systems (Rafael et al., 2014).

The statistic given in Figure 1, shows the results of a survey conducted among 559 industrial organizations on the views on the leading country in Industry 4.0 by 2016. Twenty percent of respondents said that Japan was the leading country in Industry 4.0 (World Economic Forum (WEF), 2018).
The WEF released a report in 2018, analyzing how the changing nature of production shapes well-positioned countries and how these countries benefit from this change. The main components of this assessment, together with related drivers and sub-categories, are given in Figures 2 and 3 (European Parliament, 2016).

Fig. 1. Leading nations in Industry 4.0 (WEF, 2018)

Fig. 2. Structure of Production: Concepts Measured (European Parliament 2016)
In the report, under the two drivers related to a country's Structure of Production, two sub-categories are defined: Economic complexity and manufacturing value added, whereas the Drivers of Production includes six headings (European Parliament, 2016). "Technology & Innovation" evaluate the extent to which a country has an advanced, secure, and connected Information and Communication Technologies (ICT) infrastructure in order to support the adoption of new technologies in production. Under this heading the first category is the "technology platform" including the availability of ICT which has the data related to the number/percentage of individuals using mobile networks and the foreign direct investment (FDI); the use of ICT, giving the data related to what extent do ICTs enable new business models; and the digital security & data privacy which specify cybersecurity commitment. "Ability to innovate" is the second category including the industry activity which contains the data related to the investments of companies; research intensity that defines the research and development (R&D) expenditures and related outcomes; and available financing, including the information related to the average value of venture capital deals. Under the category of "Human Capital", "current labor force" including the labor force capabilities of manufacturing employment, female participation, scientists and engineers, and the data related to what extent does the active population possess sufficient digital skills; and "future labor force" including the migration, education outcomes, and agility and adaptability related issues, are included. "Global Trade & Investment" defines a country's participation in international trade. The first issue under this heading is "trade" which is defined by the sum of exports and imports of goods and services measured as a share of Gross Domestic Product (GDP), trade-weighted average tariff rate, and the average score of components from the International Logistics Performance Index. The second component is "investment", including the investment and financing which is related to the greenfield FDI projects, FDI flows, and financial resources provided to the private sector by financial corporations. And the third one is "infrastructure", including the issues of the transport infrastructure and electricity infrastructure. "Institutional Framework" defines the effectiveness of the contribution of government institutions, rules, and regulations towards technological development and advanced manufacturing. This category is related
to governmental issues as; "efficiency & effectiveness" including the regulatory efficiency, and the future orientation of government, and the "rule of law" which is defined by the score for the Rule of Law dimension issued by the World Bank. "Sustainable Resources" assesses how production affects the environment, including the use of natural resources and alternative energy sources. "Sustainability" includes the alternative and nuclear energy use, intensity levels for CO2, CH4, and N2O, and score for Wastewater Treatment from the Yale Environmental Performance Index.

Fig. 3. Drivers of Production: Concepts Measured (WEF, 2018)

"Demand Environment" evaluates foreign and local demand access to scale production. This heading includes the "foreign and domestic demand" related to the market size together with the "consumer base", including the buyer sophistication and the extent of market dominance. In the ‘Readiness for the Future of Production Report’, the application was made to analyze 100 countries and economies. The top 10 countries/economies determined in this report are given in Table 1.
Table 1. Top 10 countries according to the “Readiness for the Future of Production Report” (European Parliament, 2016)

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<td>Ireland</td>
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"Demand Environment" evaluates foreign and local demand access to scale production. This heading includes the "foreign and domestic demand" related to the market size together with the "consumer base", including the buyer sophistication and the extent of market dominance. In the ‘Readiness for the Future of Production Report’, the application was made to analyze 100 countries and economies. The top 10 countries/economies determined in this report are given in Table 1. According to the Industry, Research and Energy Report which was requested by the European Parliament (EP)’s Committee on Industry, Research and Energy (ITRE), Industry 4.0 can be successfully applied if and only if the following essential requirements are focused on: standardization of systems, platforms, protocols; changes in the work organization that reflect new business models; digital security and know-how protection; the availability of skilled workers; research and investment; and a common EU legal framework supporting the dissemination of Industry 4.0 in the Internal Market. The existence of these preconditions and the ability to establish these preconditions in places where they are not present, differ between the Member States. Figure 4 shows the ranking of the challenges identified according to a survey conducted in 2013 (European Parliament, 2016).
Fig. 4. Preconditions for implementation of Industry 4.0

These preconditions required for the successful implementation of Industry 4.0 are identified as follows (European Parliament, 2016): Standardization of systems, platforms, protocols, connections, interfaces are, and it seems that a reference architecture is needed that will facilitate the implementation of the Industry 4.0 processes by providing a technical description of these standards. Work organization reflects changes in business models. Complex systems should be managed with the help of planning and explanatory models. Real-time oriented control transforms business content, processes, and the environment, and this transformation results in increased responsibility and continuous improvement for the individuals. The availability of products used both in the production process and sold to various buyers is essential. New business models should be developed and implemented by investigating who is responsible for the costs and risks of unsuccessful initiatives. In the global competitive environment, know-how’s safety/protection is vital. Companies/governments will not be willing to make new investments if their innovations can be easily replicated by other companies that do not have to invest in R&D. It is expected that the costs of investing in equipment safety for workers’ protection to be proportional to potential gains. Manufacturers should protect themselves against misuse and unauthorized access, with the help of
unique identifiers and training of staff. The availability of skilled workers who can design and operate the industry 4.0 workplaces is important. The question of who will invest in the skills and training of these workers becomes essential. For those who do not have these skills, the effects of these developments need to be determined in terms of employment. Another critical issue is the life-long learning under this context where highly sophisticated technological systems exist, and particular skills are required. How to develop and implement a common EU legal framework to enable the digitalization of the industry is to be emphasized. This is a prerequisite for implementing Industry 4.0 in a Single Market so that companies can gather resources in order to undertake the investments they need to integrate their production systems.

3 A Roadmap for Industry 4.0

Focusing on the countries’ readiness for Industry 4.0, it is essential to understand what the primary purpose of the transition to Industry 4.0 is. Countries are in constant competition with each other in the current situation they are in and try to find ways to pass themselves on advantage. This quest is ongoing and requires constant improvement. The Global Competitiveness Index (GCI), which is announced annually by WEF, is a broad base for measuring the competitiveness of nations. This index is created using a sophisticated methodology as well as the views of industry representatives. Global competitiveness is a field of economic theory that analyzes politics that allow a nation to create more value for its own business and to provide more prosperity for its people. The index contains data sets built on twelve primary headings in three main groups. These three main groups consist of several topics, including basic requirements, productivity enhancers, and the sophistication of the innovation & business world. The 12 main topics are: Institutions, which defines the institutional environment of a country, including the legal and administrative framework within which individuals, firms, and governments interact. Infrastructure, i.e., active modes of transport, efficient electricity supplies, and a robust and extensive telecommunications network. Macroeconomic environ-
ment, meaning the stability of the macroeconomic environment. Health and primary education, which is descriptive of a healthy workforce, and the quantity and quality of the primary education received by the population. Higher education and training, indicating the quality of higher education and training, and the extent of staff training. Product market efficiency, which states efficient goods markets, healthy market competition, and customer orientation and buyer sophistication. Labor market productivity, including the efficiency and flexibility of the labor market. Financial market development which points out a trustworthy and transparent banking sector, and appropriate regulations for investors and other actors in the economy. Technological preparation, measuring the agility with which an economy adopts existing technologies to enhance the productivity of its industries. Market size, defining the markets available to firms. Business sophistication, which concerns the quality of a country’s overall business networks and the quality of individual firms’ operations and strategies. Innovation, which means adequate investment in R&D, the existence of high-quality scientific research institutions, comprehensive collaboration in research and technological developments between universities and industry, and the protection of intellectual property. It is only through proper planning that countries can achieve improvements in these competitive values. This may be at the level of material or product production, or the level of technology or information production. Industry 4.0 is a concept designed to compete with the far eastern countries that produce high quantities, as mentioned before. It is essential to pay attention to the above competition indices, which are approved by the WEF, in order to be able to adapt to this concept correctly. Looking at the indicators used in the ‘Readiness for the Future of Production Report’ presented in Section 2, and/or the preconditions given in the European Parliament’s ITRE report prepared by the EP, the readiness conditions are highly related to the competitiveness indices presented by the WEF. The ability to increase the competitiveness of the number (1) competitive index, "Institutions", will be achieved through improvements in business freedom, labor freedom, and monetary freedom, as set out in the WEF’s heading of "institutional framework", and improvements in the "rule of law" scoring set by the World Bank. Besides, the three preconditions defined in the ITRE report, i.e.,
"standardization", "security/know-how protection", and "legal framework", are related to this topic. "Infrastructure", the number (2) competitive index, is taken into account under the heading of “global trade & investment” in the report of WEF. "Macroeconomic environment", the number (3) competitive index, defines the "structure of production" including the headings of "complexity" and the "scale" of the manufacturing. The term ‘standardization’ is also valid under this heading. "Health and primary education", the number (4) competitive index, can be considered in collaboration with the number (5) competitive index, "Higher education and training", and the number (7) competitive index, "Labor market productivity". These three topics are focused on under the heading of "human capital", defining the current and labor workforces. Furthermore, the preconditions of "process/work organization", "available skilled workers", and "training / professional development" are included in the ITRE report. “Product market efficiency”, the number (6) competitive index, and “Market size”, the number (10) competitive index, are related to the “demand environment”, including the supply and demand conditions of the market. “Financial market development”, the number (8) competitive index, mostly depends on the topics of “trend”, “investment” under the heading of “global trade & investment”. In the ITRE report, the precondition of “research” also defines the owner of the business investment. “Technological preparation”, the number (9) competitive index, is related to the preconditions of “available products” and “new business models”. Together with the number (11) competitive index, “Business sophistication” and the number (12) competitive index, “Innovation”, these three topics are pointed out under the headings of “technology platform” and the “ability to innovate”.

Considering all of these indicators, preconditions, and indices; the following six headings are proposed: Macroeconomic environment: Defining ‘the stability of the macroeconomic environment’, production complexity and the manufacturing scale are considered, together with the level of standardization that is observed throughout the systems. Institutional framework: The institutional environment of a country includes the efficiency and effectiveness of the government, together with the legal framework. The rule of law and security/know-how protections are also counted under this heading. Labor market: Human
capital is of high importance in the process of transition and adaptation to Industry 4.0. As the systems to be used are highly advanced, available skilled workers, as well as the training / professional development opportunities, are also important. Product market: The efficiency of a product market, the size of the market including the foreign and domestic demand, and the customer and/or buyer sophistications affect the industry activities of a country. Financial remarks: A country’s financial situation depends on the trade, the investments and the infrastructure, together with the development of the financial market. Technological preparation: In order to adapt existing technologies to Industry 4.0; the available products and the technology platforms need to be observed. Besides, new business models and the ability of the systems for innovation, including the research and development opportunities, should be considered.

4 Case Study: Current Situation in Turkey

The upcoming digital revolution is a crucial issue for Turkey, which is in the category of developing countries. Industry 4.0, above all, should be considered as an important opportunity and seen as a chance for countries to be removed from the middle-income quintile and to be among the countries that produce and develop high value-added products and services in the upper-income group. In this direction, it is inevitable that radical reforms are being realized. Industry 4.0 transformation has already begun in the world. If Turkey wants to consolidate its place as a regional center, it should not lag behind in the manufacturing technology transformation of the Industry 4.0. Almost half of the production in Turkey is carried out with low technology. In addition to this, more than half of the nationwide initiatives are made up of low technology entrepreneurs. On the other hand, the share of high technology products in exports is around 4% (this rate is 30% in South Korea and 15% in the European Union). The majority of factories in Turkey, depending on the use of automation in industrial processes, are located between Industry 2.0 and 3.0. Nevertheless, in sectors such as automotive, pharmaceutical, defense, and aerospace, it can be said that Industry 4.0 has already been passed. Some of the decisions taken
by the institutions in Turkey, together with the reports and their contents, are as follows; Turkish Industry and Business Association (TUSIAD) carried out extensive research with 108 technology users and 110 technology suppliers in order to measure the competency levels of companies’ digital transformation in Turkey, to identify the areas of competence of technology supplier companies, and to determine the missing points to be focused. In February 2016, the High Council for Science and Technology decided to carry out studies on intelligent production systems. Within the scope of this decision, TUSIAD prepared "Intelligent Production Systems Technology Road Map" and identified critical technologies, strategic targets, and critical products under the main headings of Digitalization, Interaction and Factories of Future. Tenth Development Plan (2014–2018) Special Commission Conversion Report on Manufacturing, states that the role of the public has become increasingly critical in order for the country to transform its industry in order to achieve its goal of becoming a high-income economy in 2023. In the Medium-Term Program prepared by the Ministry of Development for the years of 2018 to 2020, the aims of digital transformation of the industry (layered production, robotics, internet, big data, artificial intelligence, efficient use of enhanced reality technologies and their domestic production), and design and establishment of digital transformation centers are presented. According to the Measures 240 and 241 of the Program of 2018, it is envisaged that studies on these targets will be completed by December 2018 under the coordination of the Ministry of Science, Industry, and Technology (Measure 240: The roadmap of digital transformation of the industry will be completed. Measure 241: Design and digital conversion centers will be established.) The citations to the digital conversion of the industry, made in the documents of Industry Strategy Paper (2015–2018), Efficiency Strategy and Action Plan (2015–2018) and Turkey Software Sector Strategy and Action Plan (2017–2019) of Science, Industry and Technology Ministry of Turkey (2015-2018), are noteworthy. Digital Transformation Platform was established in January 2017, under the leadership of the Ministry of Science, Industry and Technology, together with the participation of organizations such as The Union of Turkey Chambers and Commodity Exchanges (TOBB), Turkey Exporters Assembly (TIM), TUSIAD, Independent Industrial-
ists’ and Businessmen’s Association (MUSIAD), the International Investors Association (YASED) and Technology Development Foundation of Turkey (TTGV). Besides, the "Fourth Industrial Revolution Office" was established under the General Directorate of Science and Technology of the Ministry of Science, Industry, and Technology. Accenture consulting firm carried out a survey, regarding the "Accenture Digitalization Index" which has been implemented in many countries. The firm did its research with over 100 companies of different sectors in Turkey and calculated the average index score of digitization for the country. The calculated score is found to be around 60%. Industry 4.0 means competitiveness in the manufacturing economy, sustainability, and producing value-added products and services, for Turkey. It is possible to say that using these steps can provide increased efficiency in the manufacturing sector. It is also expected that the competitive advantage to be gained through the economy around Industry 4.0 will increase industrial production. In order to incorporate the Industry 4.0 technologies into the production process, the producers are expected to invest in high amounts of money in the coming periods. The realization of growth in Turkey’s economy may be possible with the effective and efficient use of technology. First of all, the work processes in which the IoT is used should be managed correctly. Besides, giving a higher emphasis on IT training, educating programmers, and accelerating the search for IoT, are some of the first steps that can be taken to take place on the side of innovations. Turkey already has a strong production structure but exhibits a low level of readiness for the future of manufacturing. Having a growing labor force and using the advantages of Industry 4.0, Turkey is able to create a significant transformation that will change its role around the global economy. In order for the industry to grow and to become a pioneer country, all stakeholders need to work by focusing on a common country plan and target. Historically, many of the countries like Turkey, as the more developed economies supply fewer valuable pieces with lower labor costs, has benefited from globalization. As a result, these countries increased foreign investments and market access. However, with increasing production costs, these countries are faced with the danger of losing their traditional share of production against countries that can offer cheaper labor. These countries are at risk because they are not prepared to catch up
with advanced production in the future. Turkey and some other countries need to create a strategy for the future. These countries today have a stable production base, but they need to re-educate and improve the workers, upgrade their technology platforms, and shift towards conservative innovations. Studies performed to date in Turkey are set out in this section. A road map should be drawn to assess the criteria given in Section 3.

**Conclusion**

Industry 4.0 offers companies a large number of opportunities while bringing new threats that need to be solved. First of all, it means that the way the companies do business has changed, the operations teams have to realize that and rebuild their processes. Beyond the change of a serious and radical business mentality, it offers a whole new understanding of the transition to Industry 4.0 concerning the labor force. With full automation and smart factories, most of the work will be carried out untouched, so there is a big debate about the possibility of unemployed workers. The vision of smart factory also requires the reorganization of traditional education structures, strategies, and policies, and even restructuring with multifaceted participation; as it is inevitable to develop new skills, abilities and competencies appropriate to these technologies. Unfortunately, there may be a rise in unemployment in some sectors and professions. Without reaching this level of distress, it is necessary to adapt the internal and external education processes to the needs of the new technological situation. It is necessary once again to underline that it is crucial for all stakeholders, especially the government and non-governmental organizations, to act holistically and in harmony with each other for this transformation in the industry. In particular, the provision of appropriate infrastructure and education is emerging as the main factors. The producers have to determine their priorities in the production process and improve their labor competencies. For this purpose; first, key areas to be improved, such as flexibility, speed, efficiency, and quality, should be identified. Then, it should be assessed how the nine bases of technological progress will be beneficial in the designated areas. Rather than focus-
ing on small-scale improvements at this point, the ways to make fundamental changes must be sought. Long-term impact on the workforce should be analyzed, and strategic workforce planning should be done. Together with job descriptions, recruitment and work-training should be updated, considering the additional information technology competencies needed by the workforce. With these improvements delivering a significant development potential for existing industries, building innovative factory and production processes using Industry 4.0 technologies can open up new approaches. However, these new ways of doing business should be built on the right basis taking into account the necessary preconditions: Determining which sectors have leading effect for new or improved models, establishing technological bases such as the applications required for analysis, establishing the right organizational structure and capabilities, establishing business partnerships that are essential in the digital world, establishing standards and increasing participation in technology use, creation of a supplier ecosystem for new technologies. Policy makers and the public should define the framework of the particular infrastructure, education, regulation, and investment. The best way to achieve this is through collaborative efforts of the business world, the public sector, the sector organizations, and the companies realizing the following: The technological infrastructure, mainly fixed and mobile broadband services need to be updated. Infrastructures should be at the speed and reliability level that companies can use to provide real-time data flow. Curricula, vocational education, and higher education programs need to be appropriately adapted in order to increase the workforce's skills and innovation competencies related to IT, and entrepreneurial approaches should be enhanced. An incentive system designed to enable not only large but also small or medium-sized businesses to realize the necessary investments in areas such as new technologies, production / operating methods, and access to a more competent workforce is vital. In addition to the stakeholders mentioned above, it is also possible to make critical inferences for the service sector. Naturally, the emerging value chains around Industry 4.0 will also trigger a transformation in the service sectors. In this framework, logistics, software and system integration and finance should be considered as vital areas. Applications that will strengthen the integration of the logistics industry into the value chain
according to Industry 4.0 needs, the competencies and innovation needs of solution partners, which are suppliers of the industry, to develop on new technologies, financing and risk appraisals of the financial sector’s related to the investment items with much higher balance sheets, are some of the examples of future issues in service sectors in the coming period. As mentioned, the ‘Readiness for the Future of Production Report’ states that The Fourth Industrial Revolution is thought to trigger selective revitalization, convergence, and other structural changes in the global value chains. Developing technologies will change the cost-benefit equation and ultimately, the impact of attraction to shift production activities. For this reason, all countries should develop skills to make attractive production targets and to benefit from these shifts (WEF, 2018). Together with all of these observations, it is possible to say that all countries have the opportunity to heal. Although no matter what the leader is, no country has fully achieved any preparation. Leading countries need to design, test, and pioneer and push their boundaries in the preparation of real transformations and technologies. Weaker countries can make more advanced production and offer lower cost labor and can choose to strengthen the production structure and diversify their economies. As a result, being ready for the Industry 4.0 necessitates not only national but also global solutions. Globally connected manufacturing systems need sophisticated technology, standards, norms, and regulations that transcend technical, geographical, and political boundaries. This will be necessary to release productivity and facilitate business in global value chains. Each country is confronted with difficulties that can be solved by the integrated efforts of the private and the public sectors. New approaches to public-private partnerships can help governments build these partnerships quickly and effectively. Besides, the cooperation between the public-private sector and the education sector is necessary to accelerate transformation. It is also proposed to investigate new and innovative approaches for this aim.
References


**Key Terms**

<table>
<thead>
<tr>
<th>Industry 4.0</th>
<th>Readiness for Industry 4.0</th>
<th>Roadmap</th>
<th>Preconditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial revolution</td>
<td>Digitalization</td>
<td>Cyber-physical systems</td>
<td>Cloud computing</td>
</tr>
<tr>
<td>Big data</td>
<td>Artificial intelligence</td>
<td>Internet of things</td>
<td>Competitiveness Index</td>
</tr>
</tbody>
</table>

**Questions for Further Study**

In the transformation to Industry 4.0, it was stated that especially the administrations and non-governmental organizations should work in harmony and communication with each other. Draw a relationship diagram by developing a model for this communicative / adaptive work environment.

With developing technology, it is estimated that approximately 50 billion devices will interact with each other in 2020. As a result, 46% of the global trade volume is expected to be affected. Estimate what will be the share of imports and exports within this global trade volume.

How will the implementation of Industry 4.0 affect human resources? How will this change affect the production and labor costs?

What is the place of artificial intelligence in Industry 4.0? Explain with examples.
How will the developments in robotics affect production systems, the environment, living conditions, and information technologies? Explain with examples.

How will Industry 4.0 particularly affect the logistics sector? What will be the role of Logistics 4.0 in achieving the success of Industry 4.0? What can be the criteria determined for Logistics 4.0?

Exercises

Explain the relationship between the competitiveness index and the prerequisites for preparation for the future. What is the role and importance of lifelong learning to successfully implement and sustain Industry 4.0? Which country can be selected as the leading country in Industry 4.0? Which criteria can this choice be based on? Which countries have action plans for Industry 4.0? Why?

Industry 4.0 is a concept that was designed and presented in 2011 in Hannover, Germany, in order to compete with the Far East countries, which are producing high amounts. What are the developments in the US and English-speaking world during these years? Discuss. Compare developing countries and developed countries in terms of their preparation for Industry 4.0. (Take two countries for each sample.)

Further Reading


Learning Objectives

The objectives of this chapter are to introduce the transformative effects of Industry 4.0 at the shop-floor level, to review the dimensions in the literature used to determine the maturity level of companies at the shop-floor for Industry 4.0, to express the views of experts on this dimension, and to provide a framework for companies by integrating the literature review and experts’ evaluations to guide them on their Industry 4.0 journey. Once you have mastered the materials in this chapter, you will be able to:

- Explain the concept of Industry 4.0 and its fundamental enabling technologies.
- Understand the transformative effects of Industry 4.0 at the shop-floor level.
- Identify the dimensions in the literature used to assess the maturity level of companies at the shop-floor in the context of Industry 4.0.
- Understand the opinions of experts on the way companies need to follow for Industry 4.0 implementation at the shop-floor level.
- Discuss the steps that companies need to follow in their Industry 4.0 journey.

Chapter Outline

This chapter discusses the transforming effects of Industry 4.0 at the shop-floor level and the steps that companies need to follow to progress systematically through the Industry 4.0 journey. For each company, this journey is different from one another due to many fac-
tors such as the company’s vision, mission, objectives, industry, competitiveness, and size. Companies need an overview and an approach to guide them on how to start and take steps on this journey. This chapter aims to meet this need. This chapter begins with the introduction of the concept of Industry 4.0 and its transformative effects on the shop-floor. Afterward, the literature reviews section is introduced. In this section, the criteria used in studies that evaluate firms’ Industry 4.0 maturity levels are examined by focusing on the shop-floor level. Following the literature review, the research methodology is explained. In this section, the research questions and details of conducted case studies are introduced. Then, in the analysis section, the resulting Industry 4.0 framework is presented. Finally, this chapter is ended with discussions and conclusions.

**Keywords**

Industry 4.0, shop-floor level, case study, Pre-Industry 4.0, Industry 4.0 Initiation, Industry 4.0 Implementation

## 1 Introduction

New market conditions and technologies such as cyber-physical systems (CPS) and the internet of things (IoT) have had significant effects on the manufacturing environment. These information technologies and being able to create value from huge amounts of data using advanced analytic tools provide a basis of Industry 4.0 concept. Industry 4.0, the new industrial vision of our age, configures a business environment integrating physical objects, machines, information and human with a cyber replica of the system, and forces companies to make radical changes in the way they execute operations. Even though Industry 4.0 is technologically at an advanced stage, on the implementation side this concept is still perceived as an uncertain, highly complicated and costly long way for many manufacturing companies. To effectively manage the inevitable Industry 4.0 transformation process, they need to be able to assess how ready they are for Industry 4.0 and to have a roadmap that will enable them to follow a systematic way towards its implementation. Manufacturing companies face more complex strate-
gy playbook (Porter and Heppelmann 2015) and need to reconsider how they execute operations. The future manufacturing systems will have to be built in accordance with Industry 4.0 (Almada-Lobo 2015). It is foreseen that they will need to be more flexible to respond ever-changing market demands and use plant data more efficiently to get real-time information supporting timely and accurate decisions in the context of Industry 4.0 (Theorin et al. 2016). Also, they will need real-time production plans unlike the traditional forecast based production plans (Sanders et al. 2016), to manage sufficient product-related information and to focus on the integration of company and plant management levels (Khedher, Henry and Bouras 2011; Kucharska et al. 2015). Manufacturing companies must adjust themselves and adapt faster to all these challenges to survive in this inevitable transformation process. From this point of view, the purpose of this chapter is to guide manufacturing companies towards Industry 4.0 in the context of the shop floor. This chapter begins with the concept of Industry 4.0 and its transformative effects on the shop-floor. Afterward, the literature reviews section that presents the criteria used in studies that evaluate firms’ Industry 4.0 maturity levels are examined by focusing on the shop-floor level is presented. Following the literature review, research questions and details of conducted case studies are introduced in the research methodology section. Then, in the analysis section, the resulting Industry 4.0 framework is presented. Finally, this chapter is ended with discussions and conclusions.

2 Effects of Industry 4.0 on the Shop-Floor

Today’s competitive conditions and recent developments of information and internet technologies push companies towards implementing high tech methodologies in the manufacturing environment (Lee, Bagheri and Kao 2015). The virtual world gets nearer to real manufacturing world as the integration of technology into products and factories increases (Abersfelder et al. 2016). Among these technologies, especially CPS and IoT have paved the way for Industry 4.0 concept.

CPSs provide some opportunities for production planning, controlling and monitoring, especially regarding data acquisition. CPSs
have the ability to compile data generated in production independently and economically in real-time, accurate quality and quantity (Seitz and Nyhuis 2015). Due to the transformative effects of Industry 4.0, businesses need to increase flexibility and efficiency in all processes from product design to manufacturing, and to consider the product lifecycle (Klein et al. 2014). In an Industry 4.0 environment, production planning and control must be real-time and service based. To be able to obtain accurate real-time data and provide its continuity, it is necessary to do resource planning at the enterprise level effectively and also to ensure that the data formed at the shopfloor level during production processes are controlled and managed accurately (Berger, Berlak and Reinhart 2016). The structuring of manufacturing systems with industry 4.0 requires that they must react quickly to ever-changing market conditions and be more flexible. To achieve this, they need to manage the entire enterprise effectively and make better use of plant data (Theorin et al. 2016). Many levels of planning and decision making are needed for corporate enterprise management. Tactical plans and operational activities need to be implemented effectively to achieve strategic objectives (Kucharska et al. 2015). Effective management of the whole enterprise, real-time data acquisition and management at the shop-floor level and using this data in the critical decision points, integrating product requirements with design and manufacturing information need to remove the boundaries between all the levels of enterprises. To achieve this, one of the most important prerequisites is MES (Manufacturing Execution Systems) and ERP (Enterprise Resource Planning) integration. ERP, which forms the backbone of today’s businesses, is a fundamental system that runs the job. However, especially with the transforming effects of Industry 4.0 on manufacturing environment, ERP systems need to be able to analyze the real-time and unstructured large data collected from business processes and have the functionality to enable enterprises and their partners to operate in real-time in the value chain (Stojkic, Veza and Bosnjak 2016). Today, manufacturing companies have been facing many challenges, such as increased process complexity, shorter product delivery times and complicated customer requirements (Wang et al. 2016). Being able to sustain their competitiveness, they must have higher levels of performance, quality, flexibility, and agility. MES has been pivotal in meeting
these requirements, and it will most likely become even more critical in the future (Almada-Lobo 2015). MES, developed in the 80's as systems supporting data collection and processing and thus fostering traceability, production planning, and scheduling. At the end of the 90's, MES has become an integrated system (MES / II) that uses real-time data for production operations covering all phases from the order release to product delivery. Systems called the new generation MES (MES / III), which reflect the impact of Industry 4.0 on the MES, will need to focus more on plant management to provide the high flexibility that production systems require (Romero and Vernadat 2016). Manufacturing execution systems provide both a strategic approach to the managers and an operational approach to the operation workers with real-time information from shop-floor. This system builds information bridges between strategic and shop-floor levels and links the levels of manufacturing information systems through the control and management of up-to-date information on basic enterprise resources (Panetto and Molina 2008). MES has many promises, including better planning, better management of personnel, lower production costs, better supplier management, alignment of production objectives with enterprise objectives. To be able to realize these, MES should have functions for past, present, and future (Naedele et al. 2015). There are four key pillars the MES needs to consider to cope with the new challenges that industry 4.0 has emerged: Decentralization, vertical integration, connectivity and mobile, and cloud computing and advanced analysis (Almada-Lobo 2015).

3 Literature Review

In the literature, there have been some studies proposing guidance towards Industry 4.0. In one of these studies, Erol et al. (2016) have developed a process model offering a framework to guide companies for alignment their missions and visions with Industry 4.0 and make them Industry 4.0 ready companies. Shrouf et al. (2014) have presented a guideline for IoT-based energy management. Their approach includes four phases. The first phase comprises activities to understand production processes and current energy management practices. As a result of
this analysis, improvement targets will be set. The second phase concentrates on gathering real-time data by using IoT technology such as smart metering, sensors and understanding the current system state. Machines, monitoring devices, production processes have to be identified to analyze the current practices and limitations. Those collected real-time data need to be integrated into energy management tools. The third phase includes the activities in line with this purpose. The last phase aims to improve energy efficiency by defining sustainable strategies and practices in production management. Lee et al. (2015) have proposed a 5-level architecture including smart connection, data-to-information conversion, cyber, cognition, configuration steps as a guideline for the implementation of CPS in Industry 4.0 manufacturing systems. Smart connection phase involves acquiring accurate and reliable data from machines and tools by obtaining enterprise manufacturing systems such as ERP, MES or measuring directly via sensors. In the second step, the acquired data is converted into meaningful information. In the cyber phase, advanced analytics are applied to information collected from all connected machines to provide better insight into individual machines’ status. In the cognition phase, elaborated knowledge of the monitored system is generated and transferred to the users. The last phase is a control phase to makes the machines self-configure and self-adaptive. In the literature, there have been maturity models proposed to evaluate firms’ Industry 4.0 readiness level. These models include dimensions that cover all business functions and all decision levels from shop floor to strategic level. In this section, the main dimensions used in these models are presented first; then the main and sub-dimensions of the shop floor level, the focal point of this work, is reviewed. Lichtblau et al. (2015) have prepared an Industry 4.0 readiness model including six main dimensions that are: Strategy and organization, smart factory, smart operations, smart products, data-driven services, employees. The six main dimensions of the self-assessment tool of PricewaterhouseCoopers (2016) are: Business Models, Product & Service Portfolio, Market & Customer Access, Value Chains & Processes, IT Architecture, Compliance, Legal, Risk, Security & Tax, Organization & Culture.

Schumacher, Erol, and Sihn (2016) have determined 62 items and assigned them to the nine main dimensions they defined. They have
prepared a questionnaire including these items to assess the readiness level of firms, but they didn’t provide any information regarding these items. The main dimensions they determined are as follows: Strategy, Leadership, Customer, Products, Operations, Culture, People, Governance, Technology. Leyh et al. (2016) have proposed an Industry 4.0 maturity model including five stages. They have defined the characteristics of all stages to allow companies to assess their levels and also presented some recommendations to improve their levels. They have determined five dimensions that are as follows: Vertical integration, Horizontal integration, Digital product development, Cross-sectional technology criteria. The IHK (2016) has developed a self-assessment tool that companies can test their digitization level. The main evaluation dimensions they developed are as follows: Smart products, Smart manufacturing, Smart organization, Smart technology. The criteria related to the shop-floor level included in these main evaluation dimensions are presented in Table 1.

Table 1: Criteria used to evaluate firms’ maturity level at the shop-floor level

<table>
<thead>
<tr>
<th>Study</th>
<th>Main and Sub-Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lichtblau et al. (2015)</td>
<td>Smart Factory</td>
</tr>
<tr>
<td></td>
<td>– Digital modeling</td>
</tr>
<tr>
<td></td>
<td>– Equipment infrastructure</td>
</tr>
<tr>
<td></td>
<td>– Data usage</td>
</tr>
<tr>
<td></td>
<td>– IT systems</td>
</tr>
<tr>
<td>Smart Operations</td>
<td>Smart Operations</td>
</tr>
<tr>
<td></td>
<td>– Information sharing</td>
</tr>
<tr>
<td></td>
<td>– Cloud usage</td>
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<tr>
<td></td>
<td>– IT security</td>
</tr>
<tr>
<td></td>
<td>– Autonomous processes</td>
</tr>
<tr>
<td>PricewaterhouseCoopers (2016)</td>
<td>Value Chains &amp; Processes</td>
</tr>
<tr>
<td></td>
<td>– The level of monitoring production real-time and react to changes in demand dynamically</td>
</tr>
<tr>
<td></td>
<td>– The level of IT-enabled planning and steering process</td>
</tr>
<tr>
<td></td>
<td>– Digitization level of production equipment</td>
</tr>
</tbody>
</table>
Among the criteria related to the shop-floor level, the most prominent ones are data management, the infrastructure of equipment, machine-to-machine communication, human-machine interaction and flexibility of production planning.

4 Research Methodology

This chapter aims to guide manufacturing companies towards Industry 4.0 focusing on the shop-floor. In this regard, firstly, the studies addressing the effects of Industry 4.0 on the shop floor and providing various dimensions for assessing the firms’ levels in the Industry 4.0 adoption in the literature were reviewed. Research questions were prepared in accordance with the in-depth literature review and posed to the participants. In this chapter, a multiple case study was conducted, with face-to-face semi-structured interviews with 10 participants from 5 firms, which have made significant progress in the Industry 4.0 implementation process. These interviews lasted around 65 to 105 minutes. The case study is a research method that allows a researcher to closely analyze data in a particular context, and to provide successful results when in-depth and holistic research is needed (Zainal 2007). In the interviews, these questions were used only to construct a frame for this chapter. A systematic road that firms can follow in their Industry 4.0 journey has formed by integrating the opinions of experts from practice and the literature. Information on these participants, who have significant experience with Industry 4.0, is given in Table 2.
### Table 2: Profile of Participants

<table>
<thead>
<tr>
<th>Participant</th>
<th>Organization</th>
<th>Industry type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automation and Project Development Manager</td>
<td>Company 1</td>
<td>White goods manufacturer</td>
</tr>
<tr>
<td>Method Engineer 1</td>
<td>Company 1</td>
<td>White goods manufacturer</td>
</tr>
<tr>
<td>Method Engineer 2</td>
<td>Company 1</td>
<td>White goods manufacturer</td>
</tr>
<tr>
<td>White Goods and Electronics Technical Manager</td>
<td>Company 1</td>
<td>White goods manufacturer</td>
</tr>
<tr>
<td>Research and Development Engineer</td>
<td>Company 2</td>
<td>Heating, industrial energy and cooling systems manufacturer</td>
</tr>
<tr>
<td>Human Resources and Management Responsible</td>
<td>Company 2</td>
<td>Heating, industrial energy and cooling systems manufacturer</td>
</tr>
<tr>
<td>Supply Chain Team Leader</td>
<td>Company 3</td>
<td>Apparel and garment manufacturer</td>
</tr>
<tr>
<td>Technology Development Engineer</td>
<td>Company 3</td>
<td>Apparel and garment manufacturer</td>
</tr>
<tr>
<td>Indirect Commodity Manager</td>
<td>Company 4</td>
<td>Hi-tech rubber belts and hoses manufacturer</td>
</tr>
<tr>
<td>Project Manager</td>
<td>Company 5</td>
<td>Diesel fuel injection equipment manufacturer</td>
</tr>
</tbody>
</table>

**Company 1** was founded in 1997 and started production of refrigerators in 1999. Today is one of the top 3 white goods producers in Turkey and among the 5 largest white goods manufacturers in Europe. The company produces refrigerators, freezers, washing machines, dryers, cooking appliances, dishwashers, air-conditioners and water heaters in its facilities with an enclosed area of 411.6 thousand m².  

**Company 2** is one of the leading international manufacturers of systems for heating, industrial energy, and cooling. Founded in 1917, the family business employs approximately 12,000 employees worldwide. The company maintains 22 production companies in 11 countries, subsidiaries and representatives in 74 countries, and a total of 120 sales offices worldwide. Exports account for 54 percent of sales. We interviewed two participants from the Manisa factory of this company.  

**Company 3** is one of the market leaders in the upper premium segment of the global apparel market. With some 14,000 employees around the world, the Company develops and sells high-quality fashion as well as accessories in the womenswear and menswear segments. We interviewed two participants from the Izmir factory of this company.  

**Company 4** is the world's leading manufacturer of power transmis-
sion belts and a premier global manufacturer of fluid power products. The company is headquartered in Denver, Colorado, USA. Izmir factory of this company was formed in 2009. Its machines, manufactures and assembles tensioners. Company 5 is a leading global automotive emission, fuel economy and aftermarket solutions provider. The company provides combustion systems, electrification products and software and controls, and operates in the passenger car and commercial vehicle markets, and in-vehicle repair through a global aftermarket network. The company has 20,000 employees including 5,000 engineers. It is headquartered in London, U.K. and operates technical centers, manufacturing sites and customer support services in 24 countries. It has been operating in Izmir, Turkey since 1989. Izmir operations are executed by two combined production plants, an R&D center, and an after-market regional management center for EMEA region. In this chapter participants’ statements are given in the form of quotations, and the data obtained from the interviews are explained in detail to increase the validity of the study. Interview notes were reviewed by the participants, and their statements were used after their confirmation. The research questions prepared to guide the chapter are as follows:

Which items are included in your checklist when evaluating whether a company is ready to start working on Industry 4.0?
How should a firm begin its journey to Industry 4.0 and how should it proceed in this journey?
What is the importance of data management in Industry 4.0 transition and implementation process? Where do you put data management in the Industry 4.0 roadmap?
Which characteristics should equipment have in the context of Industry 4.0? How should a firm upgrade or renew its equipment to the level required by Industry 4.0?
How to create human-machine interaction for Industry 4.0 on the shop floor? Where do you place human-machine interaction on the Industry 4.0 roadmap?
How do Industry 4.0 affect production planning and scheduling process?
What has changed in the maintenance process with Industry 4.0 and what will change?
5 Analysis

The industry 4.0 journey of each company is different from the others, depending on many factors such as vision, mission, objectives, industry, competitiveness, and size. In this chapter, it is aimed to construct a general framework for the stages that should be completed in this journey and what to do in these phases for the companies. As a result of combining the literature review and evaluations of interview notes, it has been determined that there are three main stages, each with various dimensions.

5.1 Pre-Industry 4.0 Stage

For companies to start working on Industry 4.0, firstly all business processes must be standardized, lean and correctly defined. Also, they must have a robust ERP system, and effectively manage their inventories. The statements of participants in this stage are presented here are as follows: “I think that all the business functions must have data communication and it needs to be done synchronously.” (Project Manager, Company 5) “Before Industry 4.0, I think that existing processes should be lean and correctly defined so that we can determine where we want to get faster action and achieve more practical results in the current processes.” (Method Engineer 1, Company 1). “You should not start working on E 4.0 without moving to the lean system. Before starting work on Industry 4.0, the TPM process must be initiated, managed and progressed.” (Method Engineer 2, Company 1).

5.2 Industry 4.0 Initiation Stage

Development and Internalization of an Industry 4.0 Understanding: One of the most fundamental problems in the implementation side of Industry 4.0 is that companies perceive Industry 4.0 as a long, complicated and uncertain way and have difficulties in determining how to begin this journey and how to proceed. Companies should develop an Industry 4.0 understanding within the enterprise, incorporating their
vision of Industry 4.0 in a way that is consistent with their specific characteristics, needs, and objectives, and internalize this understanding with all employees. The opinions of some experts in this regard are as follows: “If the people involved in the Industry 4.0 implementation process cannot internalize this process if they do not understand why the process is being done and the added value it creates, then success cannot be achieved.” (Human Resources and Management Responsible, Company 2). “Involving the personnel in the process and making them feel valuable is very important for them to internalize the process. In this way, you can get critical information that you cannot obtain even from the R&D or production department.” (Method Engineer 2, Company 1). To make the internalization process of the companies easier, one of the experts suggests: “Benchmarking is crucial for clarifying companies' understanding of Industry 4.0. The answers that can be taken to questions such as what companies have done, what technologies and practices they started with, what risks they faced and what gains they have achieved will increase the awareness of firms and make their adaptations easier.” (Research and Development Engineer, Company 2). Creation of Industry 4.0 Project Team and Industry 4.0 Strategies: Once companies have established their vision for Industry 4.0 and developed an Industry 4.0 understanding within the firm, a master project team of managers should be organized to identify Industry 4.0 strategies. “Each company must have an innovation team to determine its strategy and the way it should follow. This team must be an executive team. Sub-teams should be created in line with the strategy determined by this team and roadmaps should be determined.” (Project Manager, Company 5). “This team should include people from different disciplines such as R&D, engineering, production, quality, human resources, job security, supply chain management. When this project team comes up with a project related to Industry 4.0, it should evaluate whether the project is necessary, the feasibility and contribution of the project together.” (Method Engineer 1, Company 1). Companies need to gradually digitize their existing facilities, renew the technology in their traditional systems, and make changes in their structures to make the business cost-effective and multi-directional while preparing their plants for the future with the vision of Industry 4.0 (Cachada et al., 2017: 3492). Each company should develop an Industry 4.0 strategy in line with its mission and vi-
tion to be successful in the Industry 4.0 journey. In the literature, there are some transition strategies including big bang, phased, parallel and hybrid strategy can be pursued for technology renewal or implementation of information systems’ projects (Madkan, 2014: 634). Some suggestions from experts on how industry 4.0 strategies should be determined are: “Processes should be analyzed to determine at which points more resources are being used and which points need more improvement. Faster results can be achieved by concentrating on Industry 4.0 technologies at these points.” (Method Engineer 1, Company 1). “I think Industry 4.0 is a concept that will progress step by step like Kaizen. Some operations have to be done manually. For a product with low-value-added, it may be more appropriate to make a sizable investment later, perhaps not at all. Some processes are not very suitable for automation; it is necessary to do with the human.” (Automation and Project Development Manager, Company 1). “Projects should not only be assessed regarding requirements but also opportunities should be taken into consideration. For example, we started a project on the manufacturing of spare parts using a 3D printer. We analyzed products that we had to make changes because of the unavailability of spare parts and conducted a pilot study for some of these products.” (White Goods and Electronics Technical Manager, Company 1). Projects that can be implemented in line with the company's strategies, goals and objectives should be evaluated by the Industry 4.0 team and its sub-teams. Feasibility studies should be done. Companies use many evaluation criteria in assessing the feasibility of projects. “We use many factors in project evaluation such as safety, ergonomics, quality, cost, energy saving, productivity, labor saving, design simplicity.” (All participants of Company 1). “We evaluate projects based by taking into consideration lots of metrics such as First time pass rate, first time quality, Customer Quality Imperatives, Customer Delivery Imperatives, Net present value, return on investment, Payback rate and Payback value as well as how much they reduce cycle time.” (Project Manager, Company 5). “We use return on investment and ability as the main criteria for project feasibility evaluation. At the same time, we use criteria such as the number of machines to be disseminated and the predictability of the project.” (Technology Development Engineer, Company 3). Companies may not start all feasible projects at the same time due to the cost and high level of uncertainty of Industry 4.0 projects. At
this point, companies can be suggested to prioritize feasible projects in line with their aims and to start projects according to this priority sequence. These feasibility and prioritization studies will also be needed in the later stages of the Industry 4.0 journey.

5.3 Industry 4.0 Implementation Phase

Effective Management of Data and Creation of Digital Substructure: Successful implementation of Industry 4.0 implies the interaction between the physical manufacturing world and the virtual world and these two worlds to converge at the shop-floor level (Tao and Zhang 2017). Digital twin is one of the key components of Industry 4.0. (Uhlemann et al. 2017). The digital twin ensures that the data generated in different stages of the physical space can be projected in the virtual space in real-time, and these data can connect to each other. Besides, digital twin sets the structure for interaction between historical data and real-time data, mining data in-depth, and real-time updating of data (Tao et al. 2018). Integration of digital twin and technologies of big data is crucial to make the manufacturing environment intelligent and predictable (Zhuang et al. 2018). The statements of two experts on this topic are as follows: “At the beginning of the industry 4.0 implementation journey, a full digital substructure needs to be created to collect data. Digital twin of the factory must be created. All readings made from many different channels in production, data received via RFID, etc. should be collected.” (Supply Chain Team Leader, Company 3). The first step in the industry 4.0 journey should be that everything can be transferred and linked to digital.” (Indirect Commodity Manager, Company 4). Alignment of Machines and Equipment with Industry 4.0: Industry 4.0 requires an integrated use of different electronic devices, machines, and mechatronic systems and sharing of data between them. With Industry 4.0, there are changes in the design of new machines, but the existing systems are not ready to integrate with these new concepts. For this reason, existing systems need to be strengthened (Lins et al. 2017). To improve the existing system, it is necessary first to analyze the system and reveal its requirements. Companies should determine which machines and equipment are used in which processes, and what
level of automation is required for these processes. It may be necessary for some operations to be manual due to their structures. Additionally, switching to automation on machines used for low value-added and low volume products can be costly for companies. Therefore, when the technological level and automation decisions are given for the machines and equipment, the characteristics of the processes they are used, their usage frequency, and the quality, speed, and flexibility of the current situation should be analyzed. Machine and equipment renewal, replacement or upgrade decisions should be made evaluating the cost of making changes and the deformation risk of the current system, as well as this analysis results. Evaluation of an expert in this regard are as follows: “When you start working on improving the machines' technological levels, it will be reasonable to start with the machines that can provide the fastest results, whose costs and gains can be presented to the management clearly.” (Automation and Project Development Manager, Company 1). Companies can produce their technologies in their facilities. “While creating a digital twin and dealing with data management, also should be focused on automation. We have introduced a laboratory to realize our technological researches and there is an innovation team working on machine design and automation. This team focuses on creating automation that is not in the industry we operate in and to provide communication between the machines.” (Supply Chain Team Leader, Company 3). The experts' evaluations of the features that the machines should have and the cybersecurity dimension are as follows: “It is crucial to standardize the machines as much as possible. Standardization is especially important for global companies. In this way, engineering knowledge in different countries is provided at the same level, and expertise is gained.” (Indirect Commodity Manager, Company 4). “For machines to be able to communicate to each other, they must be open-source coded, but here the biggest problem is security. Machine to Machine is necessary but on the other hand cyber-attacks can happen.” (Technology Development Engineer, Company 3). “It can be considered to work with open-source coded machines in a closed loop system to ensure security.” (Project Manager, Company 5). Providing Human–Machine Interaction: Industry 4.0 has also affected the human's role in the factory. In this flexible production environment, employees are faced with more varied tasks and need to have analytical skills and rapid de-
cision-making capabilities. (Gorecky et al. 2014). Industry 4.0 technologies, especially Augmented Reality (AR), can support operators to become smarter operators (Romero et al. 2016). “It is critical to ensure that employees have easy access to data. Touch screens, tablets can be used for this. While team leaders manage their units, dashboard screens can be used to interpret the data with understandable graphics easily.” (Supply Chain Team Leader, Company 3). AR can be applied in many phases such as designing, ergonomic evaluation, training, guidance to operations during the assembly phase in product lifecycle (Wang et al. 2016). An expert has expressed the AR application they have performed in the training process as follows: “Training sets can be applied using AR to make it easier for threshold operators to adapt to the job. We are already applying this. Our operators are touring the factory, learning factory rules, observing what the fault is by watching videos with AR glasses in specially prepared rooms. The next step is the experience stage. They learn by comparing the actual operation with what they see on the tablets in front of them. Thus, we have shortened the training period significantly.” (Supply Chain Team Leader, Company 3). Making Maintenance More Predictive: Industry 4.0 has transformative effects on manufacturing systems. In this intelligent and interconnected environment, the perception of maintenance function has changed. Now, maintenance activities can be based on advanced analysis of real-time acquired big data, real-time monitoring of the status of products and better diagnosis (Roy et al. 2016). Thus, the maintenance process has evolved into a value-creating process that supports to maintain a smooth flow of machines and processes (Lee et al. 2014). The experts have considered the maintenance process as a process carried out at the data management, machine to machine communication and human-machine interaction stages, not as a separate stage. An expert's statement about the maintenance process is as follows: “Regarding maintenance approaches, especially for predictive maintenance based on estimating failures before they occur by inferring from data, a team focusing only on this process should be formed.” (Method Engineer 2, Company 1). More Efficient and Flexible Planning and Scheduling of Production: Tomorrow’s factories will be capable of producing one lot size profitably. Instead of predefined manufacturing structures, a set of IT configurations will be defined in a way that can be used to create a
specific structure meeting requirement in terms of data, algorithms, models in these factories (Kagermann et al. 2013). In the literature, the ideal Industry 4.0 environment implies complete system automatization. In this context, the experts were asked whether the production planning and scheduling could be fully automated. Experts opinions on this subject are as follows: “It seems like the scheduling requirement cannot be completely removed. With Industry 4.0, support tools for the production planning and scheduling process can be developed. It’s like a simulation program that uses big data. You can simulate the plan you made using past data and estimate the efficiency of the line. In this way, better, lower cost and more efficient plans can be prepared.” (Supply Chain Team Leader, Company 3). “Production planning and scheduling are at the end of all Industry 4.0 implementation steps. Production scheduling and scheduling cannot be as targeted by Industry 4.0 without data management, inter-machine interaction and human-machine interaction. In my opinion, automatized production planning and scheduling and self-production planning of machines are advanced levels. (Method Engineer 2, Company 1). The three-stage framework formed based on the literature review and in-depth analysis of interviews is given in Figure 1:

Figure 1: The Proposed Framework
6 Conclusion

Recent developments in information technology, advanced analytical tools that can create value from big data have paved the way for Industry 4.0 concept. Industry 4.0 has transformative effects on today’s manufacturing environment. In this transformation process, companies need to build their manufacturing systems into a robust structure before making significant investments in the technological tools of Industry 4.0. This chapter aims to offer suggestions about the steps that companies need to complete to enable them to follow a systematic way towards Industry 4.0 implementation. This chapter focuses on the effects of the Industry 4.0 on the shop-floor level. The related literature was first reviewed to draw a roadmap for companies for their Industry 4.0 implementation process at the shop-floor level. Based on the literature review, research questions were created. The research questions were asked the experts from companies that have made progress in the industry 4.0 journey via face to face interviews. Their views and the literature have been brought together, and a structure has been created for companies. Industry 4.0 journeys of all companies will have their unique characteristics. This structure aims to create a general framework for this journey. The framework proposed in this chapter consists of three stages. The first stage includes the steps to be completed to start work on Industry 4.0. All business processes need to be lean, correctly-defined and standardized; ERP systems must be robust, and inventory management must be effective to pass this stage. The second stage represents the initialization of work on Industry 4.0. Companies should first develop and internalize an Industry 4.0 understanding. Then, with the main project team to be formed, Industry 4.0 strategies should be established and coordinated with sub-teams. The third stage is the Industry 4.0 implementation stage. Digital substructure and data management, the infrastructure of machines and equipment, human-machine interaction, maintenance process, and production planning and scheduling are included in this stage. Among these processes, data management and creation of digital substructure can be regarded as the most critical fundamental process in the Industry 4.0 implementation. To summarize the recommendations of companies; companies should first analyze their current situation holistically with a system
analysis approach. They then decide how they want to move forward in their industry 4.0 journey and incorporate them into their vision. The human factor must be emphasized as well as data management and machine-to-machine communication. An Industry 4.0 understanding should be developed within the companies, and all levels of employees should adopt this understanding. In this direction, training planning should be done, and Human Resources strategies should be determined.

References


Industrie 4.0 Reifegrad – Selbstcheck für Unternehmen. 2016. URL:https://ihk-industrie40.de/selbstcheck/.


**Key Terms**

<table>
<thead>
<tr>
<th>Industry 4.0</th>
<th>Shop-floor</th>
<th>Industry 4.0 Understanding</th>
<th>Industry 4.0 Strategies</th>
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<td>Data management</td>
<td>Digital twin</td>
<td>Machine-to-machine communication</td>
<td>Human – Machine Interaction</td>
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<td>Maintenance</td>
<td>Production planning and scheduling</td>
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**Questions for Further Study**

**Compare** the processes involved in the implementation stage at the shop-floor level of Industry 4.0 in terms of importance and impact areas.

**What** kind of assessment method can be used to measure firms’ level in the implementation of Industry 4.0 at the shop-floor level?

**Which** trainings can organizations organize so that the human factor, which is one of the most critical factors in the implementation process of Industry 4.0, has the competencies required by Industry 4.0?

**It** is foreseen that future professions and education will change with the influence of Industry 4.0. Discuss the arrangements that universities need to make in to keep up with this change, especially in the curriculum.
Exercises

Suppose you are the leader of the Industry 4.0 project team at a company. How would you create your project team and sub-teams? How would you draw the Industry 4.0 roadmap for your company?
What is the process by which the most significant change is experienced when considering the effects of industry 4.0 on the shop-floor level? Explain.
Suppose that you are an expert assessing firms’ level in the implementation of Industry 4.0 at the shop-floor level. Which factors would you take into consideration in your assessment, and how would you rank the importance level of those factors?
How would you compare the Industry 4.0 adoption level of different sized firms operating in different industries? Discuss.

Further Reading

Learning Objectives

The aim of this chapter is to analyze changing processes, advantages and disadvantages of these changing processes within the implementation of 4.0 technologies in a factory. Once you have mastered the materials in this chapter, you will be able to:

- Discuss the basic parameters of Industry 4.0.
- Identify current situation of cold chain management of a dairy factory.
- Assess the current situation of the cold chain management processes.
- Explain future expectations of the cold chain management processes.
- Evaluate threats coming with Industry 4.0.

Chapter Outline

The need to meet specific demands from companies and individual consumers more quickly and to achieve better quality product and services has led to emergence of Industry 4.0 in the light of new technological developments. However, for industry 4.0, certain minimum standards, such as transparency and traceability, initially have to be fulfilled. Furthermore, problems such as costs, education and technological infrastructure deficiencies, which are obstacles in transition to industry 4.0, must be solved. The transition to industry 4.0 application is a long-term process and many companies are spreading this transition over time and so it takes place in stages. In this chapter, the level of transition of cold supply chain processes to industry 4.0 will be ex-
amined in a dairy company. In this regard, which industry 4.0 technologies are used in the related processes and the problems experienced during the implementation phase as well as improvements that could make industry 4.0 more efficient and widespread will be discussed.

**Keywords**

Industry 4.0, Cold Chain Management, threats of Industry 4.0, Intelligent Systems, IoT, Customized Services and Products.

## 1 Introduction

Every year, tons of food is wasted due to processing outside the cold supply chain standards. On the other hand, many people get sick or die due to distorted food consumption. In order to eliminate the problems related to cold supply chain in food, some regulations have been made by various private and official institutions. When making these arrangements, many parameters possibly effecting food are considered. In this sense, the temperature values that must be in cold supply chain as well as the standards of vehicles and equipment's are determined by these regulations. Thanks to new technological developments, it is possible to create more effective mechanisms to carry out cold supply chain processes smoothly. At this point, as in all other industrial processes, industry 4.0 technology has become applicable in cold supply chain processes. Here, the most basic question to be answered in this chapter is that what could be the role of industry 4.0 technology in a cold supply chain process meeting expectation with minimum standards. Before answering such a question, it is necessary to briefly mention the basic methods and concepts used in the industry 4.0 technology. Thus, in the first chapter, basic concepts and parameters of industry 4.0 technology will be discussed. In second chapter how to use industry 4.0 in cold supply chain processes, will be evaluated through a sample dairy product company. In third chapter, in the context of industry 4.0 applications, the current situation of the sample company is evaluated. In the fourth chapter, a future projection has been drawn in terms of industry 4.0 and the future of this technology is discussed. In
the last section, threats and potential problems during the implementation of the industry 4.0 will be evaluated.

2 Basic Parameters of Industry 4.0

In such a period where humanity is experiencing the information age, due to technological developments, the ease of acquiring and transferring information positively affects the business practices driving all industrial areas within the world of economy. (Atzori et al., 2010). During this period, the industry successfully achieved a new transformation. It is accepted that, the first industrial revolution started with the use of steam machines for fabric production; the second revolution began with Ford Model T production and the third revolution started with the use of the first automation system controlled by digital programming (Drath and Horch, 2014; Shafiq et al., 2015; Lu, 2017; Erkollar and Oberer, 2017). It can be said that, fourth industrial revolution where the virtual and the real world merged (Barata et al., 2018) starts with sharing information in real time among people, machines and objects and using this information in controlling and decision-making support system for business processes through intelligent software and automation systems (Dombrowski et al, 2017). For this reason, Industry 4.0 includes methods of obtaining and using information for controlling and decision-making processes. This will be possible through the widespread use of information and communication technologies and by achieving a cost-effective ratio compared with other alternative methods.

2.1 The Principles of Industry 4.0 Technology

Technological developments have the ability to direct the desires, demands and expectations of societies.; on the other hand, changing expectations of societies leads to an increasing use of technology. Six different technological developments played an important role in the transition to industry 4.0. These are (Dombrowski et al, 2017; Herman et al, 2016; Sung, 2018): IoT, Big Data, Mobile and Augmented Reality,
Additive Manufacturing, Cloud, Cybersecurity. These technologies often play complementary roles in the realization of business processes. For example, IoT technology yields big data. Big Data usually needs the cloud for recording and Cybersecurity for security. Using these developing technologies extensively for Industry 4.0 is a positive step but development of technology is not enough alone for the transition to industry 4.0. Before using this type of technologies in industry 4.0 processes, a set of minimum standards should be provided. These are (Dombrowski et al, 2017; Herman et al, 2016; Oberer and Erkollar, 2017): Decentralization, Interoperability, Transparency, Traceability, Virtualization, Real time capability, Modularity, Service orientation. With the development of IOT technology, the necessity of recording high-diversity and high-volume data to the sources at different locations arises. This means decentralization of data. To obtain information by using data from different centers and systems, service provider companies need to be transparent and their data must be traceable and usable. Thus, these raw data can be accessed with necessary software-hardware and used in real time control mechanisms. So, interoperability can be ensured in this way. In addition, these systems should be prepared visually and modularly. Hence, by using such new technologies, it is possible to achieve high operational efficiency and productivity in industry 4.0 (Thames and Schaefer, 2016).

2.2 Factors Affecting Industry 4.0

Development of technology, changes in social, economic and political life are effective triggering factors in transition to industry 4.0. The main reasons for transition to industry 4.0 are (Lasi et al., 2014): Speed: Need for acting very quickly for design, development and renewal has increased. Decentralization: The need for fast decision-making has reduced the hierarchy, so it has become necessary to make decisions with more decentralized mechanisms instead of single-center decisions. Customization of demands: It is expected that products or services should be produced considering the specific demands. Flexibility: Customization brings need for more flexible business conditions by changing production and service structures. Ecological usage: Peo-
ple in the future would prefer resources which are less harmful to environment. Three concepts have great importance for achieving customer satisfaction in Industry 4.0. These are (Hofman and Rüsch, 2017): Accessibility: Customer accessibility to products and services will be ensured using autonomous distribution systems. Digital information: Suppliers should transparently provide data and process traceability to their business stakeholders and customers. This can be achieved through the facilities provided by technology, such as virtual reality and remote control. Digital service: Usage of information management technologies throughout supply chain in Industry 4.0 make digital services possible and in addition to giving feedback for digital services. In terms of companies, technology for industrial management is a tool to earn money and to keep the continuity of earning money legally. On the other hand, customers aim generally to reach desired products and services quickly without paying huge price. Consumers are closely interested in the quality of food (Corallo et al, 2018). In addition, Customers who have environmentalist attitude demand ecological products also. Transition to industry 4.0 has mostly started in order to respond this kind of special customer’s demands. Even though it is a desirable revolutionary innovation, so many factors such as costs, employee habits, training and skills are slowing down transformation to new Industrial Revolution era. In order to test all these cases in the transition as well as to analyse effects of Industrial Revolution in cold supply chain processes and problems about them, a dairy company was selected as sample case. So, in the next chapter, cold supply chain processes in a dairy factory will be discussed as a case study.

3 Current Situation of Cold Chain Management in Sample Company

As a basic raw material of dairy products, milk contains many bacteria. In addition to beneficial bacteria, there are also harmful bacteria in milk and these harmful bacteria are multiplying faster than beneficial bacteria (Günhan et al., 2006). The preservation of hygiene of milk and other raw materials in the content of dairy products during the supply chain, requires keeping unwanted bacteria formation at acceptable levels. On the other hand, one of the most important factors in develop-
ment of the bacteria in milk is temperature. For this reason, a healthy cold supply chain has critical importance to prevent the proliferation of harmful bacteria that adversely affect quality of dairy product.

3.1 Milk Supply Process of Sample Company

Milk required for production in the factory is provided from farm centers or villagers. Here, in order to understand how milk is obtained in these farms, a sample milk farm is selected. This sample farm uses modern technologies for milking cows. Thanks to advanced technology, cows are monitored by electronic units tied their ankles. These devices, called pedometers, have accelerometer sensor, microcontroller, voltage regulator, battery and RF transmitter modules. Pedometers detect cow’s feeding and movements, through accelerometer sensors, transform these analogue data using microcontrollers and send from their RF transmitters to a RF receiver. Afterwards another microcontroller transforms these received data into digital data and sends them to computers (Ozguven and Tan, 2017). This system, tracking cow behavior, detects angry or diseased cows and automatically separate them from other cows when necessary. There is a rotating platform for milking cows in sample farm. Cows placed on this platform are connected to the milking machines with human help. How many liters of milk are collected from each cow is measured during milking. Another important practise in sample farm is detecting of mastitis. If a cow has a mammary inflammation, the milk obtained from it transmits electricity so mastitized milks can be detected using this principle. If mastitis is detected, system automatically stops milking. There is also a system for milk cleansing in the farm and after milking which automatically cleans the surfaces on which milk is passing. In sample farm, since cows and milk data are generally shared through web-based programs, it is possible to access these data by phones, tablets, etc. (Suru Yonetimli Buyukbas Sagim Sistemleri, accessed on 2.6.2018). However, this kind of farms with advanced technology are extremely low. Generally, most of farms have not any technological systems except electronic milking systems as shown in Fig. 1.
After milking, the temperature of milk is generally at approximately 35°C. It should be reduced below 5°C in 3 hours in order to increase the shelf life of the milk. Also, the principles of cold chain should be protected along transfer of milk. For this reason, milk is collected from farms in the morning and evening by using a standard route. So, villagers can milk their cows according to these standard collecting. During collection of milk from farms, only supplier name and weight of milk are recorded and all collected milk from different farms are combined in the same milk tanker. In this case, if there is a problem about some of collected milk, all of the milk in the tanker can be affected. After that those tankers are transported to the nearest milk collection centre. The officer at the milk collection centre receives milk from milk collectors. Milk collectors are also responsible for maintenance and cleaning of their vehicles. After each carrying, milk collectors clean their tankers under the control of milk collection centre officer. They have to record what time they cleaned their vehicles and what materials they used for cleaning.

### 3.2 Acceptance of Milk and Milk Processing

After coming to factory, milk in tanker is weighed first and then mixed by an employee to make a homogeneous distribution for its components. Meanwhile a sample from milk is collected and sent to laborato-
ry for analysing (Fig. 2). After various tests such as PH, oil, water, antibiotic and temperature, milk is accepted by the company. If analysed milk has acceptable values and if drivers submit a document which indicates that the milk has been at expected temperature during transportation, it is assumed that cold chain for this transport was protected.

Figure 2  Milk sampling from milk tankers

After these controlling stages, milk cooling process starts. Different methods can be applied for cooling milk. The most two preferred methods for cooling large amounts of milk are using cooling tanks or plate heat exchangers (TC Milli Egitim Bakanligi, 2013). In sample factory, after being tested, milk is transferred to cooling tanks. Temperature of the milk in cooling tanks is kept at a constant level. Afterwards, milk is sent to production lines by means of pipes established among the cooling tanks and the production lines. Then milk combines with other raw materials and transformed into dairy products such as white cheese, yoghurt and butter. After production, employees put products to pallets and transport these products to cooled storages. There are temperature control sensors connected to the wi-fi in these storages. Temperature data are sent to database of the service provider company.
3.3. Distribution of Dairy Products

For making a healthy distribution, the company set up temperature measurement systems in warehouses and vehicles, also set up CAN Bus systems for product transportation vehicles. CAN Bus systems and temperature sensors in vehicles send data to service provider company by using GSM. The company having these systems gives opportunity to query and report from its database for its customers through web-based software (Fig. 3). In addition to this, when incoming data exceeds desired values, this information is sent to the factory workers by e-mail.

![An image from web-based logistics program used in company](https://example.com/image)

The sources of queries provided by the firm can be classified under three main headings like that; CAN Bus system, GPS and temperature sensors.

3.3.1 CAN Bus (Controller Area Network Bus) System

Bus systems has been developed for communicating the devices with each other in the vehicle. The firm which is setting up logistics tracking system for the sample company, uses CAN Bus systems in its electronic units. CAN Bus system is a protocol developed to enable many devices on the vehicle to communicate with each other through a single cable (Muneeswaran. A., 2015). CAN Bus system prevents cable mixing in-
side vehicle and provides an economical and reliable system for device communication (Kara, 2009). By using CAN Bus system, company employees mainly monitor the following information: Speed of the vehicles, Rapid acceleration and braking data, Climate information, Fuel consumption during idle and cruising, Axle weights. During sudden acceleration and hard brake, both vehicle and food in the vehicle may be damaged. Using sudden acceleration and hard brake data provided by CAN Bus systems, make it possible to take records about damaged products during transport and to take necessary measures. In addition, since drivers know that these records are stored in a database, they can use vehicles more carefully and by this way maintenance costs reduce. By using CAN Bus systems, information such as when fuel tank cover is opened and how long it has been open can be seen. On the other hand, fuel levels of vehicles also can be obtained from sensors in fuel tanks. These systems ensure traceability of when and how much fuel is bought, so that any fuel hijacking can be prevented. It is also possible to follow information about the range of the vehicle and whether fuel is wasted or not.

3.3.2 GPS (Global Positioning System)

GPS clocks continuously send their signals to earth. GPS receivers around the world calculate their position on the earth by evaluating data from different GPS clocks. GPS receivers embedded in logistics vehicles also identify online locations of related vehicles. In the sample company, GPS systems are installed in the vehicles transporting products. Data obtained from GPS systems in vehicles are sent to database through GSM. On the other hand, the service providing company offers reports to sample company through web-based program. To query from web based program, it is necessary to enter start and end times to the program and the following reports can be generated related with GPS data: Location information of the selected vehicle over previously defined time-frequency ranges, Start position, end position, duration, maximum speed and idle time for each cruise of the selected vehicle Idling and parking times with locations for selected vehicle, How many kilometres the vehicles travel in total, display of last position of vehicles on the map (not related with start and end times).
Temperature and moisture sensors generally are located in warehouses or transportation vehicles. For internet connection of sensors, warehouses use wifi or ethernet cables. On the other hand, sensors in vehicles, are integrated with CAN Bus systems and send data via GSM. If data value received from these sensors is out of required limits, an e-mail is sent to relevant persons to warn them about the problem.

In the sample company, employees use data records from many sensors to take some decisions. In addition, manpower in milk transport is reduced through a system based on automation established in the factory. However, when the sample company’s cold supply chain process is evaluated in terms of Industry 4.0, it is seen that it has not yet reached the appropriate level. Thus, opportunities provided by Industry 4.0 have not yet been utilized. The reasons of this can be listed as follows: The service provider company does not want to share its database: The service provider company which sets the logistics tracking systems in the sample company, stores data from CAN Bus systems,
GPS systems in vehicles and sensors in warehouses, in its own database. In this case, it does not open its database to sample company in an inquarible way. That is to say, in this case transparency, one of the basic principles of Industry 4.0 is not provided. Instead, service provider company offers a web-based program developed by its own software experts to its customers and enables them to report their data from here. One reason for this can be that the service provider company may not want direct access to its database by its customers because it stores data from different customers in the same database. In this case the firm may be worried about its customers’ information could be obtained by other customers. However, since companies can’t access this database from their own system, integration of data with ERP system in these factories become impossible. Therefore, data first can be taken through web-based program prepared by the service provider company and then it can be transformed to ERP system used by sample company. Thus, real time, which is another core process of 4.0, cannot be provided. In order to prevent this, decentralization must be done to record data and transparent of data should be provided so that each customer can access its own database. One-sided Data Flow: One of the basic technologies in Industry 4.0 is IoT. IoT is an internet communication network system where objects are linked to each other or to larger systems. Some objects in cold chain management of the company send data to take some decisions. In the sample company, however, data go one-way only. For example, it is possible to receive data when temperature is out of desired level by e-mail or reporting but there is not an intelligent decision support system to control temperature. Failure to provide digital traceability. Traceability can be classified as follows: Product Traceability: Traceability is defined as "the ability to trace the history, application or location of which is under consideration" in the International Standard Organization (ISO) 9000 quality standards (Olsen and Borit, 2012). It is compulsory to follow food, especially at every stage of food supply chain through many legal regulations. Labels of party numbers, identifying food produced or packaged on the same conditions and usually found on the package of the product, are used to ensure traceability. RFID technology is used to read product number and party number labels quickly and without the need for manpower. Because RFID labels are too expensive compared
to barcode labels, barcode systems are used during stock movements in the sample company. During the transfer of products to outside of factory, they generally use hand terminals and record product and lot numbers, dealer or customer numbers to these hand terminals. Since the data of previous day is transferred to ERP system, real time cannot be provided. In addition, traceability in this system depends on employees doing their job properly. It would be problem if an employee forgets to read a barcode or reads wrong bar code. For this reason, traceability is not achieved at the desired level in terms of transport of products and materials. Traceability of customer demands: In sample company they wanted to create a smart system that would record customers' demands and direct production accordingly. But this smart system could not be practiced because it was impossible to change some employees 'old habits. In the current situation, customer 's demands come to the company via telephone or mail and production plans are prepared according to the decisions of the persons in the planning department. Following money: Account movements which have monetary value are recorded into ERP system by employees. In future, when ERP systems are integrated with banks, customer and supplier records, system entries by employees will be greatly reduced. Other traces: Follow-up of employees, follow-up of works, quality monitoring based on products and methods, monitoring of equipment are recorded by the employees. So, automation is not provided yet. Use of the human factor for operations: With Industry 4.0, it is anticipated that people will work in administrative and strategic decision-making stages, while processes based on muscle power will leave to robots or automatic machines (Benešová and Tupa, 2017). However, in the sample company, employees have a lot of operational works, such as milking, transportation, production, distribution and sales of milk and dairy products (Fig.5). Frequent breakdown of installed integrated systems: There are frequent problems related with electronic devices used in the company's processes. Since companies establishing these electronic devices are new in the sector generally, they do not have required experience. For all these reasons, although technology is partially used in the cold chain processes, it is seen that these processes are not at Industry 4.0 level.
5 Future Expectations

It is not possible to use all concepts and elements of Industry 4.0 that are found in future implications (Hofman and Rüsch, 2017). However, concepts and elements of Industry 4.0 guide us and give us an idea about the future. By using Industry 4.0 elements, possible developments in cold supply chain in future can be grouped into five main categories.

5.1 Traceability of Product and Service Using RFID

One of the base processes of Industry 4.0 is traceability. Undoubtedly RFID (radio frequency identification) is an increasingly widespread technology for traceability. RFID is a generic name given to the systems in a place which receive digital information of moving objects using short-range radio waves (Bouzakis and Overmeyer, 2012). Generally, RFID technology is used to track products in transportation and storage activities. In farms using advanced technology, the pedometer in cow’s feet, are used for cows’ follow-up through RF. RF technology is supported by different devices and algorithms to make observations.
about the movements of cows on the farms. However, outputs of these systems do not have 100% accuracy. For example, there is an average 10% margin of error in the detection of activities such as stopping, lying, walking activity (Ozguven, 2016). In future it is expected that these systems will work with higher accuracy percentages. In addition, number of farms will increase greatly using Industry 4.0. In current situation there is no use of RFID except some developing farms. In the future, it is expected that online traceability will be possible for the companies thanks to RFID readers in vehicles and warehouses. Looking at the different sectors, it appears that RFID is not only used for product follow-ups but also for employees and mobile equipment follow-ups. RFID is also used for ease of use and security. For example, with RFID cards they have, vehicle drivers can open the vehicle doors automatically. On the other hand, face-scan systems for employee traceability are more likely to be preferred in the future.

5.2 Interoperability with IoT and Cyber Physical Systems

Cyber physical systems contain sensors, actuators and distributed controllers. Sensors of electronic circuits send data to cloud. Using these data, software programs after deciding various controls, transfer their outputs back to cloud. Actuators reading data at certain time frequency range use outputs of the control software as their inputs and activate their physical systems according to these inputs (Barreto et al., 2017). Thus, CyberSecurity systems work as closed box systems without human intervention. Companies should be more transparent and while integrating their systems to other systems, they must share their data, algorithms and systems. Thus, data can be evaluated instantaneously; IoT technology can be used to trigger necessary controls and decision mechanisms. IoT technology provides interoperability and decentralization. So, if IoT is used in cold chain processes, many decision-making at operational level and activation of control mechanisms are provided with intelligent systems rather than employees. Instead of warning people for problems by email or with sound and light, data will be evaluated with intelligent systems and smart systems will manage objects which prevent problems. For example, electronic devices used in
storages or transport vehicles can determine type of products in vehicles during temperature changings so that the coolers can be operated according to their needs or the doors can be remaining locked for a period of time. Thus, real-time control will be provided.

5.3 Intelligent Systems

In future, applications of intelligent systems and artificial intelligence will be seen more commonly. In its physical environment, every feature that will create value for the customer will be analyzed by sensors and decisions taken in digital environment will direct physical environment (Fleish et al., 2014). By this way desired value ranges can be provided. Intelligent systems used for cold chain management can be classified as follows (Fig. 6).

Figure 6  A model for the aims of Intelligent Systems

**Time savings:** Because speed is one of the most valuable concepts in Industry 4.0, intelligent systems will be used commonly for time analysis. Movements, routes and sequences in the logistics and handling
processes will be generated as a result of analysis by intelligent systems, thus time spent for these purposes will be reduced. **Space savings**: Intelligent systems ensure products to be stored in the most efficient manner, thus they allow space for more products. (Tjahjono et al., 2017). **Energy Savings**: One of the most valuable resources of our age is energy. Intelligent systems will be commonly used in cold supply management to reduce energy consumption in future. For example, electronic sensors in warehouse will analyse and predict how much the products are heated during the transfer, by using air temperature data in internet, product properties and carrier information. So, they can made automatic temperature controls for transferred products. **Error Analysis**: Intelligent systems will not only use acquiring information through various channels to make decisions, but also, they will question the accuracy of this information. In these processes, different error analyses will be used like artificial intelligence, information comparisons from different media. Thus, unusual situations will be detected, any unaware or deliberate mistakes will be corrected and notification will be given to relevant employees. **Future forecasts**: Intelligent systems can be used not only for taking structured decisions, but also for taking semi-structured decisions. These intelligent systems will use different parameters of physical environment as well as internet and will improve themselves with artificial intelligence. For example, intelligent systems that know customer’s location, behaviours and habits by monitoring customer data will be used in markets. These systems will also be used to predict and meet customer demands.

### 5.4 Robots, Automatic Machines and Unmanned Transportation Vehicles

Nowadays, usage of navigation has become very popular. Navigation devices not only calculate the distance to be travelled but also calculate the road traffic by evaluating data received from other navigation devices. Thus, the shortest distance navigated smoothly can be found via navigation. Intelligent systems determining routes will take decisions with more extensive calculations in future. For example, transport vehicles will move by analysing different parameters such as road tem-
perature, road topological and geological structure and customer pro-
file as well as traffic and road information. It will be normal for un-
manned vehicles to work with integrated drones. So that, it will be
possible to deliver products for any places such as apartment windows
or picnic areas in the future. As well as transportation, the other pro-
cesses like production, transfer and distribution operations will be car-
rried out by robots and automatic machines and so become indepen-
dent from people.

5.5 Customized Services and Products

Increasing competition conditions lead firms to take much more ac-
tions for customer satisfaction in order to stay in the business. This
orientation leads firms to work more flexibly and to use more technol-
gy. In future, customers will be able to examine products and services
they want to purchase using virtual reality. Moreover, using augmented
reality, they will be able to see the product designs they have modified
and demand personal products. Customization will not be limited only
with products, at the same time it will be provided for services. This is
also valid for cold supply chain service as a part of industry. That is,
customers will be able to track the products they demand from cold
chain and be able to make personal demands for product or service.
For example, they can determine combination of ingredients for a cake
and they can buy this cake in desired shapes and colours. In addition,
customers can also ensure that cake they are going to buy is brought to
the right place at the exact time.

5.6 Globalizing Systems

By having communities of objects together, Industry 4.0 will allow
companies having similar industrial processes to work together. This
will reduce transport and warehouse costs. For example, food trans-
port vehicles will report the route, time, temperature and transport ca-
pacity via internet. These data will be evaluated by intelligent systems
and integration will be provided for transporting different companies'
products on same vehicles. It is also possible to establish new companies that will earn money from such integrations in future.

6 Threats Coming with Industry 4.0

Every technology comes with its disadvantages as well as advantages. Threats arising as a result of industrialization are quite common in this age. Threats possibly seen together with the spread of industry 4.0 applications can be classified as follows: Data Security: Soon after the Facebook data scandal, it is seen that even big companies could experience difficulties in data security. In the cold supply chain, it is not known how much cyber security can be achieved in the use of IoT and cloud in Industry 4.0. If cyber security cannot be ensured, a company's private information can be easily learned by its competitors. In such a case, usage of these information by competing companies to take strategic and tactical decisions will be an unfair situation. In order not to cause such incidents, both private and public institutions should implement necessary measures and regulations to combat cybercrimes. Privacy: The widespread availability of traceability with Industry 4.0 can make it difficult to protect personal privacy. The last actors of the cold supply chain are consumers. Information obtained as a result of monitoring consumer identities and behaviours, can cause an unfortunate use to direct customer behaviours by intelligent systems. Environment and Health: Increased usage of robots, machines, sensors and electronic devices in industry will cause many adverse effects. Consumers mostly concern with the price and quality of products and don't consider how much the environment is damaged as a result of the production, transportation, storage and cooling of products (Tanrivermis and Mulayim, 1997). In addition, the increased electromagnetic systems used for communication with Industry 4.0 will also affect the health of not only humans but also plants and animals in a negative way. Difficulty in Finding Qualified Employee: The industry 4.0 brings together instruments from different disciplines and directs them to work together. Lack of qualified persons who know the different disciplines and know how to integrate them will continue to be a problem especially in the beginning of transition to Industry 4.0 (Tupa
et al., 2017). On the other hand, the use of automatic machines and robots to perform operations at the operational level, which requires muscle strength, will make it difficult for future unskilled workers to find work. Technology increment with Industry 4.0, rises the need for technologists like data analysts, software and electronical engineers, system analysts in all sectors. For this reason, it is expected that the curriculums in schools and other educational institutions will be shaped accordingly (Benešová and Tupa, 2017). Difficulties in Determining Responsibilities: In Industry 4.0, the fact that processes are fed from different disciplinary sources has raised the question of how to share responsibilities in an event of a crime. For example, Uber's driverless test vehicle crashed a rider of bicycle in recent times. This event brought debates about who were the responsible for these kinds of accidents. The company producing tool or writing software, service provider such as Uber or owner of vehicle can be guilty in different ratios for this accident (Onat, 2018). Similar problems can be encountered with industry 4.0 and these problems must be solved.

7 Conclusion

Intensive use of technology will be an indispensable element of life in the future. As an inevitable consequence of this, industry will revise its business processes according to this so-called developing technology. In order to practice these technological developments, it is necessary to achieve some competencies in business processes such as transparency, traceability and visuality. The realization of an integrated use of resources from different disciplines and different firms depends on provision of these conditions as a minimum. From this point on, Industry 4.0’s technology provides person-specific services and products depending on customer’s special demand for speed, quality and cost. In this chapter, the level of the industrialization in the cold chain management responding customer’s expectations is studied. Along with the automation of technology-supported farms providing milk to the sample company, it has been observed that there has been a certain reduction in the manpower used in these processes such as cow management, milking, evaluation of milk quality. However, the number of...
such technology-supported farms remains limited due to high cost of investment and therefore automation is limited only by milk supply. After this stage, transportation and distribution of milk is carried out with manpower. Taking samples and analysis in the company while accepting incoming milk are also done by an employee. After these operations are completed, milk is transferred from the tankers to the cooler store and processes before production such as pasteurization, sterilization start. Although a partial automation has been achieved at this stage, most of the processes in the supply chain are controlled by employees. In addition to this, many muscle-based activities such as transporting the products to the cold storage depots after production, transfers to carrier vehicles for distribution are performed by employees. On the other hand, different technologies such as sensors, CAN Bus and GPS systems are used to ensure traceability which is one of the core processes of Industry 4.0 in cold chain transport. Company employees receive information from these systems via mail or reports. However, intelligent systems that will move objects according to incoming data have not been set up in the sample company yet. For this reason, operational decisions and actions are still carried out by employees. As a result of this study, it is seen that current technological developments are at a level that will enable the applicability of Industry 4.0. In spite of this level of technology, due to the high costs of technological investments and problems about adaptation to the basic concepts necessary to implement Industry 4.0, companies are not able to change the system they have been using in a short time. Transition to Industry 4.0 primarily needs training of multidisciplinary thinking employees. For this aim, education system should be revised and employees should take training in this new system within the scope of new technologies. Secondly companies willing to set up Industry 4.0 systems need to be transparent and share information in such a way that the customer can get the highest benefit. On the other hand, when sharing data with customers, maximum paying attention to privacy is necessary for not jeopardize the data security of other companies. That’s why companies providing Industry 4.0 applications must build their databases in a decentralized way and must make investments to realize this. Thirdly, statesmen and scientists also have a variety of responsibilities. Primarily statesmen should be able to see and under-
stand the problems possible to arise in the future, such as preventing the address confusion probably caused by the use of the Internet by every object and develop standards and sanctions to overcome such difficulties. On the other hand, provision of food traceability is of great importance in terms of protecting people's health and safety. For this reason, it is necessary for states to support the technologies to make the systems cheaper like RFID which increases the effectiveness of food traceability. It is expected that Industry 4.0 understanding and technology will overcome problems and in the near future will spread rapidly. It is true that it will take time to meet necessary conditions for industry 4.0 but providing these conditions will be indispensable to companies in the future since the companies that cannot make the transition to Industry 4.0 will lose their competitive advantage to a large extent.

References

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A Review on Cold Chain Management for Industry 4.0


**Key Terms**

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<th>IoT</th>
<th>RFID</th>
<th>Interoperability</th>
<th>Virtualization</th>
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<td>CAN Bus</td>
<td>Traceability</td>
<td>Cyber Physical Systems</td>
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<td>GPS</td>
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**Questions for Further Study**

**What** are the requirements that lead to transition to Industry 4.0?

**What** are the technologies used to distribute dairy products? What benefits do these technologies provide?

**What** are the obstacles to achieving Industry 4.0 in the cold chain management?

**Which** technologies are expected to be used in cold chain management in Industry 4.0 applications?

**What** are the threats coming with Industry 4.0?

**Exercises**

**Suppose** you are an executive in a company that provides Industry 4.0 applications in the cold supply chain. What skills do you want the staff to hire?

**In** the cold chain process, consumers are the last actors and they contribute to the preservation of the cold chain with the refrigerators they
use in their homes. In the future, what kind of functions will be expected from refrigerators in our homes with the widespread use of Industry 4.0 applications?

Please discuss the limits of traceability and transparency for business processes.

Further Reading


Connection between industry 4.0 and smart factories

Learning Objectives

The main objective of this chapter is to show the connection between Industry 4.0 and smart factory. Once you have mastered the materials in this chapter, you will be able to:

– Understand why we are living the Fourth Industrial Revolution and what it is.
– Identify the technologies used with Industry 4.0.
– Discuss about the difference and Industrial Internet of Things (IIoT) and Industry 4.0.
– Understand what is smart factory and how can it facilitate our lives.
– Explain the relation between Industry 4.0 and smart factory.

Chapter Outline

This chapter discusses the connection between Industry 4.0 and smart factories. Current Industry 4.0 technologies and smart factories allows numerous developments. Today, manufacturers seek for a more advanced and useful factory structure to improve overall effectiveness and for cost-cuttings. Industry 4.0 remarkably changes products and production systems regarding the design, processes, operations and services. Smart factory at this point, can connect the digital and physical worlds. Also, smart factory creates a flexible environment. Industry 4.0 and the smart factory is the future because they integrate new technologies, improve work conditions, and increase productivity.
1 Introduction

In 21st century, information and communication technologies are developing and desire of demand is growing rapidly like a snowball effect. New technologies are born such as: Internet of the things (IoT), big data, augmented reality, artificial intelligence (AI), cloud computing and so on (Chen et al., 2018). Now companies, firms and many corporations use these technologies in a new level of industry called Industry 4.0. For the first time, Industry 4.0, which is considered as the fourth generation of industrial revolution, was presented to the people at the Hannover fair in Germany in 2011. New technologies are implementing by the manufacturing industry and enable the mix of physical and virtual worlds through cyber-physical-systems (CPS) contained. However, the Industry 4.0 simultaneously shows characteristic that represent the challenges regarding the development of cyber-physical-systems, reliability, security and data protection according to Jazdi (2014). Furthermore, it introduces what has been called “smart factory”. With these smart factory terms, factories can adopt the physical and cyber technology. The vision of future production contains more efficient manufacturing systems and makes predictable scenarios can be applicable. Smart Factory is consisted of three primary layers, namely perception layer, deployment layer and executing layer. As the smart factory slowly emerges by the time the roles that people take on will enhance from what they are currently doing in today’s factories. In addition, as factories progress more technologically, the number of indirect job opportunities will increase proportionally. In turn, new suppliers in the new industries will emerge and they will have to find and find new workers. At the same time, the components of today’s advanced automated plant machines will be equipped with sensors and communication systems in connection with Industry 4.0, thus increasing speed and efficiency. It will also allow the production of low-cost product. These smart factories will create the possibility of using simu-
lation, virtual reality and virtual prototypes and will enable us to learn more about the future of the product without being put on the market. Now, the most commonly used trend and systems are in Industry 4.0 and smart factories. These terms help us to meet the increasing demands of human beings in appropriate way and work efficiently while doing these works.

In conclusion, new level of industry, namely Industry 4.0 which is more digital, flexible and efficient is more usable and helpful for manufacturing products, service etc. Smart factories can be more effective to start small, test out concepts in a manageable environment, and then scale once lessons have been learned (Burke et al. 2018). Manufacturers can implement the smart factory in many different ways. Our future will blend more with technology and will be used in many sectors such as health, automotive, transportation, agriculture, etc. The smart factories and the fourth revolution of industry is a direct way for manufacturers to achieve in a competitive and dynamic marketplace.

2 Overview of Industry 4.0

Industry 4.0 also known as “smart manufacturing”, “industrial internet” or “integrated industry”, is the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the IoT, cloud computing and cognitive computing. Fourth Industrial Revolution concept comes from Germany because since Germany has one of the most competitive manufacturing industries in the world and is even a global leader in the sector of manufacturing equipment. "Industry 4.0" term was presented to the people at the Hannover fair in 2011 in Germany. It is a strategic initiative of the German government that traditionally heavily supports development of the industrial sector (Rojko, 2017). In connection with this, Industry 4.0 can be seen also as an action towards sustaining Germany’s position as one of the most influential countries in machinery and automotive manufacturing. Since that time, its introduction, Industry 4.0 is in Germany a common discussion topic in research, academic and industry communities at many different occasions. Industry 4.0 has a significant role in strategy to take the opportunities of digitalization of
all stages of production and service systems. Digitization of manufacturing process is the need for today’s industry. Digitizing manufacturing processes is not as effortless as connecting devices to Wi-Fi. Firstly, the manufacturing industry knows how to use oil and steel to move metal parts; not cloud computing and cyber-physical systems. Understanding Industry 4.0 and integration of it in local industries will help the developing countries to get their parts in the international division of labour (Alcin, 2016). Industry 4.0 capabilities can improve business operations and revenue growth, transforming products, the supply chain, and the customer experience. In addition to, Industry 4.0 makes possible enterprises to optimize their production operations and race internationally. Against all stages of the customer journey, Industry 4.0 can create new opportunities for innovation and growth. Customer experience in the age of Industry 4.0 would be driven not just by the physical object but by the information, analytics, and customization that make the customer’s interaction with that object more transparent, and the ways the company acts on the insights they gather (Deloitte Insights, 2018). Industry 4.0 technologies create the potential for interactions between every point of a network. In addition to these, Industry 4.0 brings in a new wave of connected manufacturers and smart factories. The word "revolution" denotes abrupt and radical change (Schwab, n.d.). Stages in the development of industrial manufacturing systems from manual work towards Industry 4.0 concept can be presented as a path through the four industrial revolutions (Rojko, 2017). The term "Industrial Revolution" was first popularized by the English economic historian Arnold Toynbee (1852–1883) to describe Britain’s economic development from 1760 to 1840. Revolutions have occurred throughout history when new technologies and novel ways of perceiving the world trigger a profound change in economic systems and social structures (Schwab, n.d.). The term Industry 4.0 stands for the Fourth Industrial Revolution. Development of productive technological capacity through creativity is a key factor for the growth, development and change of the condition of human society and the environment. Industry 4.0 comprise of putting everything together all advanced researches in biology, technology and industrial automation, for improving the current way of living. Technical advances also modify the way humans produce materials, service, product etc. The step
into production technology, which was entirely distinct from the past, is also called the industrial revolution. The First Industrial Revolution began by the end of the 18th century through the use of steam power and mechanization of production in England then spread to the other parts of the world. Henry Cort has created the first mechanical looms in 1784, emerged the starting contextualization of the First Industrial Revolution in time frame. What before manufactured threads on simple spinning wheels, the mechanized version achieved eight times the capacity in the same time. Mechanization of production is facilitated with water and steam power. In the first industrial revolution, steam engines were used for power. The use of these for industrial purposes was the greatest innovation for increasing human productivity. The Second Industrial Revolution also known as the Technical Revolution began in between 1870 and 1914 in US with discovering of electricity and assembly line production. The second industrial revolution took place in the midst of wave immigration, as masses of people moved to the United States, primarily in search of employment in the country’s burgeoning industries (Sawe, 2017). During the Second Industrial Revolution, the existing manufacturing and production methods were developed. For example, steel replaced iron in the building business. It was strong and cheap. Therefore, it made possible to build rail lines at competitive cost and spread transportation. The steel industry was further revolutionized by the adoption of the open-hearth process. Steel also facilitated the construction of ships, skyscrapers and larger bridges. In 1870, carbon filament lamp was developed by Thomas Edison. This bulb is familiar to the electric bulb which we use today. The innovations and inventions of the technological revolution are the building blocks of modern life. The Third Industrial Revolution began in the 1970s through partial automation using memory-programmable controls and computers. First programmable logic controller (PLC) in 1969 and growing application of electronics and IT to automate production processes are the key developments of third industrial revolution. Since the introduction of these technologies, we are now able to automate an entire production process without human assistance. We are currently living the Fourth Industrial Revolution. The Fourth Industrial Revolution is not only connected machines, devices and systems. The most breathtaking revolution is definitely the Fourth Indus-
trial Revolution. It was coined as the main subject of the exhibition and highlighted the fourth industrial revolution as envisioned by German experts. It builds on the developments of the Third Industrial Revolution. New technologies are implementing by the manufacturing industry and enable the mix of physical and virtual worlds through cyber-physical systems (CPS) contained. This is the next step in production automation. Industry 4.0, appears to be modifying the way businesses function and, by extension, the stakes by which they are forced to compete. The value of the Industry 4.0 concept can be enhanced through a clarification of the role played by technologies that facilitate the physical manipulation of objects (Sniderman, Mahto & Cotteleer, 2016). This flexibility allows a dynamic configuration of different aspects of the value chain at the same time that combines an optimization of the decision model to cope with the real needs of the market (Correia, 2014). Up to now, most companies have used Industry 4.0 technology to make their production operations faster and cheaper or to reduce cost. The networking of all systems direct to "cyber-physical production systems" and therefore smart factories, in which production systems, components and people communicate via a network and production, is just about autonomous. The result of implementing Industry 4.0 is a system in which all processes are fully integrated and system in information in real time frame. The new digital industrial technology is rising at this point. Industry 4.0 is a transformation that makes it possible to collect and analyse data across machines, enabling faster, more efficient, and more flexible processes to produce higher-quality goods at reduced costs. Advanced digital technology is already used in manufacturing, but with Industry 4.0, it will transform production. It changes traditional production relationships among suppliers, producers, and customers as well as between human and machine. Organizations should decide how and where to invest in these new technologies and identify which ones might best meet their needs. In conclusion, Industry 4.0 technologies mean greater levels of automation for production and product inspection. In other words, it means more efficiency in terms of energy and raw material use. These new technologies are: Alternative energies and new materials: Discovering novel ways is to get energy from numerous sources, developing a new ecosystem to provide the health of the earth is creating new possibiliti-
ties. The Fourth Industrial Revolution is making possible us to get unlimited clean-energy through this upcoming technology. Developing countries, such as China, India, the US and Middle Eastern countries, have forwarded the development and construction of large-scale solar energy and wind farms in recent years. Big Data: There is a technology that can conduct analysis is Big Data. There are still massive sets of untapped data in the industrial world. Inside the sources from the supply system is information from retailers, transport, invoices and more. Data from customer profiles, social networking profiles, orders, market forecasts and geographical schemes also plays a big role. In Industry 4.0, Big Data is a collection of data from traditional and digital sources inside and outside your company that represents a source for ongoing discovery and analysis (OTTO Motors, n.d.). Now, data is gathered everywhere, from systems and sensors to mobile devices. Using customer data to analyse information from the delivery system, retailers can meet the expectations of customers by anticipating their behaviour. The challenge is that the industry is still in the process of developing methods to best commentate data. To keep up with the data, rather than being mired in it, manufacturers will need to adopt more robust technologies than traditional data processing software. Digital Twin: Digital twin is a virtual model of a process, product or service. Digital twins can be utilized to show how an item is serviced. For the most part, this can be used in combination with AI tool sets, software analytics, and real-world data to create living digital simulation models that update and change along with their physical counterparts (Weallans, 2018). It was named one of Gartner’s Top 10 Strategic Technology Trends for 2018. A digital twin can use smart components and sensors to collect data about real-time status, working condition, or position are integrated with a physical item. The components are connected to a cloud-based system that takes and processes all the data the sensors monitor. This input is analysed against business and other contextual data. At a high level of digital twin technology ensures a digital representation of the past and current behaviour of an object or process. Also, the digital twin needs cumulative, real-world data measurements across an array of dimensions, including production, environmental, and product performance. Thomas Kaiser, SAP Senior Vice President of IoT, highlighted digital twin technology’s importance in this way;
“Digital twins are becoming a business imperative, covering the entire lifecycle of an asset or process and forming the foundation for connected products and services. Companies that fail to respond will be left behind.” Internet of things: Internet of Things (IoT) was coined by Kevin Ashton in 1999 during his work at Procter & Gamble (Lueth, 2014). IoT is the connection of every device to the internet and each other. Gartner estimated 20.8 billion connected things will be in use by 2020. This is where hardware has the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction (Duivenvoorden, 2017). Today, there is no doubt that the existence of the internet has a direct influence on everything. The IoT is predicted as one of the most important areas of future technology and is gaining vast attention from a wide range of industries. IoT is helping to release new age of digitalization across industries. Architecture for IoT-based smart factories, defines the main characteristics of factories with a focus on the sustainability perspectives. With the IoT, data, in addition to physical objects, are a source of value. This connectivity makes possible to build smarter supply chains, manufacturing processes, and even end-to-end ecosystems. Using the IoT, a manufacturer can connect devices, assets, and sensors to collect untapped data. Firms will pay into in the IoT to redesign factory workflows, improve tracking of materials, and optimize distribution costs. There are five fundamental technologies are widely used for the deployment of successful IoT-based products and services: Radio frequency identification (RFID), wireless sensor networks (WSN), middleware, cloud computing and, IoT application software (Lee & Lee, 2015). RFID allows automatic identification and data capture using radio waves, a tag, and a reader. WSN consist of spatially distributed autonomous sensor-equipped devices to monitor physical or environmental conditions and can cooperate with RFID systems to better track the status of things such as their location, temperature, and movements (Rghioui, 2017). Middleware is a software layer interposed between software applications to make it easier for software developers to perform communication and input/output (Lee & Lee, 2015). Cloud computing is a model for on-demand access to a shared pool of configurable resources (e.g., servers, networks, computer, storage, applications, services, software) that can be provided as Infrastructure as
a Service (IaaS) or Software as a Service (SaaS). The IoT facilitates the
development of industry-oriented and user-specific IoT applications.
The true value of the IoT for enterprises can be totally realized when
connected devices are able to communicate with each other and inte-
grate with vendor-managed inventory systems, customer support sys-
tems, business intelligence applications, and business analytics. Cyber-
security: Cybersecurity is the protection of internet-connected systems,
including hardware, networks, programs, software and data, from cy-
berattacks. These attacks are in general aimed at accessing, changing,
or destroying sensitive information; extorting money from users; or in-
terrupting normal business processes and increase time for solving
these problems. One of the biggest problems of cybersecurity is the fre-
quently evolving nature of security risks. In a conclusion of security
risks, investments in cybersecurity technologies and services are in-
creasing. The utilizing of cybersecurity can help obstruct cyberattacks,
data breaches and identity theft and can aid in risk management. Cy-
bersecurity is important because in today’s connected world, everyone
benefits from advanced cyber defence programs. Interoperability: In-
teroperability is the connection of cyber-physical systems, humans and
smart factories. With this, these elements can communicate each other.
Furthermore, information transparency: creating a copy of the real-
world through sensor data to review information. Industry 4.0 tech-
nologies are taking a step the manufacturing industry with new means
of efficiency, accuracy and reliability. Also, in doing so, manufacturing
partners can effectively share information, error-free transmission and
translation. In the realm of manufacturing, interoperability among a
variety of systems, in or across industries, has been gradually accepted
as one key feature along the life cycle of a product (Liao et al., 2017).
Wearables: As the name suggests, a wearable device is a technology
that is worn on the human body. Wearables are predicted to become
increasingly significant in future as soon as possible. Companies like
Apple, Fitbit, and Google etc. have started to evolve more types of de-
vices that are small enough to wear and that contain powerful sensor
technologies that can collect and deliver information about their sur-
roundings. Wearable device models may depend with short-range
wireless systems like Bluetooth or local Wi-Fi setups. Wearable tech-
nology has enormous potential, as was promised by smartwatches,
medical devices and virtual reality headsets. Wearable will move beyond the wristband into smart jewellery, clothing, and tattoos. Wearable usually incorporates smart sensors that can measure the wearer's personal data like heart rate, step count etc. All of this has contributed to a marketplace that experts predict will reach $53 billion in 2019. Nanotechnology: Nanotechnology is a field of research and innovation concerned with building 'things' – generally, materials and devices – on the scale of atoms and molecules (AZoNano.com, 2005). A nanometre is one-billionth of a meter: ten times the diameter of a hydrogen atom. It helps us to find, cure, solve and predict in human body. Nanotechnology enhances the properties of tools and materials, such as; greater strength, lighter weight, more durable, better electrical conductors, increased control of light spectrum and greater chemical reactions. Nanotechnology is helping and serving to considerably develop, even revolutionize, many technology and industry sectors: information technology, homeland security, medicine, transportation, energy, food safety, and science, and among many others. Decentralized Decision-making: It mentions the possibility of cyber-physical systems to make their own simple decisions and become as self-ruling as possible. Decisions are spread throughout the system to maximize response time and optimize flexibility while continuing to operate. Only in case of exceptions, interferences or conflicting goals are the tasks given to a higher level. Artificial Intelligence (AI): Artificial intelligence (AI), as it is understood, describes the ability of machines to imitate human mental prowess. As AI emerges from science fiction to become the frontier of world-changing technologies, there is an urgent need for systematic development and implementation of AI to see its real impact in the next generation of industrial systems, namely Industry 4.0 (Lee et al., 2018). Machine learning enables predictions to be made based on large amounts of data. AI also brings to the manufacturing table is its capability and quality to open up completely new avenues in business. The advantages are numerous and can significantly reduce costs. With pre-empting a failure with a machine learning algorithm, systems can continue to function without redundant interruptions. By the end of 2018, there will be 1.3 million industrial robots working in factories around the world. The general approach about the future is that as jobs get taken over by robots, workers will be offered
training for higher-level positions in programming, design, and maintenance. Meanwhile, the efficiency of human-robot collaborative work is being improved as manufacturing robots are approved for work alongside humans. AI will play a major part in ensuring the safety of human personnel as well as giving robots more responsibility to make decisions that can further optimize processes based on real-time data collected from the production floor when the adoption of robotics in manufacturing increases. Furthermore, AI permeates the entire Industry 4.0 ecosystem. Machine Learning: Machine learning is the ability that computers have to learn and develop on their own through AI and without being explicitly told or programmed to do so. Machine learning focuses on the development of computer programs that can access data and utilize it learn for themselves. In the past decade, machine learning has given us self-driving cars, effective web search etc. developments. Amazon, Google, Microsoft, IBM and other companies, are racing to sign customers up for platform services of machine learning activities. Real-time Data Processing: A real-time data processing system is able to take input of quickly changing data and then provide output near immediately so that change over time is readily seen in such a system. In contrast, real time data processing contains a continual input, process and output of data. Real-time data processing is also called as stream processing because of the continuous stream of input data required to yield output for that moment. Collaborative Robot: A collaborative robot (cobot) is a robot designed to collaborate with human workers closely, and without the usually required security restrictions applied in industrial robotics typical applications. Cobots are programmed, configured and controlled locally in the factory, companies which choose the cobot’s route can retain ownership over their automated processes and the precious knowledge it takes to exploit them. This result comes with greater operational agility, flexibility, and greater competitive power in world markets. 3D Print: 3D printing is the action or process of making a physical object from a three-dimensional digital model, typically by laying down many thin layers of a material in succession. The 3D printer is controlled by a computer, depositing successive layers until they reach the wanted latest shape. Its use in prototyping, design iteration and small-scale production is already significant but we are now on the cusp of changing discrete man-
ufacturing forever. Three major changes are starting to take place in additive manufacturing, or 3D printing that will lead to fundamental change: speed, quality, materials. As these fundamentals evolve rapidly, new opportunities will arise that take 3D printing ever closer to mass production. 3D printing brings design, manufacturing and service flexibility to many industries. Optimize Logistics and Supply Chains: A connected supply chain can set and accommodate when new information is presented. A connected system can adapt to the situation and change production priorities. By leveraging supply chain management capabilities, companies can deliver products and services to market faster, cheaper, and with better quality to gain an advantage. Thanks to this, cost is avoided and there is no delay in production. RFID: RFID stands for Radio-Frequency Identification. This acronym refers to small electronic devices that comprise a small chip and an antenna. The chip is capable of carrying 2,000 bytes of data or less. RFID is similar to barcoding, and in that data from a tag or label are captured by a device that stores the data in a database. Universal Product Code (UPC) bar code is replaced with smart labels, also called RFID tags, and percentage of using of RFID tags will be increase. RFID tags are smart bar codes that can talk to a networked system to follow all products that you put in your shopping cart. UPC bar codes were created to help grocery stores speed up the checkout process and keep better track of inventory, the system was so successful, and quickly spread to all other retail products. But RFID tags have many advantages. The crucial advantage of RFID tag is data can be read outside the line-of-sight, whereas barcodes must be aligned with an optical scanner. RFID systems contains of three components: an RFID tag or smart label, an RFID reader, and an antenna. An RFID tag includes an integrated circuit and antennas, which are used to carry of data to the RFID reader (also called as interrogator). Then the reader converts the radio waves to a more utilizable form of data. This technology can perform tasks such as: inventory management, asset tracking, personnel tracking, ID badging, supply chain management, etc. Most companies invested in RFID technology only use the tags to track items in their control. Many of the benefits of RFID come when items are followed up from company to company or from country to country. Human-Machine Interfaces: Human-machine interface (HMI) is another function that
demanding processing power. Easy to use, visual interfaces facilitate operator control of machines. High-resolution screens allow viewing the output of high-definition cameras inspecting goods as they are manufactured. Cloud Computing: Cloud computing is one of constructive blocks in foundations of the internet of the future which can allow the management of all these systems in a dynamic manner, swift and comprehensive, in the most varied volumes and ratios (Correia, 2014). Cloud computing is the technology that can storing, accessing data and programs over the Internet instead of your computer’s hard drive. When someone stores data or runs programs from the hard drive, that’s called local storage and computing. Cloud computing is very important for the continuing development of the Fourth Industrial Revolution. Cloud tech helps to pool and centralize information for your business, while also offering a platform for open source collaboration to expedite and refine research for entire industry gains. Cloud computing assistant business in all industries adapt to today’s rapidly changing technology. With AI and automation being integrated more frequently into industry, cloud computing is a way for businesses to easily modify with the times without losing data. Smart Sensors: Development and spread of smart sensors is one of the major improvements in automation. A good working "smart sensor" definition comes from Tom Griffiths, product manager, Honeywell Industrial Measurement and Control (Cleveland, 2006). A smart sensor has also been called an intelligent transducer with the terms also expressed as a smart transducer or intelligent sensor. A smart sensor must communicate. Main job of those sensors is to aid manufacturers run the work smoothly and easily. Sensors will be at every stage of production will exchange data in real time which will then be analysed to guarantee the ideal operation. A key characteristic of intelligent sensors is that it processes the input signal at a logical level, on account of increase the level of information processing. The smart sensors can aid minimize installation and increase equipment uptime. Smart sensor takes input from the physical environment and handles data by performing predefined operations and functions. The specific input could be light, water, heat, humidity, motion, touch, pressure, or any one of a great number of other environmental factors. This technology integrates sensors and circuits to process information obtained from the environment with-
out a significant human interference, and this is the benefit of using smart sensors. Various kinds of smart sensors can be used for production tracking and historical trace requirements. Smart Factory: The term smart factory describes a vision of what industrial production will look like in the future. In this vision, the smart factory will be much more intelligent, flexible, automated, cheaper and dynamic in industry. Terms such as smart production, smart manufacturing, smart factory, and advanced manufacturing among others that may exist are synonyms for the same technological term used. Information technology (IT) and operations technology (OT) have made the transformation of the supply chain progressively and increasingly possible (Burke et al., 2017). Each factory has implemented a smart factory in distinct ways to reach a variety of goals. Some of the smart factories are about sustainability or zero-waste production. When the smart factory is success, it will represent an important shift for Industry 4.0, as the revolution will begin to roll out across multiple verticals. These are capable of producing a more rapid and effective decision-making of smart factories. There are some significant advantages also using these technologies. Using these new technologies makes you more competitive. To stay competitive, you have to have the systems and technology in place to allow you to ensure the same level of service (or better) to your customers and clients. Definitely, companies that invest in advanced, innovative Industry 4.0 technologies are better positioned to attract and retain new workers. They increase efficiency, boost collaboration among departments, allow predictive and prescriptive analytics, and allow people including operators, managers, and executives to make better decisions while managing their day-to-day responsibilities. It allows companies to address potential issues before they become big problems. Automation can help companies and manufacturers to be more proactive when solving potential maintenance and supply chain management issues. Industry 4.0 technologies helps companies operate and optimize all aspects of your manufacturing processes and supply chain.
2.1 Cyber physical systems

The term "cyber-physical systems" showed up in 2006, coined by Helen Gill at the National Science Foundation in the US (Lee, 2015). The roots of the term CPS are older and deeper. The increment of cyber-physical systems introduces the fourth stage of industrialization, generally known as Industry 4.0. Driven by the need to advance reliable systems for renewable energy, wireless health, advanced manufacturing, smart materials, and electrified ground and air vehicles, the research and progress effort for CPS offers an unprecedented opportunity to redesign and rethink numerous existing concepts and systems. The basic assumption in terms of cyber–physical production systems is reflected in the research and defining relations through the prism of autonomy, cooperation, optimization and response to the assigned tasks (Hozdić, 2017). In cyber-physical systems are addressed for systems purpose of industrial integration production. In an easy and overall way, it can be defined that the cyber-physical systems, are systems allowing to humans performing complicated tasks requiring a minimum of suitability and specialized education. Cyber-physical systems are more productive intelligent and efficient. They are composed from diverse constituent parts that associate together to create some global attitude. These constituents will include software systems, communications technology, and sensors that interact with the real world, often including embedded technologies. It is using computational capacity. The economic and societal potential of such systems is very greater than what has been realized, and major investments are being made global to develop the technology. One cyber-physical system will often contain components from many different manufacturers or service providers, and therefore many businesses are already contributing towards cyber-physical systems without being aware of it, as their products and services are integrated with others to create new cyber-physical systems. Also, cyber-physical systems are of great importance in the industrial production, in order to meet customer requirements. A cyber-physical system (CPS) is a unification of computation with physical processes whose behaviour is defined by both cyber and physical parts of the system. CPS is the intersection, not the union, of the physical and the cyber. We are now experiencing the Fourth Industrial
Revolution from the point of cyber-physical systems. These systems are industrial automation systems that facilitate much innovative functionality through their networking and their entry to the cyber world, thus changing our everyday lives importantly. Recent advances in manufacturing industry has paved way for a systematically deployment of cyber-physical systems, within which information from all related perspectives is closely monitored and synchronized between the physical factory floor and the cyber computational space (Lee, Bagheri & Kao, 2015). However, there are considerable challenges, particularly because the physical components of such systems introduce safety and reliability requirements qualitatively different from those in general-purpose computing. A collection of challenges not always found in a classical business information system or embedded system. Furthermore, physical components are qualitatively different from object-oriented software components. Standard abstractions based on method calls and threads do not work. To realize the full potential of CPS, we have to rebuild computing and networking abstractions (Lee, 2008). Sectors, family life, markets, etc. will have to be redefined because these changes will also strongly influence the society and people.

2.2 Industry 4.0 and Industrial Internet of Things (IIoT) difference

The industrial internet of things, or IIoT, is the use of IoT technologies to enhance manufacturing, industrial processes, and applications. In addition, IIoT is a subset of IoT, aimed specifically at industrial applications. IIoT is about, as its core, connecting machines to other machines/data management and the optimization and fertility. It is connecting devices on the plant floor, allowing for the development of cyber-physical systems and inter-device communication, which provides alternative ways to generate and gather interesting data throughout the industrial space. First, General Electric talked about IIoT. The IIoT prominently illustrate the convergence of IT and OT. Obviously, IIoT technologies aid field service technicians detect potential issues in customer equipment before they become major issues, enabling techs to set aright the problems before they inconvenience customers. The IIoT system will send momentary alerts to stakeholders if the goods are
damaged or at risk of being damaged, giving them the chance to take immediate and preventive action to solve the situation. On the other hand, Industry 4.0 is a mixture of digitalization, new technology, and practical decisions focused on dramatically changing how we manufacture products through unprecedented flexibility, efficient production, and visibility at all level of production. Industry 4.0 focuses principally on the manufacturing sector. However, IIoT consist all sectors where industrial/professional equipment is used. Industry 4.0 is closely associated with governmental and institutional initiatives, and only winning traction in professional setting. Industry 4.0 is an increased visibility, flexibility, and efficiency across our production to be more competitive. In contrast, IIoT is an allowing force for Industry 4.0: connecting our devices, our data, our devices, and our people to utility our company and customers. Industry 4.0 consist not only the connection of assets and data management but the digitization of the entire value chain. By accepting both, it is easier to reach positive outcomes and sustain global competitiveness.

3 Smart Factories

Industry 4.0 encourages what has been called a "smart factory". "Smart" is about collecting data from the manufacturing process, and turning that data into information and then acting on that information. Industry 4.0 is a current trend in manufacturing that involves a combination of cyber-physical systems, automation and the IoT, which together create a smart factory. The smart factory is the concretion of all recent IoT technological developments in computer networks, data integration, and analytics to bring transparency to whole manufacturing factories. It represents a context-sensitive manufacturing environment that can handle difficulties in real-time production using decentralized information and communication structures for an optimum management of production processes. The introduction of IoT devices to the factory is the most powerful and effective ways to begin the transformation into a smart factory. The smart factory will substantially change how products are invented, manufactured and shipped. Machines take up the human role in factories. But still the human integra-
tion is inevitable with a digital, electronic, virtual world, so that our work is preceded by further development of production systems in terms of reliability, efficiency, safety, etc. (Hozdić, 2017). This contains AI, machine learning, and automation of knowledge work and machine-to-machine communication with the manufacturing process. It will improve worker safety and protect the environment by enabling low-emissions and low-incident manufacturing. The arrival of smart factory technology except significantly that how highly automated production machines and assembly lines change from producing one product to another. Smart factory is considered an important outcome of the Industry 4.0. A highly digitized and connected production facility that relies on smart manufacturing is smart factory. The smart factory is a flexible system that can self-optimize performance across a broader network, self-adapt to and learn from new conditions in real or near-real time, and autonomously run entire production processes (Burke et al., 2017). Visibility, connectivity and autonomy are defining of smart factory structure. The structure of Smart factory is the seamless connection of singular production steps, from planning stages to actuators in the field. The physical systems become IoT, communicating and cooperating both with each other and with humans in real time via the wireless web (Marr, 2016). The smart production environment, is structuring the smart factory. The structure of a smart factory can include a combination of production, communication technologies and information, some with the potential for integration across the entire manufacturing supply chain. For a smart factory, it must be supported by a background system that takes information from both the virtual and physical worlds surrounding it. The infrastructure can be operated independently in operational decision-making with less human intervention. Diverse markets spanning healthcare to consumer goods will adapt Industry 4.0 technologies primarily modelled in the smart factory. Used by manufacturing companies, a smart factory works by employing technology such as AI, robotics, big data, analytics and the IoT, 3D print, and can run largely autonomously with the capability to self-correct. Manufacturing processes will be organized differently, with entire production chains – from suppliers to logistics to the life cycle management of a product – closely connected across corporate boundaries. Individual production steps will be seam-
lessly connected. The processes impacted will include: Factory and production planning, Product development, Logistics, Enterprise resource planning (ERP), Manufacturing execution systems (MES), Control technologies, Individual sensors and actuators in the field. A smart factory, machinery and equipment will have the capability to advance processes through self-optimization and autonomous decision-making. In the vision of a fully connected smart factory, every facility is connected to the others and the entire enterprise is linked across departments and externally to customers and suppliers. In this way, needs and activities can be followed up and collaboration is enabled across the extended enterprise to enhance speed and efficiency. And the structure isn’t just confined to the four walls of a factory, it goes much further and influencing the entire supply chain. There are five key characteristics of a smart factory: connected, optimized, transparent, proactive, and agile (Burke et al., 2017). Possibly the most important feature of the smart factory, its connected nature, is also one of its most important sources of value. Smart factories request the underlying processes and materials to be connected to generate the data essential to make real-time decisions. The connected factory is a total reorganization of the approach to production with using existing tools. A smart factory which is working correctly can fitted with smart sensors so systems can continuously pull data sets from both new and traditional sources, ensuring data are frequently updated and reflect current conditions. An optimized smart factory allows operations to be executed with minimal manual intervention and working with high reliability. In addition, it contains automated workflows, synchronization of assets, improved tracking and scheduling, and optimized energy consumption. In the smart factory, the data captured are transparent: Real-time data visualizations can transform data captured from processes and fielded or still-in-production products and convert them into actionable insights, either for humans or autonomous decision making (Burke et al., 2017). In a truly working smart factory, the manufacturing process becomes transparent from beginning to end, and this transparency goes on the further side of the factory floor to the supply chain to the delivery process and stretches out to the user experience. A transparent network can make possible greater visibility across the facility and ensure that the organization can make more correct deci-
sions by providing tools such as role-based views, real-time alerts and notifications, and real-time monitoring (Burke et al., 2017). Employees and systems can anticipate and move before matters or challenges arise, rather than simply reacting to them after they occur in a proactive system. With this feature, factories include identifying anomalies, restocking inventory, identifying and predictively addressing quality, and monitoring safety and maintenance concerns. Agile flexibility enables the smart factory to adapt to schedule and product changes with minimal intervention. The developed agile factory prototype transfers agile software engineering techniques to the domain of manufacturing (Scheuermann et al., 2015). Also, an agile factory is component based, using trackable mobile work tables in combination with constant workstations. Accordingly, any product with its associated request is trackable during assembly-time which enables us to implement a customer feedback loop. The feedback loop allows replacing requests during assembly-time. Besides, agility can increase factory uptime and efficiency by minimizing changeovers due to scheduling or product changes and facilitate flexible scheduling. These characteristic features afford producers greater visibility against their assets and systems, and let them to navigate some of the challenges faced by more traditional factory structures, ultimately leading to improved productivity and greater responsiveness to fluctuations in supplier and customer circumstances. Over the next years, to 2025, industry will use the smart factory concept to roll out, spearheaded by companies at the high end of manufacturing, such as automotive and select consumer electronics manufacturers. While automation and controls have existed, the entirely smart factory has only recently earned traction as a viable pursuit for manufacturers. Five big trends seem to be accelerating the drive toward smart factories. First one is rapidly evolving technological capabilities. Technology has a large share in our lives. We are now using the most advanced version of technology from large areas such as medicine, management, industry. Before a company can have a smart factory, it needs to detect equipment and processes that generate valuable data. Until recently, the realization of the smart factory has improved the products and made happier customers. Furthermore, the abilities of technologies themselves have grown even complexed: AI, cognitive computing, and machine learning have allowed systems to
commentate, adjust to, and learn from the data collected from connected machines. Furthermore, the abilities of technologies themselves have grown even complexed: AI, cognitive computing, and machine learning have allowed systems to commentate, adjust to, and learn from the data collected from connected machines. This capability to develop and adapt, coupled with powerful data processing and storage capabilities, enables producers to move beyond task automation toward more complex, connected processes and when producers achieved this hard task they use more technology to never lose. Next one is increased supply chain complexity and global fragmentation of production and demand. As producing has grown progressively global, production has fragmented, with stages of production extended within multiple facilities and suppliers across multiple geographies because companies want to grow. These shifts, coupled with the increased demand for local, and even individual customization; strong demand fluctuation; and increasingly limited resources, among other shifts, have made supply chains more complicated. Because of these changes, numerous manufacturers have found it significant to be agile, connected, and proactive to address ever-shifting priorities. Third trend is growing competitive pressures from unexpected sources. What is competition? It is an activity or condition of striving to gain or win something by defeating or establishing superiority over others. Race wins first in the sector. The increase in smart digital technologies has been threatened by completely new competitors to achieve digitalization and lower entry costs to take part in new markets or industries where manufacturers have never been before. Fourth one is organizational realignments resulting from the relationship of IT and OT. The increasing relationship of IT and OT has made it feasible for organizations to move many formerly plant-level decisions to the business-unit or enterprise level. Connected companies are becoming more visible because they are crossing the network beyond the four walls of the factory. Connectivity inside of the factory is not new and many manufacturers have long been stymied about what to do with the data they collect. This can brighten where inefficiencies obtain or where changes in one plant have resulted in complications in other facilities. The final trend is ongoing talent challenges. There are some multiple talent-related challenges. These challenges contain an aging workforce, an in-
creasingly competitive job market, and a scarcity of younger workers interested in or trained for manufacturing roles mean that many conventional manufacturers have found themselves struggling to find both skilled and unskilled labour force to keep their processes running. Many companies are making investments in smart factory capabilities to reduce the risk. Besides, this move can create a new set of talent-related outcomes, as automated assets typically need highly skilled personnel to operate and maintain; even the location of manufacturing facilities would need to take in consideration factors such as this. Also, these trends are not only about the government. Consumers will be more likely to seek out products that are using smart factories as their point of origination. In the near future, it will get to the point where consumers will avoid products that are crafted in traditional factories. If consumers have a choice they will choose the products that are coming from a factory that causes less influence and harm on the nature. Every smart factory could look dissimilar because of variations in line layouts, products, automation equipment, and other factors. Except that, simultaneously, for all the potential distinctions across the facilities themselves, the components needed to allow an accomplished smart factory are largely universal, and each one is important: data, information, technology, process, people, and security. Smart factory technologies will change the system entirely from the beginning and it will be more usable. Smart factories are becoming even smarter with AI, data analytics, AR and connected everything bring about an environment where self-correction, automatic streamlining and the elimination of expensive prototype development are entirely possible (Wright, 2018). Smart factory will make the interactions between humans, machines, and products become an extremely competitive and current area for market capitalization. With the foundations of smart factory based on IoT and cyber-physical system, diverse system technologies and architectures have emerged over the past few years. The AI bot monitors the whole production line and operation, collecting data from diverse sensors, machines and devices to teach it what the parameters of “normal” operations are. With the time, the AI bots experiences the intricacies of the factory and can advise on where to optimize or can even achieved this without human intervention. This fast, reactive process saves time and product loss, and rapidly becomes...
proactive as the bot learns patterns and shapes, identifies triggers in advance. AI can then help with inventory review and monitoring market pricing. The result is having more direct demand prediction, along with the ability to buy at market lows. Other technology of smart factory is AR and it offers manufacturers a solution that can save them years in research and development, while also saving money, testing, rebuilding and retesting prototypes. AR devices can help with picking/kitting instructions, with potential productivity developments up to 40 percent. AR allows manufacturers to virtually ‘build’ a prototype and trial various materials, looks and feels, and make tweaks without ever making or using a single component. The biggest concern most manufacturers have when it comes to technologies such as AR, is the effect on specialist skills usually used in the concept stage. In addition to this, AR still requires expert opinion that only humans can provide to design and test the simulation as the engineering principles are still in effect. When AR is capable of to produce and test prototypes without physically building anything, and bots are able to augment with machines to optimize production and reduce risk, the results are smarter than ever. Many companies using augmented reality work instructions have reported 30+ percent productivity on specific operations. Companies which are using this technology have also realized improved quality for complex tasks. Factories have long relied on automation, but smart factories take this concept much further and are able to carry out without much human intervention. From early beginnings in 1954 when robots were used to automate the production robots have become steadily more developed. Using of robotics becoming ever more adaptive and responsive to their environment. Sensing devices, currently in development, will be able to communicate the need for new materials. In the next years, manufacturers will see the deployment of autonomous vehicles equipped with reliable sensing devices that will know when to collect and deliver production output. With big data, the volume, variety and rapidity of data produced through a myriad of connected devices in the smart factory will be of greatness greater than anything ever seen before. Within industry, Big Data is already being used to optimize production schedules for gaining real-time actionable intelligence has the potential to increase productivity, undertake pre-emptive maintenance and besides generate cost savings.
In the next years of data use, production information will be connected through to the supply chain from customer specification to raw material. Machine-to-Machine (M2M) communication systems are currently changing into systems of networks that transmit data to appliances. It contains a device (such as a sensor) to capture an event, status or fact which is relayed through a network to a software program that translates the captured event into meaningful information. There are two important enabling technologies for M2M communications are RFID and Near Field Technology (NFC). Implementation of these two technologies allows M2M communication in wireless mode, in this way opening a confined manufacturing space where the machines that are supposed to interact with each other do so flexibly and without unwanted interception but there are still in development. Additive manufacturing, or the other name 3D printing, is the process of starting production with slack material, either liquid or powder, and then building it into a three-dimensional shape using a digital template. 3D printing is already used to make some design items, such as medical implants, and to produce plastic prototypes for engineers’ designers, producers. These technologies that I described above must be bonded together to obtain, transfer, interpret, and analyse the information, and to control the manufacturing process as intended. Also, these technologies will know precisely what components need maintenance and helping to reduce the risk of equipment failure by the time. Using these technologies will make it possible to: Transfer large quantities of data in real-time and with minimum delay, connect a large number of individual devices in a very reliable manner and with the highest standards of data security, utilize more wireless technologies, both within the plant and for remote connectivity, Operate in an energy-efficient manner. A lot of money and time has been spent and will be spend to control production processes to deliver intended quality outputs. Through the usage of these modern technologies, the smart factory systems can learn and adapt in near real time, making possible factories that are far more flexible than those of the past. Producers are taking up seriously smart technologies to improve efficiencies in their factories. The adoption of the smart factory can be a crucial process that can transform the interaction of engineered systems just as the internet transformed the way people interact with information. A smart factory works by utilize
technology such as AI, robotics, analytics, big data and the IoT and can operate largely autonomously with the ability to self-correct. The use of these technologies even helps the manufacturer, the environment and even the nature. Manufacturers expect for smart technologies to drive a sevenfold increment in annual yield winnings by 2022. Some industries can wait for to almost double their operating profit and margin with smart technologies. The successful integration of Industry 4.0 and cyber-physical systems ensure significant benefits for the overall manufacturing industry. The smart factory logic contains automation of factory floors, M2M, robotics working 24 hours, seven days a week, and remote operations of components. When something is amiss, the ideal smart factory runs itself on a much larger scale, self-correcting where suitable and alerting for human intervention where needed. The main advantages of smart factories: Predictive maintenance: The visibility of smart factories enables manufacturers to catch problems or maintenance matters before they create an important effect on the rest of the equipment or the entire production chain. Systems can sense when problems are arising this can provide advanced warnings when pieces of equipment are about to fail. Furthermore, machinery can be fixed. Predictive analytics allow companies to ask proactive questions like, “what is going to happen,” and, “what can we do to prevent it from happening?” This sight of smart factories also evolves safety on the factory floor for employees by reducing the risk of accidents from malfunctioning equipment. Asset efficiency: Asset efficiency is a performance attributes describing the capability to optimally utilize assets in support of generating revenue or performing a task (Burke et al., 2017). Every direction of the smart factory generates data that, through continuous analysis, reveal asset performance issues that can require some kind of corrective optimization. This is one of the most evident benefits of a smart factory. Quality: Aspects of smart factories, such as digital twins, allow the constant following of the quality of products before they are released in the market. Smart factories are capable of implementing a corrective course of action on their own smart factory can predict and detect quality defect trends sooner and can help to detect discrete human, machine, or environmental causes. And a better-quality process also may mean a better-quality product. Lower Cost: The self-optimization characteristic of smart factories
helps facilitate processes and provides feedback for manufacturers to identify unnecessary or counterproductive steps on the whole production chain. With this knowledge, they can decrease costs related to excessive inventory or unexpected production volume. Safety and sustainability: The smart factory can also impart real benefits around labour wellness and environmental sustainability. Smart factories will become more robust and safer. Greater process autonomy may ensure for less potential for human error, including industrial accidents that cause injury. Undoubtedly, the role of the human worker in a smart factory environment may take on greater grades of judgment and on-the-spot discretion. Manufacturers can adjust increase yields, improve quality, and reduce waste. The Speed of Innovation: With data patterns from the initial production process through to client usage provides ample benefits beyond factory maintenance and business development getting better acquainted. This information can be used to inform engineering teams about components that reason production defects, boosting waste. Reduce workforce challenges: Automation helps manufacturer's initiate and complete projects with fewer workers. Having real-time access to data across plural platforms frees workers to focus on their core responsibilities and increases their ambition for working. This allows manufacturers to innovate faster without investing in extra resources. It creates labour yields that result in fewer or more-productive man-hours. Streamlined and automated data: Smart technologies automate data gathering and ensure advanced production analytics, so executives can make more informed and intelligent decisions. In a smart operating environment, manufacturers can connect their operations technology with business systems to measure their key performance indicators counter business goals. As highlighted above, the main benefits of the smart factory is a more efficient, increased agility, maximum flexibility, improved predictability, proven productivity and transparent way of working, which leads to greater efficiencies. More importantly, benefits of being a smart factory of the future are not only customer facing. Although customer centricity is a substantial part of the modernization strategy, a thorough refresh of technology needs to be applied all along the organization. In addition, it is important for manufacturers to understand how they want to compete and align smart factory investments. In conclusion, the investment of building a
smart factory benefits producer by creating a safer and more trustworthy plant.

Considering Industry 4.0 and smart factory, many manufacturers and companies seem to be overwhelmed by challenges. An enterprise, despite the positive factors of smart factories, it can make a big choice for adapting new technologies and system and do this for evolving itself. Even a small change in the manufacturing process can be a severe decision for an enterprise, because it may harm the enterprise’s reputation with its customers as well as the quality and speed of its production. A smart factory with fully implemented, consequently, involves not only setting it up but also preparing for the challenges it may show up. Whether or not to invest in smart factory, manufacturers may be thinking about some of the potential challenges associated with incorporating new technology and processes in organization. This, in turn, composes a risk to the sustained uptake and growth of smart factory. In a smart factory also expands the enterprise’s attack surface, which may not be always fully considered in traditional security measures, e.g. and probably one of the most urgent concerns is how to guarantee the cyber security of the smart factory. By implementing connected technologies, as their nature, also factories are opening their gates to security problems. Smart factories are required to expand far beyond the walls of their own facility because of their connected structure. Naturally, this increased connectivity brings new operational risks and unknown security challenges. Probably one of the most urgent concerns is how to guarantee the cyber security of the smart factory. Manufacturers who have implemented Industry 4.0 technologies suffer many of the same cyber-security threats as other industries. However, not all cyber-security breaches in the manufacturing industry are a result of malevolent attacks. When planning for Industry 4.0 implementation, manufacturers should also consider training and preparing their staff on the importance of cyber-security measures. This method can help manufacturers to prevent from accidental data losses and improve the overall security strength of the facility. The other challenge about smart factory is unpredictable costs. Because of automation, there can be several unpredictable costs that may exceed the actual cost. Some of these costs could contain research and development costs of automating a process, preventative maintenance costs, and the
cost of training employees to set to work automated machines. In general, the latest technological innovations are the most expensive. Cash-strapped companies can slow down updating their production due to the increased costs of new technologies, such as setting up robots on a production line and training workers' use. Moreover, once a company try to making a transition to a particular technology, the time, effort and cost of doing so can force the factory from updating itself yet again when technology changes in a few years.

4 Relation between Industry 4.0 and Smart Factory

Industry 4.0 is a binder term in production and networks the entire value chain. This means it connects machinery, products, people and systems so as to allow processes that are largely automated. The term smart factory is a new manufacturing trend with end-to-end, modern, connected technology. Industry 4.0 and the smart factory is really the future because integration of new production technologies geared towards improving work conditions, to increasing productivity and enhancing the production of quality plants. Around one-fifth of German companies have applied primary Industry 4.0 projects at present. The forerunners are major companies with an IT budget of over than ten million euros. The smart factory of Industry 4.0 can ensure a remedy and solution for handling the complexity through the establishment of intelligent products and production processes. As Industry 4.0 moves from potential to reality, it’s obvious that no single company or organization can do it alone. Each smart factory would wish transformation support across solution design, technology, and change management dimension. Furthermore, to power up smart factory, manufacturers should create and collect ongoing streams of data, manage and store the massive loads of information generated, and analyse and act upon them in varied, potentially sophisticated ways. Investing in a smart factory configuration can enable manufacturers to diversify themselves and function more effectively and efficiently in an ever-more complex and quickly shifting ecosystem. Materialization of smart factory will be possible with the increased adoption of IoT and CPS. Smart factories modify considerably as companies that use them utilize components
and processes that are specific to their respective products. In addition, smart factories can still be distinguished by certain shared characteristics that set them apart from traditional factories. Smart factory will make the mutual effect between humans, machines, and products become an extremely competitive area for market capitalization. The principle of a smart factory can not only be applied locally, but machines at different locations all over the world can be connected to create one big, virtual factory. To become a mainstream in this time, Industry 4.0 and the smart factory need more standardization and more transparency. Now, smart factories can adapt to workflows in real-time, by machines communicating with each other machines, and humans. By connecting all of the parts of the manufacturing process, a producer can facilitate and speed up the process of building and testing applications against every platform. This system brings together people, operations and products to make possible continuous delivery of value to a company’s customers. Even though, the smart factory plays an important role in Industry 4.0, it faces many challenges including structural, operational, and managerial independence of the shop floor and enterprise constituent systems, interoperability, plug and play, self-adaptation, reliability, energy-awareness, high-level cross-layer integration and cooperation, event propagation and management, and industrial big data analysis (Access, 2017). The reasons for most companies to shift towards Industry 4.0 and automate manufacturing include: Increasing productivity, minimizing human/manual errors, optimizing production costs, focusing human efforts on non-repetitive tasks to improve efficiency. The Fourth Industrial Revolution is forcing companies to re-examine the way they do business that’s why some manufacturers could decide to compete via speed, quality, and cost, and may invest in smart factory abilities to bring new products to market faster, increase quality, and reduce per-unit costs. Business leaders will need to figure out that they are dealing with a changing environment. They need to challenge the assumptions of their teams and keep innovating and adjusting for developing. Business and the global economy will evolve by smart factory and Industry 4.0 and these terms includes the convergence of innovative technologies, methods, materials and products. Another dimension of Industry 4.0 is the use of new smart factory machines that adapt to the requirements for the part be-
ing made. And so, this makes possible a highly flexible, lean, and agile production process enabling a variety of different products to be produced in the same production facility.

5 Conclusions

Each revolution requires an advanced technology tools and systems. Industry 4.0 is a new era and it can be highly flexible in production volume and customization (Shrouf et al., 2014). Industry 4.0 presents a new wave of revolution and smart factories. Smart factory and Industry 4.0 are the key of business world, trade, government, and numerous sectors. New advanced technologies are implemented on manufacturing industry. Due to these developments, there will be more efficient global business world. While using these implementations, resources, workers, and other helpers will use beneficial with advantages. In further, smart factories emerges a more convenient area in industry and other sectors and thanks to this our world will more liveable for our future generations. Moreover, smart factory presents efficient and powerful solutions and improvements like automation reduces the using of energy, AI helps humans, AR creates new aspects, 3D printing shows new designs. Industry 4.0 is a mixture of digitalization, new technology, and practical decisions. Industry 4.0 also presents flexibility, efficient production, and visibility at all level of production. Industry 4.0 and smart factory when are binding together, our ecosystem which we have in, will more effective and efficient in an ever-more. Global economy will evolve by smart factory and Industry 4.0 and, these terms includes the convergence of innovative technologies, methods, materials and products. In connection with this both terms, these improvements also can facilitate and speed up the process of build and test applications against every platform. Manufacturers take seriously these developments to improve their business. In addition, manufacturers as well as suppliers must work to adapt infrastructure and education as they embrace the technologies of Industry 4.0. In conclusion, the successful integration of Industry 4.0 and smart factory ensure significant benefits for the overall industry and humans.
6 References


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Key Terms

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<td>Cyber physical systems</td>
<td>Internet of things (IoT)</td>
<td>Artificial Intelligence (AI)</td>
<td>Smart factory structure</td>
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<td>Integration of new production technologies</td>
<td>Manufacturing Industry</td>
<td>Smart factory logic</td>
<td>Industrial Internet of Things (IIoT)</td>
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Questions for Further Study

What are the components of Industry 4.0? Is there a global competition among companies?
Is governments have a role in developing smart cities? If your answer is yes what are the roles of government?
What is the difference between Industry 4.0 and lean manufacturing?
How does e-learning affect your organization?
Home automation is modular so you can ease into automation one room at a time. Will home automation be a major lifestyle adjustment?
How is 5G going to affect IoT? Explain Internet of Things architecture.

Exercises

Imagine that you are a manufacturer and have a factory, which revolution year do you prefer to live in to achieve your goal? Please define your business goal by giving examples.
Suppose that you are opening a start-up company and you have to gain profit. How can Industry 4.0 help your company to achieve in manufacturing industry?
The technologies which are triggered by Industry 4.0 are discussed in this chapter. Imagine that you are a manufacturer and have a factory. Choose five of these technologies for your factory and explain why you choose these technologies.
Think that you are living in 2050 and all factory structure has been changed by technological developments. Are smart factories have a significant environmental impact?
The use of smart factory and Industry 4.0 will affect the business world. As an innovative manager in your company please discuss why would you implement the smart factory technologies?
What are the features of cyber physical systems and is it affecting Industry 4.0?

Further Reading


Technological change is one of the most important sources of change in the economy. Technology consideration must be an integral part of a firm’s business strategy. With the increasing impact of globalization on business, the scope for competition is no longer limited by national boundaries or by the definition of a particular industrial sector. A sound scientific and technological base is essential to economic growth in a competitive international environment.

To a scientist technology is the end product of research, while to an engineer technology is a tool or process that can be employed to build better products.

Technology refers to all the knowledge, products, processes, tools, methods, and systems employed in the creation of goods or in providing services.

The management function includes planning, organizing, coordinating and controlling. Innovation refers to new products, new processes, new managerial approaches, and combinations of the above.

Management of technology is an interdisciplinary field of natural sciences, social sciences, business management, engineering.

Technology management supports organizations in finding answers to the following questions:

- How are technologies created?
- How can the dimension technology be integrated in a business strategy?
- How can technologies be used to gain competitive advantages?
- How can technologies be exploited to create business opportunities?
Classification of technology

Emerging technology, new technology, low technology, medium technology, high technology, appropriate technology

Relationship between business and technology

The goal of an organization is to achieve a set of objectives
Technology adds value to the assets of a company

Business view on managing technologies

New technologies require plans for system integration, qualified champions as well as organizational integration
Challenges: lack of system integration, incompatible systems, failure of the champions and lack of cross-functional teams.

Technology management and innovation

The adoption and implementation of IT is an important aspect of innovation.
Variables to be considered with innovation are the ability to understand competitors' innovative strategies, structure and cultural context, the business technological environment, strategic management capacity in dealing with entrepreneurial behavior and resource availability and allocation. Success factors of technology management are adaptability, business focus, sense of integrity, Hands-on top management, organizational cohesion and entrepreneurial culture. Leaders must have a strong knowledge and capability in managing both technology and people. Technology and human resources must be working in an integral manner to ensure success. Technology itself does not produce commercial results. It is its application that brings commercial benefits.

How to review technological innovation?

Discovery of a new idea or product or process, evaluation of the proposed idea or design concept, verification of the theory or design, demonstration of a prototype, evaluation, commercial introduction of the innovation, adoption.
Change in technology without change in the way it is used can lead to failure.

**Technology transfer:** technology can be bought, sold, or lease

**Technology licensing:** Inward and outward licensing deals with the issue of intellectual property

**Relationship between technology and market**

Congruent of an innovation with corporate objectives and targets
Proactive approach for technical developments
Feasibility analysis of an innovation (technological and commercial view)
Balance between market pull and technology push

**How to choose technology management methodologies? Which factors have to be considered?**

the corporate maturity, the nature of the technology involved, corporate processes, best practices of the industry, industry wide risk acceptance rate, corporate learning capabilities

**Prerequisites for a successful methodology?**

Management recognizes the need for the project and enables a flexible landscape for the project to grow up with.
Availability of clear defined core competences
Willingness to provide and manage business functions that support the methodology (project management, personnel deployment, Mentor support)
People with innovative spirit are the main factor in using technology for development. They can ease both the technical development, and the social one, they can assure the link between research-development, industry and decision factors and environmental factors.
Technology transfer is developed through knowledge transfer.

**Benefits of using a methodology**

consistent and standardized approaches, faster implementation and use, better planning, development of a knowledge base
When you have chosen a methodology review it consequently

– Do we use the most appropriate methodology?
– How can flexibility be encouraged?
– Do project management and technology management properly match?
– Is the necessary administrative support provided?
– Do we build appropriate competences with the methodology applied?
– Is productivity optimized throughout the project life span?

Strategic technology lifecycle

The strategic technology lifecycle (TLC) offers a systematic approach for assessing the state of your technologies. Steps to develop a TLC: Kick off => decide => deploy => manage => develop => support => use
Learnign Objectives

The objectives of this chapter are to investigate and present current issues and trends of techno-park companies with regard to digital transformation. Once you have mastered the materials in this chapter, you will be able to:

– Explain the developments brought about by each industrial revolution.
– Understand the importance of techno-park companies in developing new technology.
– Identify the concept of Industry 4.0.
– Explain the cyber-physical production systems, their features and the triggers of Industry 4.0.
– Understand the effects of firm characteristics, number of employees and establishment year, on the company’s awareness levels regarding Industry 4.0.
– Understand the effects of firm characteristics, number of employees and establishment year, on the selection of Industry 4.0 technologies to be developed.

Chapter Outline

Today’s world is in the fourth industrial revolution, which has a crucial role in the economies and industries of the countries. With this revolution, it is expected that all of the tools used in the industry will be self-learning, smart and more efficient hardware and software products will be able to produce. Therefore, industrial production speed, volume, and productivity will step up, and social and economic life will improve. If we are not ready for this revolution as a country, we will have...
to face huge devastating effects besides its advantages, just as it is in every industrial revolution. To be able to transform the new industrial revolution into an advantage, there is a need for measures to be taken in this direction and studies to shed light on what needs to be done. Thus, the purpose of this chapter is to investigate and discuss some of the issues of techno-park companies in terms of Industry 4.0 after introducing the concept of Industry 4.0 and its technologies.

**Keywords**

Industry 4.0, digital transformation, techno-parks, developing technology.

1 **Introduction**

Industry conception is in our lives for many centuries. Today, we are in a new industrial revolution or, in other words, a period of digital transformation. With the first industrial revolution which was begun in the late 18th century, only the industrial period did not begin. With this revolution, a lot of major changes, that directly affect our lives, have also brought about such as the development of living standards, new branches of industry-economic activities, cultural changes etc. (Ozdogan 2017). The fourth industrial revolution is comparatively different from the other revolutions. The new industrial revolution, which is also called as Industry 4.0, is a digital transformation of production systems, as developed by information and communication technologies. Digital transformation of the production chain’s every stage is the development of 'Intelligent Manufacturing Systems' through the provision of machine-human-infrastructure interaction (TÜBİTAK 2016). With this, all machines and industrial devices used in the industry will generate data and will have meaningful intelligence from these data. In this way, factories will be smart and able to manage themselves. In addition to that, techno-parks have an undeniable role in technology production and development. So, the study is conducted to analysis the status of techno-parks with regard to Industry 4.0. The purpose of this study is to investigate current issues and trends of techno-park companies with regard to digital transformation in Turkey. More specifical-
ly, the study aims to find answers for the following questions: 1) What is the level of awareness about Industry 4.0 at the national level? 2) Which Industry 4.0 technologies have been used by techno-park firms on their solutions for customers in the last 5 years? 3) What is the usage level of these Industry 4.0 technologies by techno-park firms on the solutions of customers in the last 5 years? 4) What are the application areas in which they offer their products under Industry 4.0? 5) Do the awareness levels, types of Industry 4.0 technologies developed for customer solutions, their usage level and application areas that they offer their products regarding Industry 4.0 differ with respect to the firm size, which is measured as the number of employees? 6) Do the awareness levels, types of Industry 4.0 technologies developed for customer solutions, their usage level, and application areas that they offer their products regarding Industry 4.0 differ with respect to the firm’s establishment year? In this pursuit, the study is conducted in six sections. After the introduction, section 2 covers the brief explanation of industrial revolutions. Section 3 includes a brief explanation of Industry 4.0 and Industry 4.0 technologies. Section 4 has information about techno-parks. Section 5 consists of a methodology covering exploratory factor analysis and measures the effect of company size and establishment year on the company’s Industry 4.0 activities. Finally, the last section provides a summary and a conclusion.

2 Industrial Revolutions

The concept of “revolution” means instantaneous and radical transformation. During history, revolutions have taken place every time that new technologies and new perceptions of the world have brought about profound changes in economic systems and social structures (Schwab 2017). Three major industrial revolutions have taken place in the world up to now. In today’s world, we are in a fourth industrial revolution which is also called as Industry 4.0. These revolutions and their features are explained in detail in the following section.
2.1 The First Industrial Revolution

The first industrial revolution started with the use of steam and water power for the first time on handloom (Koçak and Diyadin 2018). This industrial revolution which is continued from 1760 to around 1840, led to mechanical production with the construction of railways and the steam engine (Schwab 2017). With this revolution, there has been a serious increase in production capacity and speed (Ozdogan 2017). In addition to that, according to many authors, steam engines have not only affected steam and textile industries but also affected the other industries such as transportation, communication, and banking, etc. More and more products are being produced and the improved the standards of living, while at the same time there has also emerged a poor and hard-working employee within the scope of this ear. Therefore, this revolution not only affected production but also affected people’s lives in terms of a social and psychological perspective.

2.2 The Second Industrial Revolution

With electric technology and chemical techniques, the second industrial revolution expanded to Europe, the United States, and Japan. It had become possible to achieve mass production with the production band technique used by Ford company, resulting in an increase in productivity (Koçak and Diyadin 2018). The second industrial revolution, which became to rise in the late 19th and early 20th centuries, made mass production possible with the support provided by the electricity and assembly line (Schwab 2017). The production methods continued to change until the second industrial revolution, which took place in 1870, specialization in employees began, and they were separated according to their expertise field. Organizations have transformed, and all these developments have expanded to all of the worlds. (Ozdogan 2017). The most significant features that distinguish the second revolution from the first revolution are production capacities and new machines used to increase these capacities. In this period of technological production, it was not only the production elements that were affected.
as in the first revolution. The entire life of people was also affected (Ozdogan 2017).

### 2.3 The Third Industrial Revolution

In the third industrial revolution, automation-based manufacturing processes (in which electronic and information technologies were used) were introduced (Koçak and Diyadin 2018). The third industrial revolution, which began in the 1960s; is often referred to as a computer or digital revolution. This is because, this period was improved by the catalyses of host computers (the 1960s), personal computers (1970s-1980s) and the internet (1990s) (Schwab 2017). In this period; transistors, Enterprise Resource Planning systems, Computer Numerical Controller machines were produced for the first time under the favour of the programming language of computers and machines. In this period, all kinds of data stored on paper became stored in the computer environment. Therefore, the Industry had the production speed and capacity that it has never reached before. In addition to that, administrative costs and difficulties have been eliminated and automation needs have been met in this term. The technology that has progressed in this industrial revolution has been used to the structure of companies’ strategies, designing the new business forms and increasing of the production channels (Ozdogan 2017). In the third industrial revolution, which is started in 1940 and ended in 2010, there was computers, digital products and solutions, and internet. In this revolution, the recordings were digitized, and major innovations came to exist in the field of information science, especially after 1950. Also, the rise in new technology and production capacities also created new markets (Ozdogan 2017). After the third industrial revolution, Industry 4.0, which is made up of the highest level of technology use and the cyber-physical systems that internet and information technologies combine, has been reached (Koçak and Diyadin 2018).
2.4 The Fourth Industrial Revolution

In today’s world is in a new technological era, which will trigger the fourth industrial revolution (Industry 4.0) (Magruk 2016). Industry 4.0 is a development process (which is also called as "the fourth industrial revolution"), which has been planned for the future and is now underway (Koçak and Diyadin 2018). According to this, the web-based network will support all of the smart factories at every level of the production line such as design, servicing, and recycling, etc. (Magruk 2016).

3 Industry 4.0 Concept

Industry 4.0 is a term which is arisen from Germany in 2011. It is focused on developing smart chains based on communicating with each other parts of production such as products, components, factory, people, etc. (Magruk 2016). Industry 4.0 is regarded as the “Fourth Industrial Revolution” and is expected to bring lots of significant changes in many areas (Soysal and Pamuk 2018). Industry 4.0 concept; is based on the communication of all the shareholders that are involved in the industrial production process, all the data can be reached in real time and the acquiring the highest possible value added under the favour of this data. In addition to that, this concept usually, at every phase of the entire supply chain, starting from the purchase of raw materials, producing the products, delivering them to the consumer and recycling processes are improved by taking advantage of emerging technologies (Soysal and Pamuk 2018). Industry 4.0 can be thought as a way in which a product is produced, delivered, used, repaired and recycled entirely automatically through the internet, in other words, without human intervention. According to The Federal Ministry of Education and Research in Germany, with Industry 4.0, equipment and machines will change the information constantly and be ensured that many processes in the future will be controlled and coordinated in real time at large distances. Therefore, smart factories and products will be created (Fuchs, 2018).
3.1 Technologies of Industry 4.0

The traditional manufacturing industry is trying to adapt itself by experiencing the difficulties and adversity of the industrial revolution, a digital transformation that speeds up by new technologies. The new technologies of digital transformation are demonstrated in Figure 1 (Firat and Firat 2017). Within the scope of Industry 4.0 technologies, there are such as: The Cyber-Physical Production Systems (CPPS), Machine-to-machine Communication (M2M), Artificial Intelligence (AI), Horizontal and vertical system integration, Internet of Things (IoT), Big Data, Cloud Services, Cyber Security, Virtual Reality, Simulation, Additive Manufacturing. The term of Industry 4.0 gains more and more global recognizability day by day. The expanding of market globalization, rapidly rising global competition and more complex products and services cause a need for new technologies, business models and methods. A rapidly changing market environment and customer demands require to operate logistics processes effectively (Gubán and Kovács 2017). Industry 4.0 is consisting of the combination of different types of technologies and factors for the common goal of advancing the performance and efficiency of production line systems (Ahuett-Garza and Kurfess 2018). In addition to that, industry 4.0 is developed in Europe to acquire perfect manufacturing productivity. It provides smarter and more competitive enterprises by gathering data from devices in real-time and converting them into meaningful information. For this reason, this data can be used to acquire much more market share and increasing profit (Leitão et al. 2016). Recent research shows that industry 4.0 will affect the business world in terms of three main areas such as digitalization and integration of vertical and horizontal value chains, the formation of customer relationships and digital business models and digitalization of services and products (Gubán and Kovács 2017). Therefore, with these new technologies, the entire production process will flexibly adapt to customer demands, the activities of each part of the supply chain, and the rapidly changing economic environment (Gubán and Kovács 2017).
Cyber-physical systems are generally identified as a link between embedded systems (Kai-Oliver Zander and MEng 2015). In other words, cyber-physical production systems are types of equipment which are able to communicate via a network. It generates communication between IT technology and electronic or mechanic items (Gubán and Kovács 2017). With the cyber-physical systems, the whole process of the system can automatically run itself without any human intervention or extra effort, with a program to be done at the beginning of the system. Here, the "automation" term is important. Many machines which including learning robots, are involved in the production pro-
cess. In today’s world, it is known that robots and vehicles learning in the automobile industry are already presented in some production processes (Soysal and Pamuk 2018). With the help of this link, cyber-physical systems can act and react between the virtual and the real world. For instance, to integrate the employee into the system, the cyber-physical systems provide an interface that enables a human-machine interaction (Kai-Oliver Zander and MEng 2015). Sensors provide the machines keeping contact with the other production elements such as factories, networks and people (Gubán and Kovács 2017). Intelligent production robots are the parts of the entire system that are able to communicate with the production control system and the element to be processed. For this reason, they are able to optimize the whole process and obtain system-wide optimization of resources (Gubán and Kovács 2017). Cyber-physical systems are also consolidating statistics and real-time data which are received from physical systems, to model the response of a system under various cases to make decisions in real time. The main objective is to improve the performance, at overall levels of the system (Ahuett-Garza and Kurfess 2018). Machine-to-machine communication is really important for cyber-physical systems. It provides that the devices connected to the network, activate the communication without human interference. For instance, robots that work on a production line are able to provide the needs of each other or stop the whole production systems in urgent cases (Gubán and Kovács 2017). Machine-To-Machine communication provides a horizontal integration. Machines which are in the same location, as well as different enterprises, can then be communicated over the internet. (Kai-Oliver Zander and MEng 2015). Machine Learning is also identified as a computer techniques group which is centre on getting the necessary information and make proper decisions by using big data, both structured or unstructured, which can be acquired from a business or factory at any given time (Ahuett-Garza and Kurfess 2018). One of the most important technologies that are included within the scope of Industry 4.0 is artificial intelligence and machine learning (Ozdogan 2017). Artificial Intelligence is a machine-ability that allows machines to learn and think logically. Under favor of artificial intelligence, machines are able to fulfil complex tasks (Gubán and Kovács 2017). The technology of increasing images with informa-
tion such as sound, graphics, the animation is a long-standing technology (İçten and Bal 2017). Systems that take advantage of augmented reality, support a variety of services, such as selecting parts in the depot and sending repair instructions to mobile devices. Although these systems are still in beginning, companies will benefit from enriched reality in the future to improve the decision-making and operational processes of the companies and to allow real-time information to their employees (TÜSİAD and BCG 2016). Products communicate with the other workpieces and the machines as well to work own manufacturing. In addition to, that communication is not only within the factory, but also in a whole chain such as suppliers, producers etc. (Gubán and Kovács 2017). Most of today’s information technology systems are not fully integrated each other. Firms, customers and suppliers are rarely connected to each other from end to end. A similar situation exists in engineering, design, production and service functions. But, as universal data integration networks improved on a company-wide basis, companies, units and competencies will become more and more compatible with each other (TÜSİAD and BCG 2016). Internet helps people in terms of communicating with each other despite the distance between them. It is inevitable that this communication, now carried to the size of the objects, will affect the market structure and the production and marketing strategies of the enterprises (Soysal and Pamuk 2018). The internet of things (IoT) is a network connection and data exchange of incorporated electronic devices (Gubán and Kovács 2017). Internet of things is the transfer of information from an object, for example, the device or from a human being to other systems through a network (Ozdogan 2017). In this way, the devices can be used more and more efficiently (Gubán and Kovács 2017). Today, it is possible to combine many data by using the internet. However, in spite of the fact that the data is huge and due to the increasing information pollution, the use of this information and the selection of the right information from it are really hard. Nowadays, this information is decomposed by big data applications (Soysal and Pamuk 2018). Therefore, big data has an important role in the evolution of Industry 4.0 (Ozdogan 2017). It is thought that the size of the data in existing networks will be much bigger in the coming years (Soysal and Pamuk 2018). The world is generating massive amounts of data every second. In addition to that, not
only the volume of the data but also the variety and velocity of the data created are rising day by day (Ozdogan 2017). Thus, large data will play a crucial role in Industry 4.0. According to the German government, it is expected that the most beneficial innovation technology of Industry 4.0 will be the big data (Soysal and Pamuk 2018). The main goal of cloud-based services is to hold software data on a cloud instead of storing data locally. For this reason, these data can be reached from any location or devices through the internet connection (Gubán and Kovács 2017). The most important feature of cloud computing is the rapid use of the desired service. In addition to that, cloud computing services have high sustainability rates and short turnaround times in case of possible destruction (Ozdogan 2017). In today’s world, firms are already using cloud-based software for some enterprise and some analytical applications. But, with the fourth industrial revolution, more data on products had to be shared between plants and firms. At the same time, the number of machines belonging to cloud platforms will rise day by day and provide more beneficial services to the production systems based on the database. Furthermore, even systems that monitor and control processes are likely to move into the cloud in the Industry 4.0 era (TÜSİAD and BCG 2016). On the other hand, this access also raises concerns about the security of stored data (Gubán and Kovács 2017). Many companies still use management and production systems that are not integrated with each other. But with increased integration, critical industrial systems and production lines will need to be protected against cybersecurity threats. For this reason, secure communication based on the identification of machines and management of access to machines will gain importance (TÜSİAD and BCG 2016). Manufacturers who are operating in some industries use robots in their operations. In the world, robot technology is now becoming more flexible, autonomous and collaborative by improving its abilities and decreasing the cost. With the Industry 4.0 era, robots will communicate with each other and work side by side with people more securely and they will be able to develop their learning abilities (TÜSİAD and BCG 2016). Nowadays, the design phase of products, 3D simulation of materials and production processes are started to use. On the other side, in the future, it is stated that simulations will become more widespread in the factories. The virtual reality of the physical world
will come together with machines, products, and people prepared by using real-time data under the favor of the simulation models. That’s way, for a product on the production line, the machine parameters will be tested in the virtual world before it is actually set. This will minimize the setup time of the machines and maximize the quality (TÜSİAD and BCG 2016). With the digital transformation, the actual and virtual reality come together during production. Virtuality has an important role in design and production. The simulation of processes also has a significant role in production to catch and measure unexpected cases and their effects (Gubán and Kovács 2017). With the fourth industrial revolution, in other words, Industry 4.0, firms have started to adopt additive manufacturing techniques, such as three-dimensional printing, prototyping, and manufacturing product parts. It is expected that this technique will be used more widely in the future, especially in the fields such as complex and light designs, to produce a small number of special products. To sum up, high performance and decentralized additive production systems will decrease logistics costs and stock levels (TÜSİAD and BCG 2016). In addition to that, raw materials are turned to final parts by digital dataflow of the additive manufacturing techniques. Techniques of additive manufacturing are such below: Firstly, the process begins with a digital 3D sample of the piece which is to be produced. Secondly, supportive pieces are added if it is necessary. Thirdly, the digital model is sliced or otherwise discretised to compose directives for the machine. Finally, the additive manufacturing machine receives these directives to produce the physical material (Ahuett-Garza and Kurfess 2018).

4 Techno Parks

Techno-parks are different from each other in terms of lots of aspects such as organization structure, purpose, and way of working and administrative structures. Therefore, it is really difficult to describe them with a single definition (Btgm.sanayi.gov.tr 2018). Thus, some various definitions are given such below: According to the International Association of Science Parks (IASP): A science park is an organization managed by specialized professionals, whose main aim is to increase
the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions. To enable these goals to be met, a Science Park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies, and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin-off processes; and provides other value-added services together with high-quality space and facilities. (IASP 2017). According to the Technology Development Zone Law No. 4691: The Technology Development Zone is a region where technology / software developed by companies using high / advanced technology or new technology, utilizing the facilities of a specific university or high technology institute, R&D centre or institute. Firms in this region operate to transform a technological invention into a commercial product, method or service, thereby contributing to the development of the region. In addition, the technology development zone also refers to the site with or integrated with the academic, economic and social structure within or near the same university, high technology institute or R&D headquarters or institute area. (Official Gazette 24454 2001). Techno-parks are really important structures of the innovation system that brings together the technology and science infrastructure of the university and the Industry (Pekol and Erbas 2011). They are established for inducing the formation and improvement of the new technology-based firms (Siegel et al. 2003). Techno-parks create an environment that helps companies in terms of to establish relationships with other companies and universities, under the favour of the structures that keep their companies in close proximity to each other and to the university. These relationships are helpful for expanding the knowledge and it leads to entrepreneurial and innovative cultures. (Pekol and Erbas 2011). There are 77 Technology Development Zone in Turkey and 56 of these are still in operation (Btgm.sanayi.gov.tr 2018).
5 Methodology and Findings of Research

As stated earlier, this study aims to measure the awareness level of techno-park companies on the Industry 4.0, Industry 4.0 technologies that have been used by techno-park firms on their solutions for customers in the last 5 years, application areas in which they offer their products related to Industry 4.0, and to determine these factors differ with respect to the establishment year of the firm and firm size which is measured as the number of employees (Atak, 2018). In this pursuit, a survey using a questionnaire form has been developed considering the opinions and sights who are expert in the field of Industry 4.0 and information gathered in the light of literature. In the questionnaire, the items related to the subjects indicated above are grouped into 3 questions. Overview of Industry 4.0, Application Area, Industry 4.0 Technologies. The participants in the responding organizations were asked to use a 5-point Likert-type scale to indicate the degree of agreement in the top two groups above. After that, the questionnaire was sent to 50 techno-park in Turkey. A total of 231 technology development centered companies participated in the survey. The prepared questionnaire study was conducted as a pilot study to several technology manufacturing companies located in Istanbul Technopark. In total, 231 of 830 respondents were answered. Thus, the questionnaire response rate is approximately 28%. The data obtained from the survey were analyzed with descriptive statistics, exploratory factor analysis, reliability analysis, and t-test by using the SPSS 25.0 statistical software program. In the study, 69.7% (n=161) of the responding organizations were in the software sector, 24.2% (n=56) were in engineering firms and 6.1% (n=14) of the participants did not state their sector group. Finally, most of the participants consist of managers with 33.3% (n=77), this is followed by the company owner with 22.9% (n=53) and the rest of the participant’s position were other.
5.1 Measures

5.1.1 The level of awareness about Industry 4.0

In this section, there were 23 questions. Before the factor analysis, the results of KMO and Bartlett’s tests were given in Table 1. As seen in Table 1, Barlett’s Test of Sphericity is significant (p<0.0005). Also, the anti-image correlation matrix was examined and all diagonal values were found greater than 0.50. These are enough to use the factor analysis. In addition to that, the sample size is sufficient for analysis. The value of Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) is 0.878 and 0.878 > 0.6 means that it is significant. The value of Bartlett’s test Chi-Square is 3583.792 and degree of freedom is 231. So, it is significant (p=0.000, p<0.05).

Table 1: Components and Cronbach's alpha coefficients of awareness level about Industry 4.0

<table>
<thead>
<tr>
<th>Factors</th>
<th>N</th>
<th>Cronbach's Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness about organizational impact</td>
<td>8</td>
<td>0.948</td>
</tr>
<tr>
<td>Awareness about competitiveness impact</td>
<td>7</td>
<td>0.883</td>
</tr>
<tr>
<td>Awareness about role of techno-parks and support</td>
<td>3</td>
<td>0.835</td>
</tr>
<tr>
<td>Awareness about environmental impact</td>
<td>4</td>
<td>0.792</td>
</tr>
</tbody>
</table>

K.M.O: 0.878; Bartlett Test: 3583.792; p: 0.000

As seen in Table 1, the variables were collected in 4 groups. Also, communalities for each item have a value greater than 0.30. The first factor has eigenvalue 8.063, which explains 36.649 % of total variance and factor 1 represents awareness about organizational impact. The first factor which contains nine items measures whether participants have knowledge of Industry 4.0, Industry 4.0 technologies and whether they have information about how their companies’ sector that they operate in will be influenced by the digital transformation. The second factor has eigenvalue 3.584, which explains 16.291 % of total variance and factor 2 represents awareness about competitiveness impact. The second factor seven items points out participants’ sights about the effects of digital transformation on getting more market share and increasing the competitiveness of companies. The third factor has eigenvalue
2.709, which explains 12.313% of total variance and factor 3 represents awareness about environmental impact. The third factor having three items is related to the participants’ opinions on the issue of whether Industry 4.0 is being discussed sufficiently in Turkey by the government, academics and non-government organizations, trade unions and press. Finally, the fourth factor has eigenvalue 1.076, which explains 4.893% of total variance and factor 4 represents awareness about the role of techno-parks and support. Also, the total percentage of explanation is 70.146. The fourth factor has 4 items. And it measures participants’ opinions about whether participants receive adequate support for the development of Industry 4.0 technologies and whether techno-parks’ role in the diffusion and development of Industry 4.0 technologies at the national level. After conducting factor analysis, the reliability of each factor has been calculated. As seen in Table 1, all factors have Cronbach’s Alpha value greater than the 0.7. Table 2 represents the descriptive statistics of factors. The range of factors’ mean varies between 3.33 and 4.33. Here, 5 implies “strongly agree” and 1 implies “strongly disagree”.

### Table 2: Descriptive statistics of awareness level about Industry 4.0

<table>
<thead>
<tr>
<th>Factors</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness about organizational impact</td>
<td>219</td>
<td>3.66</td>
<td>0.99</td>
</tr>
<tr>
<td>Awareness about competitiveness impact</td>
<td>224</td>
<td>4.23</td>
<td>0.72</td>
</tr>
<tr>
<td>Awareness about role of techno-parks and support</td>
<td>223</td>
<td>2.51</td>
<td>0.91</td>
</tr>
<tr>
<td>Awareness about environmental impact</td>
<td>226</td>
<td>3.33</td>
<td>0.85</td>
</tr>
</tbody>
</table>

As seen in Table 2, awareness about competitive impact has the highest mean however, awareness about the role of techno-parks and support has the lowest mean.

### 5.1.2 Technologies of Industry 4.0

In this part, participants were asked which of the technologies in Industry 4.0 were offered to their customers. These technologies are; sensor technology, big data, robot and automation, horizontal / vertical system integration, cyber security, cloud computing, augmented reality...
technology, additive manufacturing, internet of things, machine learning and artificial intelligence, simulation and virtual reality. On the other hand, the participants were asked to indicate which frequencies they have been using these technologies for solutions to customer’s problems. Participants’ responses to Industry 4.0 technologies are given in Table 3.

Table 3: Descriptive statistics of Industry 4.0 technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>0–4</th>
<th>5–9</th>
<th>10–14</th>
<th>+15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor Technology</td>
<td>91(39.4)</td>
<td>29 (12.6)</td>
<td>11(4.8)</td>
<td>4(1.7)</td>
</tr>
<tr>
<td>Big Data</td>
<td>93(40.3)</td>
<td>37(16.0)</td>
<td>15(6.5)</td>
<td>5(2.2)</td>
</tr>
<tr>
<td>Robot and Automation</td>
<td>65(28.1)</td>
<td>17(7.4)</td>
<td>10(4.3)</td>
<td>9(3.9)</td>
</tr>
<tr>
<td>Horizontal / Vertical System Integration</td>
<td>61(26.4)</td>
<td>22(9.5)</td>
<td>10(4.3)</td>
<td>4(1.7)</td>
</tr>
<tr>
<td>Cyber Security</td>
<td>71(30.7)</td>
<td>21(9.1)</td>
<td>12(5.2)</td>
<td>4(1.7)</td>
</tr>
<tr>
<td>Cloud Computing</td>
<td>74(32.0)</td>
<td>28(12.1)</td>
<td>20(8.7)</td>
<td>12(5.2)</td>
</tr>
<tr>
<td>Augmented Reality Technology</td>
<td>71(30.7)</td>
<td>17(7.4)</td>
<td>8(3.5)</td>
<td>2(0.9)</td>
</tr>
<tr>
<td>Additive Manufacturing</td>
<td>66(28.6)</td>
<td>7(3.0)</td>
<td>5(2.2)</td>
<td>4(1.7)</td>
</tr>
<tr>
<td>Internet of Things</td>
<td>79(34.2)</td>
<td>21(9.1)</td>
<td>12(5.2)</td>
<td>9(3.9)</td>
</tr>
<tr>
<td>Machine Learning and Artificial Intelligence</td>
<td>82(35.5)</td>
<td>21(9.1)</td>
<td>5(2.2)</td>
<td>3(1.3)</td>
</tr>
<tr>
<td>Simulation</td>
<td>74(32.0)</td>
<td>11(4.8)</td>
<td>7(3.0)</td>
<td>4(1.7)</td>
</tr>
<tr>
<td>Virtual Reality</td>
<td>75(32.5)</td>
<td>13(5.6)</td>
<td>4(1.7)</td>
<td>3(1.3)</td>
</tr>
</tbody>
</table>

It appears that most of the participants who answered this question offered their solutions which are related to these technologies is in the range of 0–4 predominantly. In this section, factor analysis is also applied to those 12 items related to Industry 4.0 technologies seen in Table 3.
Table 4: Results of KMO and Bartlett’s test of Industry 4.0 technologies

<table>
<thead>
<tr>
<th>KMO and Bartlett’s Test</th>
<th>Kaiser-Meyer-Olkin Measure of Sampling Adequacy</th>
<th>Bartlett’s Test of Sphericity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.858</td>
<td>Approx. Chi-Square</td>
</tr>
<tr>
<td></td>
<td></td>
<td>610.751</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Df</td>
</tr>
<tr>
<td></td>
<td></td>
<td>66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sig</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 4 presents the results of KMO and Bartlett’s tests. As seen from the table, the value of the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) is 0.858. So, it can be said that the sample is enough for the analysis. From the table, the value of Bartlett’s test Chi-Square is seen as 610.751 and degree of freedom as 66. The significance of the test is 0.000 (p=0.000, p<0.05). These results indicate the factor analysis to be suitable. In addition, the anti-image correlation matrix was examined and all diagonal values were found greater than 0.50. These are enough to use the factor analysis. Also, the sample size is sufficient for analysis. The results of the factor analysis are given in Table 5.

Table 5: Components and factor loadings of technologies of Industry 4.0

<table>
<thead>
<tr>
<th>Factors</th>
<th>Factor Loading</th>
<th>Communality</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factor 1: Digital manufacturing systems technologies</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensor Technology</td>
<td>0.618</td>
<td>0.804</td>
</tr>
<tr>
<td>Robot and Automation</td>
<td>0.822</td>
<td>0.724</td>
</tr>
<tr>
<td>Horizontal / Vertical System Integration</td>
<td>0.731</td>
<td>0.680</td>
</tr>
<tr>
<td>Additive Manufacturing</td>
<td>0.601</td>
<td>0.681</td>
</tr>
<tr>
<td>Internet of Things</td>
<td>0.616</td>
<td>0.539</td>
</tr>
<tr>
<td><strong>Factor 2: Virtualization technologies</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Augmented Reality Technology</td>
<td>0.790</td>
<td>0.803</td>
</tr>
<tr>
<td>Simulation</td>
<td>0.784</td>
<td>0.739</td>
</tr>
<tr>
<td>Virtual Reality</td>
<td>0.843</td>
<td>0.807</td>
</tr>
<tr>
<td><strong>Factor 3: Data management technologies</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big Data</td>
<td>0.758</td>
<td>0.643</td>
</tr>
</tbody>
</table>
As seen in Table 5, communalities for each item have a value greater than 0.30. Also, the variables were collected in three groups. The first factor has eigenvalue 4.420, which explains 45.166% of total variance and factor 1 represents digital manufacturing systems technologies. The second factor has eigenvalue 1.455, which explains 12.123% of total variance and factor 2 represents virtualization technologies. The third factor has eigenvalue 1.174, which explains 9.780% of total variance and factor 3 represents data management technologies. Also, the total percentage of explanation is 67.069. After conducting factor analysis, the reliability of each factor has been calculated. Table 6 represents Cronbach’s alpha internal consistency coefficients of all factors.

Table 6: Cronbach's alpha coefficients of technologies of Industry 4.0

<table>
<thead>
<tr>
<th>Factors</th>
<th>N</th>
<th>Cronbach's Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital manufacturing systems technologies</td>
<td>5</td>
<td>0.814</td>
</tr>
<tr>
<td>Virtualization technologies</td>
<td>3</td>
<td>0.886</td>
</tr>
<tr>
<td>Data management technologies</td>
<td>4</td>
<td>0.767</td>
</tr>
</tbody>
</table>

As seen in Table 6, all factors have Cronbach’s Alpha value greater than the 0.7.

### 5.1.3 Application areas

In this section, participants were asked which application area that they would like to present their solution and its degree, within the scope of Industry 4.0. Before the factor analysis results of KMO and Bartlett’s tests were given in Table 7.
The value of Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) is 0.906 and $0.906 > 0.6$ means that it is significant. The value of Bartlett’s test Chi-Square is 1045.072 and degree of freedom is 45. So, it is significant ($p=0.000$, $p<0.05$). The results of the factor analysis are given in Table 8. Also, the anti-image correlation matrix was examined and all diagonal values were found greater than 0.50. These are enough to use the factor analysis. Also, the sample size is sufficient for analysis.

Table 7: Results of KMO and Bartlett’s Test of application area

<table>
<thead>
<tr>
<th>KMO and Bartlett’s Test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiser-Meyer-Olkin Measure of Sampling Adequacy</td>
<td>0.906</td>
</tr>
<tr>
<td>Bartlett’s Test of Sphericity</td>
<td></td>
</tr>
<tr>
<td>Approx. Chi-Square</td>
<td>1045.072</td>
</tr>
<tr>
<td>Df</td>
<td>45</td>
</tr>
<tr>
<td>Sig</td>
<td>0.000</td>
</tr>
</tbody>
</table>

As seen in Table 8, communalities for each item have a value greater than 0.30. Also, the variables were collected in two groups. The first factor has eigenvalue 6.094, which explains 60.944% of total variance.

Table 8: Components and factor loadings of application area

<table>
<thead>
<tr>
<th>Factors</th>
<th>Factor Loading</th>
<th>Communality</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factor 1: Primary Activities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>0.609</td>
<td>0.551</td>
</tr>
<tr>
<td>Purchase</td>
<td>0.890</td>
<td>0.871</td>
</tr>
<tr>
<td>Logistics</td>
<td>0.664</td>
<td>0.492</td>
</tr>
<tr>
<td>Sales</td>
<td>0.792</td>
<td>0.762</td>
</tr>
<tr>
<td>Finance/Accounting</td>
<td>0.831</td>
<td>0.755</td>
</tr>
<tr>
<td>Human Resources</td>
<td>0.790</td>
<td>0.727</td>
</tr>
<tr>
<td><strong>Factor 2: Supportive and Service Activities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service</td>
<td>0.692</td>
<td>0.704</td>
</tr>
<tr>
<td>Information Technologies</td>
<td>0.814</td>
<td>0.727</td>
</tr>
<tr>
<td>After sales service</td>
<td>0.605</td>
<td>0.699</td>
</tr>
<tr>
<td>R and D</td>
<td>0.813</td>
<td>0.708</td>
</tr>
</tbody>
</table>
and factor 1 represents primary activities. The second factor has eigen-value 0.916, which explains 9.157 % of the total variance and factor 2 represents supportive and service activities. After conducting factor analysis, the reliability of each factor has been calculated. Table 9 represents Cronbach’s alpha internal consistency coefficients of all factors.

<table>
<thead>
<tr>
<th>Factors</th>
<th>N</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Activities</td>
<td>6</td>
<td>0.909</td>
</tr>
<tr>
<td>Supportive and Service Activities</td>
<td>4</td>
<td>0.852</td>
</tr>
</tbody>
</table>

As seen in Table 9, all factors have Cronbach’s Alpha value greater than the 0.7.

5.1.4 Effect of Size and Establishment Year

This section investigates the effect of firm characteristics which are measured as the number of employees and establishment year on the following issue: Industry 4.0 awareness levels of Technopark, Type of Industry 4.0 technologies on customer solutions, Usage level of Industry 4.0 technologies on customer solutions, Application areas that they offer their products regarding Industry 4.0. More specifically, the study test whether the mean score of the issues mentioned above differs with regard to the number of employees and the establishment year of the firm. the t-test is selected for the analysis. In this pursuit, the mean score of each factor illustrated in Table 1, Table 5 and Table 8 is calculated. Then, the firms are divided two groups with regard to number of employments: ones having 49 or less than 49 employees and others having more than 49 employees while the firms are grouped into two with regard to establishment year: ones with earlier than 2010 of establishment year and others with 2010 or later that establishment year. The results of the t-test have shown that company’s awareness levels, types of Industry 4.0 technologies on customer solutions, their usage level, as well as application areas that they offer their products regarding Industry 4.0 do not differ with respect to number of employment and establishment year.
Conclusion

This chapter discusses some of the issues of techno-park companies’ Industry 4.0 activities in Turkey. The findings of the study are summarized as follows:

Awareness level about Industry 4.0 is classified in four main categories, which are “awareness about the organizational impact”, “awareness about competitiveness impact”, “awareness about the role of techno-park and support” and “awareness about the environmental impact”. The mean of awareness about competitiveness impact is too high. This result is also supported by a study which is conducted by Boston Consulting Group and Turkish Industry and Business Association in manufacturing firms in 2016. According to two research, most of the companies think that Industry 4.0 technologies will contribute to getting more market share (TÜSİAD and BCG 2016). On the other hand, the mean of awareness about the role of techno-park and support is low. Industry 4.0 technologies are classified into three main categories, which are “digital manufacturing systems technologies”, “virtualization technologies” and “data management technologies”. Results showed that most of the participants who answered this question offered their solutions which are related to these technologies is in the range of 0–4 predominantly. The application area is classified into two parts, which are “primary activities” and “supportive and service activities”. Company’s awareness levels on Industry 4.0, type of Industry 4.0 technologies for customer solutions and their usage level, and application areas of Industry 4.0 technologies that they offer do not differ with respect to firm characteristics which are measured with regard to number of employees and establishment year. The t-test applied to each factor obtained in this study did not yield a statistically significant result. Although, scholars who analyzed the correlation between firm size and the ability of digital transformation found that “the relationship is stronger for newly established and smaller firms than others (Auger et al. 2003).
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**Key Terms**

<table>
<thead>
<tr>
<th>Industry 4.0</th>
<th>Digital Transformation</th>
<th>Techno-parks</th>
<th>Application Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Revolution</td>
<td>Awareness Level</td>
<td>Firm Size</td>
<td>Industry 4.0 Technologies</td>
</tr>
</tbody>
</table>

**Questions for Further Study**

**What** are the main outputs and the innovations of Industry 4.0 that will bring our lives?  
**Compare** and contrast techno-park companies and other technology development companies in terms of developing industry 4.0 technologies. What are the advantages of techno-park companies on this subject?
What are the main advantages of using big data? In which areas can you use this technology?

Three major industrial revolutions have taken place until today and we are now experiencing a new revolution. What kind of results do you expect from the enterprises that cannot keep up with this revolution, why?

**Exercises**

Suppose that you developed a new warehouse management software and this application's database, that holds all of your customer's data, is on the cloud. What may be some concerns about using cloud computing and what measures can be taken against it?

Suppose that you are the owner of a company that produces high technology. Which Industry 4.0 technologies would you focus on using in your products and services? Why?

The technologies of Industry 4.0 are explained in this chapter. Suppose that you are a Sales Manager and you want to analyse customer behaviours and obtain the target of the customer to launch your new product. Which industry 4.0 technology can help you? Why?

**Further Reading**


Mustafa Aldülmetin DİNÇER, Yasemin ÖZDEMİR

An Evaluative Perspective from Institutional Logic and Pragmatism on the Relationship between Industry 4.0 and Outsourcing

Learning Objectives

The objectives of this chapter are to obtain a holistic perspective between different subjects such as industry 4.0, outsourcing and institutional logic. Once you have mastered the materials in this chapter, you will be able to:

– Discuss the relationship between industry 4.0 and outsourcing.
– Explain the main concepts such as institutional logic, industry 4.0 and outsourcing.
– Identify pragmatism.
– Understand one of the main reasons for outsourcing especially in technology-related areas like industry 4.0, which is pragmatism.
– Conceptualize the loose coupling in the pragmatism logic and industry 4.0.

Chapter Outline

In this chapter of the book, outsourcing and industry 4.0 and the relationship between these two phenomena are discussed from the perspectives of institutional logic and pragmatism. To this end, first of all, industry 4.0, outsourcing, institutional logic and pragmatism are briefly defined and then the relationship between these phenomena is discussed. In this framework, some organizational theories and terms are used to expand the perspective of this debate, such as legitimacy and loose coupling. After this discussion, some samples from literature are given, and final stage of the chapter deals with the holistic perspec-
tive which is aimed to provide to the reader by the authors in the conclusion section.

**Keywords**
Industry 4.0, Outsourcing, Institutional Logic, Pragmatism, Loose coupling.

The boundaries between organization theories and managerial phenomena such as outsourcing, organizational logic, pragmatism, outsourcing and industry 4.0 are becoming blurry and conductive, and this situation raises the need for a holistic view of these phenomena. In this theoretical study, a complementarity perspective was administrated to obtain a holistic view and try to enlighten the field with the new interpretations. Most of the scholars have related outsourcing to the transaction cost theory (TCT), due to the practical reasons and pragmatism, this approach is pretty valid for the logic of this phenomenon, especially from the angles of strategy and pragmatism. Institutional logic can explain the working mechanisms of this double looped structure, which are industry 4.0 and outsourcing, and we believe that it covers not only the logic of these patterns but also comprises the logic of TCT approach. The current paper advocates that organizations use institutional logics and pragmatism to produce and reproduce themselves in order to preserve organizational productivity. With the institutional logics, conflicting applications and opinions inherent in the institutions became a very pragmatic and useful tool to realize their strategic existence and aims. Moreover, through outsourcing and industry 4.0 implementations, organizations get a large movement field for their sustainability and strategic actions. Again, in this context, loose coupling become a very useful tool to realize produce and reproduce themselves in the market. And in this phenomenon, all these dimensions became a symbiotic form so as to sustain companies’ life in the markets.

1 **What is Industry 4.0?**

Industry 4.0 phenomenon has been defined in several aspects in different articles. However, as stated in Hofman and Rüsch’s study (2017:206...
there is no generally fixed description and perception of industry 4.0 in the field. For this reason, to refrain from the needless debates, industry 4.0 will be defined shortly. According to Hofman and Rüsch (2017: 33), this industrial revolution, which is called the Fourth Industrial Revolution, may be the best explained as the transformation in the production logic against exponentially diffused, the self-regulating approach of value creation which is facilitated by concepts and technologies. These facilitators are as follows: the internet of things (IoT), cyber-physical systems (CPS), internet of services (IoS), additive manufacturing and smart factories, which are to assist firms to fulfil the next manufacturing demands.

1.1 Why is Industry 4.0 Important?

There is an enormous opportunity for the fourth industrial revolution for the whole manufacturing ecosystem. As cited in Bartodziej’s study (2017: 36), Kagermann et al. (2013) portrayed eight essential transformation: “Meeting individual customer requirements, Flexibility, Optimized decision-taking, Resource productivity and efficiency, creating value opportunities through new services, responding to demographic change in the workplace, Work-Life-Balance, A high-wage economy that is still competitive” which are likely to be facilitated by the changing process. There is a powerful relationship between these changes and cost-reduction potentials. Even though it is difficult to make a prediction of reliable cost-saving potentials at present, the probable interventions and maximizations into continuing processes throughout the whole value chain will have an immense influence on energy cost, capital and labour costs (Heng, 2014: 7; Bartodziej, 2017: 37). As seen above, it is not easy to adapt all these changes effectively and efficiently in a short time. Because industry 4.0 is related to strategic decisions, technology requires human resources to be adopted in this process and change in a short time, with high acceptance of the technology. This is why businesses need to focus on strategic shifts in the direction of industry 4.0. In this context, they will prefer to outsource many of their activities, especially those with the technology focus.
1.2 **What is Outsourcing?**

Outsourcing is a significant managerial decision for many organizations and it is a continuing trend. And it can also be defined in several ways with different aspects. Some of the definitions are as follows: “Outsourcing can be defined as the significant contribution by external vendors of the physical and/or human resources associated with the entire or specific components of the information technologies infrastructure in the user organization” (Aubert et al., 1996). “Outsourcing is a choice that lies in the corporate policy, not just business strategy area, as it modifies the firm’s boundaries as a legal entity and generally involves top management decision makers” (Quelin and Duhamel, 2003). “Outsourcing is a management strategy and operation form. That means a certain company, in line with the agreement reached with external other enterprise, outsources its business and function for which internal employees are responsible to the professional and efficient provider. Outsourcing is regarded as an effective means to help enterprise to administer the environment of end users” (Li-jun, 2012: 126–1269). “In the context of managing the potential risks of outsourcing, the various forms of outsourcing (e.g. IT outsourcing, business process outsourcing, out-tasking, infrastructure outsourcing etc.) should be considered. Because the boundaries of these forms are floating and change certain extent in the course of a customer relationship. Especially IT outsourcing, containing all the services based on IT infrastructure services, are provided by a service supplier to an economically and legally independent customers” (Rennung et. al, 2015: 758) Lee-man and Reynolds (2012) stated that outsourcing is the application by a firm which outside organization to fulfill the tasks that have typically been conducted inside the firm. The most outsourced business processes or the functions in the USA and Europe are basic services such as IT services, human resources, telecommunication services and facilities management. The most outsourced business processes have different importance such as supporting/critical, supporting/non-critical, property product/service, affecting all the organization, supported by mature technology and strategic (Kakabadse and Kakabadse, 2002).
1.3 Why do Organizations Outsource?

Several reasons make outsourcing a continuing trend. Outsourcing decision can be a result of organizational strategies or external factors. Generally, firms take some processes from an external service provider such as logistic or education to focus on their core competencies (El Mokrini et al., 2016). The primary motives that make organizations outsource some business process, which are emphasized in the literature, are probably to lessen the operational costs, concentrate on core competencies, derogate financial invest, upgrade ponderability of expenditures, getting access to external skills and develop value, convert fixed expenditures into variable expenditures and recapture control over internal divisions (Quelin and Duhamel, 2003).

Furthermore, via outsourcing, organizations can concentrate on their core skills, improve quality and efficiency, become flexible, reduce the inventory-carrying and investment costs, reduce the need for capital assets, save money, improve response times, and feel the need for staff less (Leeman and Reynolds, 2012). Additionally, through these applications, organizations lower the risks, expand innovative capabilities and opportunities for creating value-added stakeholder returns (Kosnik et al., 2006). Outsourcing seems to be a solution when it is necessary to hire experts or train them, but the organization cannot afford this (McCauley, 2000). In the literature, there are lots of evaluations and classifications about the reasons for outsourcing in the organizations (e.g., Masten & Crocker, 1985; Haour, 1992; Alexander, & Young, 1996; Adler, 2003). But most of these classifications take this phenomenon in two or three dimensions. In this study, Belcourt's classification about outsourcing reasons for the organizations was used. Since his classification is more comprehensive and has more dimensions than the other typologies, the researchers got a more comprehensive comparison chance for the present study. Besides, through this classification, it is anticipated that the researchers will have a better opportunity to build the theoretical fiction on a more solid basis. In Belcourt's study (2006) depending on various reasons and assessments, it can be said that there are at least six prominent causes that firms apply outsourcing, which are: "financial savings, strategic focus, access to advanced technology, improved service levels, access to specialized expertise,
and organizational politics” (Belcourt, 2006). In addition to the aforementioned reasons, some external factors prompt the company to outsource as shown below (Quelin and Duhamel, 2003): “the frequency of technological process and product evolutions, the speed of new product launches on the market, seasonal nature of the activity, cyclical character of the firm’s markets, degree and frequency of fluctuations in the workload, uncertainty about future markets.” Outsourcing decision given for these reasons also confirms some risks. A business needs to assess the risk factors and how to manage them. Transaction cost and agency theory as the prominent theoretical roots can be useful to categorize the risk factors (Aubert, Patry and Rivard, 1998). Also, it needs to be keynoted that technological improvements are really useful while managing these risks. Furthermore, the business may reduce the uncertainties by redesigning workflows and dividing work between the multiple suppliers, enhancing the scope of tasks that are suitable candidates for outsourcing (Aron, Clemons and Reddi, 2005: 37).

1.4 Some Samples for the Outsourcing Reasons in Different Countries

Related with these reasons and factors, the results of a study are shown in Figure 1. The study aimed to reveal why businesses in America and Europe outsource some activities. In total, 747 respondents returned fully completed questionnaires (Kakabadse and Kakabadse, 2002): Figure 1 shows the first three important reasons why firms outsource: the purpose to realize the best practice cost control and concentrate on core competencies in the USA. The range for European firms is: cost control, accomplish the best implementation and promote service quality. Although the scope of the reasons is different from cost control, the best method seems to be the main reasons for outsourcing in both the USA and Europe. For the success of outsourcing decisions, an analytical model can be useful. This model contains three main steps as background and results in both internal and external, structure and process (relational governance structure in interaction with the selection, implementation, and institutionalization). This model can be more useful in different sectors to point out the importance of the transitional stage to ensure that both allies obtain advantages in the
short term and distinguish better opportunities for transition, it is necessary to add new aspects related to the dynamics among the diverse stakeholders and better understand the methods that promote the development (Beaulieu et al., 2018). To realize these aims, it is vital to find the most suitable partner. This decision is the main topic of the next section.

All post graduate and doctoral theses in Turkey are accessible from the Council of Higher Education’s (shortly YÖK in Turkish) Thesis Center’s web site. In this context, when the theses written about outsourcing are examined, as a general view about outsourcing in Turkey it is seen that outsourcing in Turkey was investigated related to the following topics in last few years (https://tez.yok.gov.tr, 2019): -logistics, information technologies as services, -core competencies, resource dependence, service quality, employees’ perceptions (organizational commitment, organizational citizenship behaviour), performance, cost, customer satisfaction as results, -banks, hospitals, foreign trade companies, defence sector, schools, aviation industry, textile companies as the sector that prefer outsourcing.

Fig. 1 (Kakabadse and Kakabadse, 2002: 192)

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Das Erstellen und Weitergeben von Kopien dieses PDFs ist nicht zulässig.
2 Convergence Point of These Two Phenomena „Outsourcing and Industry 4.0“: Technology

As seen above, technology is one of the most preferred areas in outsourcing decision, which is also one of the core components of industry 4.0. Furthermore, as depicted in Hofmann & Rüschi’s study (2017: 23) last few decades, the demand of manufacturing industry to the new and more complex processes has increased much more than ever. The factors such as growing high competition, fluctuations in markets, claims for the products, which is more individualized, and the decreased product life cycles bring significant hurdles to the firms. [2]. It reveals that current "approaches" for the value creation are not enough to overcome the growing necessities about to cost efficiency, flexibility, adaptability, stability, and sustainability. In addition to all these, fast technological improvement in the last decade has created new business potentials and opportunities. This digitalization era which is called the cyber physical systems (CPS), internet of services (IoS) and mostly known internet of things (IoT) is becoming more significant and beyond. Considering these outsourcing and industry 4.0 patterns, a significant question mark and phenomena are emerging on the minds which is called institutional logic. And interestingly the relationship between these three phenomena, which are outsourcing, industry 4.0 and institutional logic, have not been emphasized sufficiently enough and researched together in the field. We believe that forming the complementarity perspective in this inquiry will enlighten many aspects and the dark sides of this field. As stated by Crouch (2010), the complementarity idea will be used as a combining pot for both phenomena (Crouch, 2010: 118). Although the everyday meaning of complementarity implies contrasts and differences in the constitution of elements deemed to be involved, these differences are clearly nested in certain kinds of similarity, or they would not 'fit'. To revert to one of the mathematical examples, the two hemispheres that form a sphere contrast together, thus they have to face different directions in order to make the sphere. However, they are both hemispheres; it would not work if one were a cube (Crouch, 2010: 121). In the field, most of the scholars have related this phenomenon to the transaction cost theory (TCT) (see: Huff, 1991; Gupta and Gupta, 1992; Aubert, Rivart and Patry,
1996; Ngwenyama and Bryson, 1999; Arnold, 2000; Wang, 2002; Quelin and Duhamel, 2003). Due to the practical reasons and pragmatism, this approach is absolutely valid for the logic of this phenomenon, especially from the angles of strategy and pragmatism but from a different perspective, indeed a more complementary perspective, which is institutional logic, can explain the working mechanisms of this structure. And we believe that it covers not only the logic of these patterns but also comprises the logic of TCT approach. To this end linked with the institutional logic, some organizational theory and terms are used in this study to expand the perspective of this debate, such as pragmatism, legitimacy and loose coupling. Through this theoretical lens, we assume that a new perspective can be put forward for the delineation of this phenomenon in the field. In this framework, this phenomenon is initially discussed in mainstream dimension then discussed in our perspective, and finally, we try to build a holistic perspective between these three approaches. In this sense, below in the next section, the relationship between these three approaches will be discussed.

3 The Relationship between the Institutional Logic, Pragmatism, Industry 4.0 and Outsourcing

Alford and Friedland (1985) used the institutional logic term to delineate "the contradictory practices and beliefs inherent in the institutions of modern western societies" (Thornton and Ocasio, 2008: 100–101). These authors depicted three contending institutional orders which are capitalism, state bureaucracy, and political democracy. And, according to them, all these three concepts have divergent applications and cults forming how individuals connect in political combats (Thornton and Ocasio, 2008). Then, scholars (1991) enhanced their opinion in the context of investigating the interrelationships among society, individuals, and organizations (Thornton and Ocasio, 2008: 101). As stated in Thornton and Ocasio (2008: 101) Alford and Friedland (1991) "accepts institutions as supra-organizational patterns of activity rooted in material practices and symbolic systems by which individuals and organizations produce and reproduce their material lives and render their experiences meaningfully". When this framework is considered for outsourcing
phenomenon, there is a structural overlap between the logic of outsourcing, industry 4.0, and the institutional logic. In the previous section, it was stated "Why Industry 4.0 is So Important? And Why Do Organizations Outsource?" And implementing the industry 4.0 and outsourcing reasons of the organization were expressed to be “decentralized, autonomous approach for the value creation, enabled by concepts and technologies like the internet of things (IoT), internet of services (IoS), cloud computing or additive manufacturing and smart factories, so as to help companies meet future production requirements” (Hofman and Rüsch, 2017: 33) and “financial savings, strategic focus, access to advanced technology, improved service levels, access to specialized expertise, and organizational politics” (Belcourt, 2006) reveal themselves clearly. All these dimensions make outsourcing and industry 4.0 necessary for the organizations to produce and reproduce themselves. In this context, other crucial phenomena, which are legitimacy, pragmatism and loose coupling, emerge as important dimensions and explanatory concepts for the fiction of the current study. As to Meyer and Scott (1983:201) “the view that organizational legitimacy refers to the degree of cultural support for an organization – the extent to which the array of established cultural accounts provide explanations for its existence, functioning, and jurisdiction, and lack or deny alternatives... In such a[n] instance, legitimacy mainly refers to the adequacy of an organization as the theory. A completely legitimate organization would be one about which no question could be raised. [Every goal, mean, resource, and control system is necessary, specified, complete, and without the alternative.] Perfect legitimation is the perfect theory, complete (i.e., without uncertainty) and confronted by no alternatives.” In James William's study, pragmatism is regarded as an apparatus or devise for the estimation, problem-solving and action, and the function of thought is rejected by the James to portray, symbolize, or mirror reality (William, 1909). In this context, Gutek (2014) notes that the pragmatism underlines the practical application of concepts by acting on them to test them in real life originally. Moreover, Gutek stressed that pragmatism concentrated on a dynamic universe rather than a stable universe as the Idealists, Realists, and Thomists had declared" (Gutek, 2014). In Weick's (1976: 3) study, loose coupling was depicted as a “situation in which elements are responsive, but retain evidence of separateness and
identity”. In his next study, Weick (1982: 380) stressed that when elements influenced each other abruptly, occasionally, insignificantly, indirectly, and eventually, loose coupling is imminent. When all these theoretical aspects are combined, outsourcing and industry 4.0 not only emerge as an important institutional logic but also appear as a vital legitimacy source. In this respect, organizations need outsourcing and industry 4.0 as an institutional logic to gain the legitimacy to produce and reproduce themselves in their organizational environment and systems. Due to the fact that organizations do not want to lose their legitimacy in their organizational environment and their market, they build their structure loosely coupled. Thanks to this pragmatic approach by using outsourcing and industry 4.0., they produce and reproduce themselves in their organizational life. When all these examples are put together in the framework of the concept of pragmatism and loose coupling, double looped relationship between all these phenomena reveals themselves explicitly. In order to focus on core competencies or get competition advantages, organizations display an inclination for outsourcing and industry 4.0. applications. As stated in Lee-man and Raynolds (2012), Kosnik et al. (2006), Hofman and Rüsch (2017), which were mentioned in the previous section, organizations focus core competencies, improve quality and efficiency, become flexible, reduce the inventory-carrying and investment costs, need more decentralization and self-regulation for value creation owing to the nature of market life and the requirements of the competitions. They also focus on lessening the requirement for capital assets, saving money, improving response times, hiring less staff, lowering risks, expanding innovative skills and opportunities for creating value-added stakeholder revenues. And all these realities or requirements make outsourcing and industry 4.0. as a fundamental institutional logic for the organizations in the industry or the other market fields for their survival. Through outsourcing and especially industry 4.0., the notions and technologies such as CPS, IoT, IoS, and smart factories were enabled in order to assist firms to fulfil future production necessities. Also, this survival pattern coincides with the Friedland and Alford’s definition (1985), which is about the simultaneous existence of contradictory practices and beliefs in institutional logic. Above in Figure 1 in previous section, high and the diverse outsourcing practices in Europe and
America “most prominent reasons in Figure 1: aim to achieve best practice, cost discipline/control focus on core competencies, etc.” reveal that our complementarity approach is accurate for these phenomena. As supra-organizational forms of operation which are originated in material exercises and symbolic systems, outsourcing and industry 4.0 revealed themselves as a supra-organizational pattern in the field. In Thornton and Ocasio’s study (2008), according to Jackall, Friedland and Alford, cultural assumptions and political struggles, which are embodied practices, have been sustained and reproduced by institutional logic. (Thornton and Ocasio, 2008: 101). These embodied practices have a pragmatic reason, and thorough these pragmatic reasons, they become more operational, and this operationalization will help produce and reproduce themselves in the market again. Transaction cost theory (TCT) (in ex: Huff, 1991; Gupta and Gupta, 1992; Aubert, Rivart and Patry, 1996; Ngwenyama and Bryson, 1999; Arnold, 2000; Wang, 2002; Quelin and Duhamel, 2003) is still a very powerful tool for the explanation of the outsourcing reasons in the field. But from a different perspective, indeed a more complementary perspective, which is institutional logic, can explain the working mechanisms of this structure in more detail. Besides, we believe that this comprehensive tool not only covers the logic of these patterns but also comprises the logic of TCT approach. When the Belcourt’s (2006) six-dimensional description is reconsidered, which is “financial savings, strategic focus, access to advanced technology, improved service levels, access to specialized expertise, and organizational politics”, all these practices gain embeddedness to the outsourcing practices. And also, these practices gain embeddedness to the industry 4.0. practices. Since we believe that there is a high convergence between Belcourt’s (2006) six-dimensional description and Kagermann et al’s (2013) eight fundamental points “fulfillment the individual customer necessities, flexibility, optimized decision-taking, resource productivity and efficiency, value creation chance via the new services, responding to demographic change in the workplace, work-life-balance, a high-wage economy that is still competitive”. In this sense, we provided some sample titles and various combinations of these titles from the literature (Belcourt, 2006):

Financial Savings, Resource Productivity, and Efficiency. According to Ngwenyama and Bryson (1997: 352), “the firms in different in-
dustries have applied these applications for many years. In their study, they stated that Ford and GM (General Motors) have outsourced more than 50% of the components to compose their final products”. Financial Savings and Reaching Advanced Technology, Flexibility, Resource Productivity and Efficiency. Haour (1992: 181–182) reveals that companies concentrated on effectually applying technological development in a global way. Due to the financial necessities, some firms actually respond to that need partly by setting up their R&D as a local organization which works on projects directly sold to the department or business units. (Haour, 1992: 182). Highly complex R&D process swells the costs of research. And this high burden makes research less appealing without stakeholders to share the cost. Also, the company could not have the financial assets to apply research yet if it remains a charming offering. Besides, the obstacles among the scientific disciplines and technical branches are also overcome as the exchange among research and development improves (Howells, 2009: 21). Financial Savings, Reaching Advanced Technology, Specialized Expertise, Flexibility, Optimized Decision-Taking and Strategic Focus, a Competitive Economy with a High-Wage. The elements, which are linked with employing CRTOs, are probably to concentrate on cost, the pace of delivery and the existence of professional expertise, yet it should be underlined that there probably appears quite national distinctness in the light of motives for research and technical collaboration (Howells, 2009: 22). According to the Commission of the European Communities study carried out under Ringe's (1992: 7) editorial indicated: “the UK has a large body of organizations that are able and willing to undertake contract research. These organizations are, in general, well established and technically sophisticated with close links with the UK (and overseas) industry. They are well placed to disseminate new technologies rapidly and effectively to a wide industrial base.” Since the contract research & development market became more aggressive, many firms took some measures to empower their status. This has brought about the incorporations of CROs and the conversion of status from a research association to a private limited company (Ringe, 1992: 43). Moreover, Ringe's (1992: 43) study reveals that most of the “UK CROs are relatively small, well-run technological organizations that could be incorporated into a consortium, to both work on particular projects and to remain as a prof-
itable technological arm”. According to Ringe’s report, there are some reasons underlying this situation, which are needed to tap additional manpower—desire to get strict control ability of research & development timelines and financial plans so as to finish the job and the progress of research and technical outsourcing. Strategic Focus and Access to Specialized Expertise, Flexibility, Value Creation Facilities by the Agency of New Services, a Competitive Economy with a High-Wage. In the strategic field making innovation capability as seen being one of the strategic competencies, Arora and Gambardella’s (1990) study gives us a significant proof of the relationship between strategy and outsourcing phenomenon. Arora and Gambardella (1990:374), who conducted a research on biotechnology firms, revealed that there is a positive correlation between biotechnology firms, which make research agreements with universities, even they have small participation, albeit they try to control the firm characteristics. Arora and Gambardella (1990) infer that these approaches are complementary to each other because firms which have these strategies target distinct and complementary sets of resources. The results of their study indicate that major companies are no more the unique centre of innovation activities. The core of innovation should be seen as the "network" of the inter-organizational tie. Strategic Focus, Reaching Advanced Technology, Reaching Professional Expertise and Organizational Politics. As revealed in Howells’ study (2009: 20–21), many facilitators of scientific and technical discoveries have now been realized, firms have to handle with much more complicated, difficult and rigid scientific obstacles. Moreover, according to Howells, the amount of technology used for each product increases in several consumer and business products since it varies from mechanic to electro-mechanic systems in the automobile industry (Howells, 2009: 21)”. Most of the firms do not have all the requirements of scientific resources to handle these obstacles and extra burdens (Haour, 1992). Additionally, many of these new elementary realities embrace several scientific and technical disciplines as well as prompting the association among organizations with strengths in various fields (Howells, 2009: 21). Howells’s study (2009: 17–18) displays that focus on technology outsourcing and supply, dynamics is important for many causes.
"Firstly, because of the absolute and relative growth of R&D externalization and outsourcing in advanced industrial economies; it, therefore, represents a growing phenomenon that deserves more attention. Secondly, this approach is valuable because it seeks to posit such change from the perspective of research and development as a corporate function and activity. The internal R&D process is changing, and it is no longer the sole generator of a firm's innovation stream; it now has an important technological scanning role and as a purchaser and adapter of other organizations’ technology. Much of the analysis of inter-firm research and technological collaboration has focused on the wider issues to do with the external relations of the firm and competitive performance and treated the R&D function as largely given. Thirdly, because the growth in the external sourcing of R&D and other design and technical activities by firms has played an important role in the creation and development of the 'research market', in terms of the commercial purchasing and trading of R&D and technology. Fourthly, and related to this, the establishment and growth of organizations serving this contract research and technical market. This includes what may be termed 'Contract Research and Technology Organisations' (CRTOs) as well as a wider group of companies and organizations with some involvement in the CRT market. This has significant implications for the development of the innovation support infrastructure in national and local systems of innovation (Howells, 2009: 17–18)."

Reaching Professional Expertise and Organizational Politics, Flexibility and Financial Savings, Work-Life-Balance. There are several reasons for outsourcing companies’ services to the external firms and this phenomenon is exemplified in a detailed way in Belcourt's study (2006); British Petroleum company outsourced HR services to Exult Company which is specialized in HR services. As the vice-president for HR stated "Our cost of delivering HR activities was uncompetitive, and the quality of the delivery was uncertain. Further, the burden of administration on the HR departments in the business units was preventing the function from performing more effectively in the more strategic HR services (Belcourt, 2006: 269)". Also, Belcourt notes that “through this way, the following results were obtained by BP company: a 40% reduction in HR staff, a reduction in operating costs of $15 million a year, and the avoidance of funding $30 million in capital costs for technology. The outsourcing allowed HR professionals the time to support the business lines” (Adler, 2003; Oshima, Kao, & Tower, 2005; Belcourt, 2006: 269). As cited in Thornton and Ocasio’s study, (1999: 804) these three scholars which are the pioneer definers of the institutional logic, Jackall (1988), Fried-
land and Alford (1991), have defined the institutional logig as “the socially constructed, historical patterns of material practices, assumptions, values, beliefs, and rules by which individuals produce and reproduce their material subsistence, organize time and space, and provide meaning to their social reality”. In this sense, due to pragmatic reasons, outsourcing and industry 4.0 emerge as a fundamental issue on the organization agenda and the environment. Also, other contemporary organizing structures such as network organization, clusters, and strategic unions prompt organizations to apply outsourcing and industry 4.0. As to this approach, institutional logics create a tie among the cognition, social rules, individuals and socially constructed institutional practices. Although Friedland and Alford’s, and Jackall’s approaches are slightly different from each other, Thornton and Ocasio (1999) unite the structural, normative, and symbolic phenomena with institutional logic in a single pot as three essential and interconnected dimensions of institutions, more than detachable structural (coercive), normative, and symbolic (cognitive) transmitters, as proposed by other scholars (e.g., Scott, 2001) (Thornton and Ocasio, 2008). In their study, Thornton and Ocasio (2008: 104) stated that three dimensions, which are competing and negotiating individuals, contradicted and interdependent organizations, conflicting and coordinating organizations, build society levels. When the limitations and chance gradually emerge in organizations and institutions for individuals’ actions, these three embedded levels are essential to understand society in detail (Thornton and Ocasio, 2008: 104). As the institutions and organizations are socially constructed and established by the individuals’ actions, rather than dominance one to over, this viewpoint proposes that individual and organizational action are embedded inside institutions (Berger and Luckmann, 1967; Thornton and Ocasio, 2008: 104). The recent studies on institutional entrepreneurship (i.e: Battilana, 2006; Greenwood and Hinnings, 2006) have combined the connection among the levels as an essential treatment for organizational and institutional transformation (Thornton and Ocasio, 2008: 104). Monitoring the society as an inter-institutional order enables the roots of heterogeneity and agency to be theorized and perceived from the inconsistencies among the logic of various institutional systems. Rationality is not based on a single source, on the contrary, it is based on multiple
sources according to a holistic perspective (Meyer et al., 1997). Institutional logics perspective regards every context as possibly affected by competing logics of various societal sectors, more than asserting homogeneity and isomorphism in organizational fields. For instance, the field of healthcare is formed by the institutional market logic, state democracy logic, and the professional medical care logic (Scott et al., 2000; Thornton and Ocasio, 2008: 104).

**Conclusion**

The boundaries between organization theories and managerial phenomena such as outsourcing, industry 4.o., organizational logic, pragmatism, and loose coupling are becoming blurry and conductive day by day, and this situation raises the need for a holistic view to these phenomena. Hence, in this theoretical study, a complementarity perspective was administrated to obtain a holistic view and try to enlighten the field with the new interpretations. According to our theoretical fiction, which we tried to create in this study, organizations use institutional logics and pragmatism as a tool to produce and reproduce themselves in order to preserve organizational productivity. In this context, thanks to the institutional logics, contradictory practices and beliefs inherent in the institutions became a very pragmatic and useful tool to realize their strategic existence and aims. Moreover, these structures support loose coupling for the organizations, such as outsourcing and industry 4.o., and they get a large movement field for their sustainability and strategic actions. As in the examples given in the previous section, the relationship between financial savings, access to advanced technology, access to specialized expertise, flexibility, optimized decision-taking, resource productivity and efficiency, pragmatically serve as the strategic focuses of the organizations. Institutional logics which were created by all these concepts give organizations a loosely coupled movement field to produces and reproduces themselves and their strategic focus.
References


Internet Sources

Key Terms

<table>
<thead>
<tr>
<th>Organization Theories</th>
<th>Strategy</th>
<th>Outsourcing</th>
<th>Industry 4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional Logic</td>
<td>Finance and Loose Coupling</td>
<td>Core Competencies</td>
<td>Pragmatism</td>
</tr>
</tbody>
</table>

Questions for Further Studies in the Field

Explain the main motivation of organizations to outsource.
Why is industry 4.0 so important for companies?
What is the common point of outsourcing and industry 4.0?
Explain the relationship between the institutional logic, pragmatism, industry 4.0 and outsourcing.
Explain how industry 4.0 affects outsourcing decisions.
Discuss that if there are any differences for various manufacturing sectors in outsourcing decisions related with industry 4.0.
What are the main benefits and risks of outsourcing?
Explain how the outsourcing risks can be managed.

Exercises

It became more difficult for your company to compete in the new conditions caused by industry 4.0 with your rivals. In this sense which technical issue will you take support for your company?
Suppose you are the human resources (HR) manager of a company, do you think that it will be necessary to outsource some HR activities in the industry 4.0 transformation? If you think it is necessary, which HR activities will be outsourced and how?
When you analyse the market which institutional logics (competition, core competencies, legitimacy, etc.) stimulate your company to outsource and which institutional logics motivate your company to use industry 4.0?
Think about your ideal manager position. And you decided to outsource. Which criteria will you use to determine which areas you will outsource and which organizations will be your partners?
Industry 4.0 causes many changes in several business just as in job requirements. Think about which HR qualities will become more important to be hired. 

Imagine that you are the manager of a business and you see some problems in the annual reports after the outsourcing decision. How will you solve these problems?

Further Reading


Definitions

**Software** is the product that software professionals build and then support over the long term. Software encompasses (a) instructions, function, and performance, (b) data structures that enable the programs to adequately store and manipulate information and (c) documentation that describes the operation and use of the programs.

**Software engineering** is concerned with theories, methods and tools for professional software development. It is the science and art of building significant software systems that are on time, on budget, with correct operations and with acceptable performance. Software costs often dominate system costs; software costs more to maintain than it does to develop. Software engineering forms a bridge from customer needs to programming implementation. Software engineering is concerned with cost-effective software development. *‘Software Engineering: (1) The application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software; that is, the application of engineering to software. (2) The study of approaches as in (1).’* IEEE definition.

Stakeholders

A **customer** requires a system to achieve some business goals by user interaction or interaction with the environment in a specific manner. **Software engineers** have to (1) understand how the system-to-be needs to interact with the user or the environment so that customer requirements are met and (2) design the software-to-be. The **programmer** has to implement the software-to-be designed by the software engineer.
Software products

(1) 1:1 developed product: systems which are commissioned by a specific customer and developed specially by some contractor.

(2) 1: N developed (generic) products: Stand-alone systems which are produced by a development organization and sold on the open market to any customer.

(3) M: N (hybrid) systems: generic products sold as stand alone, customized according to customer needs.

Software product evaluation criteria

Maintainability, dependability, effectiveness, efficiency, usability, hybridness

The relative importance of these evaluation criteria (attributes of software products) depends on the product and the environment in which it is to be used. In some cases, some attributes may dominate. Software engineering focuses on a layered technology, based on the layers (a) quality focus, (b) process, (c) methods and (d) tools.

Process layer as the foundation defines a framework with activities for effective delivery of software engineering technology. Method provides technical how-to’s for building software. Tools provide automated or semi-automated support for the process and methods. The quality focus is the general commitment of an organization to quality which fosters a continuous process improvement culture.

Attributes of good software

| Maintainability | Software should be written in such a way so that it can evolve to meet the changing needs of customers. This is a critical attribute because software change is an inevitable requirement of a changing business environment. |
| Efficiency | Software should not make wasteful use of system resources such as memory and processor cycles. Efficiency therefore includes responsiveness, processing time, memory utilization, etc. |
| Acceptability | Software must be acceptable to the type of users for which it is designed. This means that it must be understandable, usable and compatible with other systems that they use. |
| Dependability and security | Software dependability includes a range of characteristics including reliability, security and safety. Dependable software should not cause physical or economic damage in the event of system failure. Malicious users should not be able to access or damage the system. |
Classification of software process models

Generic software process models

Waterfall: Separate and distinct phases of specification and development
Evolutionary: Specification and development are interleaved
Formal Transformation: A mathematical system model is formally transformed to an implementation
Reuse-based: The system is assembled from existing components

Engineering process model

Specification: Set out the requirements and constraints on the system.
Design: Produce a model of the system.
Manufacture: Build the system.
Test: Check the system meets the required specifications.
Install: Deliver the system to the customer and ensure it is operational.
Maintain: Repair faults in the system as they are discovered.

Hybrid process models

Large systems are usually made up of several sub-systems. The same process model need not be used for all subsystems. Prototyping for high-risk specifications. Waterfall model for well-understood developments.

Spiral model

Focuses attention on reuse options. Focuses attention on early error elimination.
Focuses attention on reuse options. Focuses attention on early error elimination.
Potential problems of process models

<table>
<thead>
<tr>
<th>Model</th>
<th>Visibility</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterfall</td>
<td>High risk</td>
<td>High risk for new systems because of specification and design problems.</td>
</tr>
<tr>
<td></td>
<td>Low risk</td>
<td>Low risk for well-understood developments using familiar technology.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unidirectional, no way back, finish this step before moving to the next.</td>
</tr>
<tr>
<td>Prototyping</td>
<td>Low risk</td>
<td>Low risk for new applications because specification and program stay in step.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High risk because of lack of process visibility.</td>
</tr>
<tr>
<td>Transformational</td>
<td>High risk</td>
<td>High risk because of need for advanced technology and staff skills.</td>
</tr>
</tbody>
</table>

Process visibility

Software systems are intangible so managers need documents to assess progress.
Waterfall model is still the most widely used model.

<table>
<thead>
<tr>
<th>Model</th>
<th>Visibility</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterfall model</td>
<td>good</td>
<td>Each activity produces some deliverable</td>
</tr>
<tr>
<td>Evolutionary development</td>
<td>poor</td>
<td>Uneconomic to produce documents during rapid iteration</td>
</tr>
<tr>
<td>Formal transformations</td>
<td>good</td>
<td>Documents must be produced for each phase of the process to continue</td>
</tr>
<tr>
<td>Reuse-oriented development</td>
<td>moderate</td>
<td>Sometimes artificial to produce documents describing reuse and reusable components</td>
</tr>
<tr>
<td>Spiral model</td>
<td>good</td>
<td>Each segment of the spiral should produce some document</td>
</tr>
</tbody>
</table>

Questions on Software engineering

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is software?</td>
<td>Computer programs, data structures and associated documentation. Software products may be developed for a particular customer or may be developed for a general market.</td>
</tr>
<tr>
<td>What are the attributes of good software?</td>
<td>Good software should deliver the required functionality and performance to the user and should be maintainable, dependable and usable.</td>
</tr>
<tr>
<td>What is software engineering?</td>
<td>Software engineering is an engineering discipline that is concerned with all aspects of software production.</td>
</tr>
<tr>
<td>What is the difference between software engineering and system engineering?</td>
<td>System engineering is concerned with all aspects of computer-based systems development including hardware, software and process engineering. Software engineering is part of this more general process</td>
</tr>
<tr>
<td>What is the difference between software engineering and computer science?</td>
<td>Computer science focuses on theory and fundamentals; software engineering is concerned with the practicalities of developing and delivering useful software.</td>
</tr>
</tbody>
</table>
Usual of Enterprise Resource Planning (ERP) in Turkey and Information Safety

Learning Objectives

The objectives of this chapter Enterprise Resource Planning in Turkey are discussed and new technical approaches to secure an Enterprise Resource Planning system. Once you have mastered the materials in this chapter, you will be able to:

- Discuss Enterprise Resource Planning in Turkey.
- Understand the difference national and international ERP system.
- Identify ERP system with high vulnerability and high confidentiality in which the security is critical for it to operate.
- Discuss information security in ERP system.
- Supporting security solution in ERP as well as directions for secure ERP systems.

Chapter Outline

Businesses have to adapt to the increasing competition conditions in today's business world to ensure their sustainability. Knowledge management systems are the most important tool for helping enterprises in this competitive environment. In parallel with the developments in the information management systems technologies, the new management and business approach and the increase in the use of computers, the result of Enterprise Resource Planning (ERP) became more evident. The ERP system is becoming the system with high vulnerability and high confidentiality in which the security is critical for it to operate. ERP vendors have already integrated their security solution, which may work well internally; while in an open environment, we need new
technical approaches to secure an ERP system. This study introduces ERP technology from its evolution through architecture to its products. Further information will be made regarding the use of ERP in Turkey. The security solution in ERP as well as directions for secure ERP systems is presented. The information security that should be in ERP will be discussed.

**Keywords**


1 Introduction

As being parallel to developments in information and communication technology, an outcome of increase in computer usage in enterprises with new management and business conduct approach is Enterprise Resource Planning- ERP. Enterprise Resource Planning (ERP), is a wide spectrum computer software enabling for enterprises to manage all their functions ranging from procurement to distribution with the support of an integrated information system.

Enterprises show significant efforts in the last forty years period to use the resources they have in an effective way. According to the efficiency definition in the form of ratio of output to input, decrease in the value of denominator is synonymous with increase in efficiency. Many resources owned by enterprise are among particulars effecting the denominator. Idle materials which don’t attract attention of anyone in the warehouse and which have been purchased once by making payment for significant amount of money can be shown as example for this. "Corporate Resource Planning" software helps for all these inputs to be effectively used (İnal 2004). ERP system covers a very wide business net such as accounting, logistics, production planning, stock management, purchasing, production, marketing, and human resources. Basic target of ERP systems is to manage these activities in a coordinated way. As it is the case with all the systems, ERP has attained its current status as a result of making additions to various systems. ERP covers Material Requirements Planning (MRP), Closed Circuit (MRP), Main
Production Schedule (MPS), Capacity Requirements Planning (CRP) and Production Resource Planning (MRP II) systems (Al-Mashari et al. 2003). Intentional or unintentional threats can come from people within the enterprise (operational personnel) or from people outside the enterprise. These people can give harm to software, hardware, data, system, communication net and information. People within or outside the enterprise can threaten safety either intentionally or unintentionally with technological developments. These can be listed as computer viruses, information hackers/unauthorized accesses, information technology robberies, technical problems, misuse of authorized accesses either intentionally or unintentionally and computer tricks (Demir 2005). In this study, it has been focused on the definition of ERP, its historical development, basic technical features, and its market structure in Turkey and in the world. Besides, information safety particulars in ERP systems have been examined.

2 Definition and Scope of ERP

Enterprise Resource Planning (ERP) is a software system including planning, coordination and controlling functions of supply, production and distribution resources in different geographic regions in accordance with strategic objectives and targets of enterprise in the most effective and efficient way (Keçek and Yıldırım 2009; Laudon and Laudon 2004). ERP is formed with initial letters of the words. Even if it has come to a status that appeals to other functions and sectors in a short time, roots of ERP are based on production. Realization of ERP application is based on organization changes. In a simple way, ERP system can be defined as an integrated information system that serves for all particulars of enterprise. It handles the processes, keeps the records, provides real time information, and facilitates planning and control. Furthermore, its effectiveness is an output of success of application cycle (Erkan 2008). According to the definition made by APICS (American Production and Inventory Control Society), Enterprise Resource Planning systems provides a method including receiving of customer orders, their being fulfilled, delivered and reports prepared as relating with their calculations for having effective planning and con-
trolling of all necessary resources. Finally, ERP systems plan resources of factories of enterprise, their supplier companies and distribution centers which are geographically located at different regions in a coordinated way. It plans from which distribution center the customer order should be met or at which factory it should be produced, how machinery, material, labor force, energy, information and other production and distribution resources that are available at the factories can be used commonly and in a coordinated way as being appropriate for meeting material and service requirements of all factories (Manetti 2001). Most important feature of ERP is to be able to share resources of factories of enterprise in different regions (local and abroad), their supplier companies and distribution centers (warehouse) in a coordinated way. Within this frame, it is determined from which distribution center which order of which customer should be met or at which factory it should be produced, how machinery, material, labor force, energy, information and other production and distribution resources that are available at the factories can be used commonly and in a coordinated way as being appropriate for meeting material and service requirements of all factories (Avunduk and Güleryüz 2018). An ERP system is a business management system that is enabled with information technology, that plans all resources of enterprise, that meets all information requirements as having completely integrated computer support. It combines software and processes of all divisions within a single software application operating over a single database. ERP software is a software application series providing opportunity to an institution to share information during the whole period of organization (Usmanij et al. 2013). It is possible to look at ERP concept in 3 different ways; ERP is a commercial product which can be bought and sold in the form of a computer software. ERP is a development tool that gathers all processes and data of an institution under a single wide spectrum and integrated structure. It is the key factor of an infrastructure providing solutions for work processes. The purpose in using ERP system applications that begin to be more widespread in different sectors is to develop connections outside the enterprise and to support value chain activities of company, going beyond provision of process integration within the enterprise.
3 Development of ERP System

Evolution of ERP systems has closely followed up big scale improvement of computer hardware and software systems (Sumner 2005). When it is looked at historical development of ERP system, it is seen that foundation of this system is based on 1960s. In 1960s financial situation of enterprises could not enable them to buy their own computers. For this reason, stock counting and recording were done manually. While this method caused for problems to be faced in timely delivery of orders, it has not provided a health method for giving net information about product stocks. In the following years, system is developed on listing of materials. Material Requirements Planning (MRP) systems including part requirements or product planning as per the main production plan came out in 1970s. Following this development in 1980s, it is met with production resources planning (MRP II) that enables best usage of production process by synchronizing production needs and materials as being a new software (Aydoğan 2008). MRP II was a system including logistics management, project management, finance, human resources, and engineering. Finally, ERP systems evaluates functions that were previously handled separately in institutions in an interconnected way for fulfilling corporate purposes and by benefiting from this, it aims to make efficiency relating with all kinds of resources, labor, materials, money and machinery in the institutions reach to the utmost level. With a different approach, ERP systems enable for information being obtained from company data that are stored in a common area to be transmitted to the correct authorities in a correct way (Loh and Koh 2004).

Reasons for development of ERP system can be summarized as stated below; Physically dispersed production operations, International distribution chains, Requirement to open to international markets (as a result of strategy for improving internal market strength by being heard of in international markets due to local markets becoming saturated), Timely Production (JIT) supply system, High competition, Variable global market conditions, Expansion of global entrepreneurship with the globalization, Lean approach in management organizations. When the requirement arising due to these reasons is supported with developments in information technologies, ERP has come out. As
it is known, client/server distributes design and information to physical points through a net and store them in different computers, and connections are provided within this dispersed database system with electronic communication technology and graphic user interfaces. In this way without looking at any user program and physical status of database, global data can be reached and distributed data system can be used like a single unit. Historical development of ERP Systems can be seen in a more clear and precise way on Table 1.

**Table 1. Historical development of ERP systems (Sumner 2005).**

<table>
<thead>
<tr>
<th>System Type</th>
<th>Time</th>
<th>Purpose</th>
<th>Target Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order Point Systems</td>
<td>1960s</td>
<td>Prediction and stock management by using past data</td>
<td>Stock systems supporting high amount of production environments, costs</td>
</tr>
<tr>
<td>Material Requirements Planning (MRP)</td>
<td>1970s</td>
<td>Planning of production and material processes on request basis with respect to quantity and time</td>
<td>Production integration and planning</td>
</tr>
<tr>
<td>Production Resources Planning (MRPII)</td>
<td>1980s</td>
<td>Application and monitoring of production plans at workshop level with capacity planning</td>
<td>Integration of all production resources, detailed cost reports and quality</td>
</tr>
<tr>
<td>Enterprise Resource Planning (ERP)</td>
<td>1990s</td>
<td>Integration of all divisions in an enterprise by including customer and supply dimensions</td>
<td>Integration of production, supply and customer data</td>
</tr>
<tr>
<td>Enterprise Resource Planning II (ERP II)</td>
<td>From 2000s till today</td>
<td>Integration of Customer Relations Management (CRM), Supply Chain Management, Electronic Commerce (E-Commerce) systems</td>
<td>Integration of all functions of enterprise and all stakeholders with internet technology</td>
</tr>
</tbody>
</table>

4 **Fundamental Features of ERP System**

Features of ERP software answering to requirements of different sectors can be generally listed as below (Braggs 2005); It is a standard software package that targets all the sectors and that can be privatized during its instalment. When compared with other software ERP software has a more convenient structure for privatization. Because this standard software, target sector of which has not been defined, can be privatized during the instalment as per private requirements of institution. ERP is more of an application software than a database management.
software, middle ware or an operating system. It is an integrated
database that both stores main data and the data relating with work
processes. It provides solution proposals about basic work processes. It
has a high level of functional structure due to its aiming to support
various corporate functions. ERP software are designed throughout
the world to provide solutions as being independent from countries
and regions. ERP software realizes functions such as accounting pro-
cesses that show variations from country to country, issuance of docu-
ments with private forms (bids, invoices etc.) and human resources
management in accordance with country-based requirements. Funda-
mental ERP product software aims at all sectors and not just some of
the sectors due to its comprising adequate functionality for usage at
global scale. Another feature that differentiates ERP software from oth-
ers is that ERP software supports repeating and continuous work pro-
cesses such as supply management, order management and payment
processes.

5 Components of ERP System

ERP operates various software components (modules) that handle var-
ious business activities of enterprise under a single database. Most im-
portant feature of ERP systems is to have a modular structure that is
composed of components. ERP components (modules) are system ele-
ments that make important contributions to operational functions.
ERP component of each section operates by considering quality proce-
dures and instructions which are required to be implemented within
the process, forms that are filled in, and sub-processes being developed
within work process. Components make connections between differ-
et operational steps with the aim to form work flow chain, to control
information flow from one section to another, and to provide enter-
prise to the customers and suppliers (Ross and Vitale 2000). Feature of
ERP enabling it to be modular ensures assembly of components har-
monizing with corporate requirements within institutional bodies and
for desired functions to be used at desired times. Although compo-
nents can be established as being independent from one another, they
all realize their functions in an integrated structure with each other.
While there are various and numerous components in ERP software, basic components are shown in Fig. 1.

![ERP components](image)

Fig. 1. Components in ERP software

### 6 ERP Software in Turkey

In a research being conducted in Turkey, it was revealed that corporate application software market of Turkey (ERP) has reached to a volume of 301.64 million dollars in 2016. Corporate application software market has achieved an annual growth rate of 12.3 percent. Our country which is confronted with negative influences of events such as unsuccessful coup attempts and terror attacks has a growing corporate application software market despite these. For the years of 2017 -2021 annual compound growth rate of this market (CAGR) is expected to be 5.4 percent. Major factors accelerating corporate application software investments in year 2016 are stated to be various decisions that are taken as relating with invoice (e-invoice) and e-accounting investments, budget constraints, efficiency increase and digital transformation. According to a research that is conducted in our country, below data relating with corporate application software come to the forefront. In the production sector it is expected for process manufacturing sub-sector to show biggest growth with annual compound growth expectation (CAGR) of 6.6 percent. This is followed with retail sector and discrete
manufacturing sub-sector of production industry with a growth expectation of 6.2 percent. In 2016, corporate resource management (ERP) software had the biggest share of 54.8 percent in Turkish corporate application software market and throughout the year it generated license and maintenance (L&M) revenue of 165.26 million dollars. While SAP, being the global leader in this sector, became the biggest ERP supplier in Turkey with a share of 42.2 percent in the market in year 2016, LOGO ranked as the second one with a share of 23.3 percent. Microsoft remained in third row with a share of 8.4 percent. In 2016, 96.2 percent of total ERP expenditures in Turkey is provided by first ten producers. Production companies were among biggest ERP consumers in Turkey and purchasing of 84.91 million dollars constituting 28.2 percent of total market is realized by them.

7 ERP Systems

7.1 Foreign ERP Providers

SAP: The company with German origin is the most rooted company in ERP sector. It was founded in 1972 and with a market share of 25% it is the global leader in ERP market. SAP is also the leader in Turkish market. Its share in this market is 36.3% and its user numbers is 15,000. It is being preferred by nearly 230 companies. In the first 500 companies of Turkey, as ERP, SAP has been preferred with biggest ratio. ORACLE: ORACLE, which is mainly known for their database solutions, also has ERP package which is defined as “Oracle E-Business Suit”. While Oracle ranks in second row in global scale in ERP market, Peoplesoft (JD Edwards), which ranks in the third row has made a serious attempt against SAP by purchasing the company and their software. Works to combine Oracle and Peoplesoft software are still continued. In Turkey, they have nearly 200 installations. MBS (Microsoft Dynamics): Software giant Microsoft has taken its place in ERP market recently with their company purchasing strategy and they have attained nearly 5% market share in global scale. Packages that are active in Turkey are Axapta and Navision under the heading of Microsoft Dynamics. In
terms of markets, they target at SMB (Small and Medium Size Business) market. Solutions in Turkey are implemented by various local companies which are solution partners. IFS (Industrial and Financial Systems): IFS which is a Swedish originated ERP is composed of more than 60 business applications including solutions such as those relating with e-commerce, finance, maintenance, human resources, supply chain management, customer relations management, service management and engineering as expanding step by step by being installed in a short time at enterprises with different scales with the component architecture it has got. Their authorized office provides services relating with sales and marketing, localization, implementation, adaptations that are private for customers, training and consultancy services in Turkey. IFS applications are used by more than 2,000 users in more than 50 companies in Turkish market since 1995 as including companies traded at Istanbul Stock Exchange Market. IAS (Industrial Application Software): The company which is established in Germany by a Turkish entrepreneur (Hakan Karabiber) in 1989, has brought software development and R&D studies to Turkey afterwards and has entered the Turkish market. IAS, which has more than 50 customers in Turkey, is emphasizing its technological superiority with new version of CANIAS that is developed with Java, as enabling for the whole ERP to operate through the web in recent years. Although it is stated in foreign ERP classification, as it is developed in Turkey, it also has advantages of local ERPs. ABAS: ABAS, which is established in Germany, Karlsruhe in 1980, provides ERP and e-business solutions in 28 languages to more than 2,100 customers and more than 45,000 users throughout the world. Training, consultancy, adaptation and project management services are provided by 50 business partners and nearly 580 qualified personnel of ABAS throughout the world. ABAS Business Software solutions can operate in Linux, Unix and Windows platforms. In nearly %80 of installations that are made until today, Linux has been preferred.
7.2 Turkey ERP Providers

NETSIS: It is among the leading ERP producers in the sector, successful projects of which are rapidly increasing in number. Local software company, centre of which is located in Izmir, is providing services with 40 solution partners today by developing solutions that comply with modern and international criteria. With their mission to export software from Turkey to the world, they are marketing their software technologies which they develop at R&D base in Urla at their offices in Azerbaijan, Egypt, Ukraine, and Iran as of today. LOGO: Logo, being the leading company in Turkish software sector, continues their expansion which they have gained in the market with the accounting package since year 1984 with Unity which is the product they have produced in ERP area. Logo, which also exports software abroad, has released their product “Unity on Demand” with Java support recently to the market. Logo, which is an important software exporter, currently operates in 17 countries. UYUMSOFT: One of the leading ERP companies in our country is Uyumsoft. Uyumsoft, which provides solutions to many companies among first 500 companies in our country, has directed their attention to Europe as well and they realize software exports to the markets of England, Azerbaijan, Albania and Iran. WORKCUBE: WorkCube is a comprehensive e-business application software that enables for company employees, customers, and all business partners ranging from suppliers to service providers under as single and solid platform. WorkCube, being a fully web based corporate software, provides a platform to the corporations where they can carry out all their business, collaboration and communication activities through a common database from A to Z. WorkCube can be considered as a complex resultant of corporate software solutions that are defined with different categories and descriptions in the past and today. In this respect, WorkCube contains all functions in solutions such as ERP, MRP, CRM, HR, SCM, CMS, LMS, B2B, B2C, and Project Management and it offers them for usage of corporations in an integrated way with each other. Workcube which is developed and launched to the market by Workcube E-İş Sistemleri A.Ş., is the only web-based software that provides the greatest number of functions over a common database until today. SET SOFTWARE: It is the leading institu-
tion in the sector that operates since 1993 relating with ERP, CRM, MRP, IFRS, Financial software requirements of local corporations and foreign capital corporations and institutions with medium and over-medium sizes. As being a software company that produces 100% unique solutions for corporations on project basis, their main product being SET B’LACK ERP software is successfully used in various different sectors. TEKNOSOL: It is one of the leading ERP software companies in our country. With their V-Era ERP Project, they provide solutions to their distinguished customer portfolio ranging from pharmaceuticals to cosmetics, from textile to paint sector, from packaging industry to automotive, and to glass and porcelain sectors. In line with different service approach of Teknosol, with the services they provide before the project, during and after project applications, V-Era ERP, has strengthened its place among the projects that are mostly preferred in the sector. LOGIN SOFTWARE: Login Software offers Privatized Corporate Management Information Technologies System Solutions since year 1989. They provide services to medium and large-scale clients which they have determined as their target client mass, with the products which they have developed themselves. Differences that cause our solution to be differentiated from others are flexibility, reliability and production capabilities. Due to the reason that our Login Integrated ERP Solution can be comprehensively privatized by our software team, this has been the most important reason for positive opinions of our business partners about us. Capabilities of program regarding production operations respond to the requirements of companies making production on order basis in our country in confidence. Our Product Configuration logic, equivalents of which do not exceed a few not only in our country but also in the world, has brought the success which many software companies could not achieve.

8 Definition of Information and Information Safety

Before making the definition of information safety, it is required to define information in a clear and understandable way. Information is data collection being recorded on paper or in digital environments as being understandable and transmittable or they are real and imaginary
products of ideas that are transmitted, recorded, or published either officially or non-officially in any from within the mind. Information is the upper level of information and data. Information can be briefly defined as “information to which meaning is attached”. If we realize the process to transform information into usable and beneficial activity, information takes the form of information. For example, if we think of phone numbers as data, a meaningful phone guide being formed from these telephone numbers is an information. It is an information when we recall a number we have seen in this phone guide and think that this number belongs to one of our friends and that we should have called this person for a long time. By defining information and by passing it through examination, evaluation, synthesizing, and finally decision-making process and by applying it, it is reached to information. Information safety is the total of efforts shown to establish a safe information processing platform in order to protect integrity of information by avoiding unauthorized accesses during storage and transport of data or information in electronic environment. Information safety bears the purposes of ensuring work continuity, minimization of losses in case of inevitable disasters, and protection of confidentiality, accessibility and integrity of resources, being building blocks of companies (Vural and Sağiroğlu 2008). With a different definition, in an environment where continuous access can be had to information, ensuring integrity of information from the sender to receiver in confidentiality, without being disrupted or changed and being obtained by others and their being transmitted in a safe way are defined as information safety. Purposes of information safety are 3 fundamental particulars stated below (Alsmadi et al. 2018): Confidentiality: Confidentiality can be defined as information’s being close to the access of unauthorized people. Another definition of confidentiality is avoidance of disclosure of information by unauthorized people. Integrity: Integrity is protection of content of information against threats of its being changed, erased or destroyed in some way by unauthorized people. Integrity is ensuring correctness and completeness of information. It is related with information content’s not being changed, erased or destroyed with regards to any of its parts. Availability: Availability is information’s being ready to be used at each time of of being needed. Even in case of any problem that arises, information’s being accessible
is a requirement for its usability feature. This access should be within frame of user rights. As per availability principle, each user should be able to have access to information source within time slice when he is authorized.

9 Information Safety at ERP

In recent ten years’ time, as being seen in each other field, digital infrastructures have brought electronic transformations with them in commerce. Private sector has grasped digital developments beforehand and they have started to control business processes with big volumes with ERP systems. With the development of internet infrastructure, ERP systems began to be accessible from each place and from each device (Anonymous 2018). Nowadays especially cyber threats and their sources can be very heterogeneous and their targets can be various. Taking measures and being prepared before the attacks bears vital importance for avoiding social and economic damages (Canbek and Sağiroğlu 2006; Çetinkaya 2008). Cyber-attacks targeting Safety of ERP system form sort of threats. Usage of old version or non-supported software in enterprises create security weaknesses. Software companies launch new versions and new products as per security deficiencies of software and infrastructure problems. Enterprises allocate resources for updating and new versions and software companies prefer product modifications as traditional ERP upgrading is difficult (Başaran 2018). Researches show that %66 of companies do not use updated ERP products. Companies’ resisting against updates that cause additional costs give rise to serious security deficiencies. Those who will realize cyber-attacks especially examine the published updates and they determine the failures in previous versions with reverse engineering and they target at companies using software with low versions (Anonymous 2018). For a real safety of operational software, an integral approach should be followed. In ERP software safety, safety of operating system through which it operates, physical safety of server, net safety, final user safety and similar topics should be questioned. Updating of ERP that operates through an operating system that is not updated does not show that the system is secure. Customers using old
products are made subject to attacks realized towards these deficiencies in such cases. Worst example of this in industry is experienced with Windows XP operating system. According to the new researches that are made, ratio of those using Windows XP is 20%. When ratio of operating systems used in enterprises is considered, it reaches up to 60%. This situation creates serious security risks as operating systems are quite open to active and passive attacks (Başaran 2017). Inadequate reporting capabilities can cause external reporting again. Loss of data inspection is a particular which directly effects data safety. Reporting tools that are resolved by new generation ERP systems, produce vital data for correct and safe operation of system. It is required for these data to be kept in a safe place outside live system after they are produced. Most dangerous command for a data system is updating. Biggest problem relating with incapable reporting tools is that they don’t reveal retrospective data control and that they don’t show changes in data that have changed in time. Retrospective updating of data can give rise to outcomes that are difficult to detect and recover. In an ERP system where data auditing is lost, requirements for external reporting arise. It is permitted especially for critical data to be transmitted outside with user friendly intermediary systems such as Access and Excel. Opening of data to another target necessitates not only the security of main system but also the security of lower target systems where data are opened. After data is transmitted outside, their being transported, copes and controlled give rise to serious security weaknesses. Reporting tools that are more secure, more capable and central should be preferred. In ERP system data should be classified according to their importance as per the declarations to be given by the enterprise. Data inspection and authorization should be improved and while they are transmitted out, organization of data according to their classes should be realized. But at this point importance should be given for security protocols to be transparent and applications that would avoid user works or make them become difficult should be eliminated. Sensitive balance between security and operability should be tested with site testings. Rightfully many enterprises focus on threats that may come from outside, physical security of data centers and final user security issues. However, for the enterprises the possibility of having a computer pirate attack from outside is lower than a technical person-
nel’s or system provider’s using access and change authorizations in a faulty way or with misuse from inside. Damages that can be given to enterprises by the employees of enterprises is considered to be much higher than the damages that can be caused by external threats. In ERP system for ensuring security, below stated 5 items can be considered as advises (Başaran 2017; 2018). Finding a secure ERP software: Software of most producers are secure. If there are any concerns relating with software that are privately developed for a company or which have very few users other than the said company, before software is purchased, it can be requested for testing to be done by an unbiased company regarding software security and performance and for the weaknesses found to be eliminated. Making a safe installation: If there are issues relating with safety of net architecture where ERP software will be established, safety of operating systems of servers where software will work, amendment of factory set user names and passwords, additional security options/modules provided by producer, particulars relating with their being activated should be handled with care. Providing training of those managing the software: Particulars such as determining which changes will be made how on ERP software, which users will have access to this software with which authorizations, what remote access conditions will be, how user actions and database movements will be monitored should be evaluated. Increasing user awareness: Improving consciousness of users against social engineering attacks such as Phishing attacks is the most effective measure to be taken against these attacks. Security issue should be absolutely included in user training. Continuous inspection of processes: Continuous monitoring of ERP software, users, and database and determining attackers or extraordinary movements being observed and realizing necessary interventions bear vital importance.

9.1 ERP Information Safety Gaps

In the report being published by Digital Shadows Ltd. and Onapsis Inc., researchers have stated that they have observed a visible increase in attacks made by hactivist groups, national state actors, and cyber offenders on ERP systems of SAP and Oracle (Montalbano 2018). With the
publishing of this report, relevant companies have published patches closing security deficiencies relating with their software. One of the biggest attacks experienced by SAP was realized in years 2013 and 2014 and due to a security gap, in 2013 and 2014 unauthorized access was had to data of USIS that provides services to state institutions and private sector in USA to question people’s past (Haberturk 2018). Attacks towards small scale companies and especially towards the producers are increasing. In these attacks, especially ERP systems have become attractive targets. Because these data include most important business data of a company. Besides, ERP systems also serve as a corporate data center that connects with other systems on store area, customers, suppliers, mobile workers and machines.

As being a registry system for an enterprise, ERP data bear critical importance for tasks as including very confidential intellectual properties. For this reason, it is required for enterprises to attach special importance to ERP security, regardless of their being big or small sized. We can specify biggest five security threats confronted by your ERP system as below. 1: Patchless Software: In ERP software, updates and patches should be monitored and realized on time. The sad truth is that many ERP systems are being used without their patches being loaded. 2: Poor Structuring: Our second most important security risk is related with adjusting and structuring your ERP system in a non-appropriate way. Most of the time, enterprises establish their systems without considering security or by considering it as little and they open the door for cyber-attacks. Deficiencies in a configuration can include problems relating with security gaps, open ports, access parameters the lock of which has been opened relating with identity information or private code security gaps relating with a system. 3: Old Web Interfaces: ERP Web applications should be continuously updated and software developments should be followed up. Regarding SQL injection and web-based attacks (XSS, XSRF) web page rules should be followed up. 4: Inadequate Access Controls: It is an important component of a good ERP safety to determine who can see and arrange data in the system. As these systems possess all or most of critical business data, not being able to manage access process appropriately causes a permanent security threat which the companies should always focus on. 5: Complex Service Rejection Attacks: Usage of ERP security gaps in a
complex way causes an important threat for any enterprise based on ERP system as being the case for almost every enterprise. For this reason, real time monitoring is important. It is required for these five security risks to be monitored and to exhibit a proactive standing against security issues in general. Due to cybercrimes and reverse engineering developments, as ERP systems are important data stores, it is required for information security developments to be added to ERP software.

10 Conclusions

ERP systems where all kinds of information of companies such as those relating with warehouse, workplace, personnel, finance, distribution net are kept gain significant importance nowadays. Companies can even carry out their work flows and approval mechanism through these systems. In companies where it is inevitable to realize active time operations, accesses can be had through the wen and all the system becomes open to internet environment. These systems are administered by key users and most of the time users can cause security gaps without knowing to carry out their works in a fast way. While this situation is not desired by companies at all, in order to avoid it, continuous security training should be given to users. However, it is required for security protocols not to slow down work processes of users. Security of ERP systems is not only related with users. In situations relating with updating of operating system where system is installed, situation of hardware, updating of ERP system, risk is present not only for ERP but for all the systems. What should be primarily realized by companies here is to establish security stages other than ERP software in a successful way. In the end ERP is a software system as well and it should have routine security processes. Besides the fact that computer and internet usage increase each and every day and the benefits, gains, advantages and positive aspects of virtual world that influences, changes and directs our lives more as time passes, it should be considered that if attention is not paid, they could damage personal and corporate processing, cause efficiency decrease and big scale losses and even very serious local or global chaos. However, it is not possible to ensure information safety with technological measures. In enterprises information
safety should be part of business process and at each step measures should be taken to ensure safety. For this purpose, information safety policy should be established in enterprises and workers of enterprise and other relevant people should be informed about this subject.

11 References


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12 Key Terms

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13 Questions for Further Study

**Describe** Enterprise Resource Planning (ERP). What are the major deliverables?

**Compare** Turkey ERP and international ERP system.

**What** does information security in Enterprise Resource Planning?

**What** is the security solution in ERP as well as directions for secure ERP systems?

14 Exercises

**What** are ERP systems? What are the benefits? What do you say?

**While** information systems have benefits to businesses, there are problems in terms of security. What do you say?

**Discuss** national or international ERP vendors? What are the advantages and disadvantages?

**What** security measures should be in information systems. What should be considered in ERP systems especially in enterprises?

15 Further Reading


Learning Objectives

The objectives of this chapter are to understand the basic machine learning approaches to solve time prediction problems in health information systems, to learn the basics of artificial neural networks, to identify the essential concepts in the design and implementation of multilayer perceptrons with many hidden layers, and to understand the basic methodologies for evaluation of the performance of machine learning algorithms for regression problems. Once you have mastered the materials in this chapter, you will be able to:

– Discuss the key machine learning approaches and technologies that are used in management information systems and how they can be used for Industry 4.0 applications.
– Identify the essential concepts in the design and implementation of multilayer perceptrons with many hidden layers with complex architectures.
– Understand the basic methods, approaches, and implementations for data analysis, data transformation, and machine learning models for service time prediction problems.
– Design and implement artificial neural network models for solving regression problems in business.
– Understand the basic methodologies for evaluation of the performance of machine learning algorithms for regression problems.
Chapter Outline

This chapter introduces a special artificial neural network (ANN) model, which is designed and implemented in order to predict service duration of specific processes in a hospital. Service times between different phases in health information systems and medical services is one of the important measurements that affects quality of services, satisfaction of patients, change management, costs, organizational and strategic business decisions. Accurate and coherent prediction of service times or turnaround times as well as elicitation of the hidden reasons that have impact on service durations is a difficult problem. The ANN model proposed in this study has a unique multilayer perceptron architecture with four hidden layers and some hyper-parameters and methodologies, which are commonly used in deep learning, are also used in the proposed ANN model. The prediction performances of this unique ANN model is comparatively analyzed with some other ANN’s and some linear or nonlinear regression algorithms by the aid of some basic performance evaluation methods that are used for numerical prediction. The results show that the proposed model provides significantly more successful results than the other models and algorithms and it can be used by the decision makers as an accurate and reliable model to predict service times.

Keywords

Multilayer perceptron, artificial neural networks, machine learning, service duration, medical laboratory, health information systems, numerical prediction, regression

1 Introduction

The assembly of big data and machine learning with current technological advancements such as cloud computing, mobile technologies, fuzzy systems, pervasive computing and the Internet of Things has enabled tremendous new business opportunities. Data analysis has become a competitive and sustainable advantage for many organizations. To saddle the advantages of big data and machine learning, in any case,
business pioneers confront the challenge of not just getting the adequate technologies and ability to analyses the information, yet additionally to mesh an information driven attitude into the organizations’ structure and culture. In the recent decades, organizations have depended on analytics vigorously to enable them with competitive knowledge and empower them to be increasingly successful. Organizations are currently compelled to look further into their information to discover new and imaginative approaches to increase effectiveness and competitiveness. Regarding the recent advances in science and technology, especially in machine learning, organizations are developing bigger, smarter, and more comprehensive analytics models and techniques. There is a huge number of diverse alternatives for machine learning platforms and tools today. However, business managers should focus on their particular business requirements so that you could make the right choice among these alternatives. Machine learning provides “the technical basis of data mining and it is accepted as a universal discipline, which is used in cooperation with data mining” (Witten et al. 2011). Bayesian networks, support vector machines, and decision trees are examples of such algorithms, which “reside both in the area of, machine learning and data mining” (Mitchell, 2017; Nedjah et al. 2009). Artificial neural networks (ANN) are one of the “black-box models amongst machine learning” (Haykin 2009) and a multilayer perceptron, which is a type of ANN is designed, coded and implemented in this study to predict two different service durations in a medical laboratory.

2 Background

Information systems and related technologies are known to have a great influence on the enhancement of quality, efficiency, an effectiveness of healthcare services. The advances in information technologies and their alignment with business processes enables new solutions approaches for health management systems and for the decision makers (Bernardi et al. 2017; Chen 2014; He et al. 2013; Lyon et al. 2016; Ng and Chung 2012; Söderholm and Sonnenwald 2010; Stvilia and Yi 2009). There are also some studies focusing on the enhancement of the
service qualities in clinics, laboratories, and similar institutions by the analysis and reduction of service times (Goswami et al. 2010; Scagliari-ni et al. 2016; Sinreich and Marmor 2005; Willoughby et al. 2010). Turnaround time or service time is generally described as the amount of time or duration taken to fulfill a request or process. The service duration or turnaround time in medical services and healthcare systems is usually described as the time spent for a particular analysis or during any stage in medical laboratory, other commercial laboratories or a public health laboratory (Breil et al. 2011; Goswami et al. 2010). Processing time or duration for tests is often considered as one of the most significant performance measures in medical services; such as laboratory analytical service time is shown to be a reliable indicator of laboratory effectiveness (Goswami et al. 2010) or the reduction of patient service time in emergency departments is shown to impose an effective impact on decreasing the costs for emergency departments and increasing the service quality and patients’ satisfaction (Fieri et al. 2010; Sinreich and Marmor 2005; Storrow et al. 2008; Willoughby et al. 2010). However, it seems difficult to find outstanding researches, models, or applications that relates to the accurate prediction of the service times among such medical services, which was one of the primary motivations and objectives to make a research related with this subject, which is discussed in this chapter.

3 Artificial Neural Networks

Artificial neural networks (ANN) are described as computational models that were derived by the inspiration from central nervous systems and the brain in mammals (Haykin 2009; Kumar, 2017). They are generally used to “approximate or estimate functions that might depend on a large number of inputs and ANN can be used for either classification, clustering, or regression” (Haykin 2009). ANN are being used today widely in order to solve difficult tasks or problems such as decision making, computer vision, forecasting, pattern and speech recognition, and so on (Huang et al. 2004; Olivas et al. 2009; Reyes et al. 2013; Yu et al. 2006). ANN with feed-forward learning models are usually named as “multilayer perceptrons” (Bishop 2006). However, it
should be noted that there are various feed-forward ANN models and multilayer perceptron (MLP) is a specific type of feed-forward ANN, which “all of the nodes in one layer are fully connected to all of the nodes in the following layer and there exists one or more hidden layers” (Haykin 2009). It is known that “the differential error and corresponding weight updates in MLP is usually achieved by backpropagation with gradient descent methodology” (Haykin 2009). However, in the recent years, some other alternative learning rate and weight update methodologies are being preferred, such as RMSProp (Root Mean Square Propagation), AdaGrad (Adaptive Gradient), ADAM (Adaptive Moment Estimation), and so on (Goodfellow et al. 2017; Patterson and Gibson 2017).

The linear input function given in equation (1) is used for the nodes / units in the hidden layers and the output layer and it is generally used in “multilayer feed-forward neural networks” (Bishop 2006). For each node \( j \) in the hidden or output layer, “the net input \( I_j \) is calculated by the connection's weight \( W_{ij} \) from node \( i \) in the previous layer to node \( j \); \( O_i \) is the output of node \( i \) from the previous layer; and \( b_j \) stands for the bias parameter used in that node” (Larose 2005).

\[
I_j = \sum_i W_{ij} O_i + b_j
\]  
(1)

The weights and biases in an ANN are randomly initialized to continuous small negative and non-negative values with a uniform or Gaussian distribution. These weights and bias values are updated during the training phase of the neural network model. On the other hand, if the number of weights and nodes are very high in ANN, which is mostly seen in deep learning models, then some specific weight initialization strategies are preferred, such as Xavier initialization (Patterson and Gibson 2017). The network structure in any ANN learns by “adjusting the weights in order to make better or more accurate predictions or classifications” (Han and Kamber 2006). Biases are also used in most of the feed-forward neural networks and multilayer perceptron models where “each bias value within each layer of a neural network is shown to have the effect of increasing or lowering the net input of the activation function so that the output values within each layer are derived or
updated in a more balanced way” (Haykin 2009). A non-linear activation function is used “to calculate the output value within each unit in the hidden layer or the output layer, which is usually chosen as sigmoid function” (Han and Kamber 2006). The output value is calculated by using the non-linear sigmoid function that is given in equation (2), where \( I_j \) is the net input to node \( j \), and \( O_j \) is the output of node \( j \).

\[
O_j = \frac{1}{1 + e^{-I_j}}
\]  

(2)

It should be noted that hyperbolic tangent function (Graves 2012) is also used as well as sigmoid function as non-linear activation functions in MLP models and some deep learning architectures such as LSTM (Long Short-Term Memory), and GRU (Gated Recurrent Units). The output value derived by using the non-linear hyperbolic tangent function is given in equation (3).

\[
O_j = \frac{e^{I_j} - e^{-I_j}}{e^{I_j} + e^{-I_j}}
\]  

(3)

There are non-linear activation functions that are mostly preferred recently in deep learning models, as well as MLP (Samudrala, 2019). One of them is ReLU (Rectified Linear Unit), which is also used as the non-linear activation function within all of the hidden layers for the model proposed in this study. ReLU is shown in equation (4).

\[
O_j = \max(0, I_j)
\]  

(4)

If an ANN is to be used for regression problems, then the output layer is composed of a single output node, and the prediction of the dependent variable is achieved by the output value of that node. The predicted value “is usually different from the actual value and eventually, this difference is described as the prediction error” (Larose 2005). Other errors are obtained within each node in each hidden layer, and the
weights must be updated iteratively by using those errors. Backpropagation, which is also named as “backward propagation of errors” is “one of the methods that can be used in multilayer feed-forward neural networks to calculate the errors and new weights” (Dasu and Johnson 2003). Backpropagation method is usually used with the “gradient descent” optimization algorithm in order “to update the new weights in a more accurate way” (Haykin 2009). The backpropagation method for calculating the error in the output layer is given in the equation (5). It should be noted that; \( j \) stands for the output node, the predicted value is denoted by \( O_j \) and \( R_j \) is the actual value for that instance.

\[
Err_j = O_j (1 - O_j)(R_j - O_j)
\]  

It should be noted that \( O_j(1 - O_j) \) is established by the derivative of the non-linear sigmoid output function. This is due to the fact that the derivative of the sigmoid function can be expressed in terms of the function itself, which is given in equation (6).

\[
f'(x) = f(x)(1 - f(x)) \text{ where } f(x) = \frac{1}{1 + e^{-x}}
\]  

This property is also true for all the other non-linear activation functions. For instance, in equations (7) and (8), it is shown that the derivative of hyperbolic tangent and ReLU can also be expressed in terms of themselves respectively.

\[
f'(x) = 1 - f(x)^2 \text{ where } f(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}
\]  

\[
f'(x) = \begin{cases} 0, & x < 0 \\ 1, & x \geq 0 \end{cases} \text{ where } f(x) = \begin{cases} 0, & x < 0 \\ x, & x \geq 0 \end{cases}
\]  

The weighted sum of the errors of the nodes connected to node \( j \) must be included “to calculate the corresponding error of that node within
any hidden layer in the neural network” (Larose 2005). The error formula for node $j$ in a hidden layer is shown in the equation (9) where $W_{jk}$ is the connection’s weight from node $j$ to node $k$ in the following layer, and $Err_k$ stands for the error in node $k$.

$$Err_j = O_j (1 - O_j) \sum_k Err_k W_{jk}$$  \hspace{1cm} (9)$$

These error values are used to update the weights and biases within each iteration during the training process of an ANN. The iteration is also named as “epoch” in ANN terminology and each epoch can be simply described as one complete iteration or round in the training of an ANN. In other words, an epoch can be defined as “a single pass through the entire training set within ANN model where backpropagation errors are calculated and nodes’ weights are updated” (Hastie et al. 2009). The weight update calculation within each connection is given in the equations (10) and (11) where $\Delta W_{ij} (t-1)$ is the change in $W_{ij}$ in the previous iteration $(t-1)$, $W'_{ij}$ is the new weight value for the $t^{th}$ iteration, $Err_j$ denotes the error for node $j$, $O_i$ is output value of node $i$ and $\alpha$ stands for the learning rate of the ANN where $(0 < \alpha < 1)$.

$$\Delta W_{ij} = \alpha Err_j O_i$$  \hspace{1cm} (10)$$

$$W'_{ij} (t) = W_{ij} (t) + \alpha Err_j O_i + m (\Delta W_{ij} (t-1))$$  \hspace{1cm} (11)$$

There is a constant parameter $m$ in equation (11), and this parameter is named as “momentum”. This momentum constant is used to prevent the system from converging to a local optimum. In other words, “this parameter helps to increase the rate of learning while avoiding the danger of instability in artificial neural networks” (Haykin 2009).

Min-max normalization (Han and Kamber 2006; Witten et al. 2011) is used as a statistical data transformation method for all of the continuous variables and input data in any ANN model, which is denoted in equation (12). It must be noted that this transformation
method is also used in this study for all the attributes with numerical values in order to normalize the variables range between values 0 and 1 that makes it appropriate for ANN models.

\[
X_{\text{norm.}} = \frac{X - \min(X)}{\max(X) - \min(X)}
\]  

(12)

However, in ANN and deep learning models, another normalization methodology, standardization or Z-score normalization namely, is also used for data transformation (Patterson and Gibson 2017). It is a well-known methodology that transforms a numerical variable by normalizing its statistical distribution where its mean becomes 0 and the standard deviation becomes 1. Hence, all the values of the variable are transformed into small negative or positive values. This methodology is given in equation (13).

\[
z = \frac{x - \mu}{\sigma} \quad \text{where} \quad \begin{cases} 
\mu &: \text{mean of the population} \\
\sigma &: \text{standard deviation of the population}
\end{cases}
\]  

(13)

There were some attributes in this study with nominal (categorical and non-ordinal) values, which were used as input data. All of these nominal data were transformed into dummy variables so that one input node was generated and set to either 0 or 1 for each different value of a categorical variable, which is mostly used in all types of deep learning and ANN models (Dasu and Johnson 2003; Patterson and Gibson 2017). For instance, if there exists an attribute with three different nominal values such as “X”, “Y”, and “Z”, then there will be three input units for this attribute so that this single attribute is transformed and diminished into three attributes. Each categorical value of this attribute can be represented by different combinations of 0 and 1 according to the arbitrary settings. For instance, for the records originally having values “X”, the first input unit will be chosen as 1 and the other two units will be 0 such that it will have an input encoding as 001, and so on. This method is known as “one-hot encoding” or “one-hot vector representation” (Buduma and Locascio 2017).
4 Materials and Methods

The data used in this study was provided from the health information system’s medical laboratory database in one of the public hospitals in Turkey and this data had been collected in two years. The name of the hospital and some other information about the hospital could not be explicitly given in this study due to confidentiality reasons. There were 247305 records with 19 different attributes such as “Patient’s gender”, “Patient’s age”, “Department Name”, “Previous admissions to this department”, “Previous admissions to other departments” “Date of patient registration”, “Time of patient registration”, “Date of request for physician”, “Time of sample delivery to laboratory”, and so on. The list of these 19 attributes with their data types from the original data is given in Table 1, and a sample of the data set is given in figure Fig. 1. It could be considered that two previous studies (Eminağaoğlu and Vahaplar 2018; Köksal et al. 2016) might resemble the approach and the implementation in this study. However, it should be noted that in those studies the data set was entirely different and was collected from a different hospital. In addition, the proposed ANN model, its architecture, the activation, and some normalization functions used in this study are entirely different from both of these studies. The train and test data split methodology, and the use of two different prediction attributes can be considered as other aspects that make this study entirely different from the previous studies.

Table 1. The list of attributes in the original data obtained from the medical database

<table>
<thead>
<tr>
<th>Attribute index #</th>
<th>Attribute name</th>
<th>Data type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Patient’s gender</td>
<td>Categorical (nominal)</td>
</tr>
<tr>
<td>2</td>
<td>Patient’s age</td>
<td>Numerical (integer)</td>
</tr>
<tr>
<td>3</td>
<td>Department name</td>
<td>Categorical (nominal)</td>
</tr>
<tr>
<td>4</td>
<td>Previous admissions (This department)</td>
<td>Numerical (integer)</td>
</tr>
<tr>
<td>5</td>
<td>Previous admissions (Other departments)</td>
<td>Numerical (integer)</td>
</tr>
<tr>
<td>6</td>
<td>Date (Patient registration)</td>
<td>Date (DD.MM.YYYY)</td>
</tr>
<tr>
<td>7</td>
<td>Time (Patient registration)</td>
<td>Time (hh:mm)</td>
</tr>
<tr>
<td>8</td>
<td>Date (Request for physician)</td>
<td>Date (DD.MM.YYYY)</td>
</tr>
</tbody>
</table>
A sample of the data set retrieved from medical laboratory database

Some of the attributes in the data set had to be converted to different data types and formats in order to make them appropriate for both ANN architectures and numerical prediction. “Department name” attribute was a nominal attribute with eleven different categorical values such as “Urology”, “Dermatology”, and “Cardiology”. Since ANN models and algorithms can only use numerical attributes as input data, “Department Name” attribute was transformed into one-hot vectors by using the dummy coding which was explained in the previous section. The major business processes or stages that were within the scope of

Fig. 1. A sample of the data set retrieved from medical laboratory database
this study is denoted in Fig. 2. The durations between each of the seven main stages were considered as six different service durations, and they were computed by transforming them into terms of seconds first, and then calculating their differences. Hence, six new attributes were derived and they were added into the datasets. These derived attributes were also the candidates among different service times or durations to be used as the independent variable or the attribute for prediction. Two of these six candidates were chosen as target attributes for prediction because the analysis and estimation of the duration between those two stages were crucial for the hospital management. One of them is the duration between “Sample delivery to laboratory” and “Specimen collection”. The other one was the duration between “Sample delivery to laboratory” and “Report of test results” services. Hence, two different experiments were conducted in this study with two different data sets. In the first set, the duration between “Sample delivery to laboratory” and “Specimen collection” was set as the target attribute to be predicted (named as Duration_1 in this chapter), and the other remaining 24 attributes were set as features attributes. In the second set of experiments, service time between “Sample delivery to laboratory” and “Report of test results” was used as the attribute to be predicted (named as Duration_2 in this chapter), and the other 24 attributes were used as feature attributes. In other words, “Duration_1” was treated as the independent variable and the other 24 attributes as dependent variables for one of the experiment sets, and “Duration_2” was treated as the independent variable and the remaining 24 attributes as dependent variables for the other experiment sets.
Fig. 2. Major business processes and services in medical laboratory within the scope of this study

There were some attributes such as “Date of patient registration”, “Time of patient registration”, and so on. These were all originally in either date (DD.MM.YYYY) or time format (hh:mm), and they were converted into integers named as “Day of month” (ranging between 1 and 31) and “Hourly time interval” (between 1 and 24). Thus, a data set with 247305 instances and 25 attributes was established finally where a sample from this data set is shown in Fig. 3. This data set is used in different experiments with machine learning algorithms. In the proposed ANN model, Z-Score standardization was used for all the feature attributes to normalize the numerical attributes and to make it feasible for the multilayer perceptron. On the other hand, the dependent variables to be predicted, “Duration_1” and “Duration_2” were min-max normalized. It should be noted that all the feature attributes were min-max normalized while they were trained and tested by ANN models and regression algorithms in Weka, due to the default settings in Weka.
New data set with transformed variables and additional attributes derived from the service durations in terms of seconds

In order to observe the performance of the machine learning algorithms and to evaluate whether they have learned the model, the entire data set with 247305 instances was divided into three different data sets. 173113 instances (70% of the entire data set) were randomly chosen and used for training phase of each of the machine learning algorithms. Half of the remaining data (37096 instances, which is 15% of the entire data set) was chosen and used for validation phase and similarly, the remaining 37096 instances were used for the final test stages. Hence, during all the experiments in this study, each machine learning algorithm was trained first with the train data set, and then the trained model was tested by the validation data set. According to results observed after validation process, the algorithm or model’s parameters were changed (due to overfitting problem or high errors in predictions), and the training and validation stages were re-executed (Buduma and Locascio 2017). If acceptable results were observed in the validation stage, then that algorithm or model was finally tested with the third set, which is the test data set. It should be noted that all of these results within three phases are given in this study, however, the test results should be focused on, and the evaluation of the machine learning algorithms should be based on their performances with the test data (Buduma and Locascio 2017; Goodfellow et al. 2017), which is also done in this study. Statistical random sampling without replacement methodology (Dasu and Johnson 2003) was used to derive independent train, validation, and test data sets. It should be noted that
cross-validation is another reliable and accurate statistical technique in data mining and machine learning whenever the data set has to be separated into train and test data sets (Hand et al. 2001). However, due to the high number of sample sizes in this study, and the necessity of frequent updates of a lot of different hyper-parameters in some of the models, instead of k-fold cross-validation, or other methodologies, train / validation / test separation is preferred (Buduma and Locascio 2017; Goodfellow et al. 2017). One of the performance evaluation measures for numerical prediction that is used in this study is coefficient of determination ($R^2$), which is used as an evaluation metric in scientific researches (Hassanpour et al. 2018; Ravinesh and Şahin 2015; Yeh and Lien 2009). If the predicted values among the test / validation instances derived by a numerical prediction algorithm are denoted as $p_1, p_2,.. p_n$ and the actual values are denoted as $a_1, a_2,.. a_n$, then the coefficient of determination $R^2$ can be calculated as follows (Larose, 2006):

$$R^2 = 1 - \frac{SSE}{SST}, \text{where}$$

$$SSE = \sum_{i=1}^{n} (p_i - a_i)^2 \quad \text{SST} = \sum_{i=1}^{n} (a_i - \bar{a})^2$$

It should be noted that, in the equation (14), $n$ denotes the total number of instances, and denotes the arithmetic mean of actual values respectively. Another performance measure for numerical prediction that was used in this study was root mean squared error (RMSE), which is also defined as the “standard error of the estimate” (Larose 2005). Given that, the predicted values are $p_1, p_2,.. p_n$ and the actual values are $a_1, a_2,.. a_n$ within a test / validation data set, RMSE is calculated as follows:

$$RMSE = \sqrt{\frac{(p_1 - a_1)^2 + (p_2 - a_2)^2 + \cdots + (p_n - a_n)^2}{n}}$$

(15)
It is known that mean squared error and root mean squared error measures tend to exaggerate the effect of outliers. On the other hand, it is also known that mean absolute error (MAE) measure does not tend to exaggerate the error values caused by outliers (Witten et al. 2011). Since, there were several outliers in the data used in this study, and since it was strictly necessary not to discard the records having outlier values, MAE was also used as another prediction performance measurement. MAE calculation is given in equation (16).

$$\text{MAE} = \frac{|p_1 - a_1| + |p_2 - a_2| + \ldots + |p_n - a_n|}{n}$$ (16)

The descriptive statistics for the “Duration_1” and “Duration_2” dependent variables are given in the Table 2. It should be noted that all the values of “Duration_1” and “Duration_2” that are shown in Table 2 are in terms of seconds. It could be seen from Table 2 that the minimum value is observed to be zero for both of the attributes. This might be related to some errors in the original raw data records or some unusual occasions, however, these values and related records were not changed or discarded from the experiments.

Table 2. Descriptive statistics for dependent variables “Duration_1” and “Duration_2”

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Duration_1 (seconds)</th>
<th>Duration_2 (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2365.42</td>
<td>2043.78</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>7234.56</td>
<td>5964.20</td>
</tr>
<tr>
<td>Minimum</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>288720</td>
<td>226140</td>
</tr>
</tbody>
</table>

5 Design and Implementation

The architecture and design of the specific MLP model used in this study was implemented and coded with Python 3.7.1 programming language (Python 2019) and Tensorflow R1.11.0 machine learning
framework (TensorFlow 2019). TensorFlow can be simply described as “a software framework for numerical computations that is designed primarily as an interface for expressing and implementing machine learning algorithms, especially, deep neural networks” (Hope et al. 2017). Since, the MLP model proposed in this study had relatively a deeper architecture (than ordinary MLP’s) with four hidden layers, 33088 weights, and many hyper-parameter updates among a huge training dataset more than 100,000 instances, it was necessary to use such a framework. The proposed multilayer perceptron model’s training parameters that were used in both of the data sets in were as follows: Gradient descent was used with mini-batch training (Goodfellow et al. 2017) where the batch size was set to 256. The learning rate was set to 0.01, momentum was set to 0.02, and decay method was not used for the learning rate. It should be noted that some different adaptive learning rate models such as ADAM and RMSProp were tested; however, the results were not good as the results obtained by gradient descent with momentum. Dropout method (Buduma and Locascio 2017; Goodfellow et al. 2017) was used to overcome the potential overfitting problems and the dropout rate was set to 0.5 among all of the hidden layers and the output layer. This dropout rate was satisfying since the differences between the errors obtained from training, validation, and test phases were negligible, thus, overfitting problem was not observed. Thus, it should be mentioned that L1 and L2 regularization methods (Goodfellow et al. 2017) were not included in the model because dropout method was observed to be sufficient for the overfitting problem. The number of epochs was set to 1000 for the training process, where an epoch means the training step of the whole data set. The architecture of the multilayer perceptron in this study was designed and implemented with an input layer with 34 nodes, one output layer with one node, four hidden layers where the first two hidden layers had 128 nodes each and the third and fourth hidden layers were composed of 64 nodes. The input layer of the MLP was composed of 34 nodes because there were 24 feature attributes in the data sets. Among these 24 feature attributes, 22 of them were numeric attributes with integer values that necessitated 22 input nodes. Patient’s gender was a nominal attribute and since it had only two values, it could be represented by a single digit, which could be established with a single input.
node in the neural network architecture. The department name was also another nominal attribute that had eleven different values, which required the addition of eleven input nodes. Hence, 34 nodes were used in the input layer of the ANN model in this study. All the nodes were fully connected in the ANN model proposed in this study and it was composed of four hidden layers, in contrast to most ordinary MLPs having only one hidden layer. It should also be noted that ReLU function is used as the non-linear activation function within all of the hidden layers, instead of hyperbolic tangent or sigmoid function. The total number of nodes in the multilayer perceptron model was 419 (since, $34 + 128 + 128 + 64 + 64 + 1 = 419$), and all of these nodes are fully connected to each other. Eventually, the number of weights used in this model was 33088 which can be calculated as $((34 \times 128) + (128 \times 128) + (128 \times 64) + (64 \times 64) + 64 \times 1)$. The random initialization of weights and bias values were achieved by Xavier initialization method (Patterson and Gibson 2017). A simple representative diagram of the MLP architecture that is designed and used in this study is given in Fig. 4.

Fig. 4. Architecture of the MLP model proposed in this study with 4 hidden layers, 419 nodes, and 33088 weights

Weka version 3.9.1 was used for all of the other available machine learning algorithms. Weka (Weka 2019) is an open source data mining
and machine learning software that is developed in Java programming language. The algorithms in Weka were comparatively tested with the proposed ANN model in this study. Coefficient of determination ($R^2$), mean absolute error (MAE), and root mean squared error (RMSE) were used to measure and compare the prediction performances of the algorithms obtained by train, validation, and test results. The algorithms that were included in the experiments are shortly described in the following paragraphs. k-nearest neighbors (k-NN) is a type of instance-based learner algorithm that can be used for both classification and regression problems (Aha et al. 1991). The number of nearest neighboring instances to a specific instance is calculated by simple distance measures such as Euclidean distance, Manhattan distance, Mahalanobis distance, and so on (Witten et al. 2011). The feature values are used to calculate the distance between two instances by such measures. If “$k$” parameter is set to one, the closest neighbor with the shortest distance is chosen. Similarly, “$k$” values can be set to 2, 3, …, and so on, which imposes that the higher the k value, more instances will be covered as the nearest neighboring samples to that instance or record. This algorithm is also described as a lazy learner because the generalization of the training data is delayed until a test request is made (Hendrickx and Bosch 2005). In other words, there is no global approximation of the target function or model during the training phase in k-NN. It is also known that k-NN does not generate a model after the training phase. Multiple linear regression is a linear functional model that uses the Akaike criterion (Akaike 1981) for model selection. This is a linear machine learning model that is based on a linear equation where all or some of the feature attributes are used as the independent parameters of the equation (Larose 2006). Hence, the linear equation represents the relation between the dependent variable (the attribute to be estimated or predicted) and the independent variables. Isotonic regression is an algorithm that learns the isotonic regression model by choosing the attribute that provides the lowest squared error (Witten et al. 2011). It can be derived by a non-linear isotonic curve, and it is different from all the linear regression models because isotonic regression not constrained by any functional properties such as a linear equation or estimator parameters. Partial least squares (PLS) regression is a type of regression model, which calculates derived direc-
tions that, as well as having high variance, they are strongly correlated with the class (Witten et al. 2011). It is also named as “Projection to Latent Structures”, since it is based on projecting the predicted and observe variables into a new hyperspace and latent variables (Wold et al. 2001). M5 Model Tree (M5P) is derived from M5Base algorithm, which implements base routines for generating M5 model trees and rules (Wang and Witten 1997). M5P can be described as the reconstruction of Quinlan's M5 algorithm for inducing trees of regression models (Quinlan 1992). M5P combines an ordinary decision tree model with linear regression functions at the nodes. M5P is one of the few decision tree algorithms that can be used for numerical prediction and regression, since most of the decision trees can only be used for classification problems. Single layer perceptron is a type of simple ANN does not have a hidden layer. It is composed of input nodes and an output node, where the activation function is a linear signum function (Haykin 2009). The input nodes are fully connected to the output node and it can either be used for classification or regression problems. Since there is no hidden node and no non-linear activation function, this type of ANN’s success is mostly limited to linear problems. However, it is one of the fastest ANN models during the training phase due to its simplicity and its linearity. For instance, the weight updates are much faster and easier in single layer perceptron when compared to Multilayer Perceptrons or deep learning models. Multilayer Perceptron (MLP) is a type of feed-forward ANN algorithm that uses backpropagation with gradient descent for weight updates. The learning rate, momentum, number of iterations, number of hidden layers, and the number of nodes in the hidden layers can be flexibly changed. It can be used for both classification and numerical prediction (Witten et al. 2011). In most of the cases, MLP’s are designed with a single hidden layer and preferably with a few numbers of nodes in that hidden layer where all the nodes are fully connected to each other. In such MLP’s, the non-linear activation function used in the outputs of hidden nodes and output nodes are usually sigmoid (logistic) or hyperbolic tangent functions, but some other non-linear activation functions are used as well (Haykin 2009).

Radial Basis Function (RBF) Regressor is a numerical prediction model that implements RBF networks, trained in a fully supervised
manner by minimizing squared error with the BFGS (Broyden–Fletcher–Goldfarb–Shanno) method (Eibe 2014). RBF networks are a type of ANN that uses radial basis functions as activation functions. It is generally composed of one input layer, one hidden layer, and an output layer. The output of the RBF network is a combination of radial basis functions of the inputs and node parameters (Broomhead and Lowe 1988). The parameter settings for eight machine learning algorithms are given in Table 3 where some of them are used with the default values in Weka and some of them were set to alternative values according to the observations during the experiments. It should be noted that some of the other linear numerical prediction algorithms such as simple linear regression, pace regression and some nonlinear regression algorithms were not included in this study because the performance results obtained by those algorithms were much lower and more inaccurate in terms of RMSE, MAE and R².

Table 3. Parameter settings of the algorithms in Weka, which were used in this study

<table>
<thead>
<tr>
<th>Algorithm name</th>
<th>Parameter settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>k-NN</td>
<td>k=3, distance metric: Euclidean distance, weighted distance not used, all the other parameters with default values</td>
</tr>
<tr>
<td>Linear regression</td>
<td>all the parameters with default values</td>
</tr>
<tr>
<td>Isotonic regression</td>
<td>all the parameters with default values</td>
</tr>
<tr>
<td>Partial least squares regression</td>
<td>all the parameters with default values</td>
</tr>
<tr>
<td>M5 Model Tree (M5P)</td>
<td>minimum number of instances at leaf nodes: 7, all the other parameters with default values</td>
</tr>
<tr>
<td>RBF Regressor</td>
<td>all the parameters with default values</td>
</tr>
<tr>
<td>Single layer perceptron</td>
<td>transfer function: signum, learning rate: 0.9, learning rate with linear decay, number of iterations: 1000, all the other parameters with default values</td>
</tr>
</tbody>
</table>
6 Results and Discussion

All of the tests and execution of both the algorithms in Weka and the ANN model were conducted on hardware platform with a computer operating on 64-bit architecture and having an Intel Core i7 2.60 GHz central processing unit and 16 Gigabytes of random-access memory. The comparative results obtained by all of the algorithms during train, validation, and test phases are given in Table 4 and Table 5. In these tables, eight machine learning algorithms were executed and tested by the Weka software and the results for the last one was obtained with the ANN model that was implemented and developed by the author of this study. R², root mean squared error and mean absolute error of min-max normalized Duration_1 and Duration_2 prediction values obtained by different algorithms and models are comparatively denoted in Table 4 and Table 5. It should be noted there are different options and parameters in Weka for the execution of these algorithms and they were tested with different parameters as well as their default parameters. In most of the cases, it was observed that changing the parameters degraded the performance of the algorithms so only the results obtained with their default configurations are included in the tables below. The training times in terms of minutes for each algorithm for the prediction of Duration_1 and Duration_2 are also given in Table 6. The validation and test results show that the ANN model proposed in this study has obtained the best and the most accurate results for the prediction of Duration_1 and Duration_2, regarding the lowest RMSE and MAE values, and the highest R² values. The training performance is usually deceptive, which is explained previously in this chapter, hence validation and test performance should be focused on.
Table 4. Comparative performance results for the prediction of Duration_1

<table>
<thead>
<tr>
<th>Algorithm Name</th>
<th>Train</th>
<th>Validation</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R²</td>
<td>RMSE</td>
<td>MAE</td>
</tr>
<tr>
<td>k-NN</td>
<td>0.53</td>
<td>0.0134</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Linear regression</td>
<td>0.02</td>
<td>0.0460</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Isotonic regression</td>
<td>0.17</td>
<td>0.0269</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>98</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Partial least squares regression</td>
<td>0.40</td>
<td>0.0468</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>M5 Model Tree</td>
<td>0.51</td>
<td>0.0437</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>RBF Regressor</td>
<td>0.00</td>
<td>0.0556</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Single layer perceptron</td>
<td>0.13</td>
<td>0.9846</td>
<td>0.896</td>
</tr>
<tr>
<td></td>
<td>72</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Multilayer perceptron</td>
<td>0.98</td>
<td>0.0272</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>ANN (proposed model)</td>
<td>0.96</td>
<td>0.009</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Comparative performance results for the prediction of Duration_2

<table>
<thead>
<tr>
<th>Algorithm Name</th>
<th>Train</th>
<th>Validation</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R²</td>
<td>RMSE</td>
<td>MAE</td>
</tr>
<tr>
<td>k-NN</td>
<td>0.545</td>
<td>0.0144</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Linear regression</td>
<td>0.057</td>
<td>0.0242</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Isotonic regression</td>
<td>0.182</td>
<td>0.0160</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>5</td>
<td></td>
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<tr>
<td>Partial least squares regression</td>
<td>0.184</td>
<td>0.0346</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>M5 Model Tree</td>
<td>0.655</td>
<td>0.0276</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>RBF Regressor</td>
<td>0.003</td>
<td>0.0341</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Single layer perceptron | 0.0007 | 0.9836 | 0.9765 | 0.0004 | 0.9952 | 0.9884 | 0.0004 | 0.9952 | 0.9884 | 0.0004 | 0.9952 | 0.9884 |
Multilayer perceptron | 0.9808 | 0.0217 | 0.0017 | 0.9082 | 0.0213 | 0.9053 | 0.0024 | 0.9053 | 0.0024 | 0.9053 | 0.0024 | 0.9053 |
ANN (proposed model) | 0.9901 | 0.0088 | 0.0011 | 0.9898 | 0.0083 | 0.9898 | 0.0010 | 0.9898 | 0.0010 | 0.9898 | 0.0010 | 0.9898 |

<table>
<thead>
<tr>
<th>Algorithm Name</th>
<th>Training time for prediction of Duration_1 (minutes)</th>
<th>Training time for prediction of Duration_2 (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>k-NN</td>
<td>9.16</td>
<td>8.65</td>
</tr>
<tr>
<td>Linear regression</td>
<td>7.83</td>
<td>7.50</td>
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<tr>
<td>Isotonic regression</td>
<td>75.05</td>
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<tr>
<td>Partial least squares regression</td>
<td>19.26</td>
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<td>M5 Model Tree</td>
<td>56.49</td>
<td>58.15</td>
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<tr>
<td>RBF Regressor</td>
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<td>Single layer perceptron</td>
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<td>155.94</td>
</tr>
<tr>
<td>Multilayer perceptron</td>
<td>1075.92</td>
<td>1104.72</td>
</tr>
<tr>
<td>ANN (proposed model)</td>
<td>1843.14</td>
<td>1867.30</td>
</tr>
</tbody>
</table>

Table 6. Training times for Duration_1 and Duration_2

It could also be analyzed from Table 4 and Table 5 that the proposed model provides the lowest differences between the train vs. validation, and train vs. test performance measures, which shows that it has the lowest risk of overfitting. On the other hand, regarding the times spent during the training phase, it could be seen that the proposed ANN model had the worst performance among all of the algorithms (around 32 hours), which is given in Table 6. This was not something unexpected or unusual, because the proposed model is much more complex than all of the other algorithms and models used in this study. It was previously mentioned that the RMSE and MAE values given in Table 4 and Table 5 are for the min-max normalized values of Duration_1 and Duration_2. Those values can be easily de-normalized, and the de-normalized values might indicate results that are more meaningful for the decision makers and the managers. For instance, regarding the proposed ANN model, the de-normalized MAE for train, test, and validation of Duration_1 is 491, 462, and 491 seconds respectively. Similarly, the de-normalized MAE for train, test, and validation of Duration_2 is 318, 289, and 289 seconds respectively. The weighted aver-
ages of MAE for Duration_1 and Duration_2 are 486 and 309 seconds. It is also meaningful to look at these weighted averages of MAE, since 70% of the whole data set was used for training, 15% for validation, and 15% for test. Hence, it can be deduced that the proposed ANN model provided very accurate and reliable predictions both for Duration_1 and for Duration_2, which can be seen by comparing the descriptive statistics in Table 2 and the results obtained by the weighted averages of MAE. The statistical independence between the variables "Duration_1", "Duration_2", and all of the correspondent independent feature variables were also examined. The correlations between "Duration_1" and "Duration_2" and the correspondent independent variables are analyzed by means of Pearson correlation coefficient (Larose 2006). It was observed that no significant correlations between the target variables and feature attributes exist, where correlation coefficient values were close to zero, which are also given in Table 7 and Table 8.

Table 7. Pearson correlations between dependent variable “Duration_1” and independent variables

<table>
<thead>
<tr>
<th>Independent variable name (feature attribute)</th>
<th>Pearson cc</th>
<th>Independent variable name (feature attribute)</th>
<th>Pearson cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient’s age</td>
<td>0.002</td>
<td>Day of month (Report of test results)</td>
<td>-0.014</td>
</tr>
<tr>
<td>Previous admissions (This department)</td>
<td>0.011</td>
<td>Hourly time interval (Report of test results)</td>
<td>-0.001</td>
</tr>
<tr>
<td>Previous admissions (Other departments)</td>
<td>0.003</td>
<td>Day of month (Report delivery to patient)</td>
<td>0.002</td>
</tr>
<tr>
<td>Day of month (Patient registration)</td>
<td>-0.045</td>
<td>Hourly time interval (Report delivery to patient)</td>
<td>0.053</td>
</tr>
<tr>
<td>Hourly time interval (Patient registration)</td>
<td>-0.008</td>
<td>Day of month (Visit to physician)</td>
<td>-0.028</td>
</tr>
<tr>
<td>Day of month (Request for physician)</td>
<td>-0.075</td>
<td>Hourly time interval (Visit to physician)</td>
<td>-0.086</td>
</tr>
<tr>
<td>Hourly time interval (Request for physician)</td>
<td>0.018</td>
<td>Duration between Request for physician &amp; Patient registration</td>
<td>0.097</td>
</tr>
<tr>
<td>Day of month (Specimen collection)</td>
<td>0.006</td>
<td>Duration between Specimen collection &amp; Request for physician</td>
<td>0.162</td>
</tr>
<tr>
<td>Hourly time interval (Specimen collection)</td>
<td>0.034</td>
<td>Duration between Report of test results &amp; Sample delivery to laboratory</td>
<td>0.089</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Independent variable name (feature attribute)</th>
<th>Pearson cc</th>
<th>Independent variable name (feature attribute)</th>
<th>Pearson cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient’s age</td>
<td>0.001</td>
<td>Day of month (Report of test results)</td>
<td>-0.033</td>
</tr>
<tr>
<td>Previous admissions (This department)</td>
<td>0.014</td>
<td>Hourly time interval (Report of test results)</td>
<td>-0.026</td>
</tr>
<tr>
<td>Previous admissions (Other departments)</td>
<td>0.005</td>
<td>Day of month (Report delivery to patient)</td>
<td>0.018</td>
</tr>
<tr>
<td>Day of month (Patient registration)</td>
<td>-0.002</td>
<td>Hourly time interval (Report delivery to patient)</td>
<td>0.084</td>
</tr>
<tr>
<td>Hourly time interval (Patient registration)</td>
<td>-0.001</td>
<td>Day of month (Visit to physician)</td>
<td>-0.002</td>
</tr>
<tr>
<td>Day of month (Request for physician)</td>
<td>-0.152</td>
<td>Hourly time interval (Visit to physician)</td>
<td>-0.017</td>
</tr>
<tr>
<td>Hourly time interval (Request for physician)</td>
<td>0.074</td>
<td>Duration between Request for physician &amp; Patient registration</td>
<td>0.153</td>
</tr>
<tr>
<td>Day of month (Specimen collection)</td>
<td>0.027</td>
<td>Duration between Specimen collection &amp; Request for physician</td>
<td>0.132</td>
</tr>
<tr>
<td>Hourly time interval (Specimen collection)</td>
<td>0.086</td>
<td>Duration between Sample delivery to laboratory and Specimen collection</td>
<td>0.065</td>
</tr>
<tr>
<td>Day of month (Sample delivery to laboratory)</td>
<td>-0.001</td>
<td>Duration between Report delivery to patient &amp; Report of test results</td>
<td>0.091</td>
</tr>
<tr>
<td>Hourly time interval (Sample delivery to laboratory)</td>
<td>-0.004</td>
<td>Duration between Visit to physician &amp; Report delivery to patient</td>
<td>0.027</td>
</tr>
</tbody>
</table>

Table 8. Pearson correlations between dependent variable “Duration_2” and independent variables

7 Conclusions and Recommendations

This study shows that an ANN with a deepened structure with four hidden layers could be a reliable and successful model for numerical prediction of service duration amongst different medical services in hospital and other medical institutions. It can also be deduced that
ANN is usually more successful than any other machine learning algorithm in such prediction tasks. It has been observed that the training time for this ANN model was much longer than all the other machine learning algorithms. This might be considered as the only drawback of the ANN model. However, this should not be considered as a problem or drawback, because tasks such as analysis of durations do not need to be real-time or very fast. In addition, the requirement for long times is only true for the training phase, in other words, after the ANN has been trained, it will run much faster during testing or within live systems. Another general criticism for ANN is that “it is a black-box model that doesn’t have explicit rules or a simple algorithm”. However, if ANN is to be used for specific tasks or purposes in business, such as the case explained in this study, this might not be considered as a problem. In other words, if the design, architecture, all the technical details, and maintenance of the system does not have to be correlated to decision makers and managers, which is true for cases like in this study, then the management does not have to know or understand the model, but they would rather focus on the reliability, accuracy, and success of the results. A new version of this MLP model could be designed and implemented as a future study, which might overcome the computational complexity and eventually decrease the time necessary for training the model. However, this MLP model can also be executed on another hardware platform with higher CPU and RAM capacity, and most importantly, with a graphics card having high GPU capacity. The proposed model’s architecture and hyper-parameters might be changed, such as more hidden layers, different number of nodes within each layer, different learning and momentum rates, different batch sizes, different dropout rates, alternative activation functions such as leaky ReLU, and so on. All of these alternatives might be tested and their performances could be comparatively analyzed with the proposed model in this study. Some of the features used in this study might be discarded by the aid of some feature selection / reduction methodologies such as statistical ranker algorithms, feature subset selection algorithms, Relief, and Wrapper models, and so on. After the feature reduction, the new data set might also be tested with the same proposed model in this study and the results might be compared. The scope of this study could be extended for many different business ar-
Machine learning approaches for prediction of service times in health information systems

... besides health information systems; hence, the proposed model could be flexibly adapted to prediction of service times in any business such as logistics, manufacturing, telecommunications, etc., and it could be integrated to any Industry 4.0 model or application as well.

8 References


9 Key Terms

<table>
<thead>
<tr>
<th>Activation function</th>
<th>Artificial neural networks</th>
<th>Backpropagation</th>
<th>Gradient descent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health information systems</td>
<td>Machine learning</td>
<td>Multilayer perceptron</td>
<td>Normalization</td>
</tr>
<tr>
<td>Numerical prediction</td>
<td>Overfitting</td>
<td>Regression</td>
<td>Service duration</td>
</tr>
</tbody>
</table>

10 Questions for Further Study

What are the common properties of activation functions such as sigmoid and hyperbolic tangent, which make them preferable in multilayer perceptron models?

Suppose that you have obtained very low MAE and RMSE values, but also $R^2$ is observed to be close to zero for your regression problem. What would be the reason(s) for this?

For any given data and problem, how can you understand that the machine learning algorithm is properly trained or that it has actually learned? Discuss it.

If accurate prediction of durations for business processes is a goal, why and how could this be valuable or helpful for decision makers?

Why is overfitting a problematic / risky issue in machine learning systems? Describe it by giving an example.

Define two basic reasons / causes that makes min-max normalization necessary in data transformations.

11 Exercises

Suppose that you are an information technology (IT) expert and you are working in a new business intelligence project that must be implemented with an artificial neural network (ANN) model. How would you design ANN for that project? What should be included in your requirements analysis for ANN model and the project? How would you construct the architecture of ANN and how would you choose the functions and parameters for ANN?
In this chapter, a simple method for transformation of categorical / nominal attributes to numerical attributes are explained. What about the opposite cases? In other words, which methods or techniques can be used for transformation of numerical values to nominal values? Make a short research and make a list of different techniques for numeric-to-nominal transformation. (You can conduct your research by using some of the relevant resources given in “References” section of this chapter, or you can use any resource you would like, such as Internet, etc.)

As a software engineer, you are going to be developing a new software tool that is composed several machine learning algorithms. How would you decide upon the programming language and software architecture for this tool? Make a list of all the necessary criteria and requirements for this decision and use any kind of qualitative / quantitative assessment methodology to rank and prioritize these criteria. (PS: You must be focusing on “people” and “process” factors as well as “technology”. For instance, you must keep in mind that this tool will be used by non-technical business analysts and decision makers, hence ease-of-use, similarity, flexibility, maintainability, costs, etc. must also be considered.)

Suppose that you are an IT consultant for a company that is planning to develop a smart Industry 4.0 automation tool for a specific business case by the aid of a machine learning approach. There are some strict constraints for this tool. For instance, the tool will be installed and used in small digital circuits and sensors with very low data storage and computation capacity. In addition, this tool must operate very fast; hence, the training phase of the machine learning algorithm must also be fast as possible. Which type of machine learning algorithms would you recommend first? Would it be a good idea to recommend and use ANN for this tool? Why?

### 12 Further Reading


Learning Objectives

The objectives of this chapter effects of ANNs on predicting statistical growth in fishery industry are investigated. The present study provides the first information on the population structure (age, growth and sex ratio) of the tench from Cyprinidae family (*Tinca tinca*) in Yeniçağa Lake by traditional and modern methods. Besides comparisons with conventional method are performed. Once you have mastered the materials in this chapter, you will be able to:

- Discuss the growth models with artificial neural networks for fish (*Tinca tinca* in Yeniçağa Lake).
- Understand the calculating traditional and artificial intelligence in tench.
- Identify the information data with Matlab application.
- Conversion and evaluation of tench measurements into data.
- Supporting decision makers in the fishing industry.

Chapter Outline

The aim of the fishing industry is to protect the natural habitat and fish maintenance of stocks. For this reason, all studies in fisheries must be done using new approaches on mathematical models. This design should be established in the fishing industry. A defect will occur when it is fail to meet the intended design. Hence, prediction methods play an important role to forecast the number of product fish growth. In this study, traditional approaches (Length-Weight Relationships-LWR) and Artificial Neural Networks (ANNs) approaches are examined in...
the growth models used in the fisheries industry. It is used ANNs model instead of the traditional statistical growth estimation techniques used in the fisheries industry to determine how to obtain results. The data obtained with conventional growth models are compared with the data obtained with artificial neural networks. 114 fish (*Tinca tinca*-tench) were caught in 2016 from Yeniçağa Lake (Bolu-Turkey). ANNs have been shown to be an option in assessing growth characteristics. Findings of this study are important in determining the correct estimates in fisheries management and in evaluating the growth characteristics.

**Keywords**

Artificial neural networks, tench, fisheries industry, traditional methods, modern methods, Matlab, *tinca tinca*.

**1 Introduction**

The industrialization of the world that began with the Industrial Revolution of the 18th century seems to have entered a new phase today. The industrialization process, which started with the emergence of water and steam-powered mechanical production systems, passed to the second stage by the use of electricity and mass production systems at the beginning of the 20th century. Since the 1970s, electronic and information technology, which brings production automation to a higher level, has also started to take third stage. When it came to 2011, the concept of Industry 4.0, which was first used in Germany, proclaimed the beginning of a new era all over the world. The main issues that define Industry 4.0 are the emergence of production systems based on cyber-physical systems and dynamic data processing. Industry 4.0; A very fast digital transformation is an environment in which information, communication, and internet technologies affect the production processes heavily in the world. This is the firm-level effects such as productivity, cost advantage, and profitability in production, as well as macro level effects such as growth, employment, human resources, education, investment and entrepreneurship. One of the issues that are expected to affect the concept of Industry 4.0 is the emergence of new
business models and the establishment of new initiatives. In addition to the existing forms of work, there are new applications and occupations. However, it is seen that there is not enough study in the literature. The emergence of the concept of Industry 4.0 is based on a high technology themed project conducted by the German government. The project was prepared with the computerization approach of production. Inspired by the significant transformations in the previous industrial revolutions, the project was called Industry 4.0. The concept was first used in 2011 at the Hannover Fair (Banger 2016). Industry 4.0 came to the agenda with the article titled "Industry 4.0: With the Internet of Things Going to the 4th Industrial Revolution" published in 2011 by Kagerman et al (2011). The German National Academy of Science and Engineering (Acatech) published in 2013 by the report titled "Recommendations for the Implementation of the Industry 4.0 Strategic Initiative" has gained the theoretical dimension of the subject (Acatech 2013). The use of the “Big Data”, one of the main features of Industry 4.0 (ITRE 2016), in the fishing industry is exemplified. AI is the most significant tool for extracting information from data and for making decisions. At this point, in fishery industry applying modern techniques related to AI instead of conventional methods is gaining importance. Nowadays thanks to high computer technology human-beings are trying not only to resolve unsolved problems but to contribute novel approaches. From this point of view, the idea enabling intelligent machines in 1980s evolved and improved with ANNs in 1990s. In particular ANNs, a branch of AI, attracted interests of various academics and researchers. ANNs provide generalized learning based on training process (Bon and Hui 2017). Thus, ANNs has non-linear structure. Besides, ANNs outperform conventional methods in terms of performance measures and they can detect non-linear relations without any hypothesis (Türeli et al. 2011; Benzer 2015; Benzer and Benzer 2015; Benzer et al. 2015; Benzer and Benzer 2016; Benzer et al. 2016; Benzer et al. 2017; Benzer and Benzer 2017; Benzer and Benzer 2018a; Benzer and Benzer 2018b; Benzer and Benzer 2019).
have adopted modern approaches to provide interdisciplinary thinking and access to excellence. In this study, the effect of ANNs was investigated in predicting the statistical growth of fishery industry. It has also been evaluated by comparing traditional approaches with modern approaches. The present study provides the first information on the population structure (age, growth and sex ratio) of the tench from Cyprinidae family (*Tinca tinca*) in Yeniçağa Lake.

2 Methodology

2.1 Study area

The Lake Yeniçağa is located in in west Black Sea region of Turkey (40° 46' 45" N, 32° 01' 33" E), within the borders of the city Bolu and in the north of the town Yeniçağa (Fig. 1). Lake Yeniçağa is a shallow eutrophic freshwater lake with maximum depth of 5.2 m (Saygı and Demirkalp 2004), 989 m above sea level, and covers surface area of about 260 ha (Kılıç and Becer 2013).

![Fig. 1. The study area (Yeniçağa Lake).](https://example.com/fig1.png)
2.2 Data collection

This study was carried out on 114 (54 females and 60 males) caught by using a gill nets (18 mm–55 mm mesh sizes) in Yenıçağa Lake in 2016. The fish samples taken from fishermen during the hunting season were transported to the laboratory to record the fork length (L) to the nearest 0.1 cm and body weight (W) to the nearest 0.1 g. The gender of the fish was determined from the gonads. Scales were sampled from each specimen for age determination according to Lagler (1966).

2.3 Length–weight relationship (LWR) equation

LWR equation is a traditional method used for the determination of the growth features of populations. From the collected samples; sex and length composition, the average length and weight weight, and the length–weight relationship for each sex and combined sexes were identified. The relationship between length (L) and body weight (W) for nearly all species of fish can normally be represented by the "length-weight relationship" following equation:

\[ W = aL^b \]  

Where W is the body weight of fish (in g), L is the length (in cm) and 'a' and 'b' are constants. The parameter 'b' (also known as the allometry coefficient) has an important biological meaning, indicating the rate of weight gain relative to growth in length or the rate at which weight increases for a given increase in length. If b is equal to 3, isometric pattern of growth takes places, if b is not equal to 3, then allometric pattern of growth takes places, it may be positive if it is greater than 3 or negative otherwise (Ricker 1973). The a and b constants could be estimated from linear functions. However, many functional relationships observed in fishery biology such as length-weight relationship are not linear. Fortunately, such curvilinear functions can often be transformed into linear functions by taking the logarithm or the natural logarithms of both sides:
This equation is equivalent the regression equation:

\[ y = a + b \cdot x \quad \text{Equation 4} \]

This mean that; \( y \) is equivalent to \( \ln W \), \( a \) which represents the y-intercept (the point where the line crosses the y axis) of the regression line is equivalent to \( \ln a \), \( b \) is the slope of the line, and \( x \) is equivalent to \( \ln L \).

### 2.4 Artificial Neural Networks (ANNs)

ANNs are computational systems that simulate biological neural networks and can be defined as a specific type of parallel processing system based on distributional or connectionist methods (Andrews et al. 1995; Hopgood 2000).

Artificial Neural Networks (ANNs) are used in three basics methods:
- As biological nervous system models and intelligence.
- As real time adaptive signal processing controllers implemented in hardware for applications such as robots.
- As methods of data analytic.

In several years of artificial neural models (ANNs) network has developed to predict. There are three featured steps in developing an ANNs based solution:
- Scaling or data transformation.
- Definition of Network architecture as in Fig. 2, when the number of hidden layers, the number of nodes in each layer and connectivity between the nodes and set, learning algorithm construction in order to train the network.
Fig. 2. Artificial Neural Networks model diagram.

That contain of an input layer, a series of hidden layer, an output layer and connections between them. Nodes in the input layer represent possible influential factors that affect the network output and have no computational activities, while the layer of output contains one or more nodes that produce the output of network. Hidden layer may consist a large number of hidden processing nodes. A feed-forward back-propagation network propagates the information from the input layer to the output layers, compares the network output with known target, and propagates the error term from the layer of output back to the layer of input, by using a learning mechanism to adjust the biases and weights. ANNs are simulations of biological nervous systems using mathematical models. They are networks with simple processor units, interconnections, adaptive weights and scalar measurement functions (e.g., summation and activation functions) (Rumelhart et al. 1986). ANNs mathematical expression is seen in Fig. 3. Y is the neuron's output, x is the vector of inputs, and w is the vector of synaptic weights.
Fig. 3. Biological and Mathematical explanation for ANNs design.

In case of biological neuron information comes into the neuron via dendrite, soma processes the information and passes it on via axon. In case of artificial neuron the information comes into the body of an artificial neuron via inputs that are weighted (each input can be individually multiplied with a weight). The body of an artificial neuron then sums the weighted inputs, bias and “processes” the sum with a transfer function. At the end an artificial neuron passes the processed information via output(s). Benefit of artificial neuron model (Krenker et al. 2011) simplicity can be seen in its mathematical description below:

\[
y(k) = F \left( \sum_{i=0}^{m} w_i(k) \cdot x_i(k) \right)
\]

Equation 5

Where:
- \(w_i(k)\) is weight value in discrete time k where i goes from 0 to m,
- \(x_i(k)\) is input value in discrete time k where i goes from 0 to m,
- \(F\) is a transfer function,
- \(y_i(k)\) is output value in discrete time k.

As seen from a model of an artificial neuron and its equation (5) the major unknown variable of our model is its transfer function. Transfer function defines the properties of artificial neuron and can be any mathematical function.
2.5 Normalization

The supervised learning method trained with the network structure (Back-propagation Networks) will be used to solve problems in this study. The transfer function (6), (VN is normalized data, VN is data to be normalized, Vmin is the minimum value of the data, Vmax is the maximum value of the data) mostly used a sigmoid or a logistic function, gives values in the range of \([0,1]\) and can be described as (normalization):

\[
V_N = 0.8 \times \left( \frac{V_R - V_{\min}}{V_{\max} - V_{\min}} \right) + 0.1 
\]

Equation 6

2.6 Estimation Accuracy Validation

For this research, the Mean Absolute Percentage Error (MAPE) is used for estimation accuracy. MAPE is defined as:

\[
MAPE = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{|Estimated_i - Actual_i|}{Actual_i} \right) \text{ Equation 7}
\]

Comparisons can be made with more than one method by MAPE, because it is easy to interpret with its relative measurements. The smaller the values of MAPE, the closer are the forecasted values to the actual values.

\[
MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{e_i}{Y_i} \right| \times 100
\]

Equation 8

MAPE is the preferred error measure of the software measurement (MATLAB) researches.
2.7 Statistics

The MAPE benchmark refers to forecast errors as a percentage, and can therefore negate the disadvantages that may arise when correlating models developed for examines with different values. These features of MAPE are considered to be superior to those of other evaluation statistics. The MAPE results were assessed according to literature (0%–10%: Very Good, 10%–20%: Good, 20%–50%: Acceptable, 50%–100%: Wrong and Faulty) (Witt and Witt 1992; Lewis 1982). The coefficient correlation ($R^2$) calculated by the LWR regression model was 0.971. When the coefficient correlation ($R^2$) was evaluated in both ANNs and LWR model, the results of ANNs were better, although they did not seem close to each other. It is evaluated that comparing the MAPE values together with $R^2$ values can give a healthy result (Gentry et al. 1995).

2.8 Data Editing for MATLAB

Neural Network Toolbox of MATLAB was used for the ANNs calculations. This study was performed on 114 Tinca tinca (54 females and 60 males) taken from fishermen during hunting season caught in Yeniçağa Lake. The data were divided into three equal parts: training, validation and test sets. The Matlab functions were used for “training”, “testing”, and “validation”. They were used randomly; 70% in training, 15% in testing, and 15% in the validation of the fish.

3 Literature Review

3.1 Tinca tinca

In Turkey, Cyprinidae are the richest and the most important family of fish, and its members are distributed world-wide. These family members are distributed widely in fresh water sources (Geldiay and Balık 1996). Tench, Tinca tinca (L.), is widely distributed in Europe and Asia,
and has been introduced into the America, South Africa and Austria (Rosa 1958).

*Tinca tinca*, is a fish with an economic importance which shows a large distribution in inland waters of Turkey. They are highly resistance against external influences and diseases in spite of their body covered with thin scales and a mucus layer (Geldiay and Balık 1996). Due to they contact the mud of lake bottom continuously, they have an important role in the determination of mineralization (Demirsoy 1998). They also prevent the transition of inorganic nutrient salts, nitrogen and phosphorus accumulated in sediment to the water in eutrophic lakes because they feed on aquatic plants (Nikolsky 1963). Some of the researches related to Tinca tinca in Turkey and in the world are as follows: The growth properties of tench (*Tinca tinca* L., 1758) was investigated in Kesikköprü Dam Lake (Altındağ et al. 1998), Vegoritis Lake (Sinis et al. 1999), Lake Dgal Wielki (Pimpica and Pinos 1999), Bayındır Dam Lake (Altındağ et al. 2002), Çivril Lake (Balık et al. 2004), Beyşehir Lake (Balık et al. 2009), Hirfanlı Dam Lake (Benzer et al. 2009), two gravel pit lakes (Wright and Giles 1991), Seyhan Dam Lake (Ergüden Alagöz and Göksu 2010), Kapulkaya Dam Lake (Benzer et al. 2010), Çamkoru Pond (İnnal 2010) and Trasimeno Lake (Pompei et al. 2012).

**3.2 LENGTH-WEIGHT RELATIONSHIPS (LWR)**

Length-weight relationships (LWR) is a widely used method, namely, in fish biology, ecology and fisheries studies. It is widely used in the determination of fishery measurement when sampling large species, mostly because of the difficulty and time required to record weight in the field (Andrade and Campos 2002). LWR for fish are predicted using the average length and weight (Mendes et al. 2004; Tosunoğlu et al. 2007). The LWR describes the correlation mathematically between the length and weight of the fish as well as the estimated values (Beyer 1991) of its length and weight. LWR are beneficial for the conversion of length equations to weight for use in stock calculation models (Lindqvist and Lathi 1983; Deval et al. 2007) and in predicting stock biomass with narrow sample (Verdiell-Cubedo et al. 2006). These re-
results also let scientists make identifications on morphological properties among species or among populations of the same species from various habitats (Moutopoulos and Stergiou 2002; Etchison et al. 2012). Critically, LWR were used to inform on the condition of freshwater samples and to evaluate whether somatic growth was isometric or allometric (Ricker 1973). The prediction of the relationship parameters between a and b can explain the connection regarding ecological events and life history. Environmental causes may affect crayfish growth by feeding and food resources. Length-weight values may probably demonstrate the differences in growth that may be correlated with environmental stress across the species (Westman and Savolainen 2002; Olsson 2008). The most frequently researched dimensions for crustaceans are carapace length, body length, total length, body width, and wet weight (Primavera et al. 1998). Differences in length between individual body parts are used to demonstrate the morphological changes between the male and female fish species (Lindqvist and Lahti 1983). These differences are also utilized in determining fish populations, its relative growth, comparing the populations of the same species, the morphology of fish species and the systematic assignment of fish (Lindqvist and Lahti 1983; Skurdal and Qvenild 1986; Gillet and Laurent 1995). The dimensions may be favorable to be able to convert into the desired length values when only one of the other length measurements is known and the LWR may be used to predict length from weight (Tosunoğlu et al. 2007).

3.3 ARTIFICIAL NEURAL NETWORKS (ANNs)

ANNs has been used in biology and in different disciplines of fisheries rather than in sciences (Tureli Bilen et al. 2011). Exercises of ANNs has included forecast the fish species distributions (Maravelias et al. 2003), fish predicting in a river (Mastrorillo et al. 1997), predicting macro invertebrate diversities (Park et al. 2003), population of aquatic insects (Obach et al. 2001), modeling freshwater fish (Joy and Death 2004), fish population modeling (Benzer 2015; Benzer and Benzer 2015; Benzer et al. 2015; Benzer and Benzer 2016; Benzer et al. 2016; Benzer et al. 2017; Benzer and Benzer 2017; Benzer and Benzer 2018a; Benzer
and Benzer 2018b; Benzer and Benzer 2019). There are many publications on management information systems approaches in fisheries, biology and similar research areas (Fish et al. 1995; Lek and Guégan 1999; Olden and Jackson 2001; Teles et al. 2006; Goethals et al. 2007; Cabreira et al. 2009; Sholahuddin et al. 2015; Rocha et al. 2017; Ouali et al. 2017). Compared to traditional methods, ANNs has supported better conclusions in the evaluation of future data (Suryanarayana et al. 2008; Tureli Bilen et al. 2011). For limited values, the normality and their independence from the predicted values, ANNs is asserted to be an excellent model which gives excellent predictions. ANNs is also recorded to have accomplishment compared to linear regressions (Sun et al. 2009). Besides, ANNs is more favorable for its speed and flexibility (Brosse et al. 2009).

4 Results and Discussion

The data used in LWR and ANNs were about 47.37 % females and 52.63 % males (sex ratio 1:1.11). Average total length and weight values were calculated as 16.50 cm and 123.15 g. A total of 114 individuals, total size distribution was 11.5 – 24.0 cm and weight distribution ranged from 30.0 to 350.0 g. The distribution curve graph was plotted for all length and weight values using MATLAB application (Fig. 4).

![Distribution curve graph](https://example.com/image.png)

Fig. 4. Total length and weight distribution of fish data.
For all individuals; $W = a L^b$ is calculated as exponential regression equation and the graph of equation is shown in Fig. 5.

![Graph of weight vs. length](image)

**Fig. 5.** Length and weight relationship for all individuals (LWR).

When the fish data is examined, there is a strong positive correlation between the weight data with input data and length data with output data. It was evaluated that the problem can be solved by linear regression because the data are linearly related. MATLAB application was written with the coding of the shapes and ANNs parameters were calculated one by one. The ANNs distribution curve is shown in Fig. 6.
Fig. 6. ANNs regression graph.

The coding written in MATLAB, the mean absolute error and the root mean square error are calculated from the error functions used in both training and test data. In training data, MAE 0.6809, RMSE 0.8338; in the test data, MAE 0.6605, RMSE 0.7754 was found. The coding written in MATLAB, the Tinca tinca (tench) fish data obtained from Yeniçağa Lake and the estimation data obtained with ANN are shown in Fig. 7.
It is observed that the model has a positive result in solving the problem related to many variables which have no linear relationship between them (Türel Bilen et al. 2011; Benzer 2015; Benzer and Benzer 2015; Benzer et al. 2015; Benzer and Benzer 2016; Benzer et al. 2016; Benzer et al. 2017; Benzer and Benzer 2017; Benzer and Benzer 2018a; Benzer and Benzer 2018b; Benzer and Benzer 2019). Traditional statistical methods can be analyzed according to past demand conditions, factors affecting demand, economic indicator relationships and demand estimation is performed. Past events are analyzed by statistical methods and projections are made about the future. Some of the most commonly used statistical methods are the following; Regression method, Correlation coefficient method, Curve fitting method, Time series analysis method, Moving averages method (Tekin 2008). The traditional methods used in the fishing industry are the regression model and the Von bertalanffy method. The data in the weight-to-weight relationship show normal distribution. In the regression analysis of normal distribution data it is stated that there is a linear relation-
ship between dependent and independent variables (Sarı 2016; Bahçecitapar and Aktaş 2017). This is an important mistake that affects the accuracy of estimation. It is observed that it has better results due to the lack of this error factor (Türeli Bilen et al. 2011; Benzer and Benzer 2015; Benzer et al. 2015; Benzer and Benzer 2016; Benzer et al. 2016; Benzer et al. 2017; Benzer and Benzer 2017; Benzer and Benzer 2018a; Benzer and Benzer 2018b; Benzer and Benzer 2019). It was listed Box-Jenkins methods (AR-MA Model, ARIMA Model, Simulation Model), fuzzy logic and artificial neural networks as modern estimation methods. Some properties of artificial neural networks, although they depend on the nature of the problem and the neural network model used, give better results than traditional information processing methods. Today, enterprises use the artificial neural network method in prediction studies that are vital in almost all decision making processes. In this study, it has been shown that the model of length weight estimation developed with ANNs can also be used in the fishing industry. In future studies, estimations can be proposed by using ANNs models with different architecture. Time series and fuzzy logic approaches can be used as an alternative to ANNs.

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6 Key Terms

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Questions for Further Study

Describe the principal steps in the planning phase. What are the major deliverables?

Compare modern methodologies and traditional methodologies.

What does normalization mean in artificial neural networks?

How do error comparisons be made in artificial neural networks?

Exercises

In the fisheries industry, you can use the traditional methods for the samples taken from ecosystems. Find the growth models and draw growth curve. What do you say?

In the fisheries industry, you can use the modern methods (artificial neural networks) for the samples taken from ecosystems. Find the growth models and draw growth curve. What do you say?

Compare the traditional methods and modern methods (artificial neural networks).

According to the error rates, which method gave better results. What do you say about ecosystem?

Artificial neural networks can be used in other areas of the industry. Discuss.

Further Reading


Definitions

Knowledge management (KM) is the process through which organizations generate value from their intellectual property and knowledge-based assets. It involves the creation, dissemination, and utilization of knowledge. Discipline within an organization that ensures that the intellectual capabilities of that organization are shared, maintained and institutionalized. The process of systematically and actively managing and leveraging the stores of knowledge in an organization. Refers to an entire integrated system for accumulation, integration, manipulation, and access of data across multiple organizations. The way a company stores, organizes and accesses internal and external information.

Knowledge Management is the explicit and systematic management of vital knowledge – and its associated processes of creation, organization, diffusion, use and exploitation.

Knowledge generation

Data => information => knowledge

Knowledge classification

**Tacit knowledge:** This type of knowledge exists in people’s heads, not articulated or documented

**Explicit knowledge:** This type of knowledge can be processed by information systems, codified and recorded and archived and protected
Transforming knowledge

Tacit to Tacit

E-meetings, synchronous collaboration (chat)

Explicit to Tacit

Visualization, browsable video/audio of representations

Tacit to Explicit

Answering questions, annotations

Explicit to Explicit

Text search, document categorization

Knowledge management components

strategies – processes – metrics

Strategies, processes and metrics

Strategy: Motivation for knowledge management and how to structure a knowledge management program
Process: Use of knowledge management to make existing practice more effective
Metrics: Measure the impact of knowledge management on an organization

How to develop a knowledge strategy?

Making known the knowledge that already exists by sharing best practices
Innovation: Convert ideas into products, services, improved business processes
Knowledge levers: Customer knowledge, knowledge in people, products, services, processes, relationships, organizational memory, knowledge assets
Link Knowledge strategy with business one
Knowledge management architecture

Access to both internal and external information sources
People who facilitate, curate, and disseminate knowledge within the organization
Information technology to provide automation support for many of the above activities
Repositories that contain explicit knowledge
Processes to acquire, refine, store, retrieve, disseminate and present knowledge
Organizational incentives and management roles to support these activities

Aspects of Secure Knowledge Management

Protecting the intellectual property of an organization
Security for process/activity management and workflow (users must have certain credentials to carry out an activity)
Access control including role-based access control
Risk management and economic trade-offs
Digital rights management and trust negotiation
Composing multiple security policies across organizations
Security for knowledge management strategies and processes

Security Strategies

Policies and procedures for sharing data
Protecting intellectual property
Should be tightly integrated with business strategy

Security processes

Secure workflow
Processes for contracting, purchasing, order management, etc.

Metrics

What is impact of security on number of documents published and other metrics gathered
Techniques
Access control, Trust management

Knowledge management cycle
Knowledge creation – sharing – measurement – improvement

Knowledge management technologies
Expert systems – collaboration systems – trainings systems – web

People and systems

People
Knowledge Teams – multi-disciplinary, cross-functional
Learning Organization – personal/team/org development
Corporate Initiatives – chief knowledge officer

Systems
Knowledge Data-bases – experts, best practice
Knowledge Centers – hubs of knowledge
Technology Infrastructure – Intranets, Domino Document Management

Two ways to generate and use knowledge
– sharing existing knowledge ‘Knowing what you know’
– knowledge for innovation ‘Creating and converting’

Knowledge cycle
Knowledge management has exploded due to the web and has different dimensions (technology, business, goal is to take advantage of knowledge in a corporation for reuse, services will play a key role in technology). Tools are emerging, effective partnerships between business leaders, technologists and policy makers are needed. Knowledge
management may subsume information management and data management.

**Levers**

Customer knowledge – the most vital knowledge
Knowledge in people – but people ‘walk’
Knowledge in processes – know-how when needed
Knowledge in products – ‘smarts’ add value
Organizational memory – do we know what we know?
Knowledge in relationships – richness and depth
Knowledge assets – intellectual capital

**Principles of effective learning**

**understanding**

Mental models, paradigms, context, observation, assumptions, opinion, fact, truth
systems thinking – variation

**skills**

Ability to challenge assumptions
Listen to understand

**processes**

Complete observe, assess, design, implement, cycle
Teach others

**The goal of knowledge management metrics**

Measuring success (How am I doing?)
Tracking improvement (Am I getting better?)
Benchmarking (How am I comparatively doing?)
Strategy
Alignment (culture, incentives)
Direct future investment (technology, employees)
Recep Benzer, Semra Benzer

Alternative approaches to traditional methods for growth parameters of fisheries industry: Artificial Neural Networks

Learning Objectives

The objectives of this chapter effects of ANNs on predicting statistical growth in fishery industry are investigated. Besides comparisons with conventional method are performed. Once you have mastered the materials in this chapter, you will be able to:

- Discuss the growth models with artificial neural networks for crayfish.
- Understand the difference traditional and artificial intelligence in fisheries.
- Identify the information data with Matlab application.
- Conversion and evaluation of crayfish measurements into data.
- Supporting decision makers in the fishing industry.

Chapter Outline

The aim of the fishing industry is to protect the natural habitat and fish and crayfish maintenance of stocks. For this reason, all studies in fisheries must be done using new approaches on mathematical models. This design should be established in the fishing industry. A defect will occur when it is fail to meet the intended design. Hence, prediction methods play an important role to forecast the number of product crayfish growth. For this study, Artificial Neural Network (ANNs) used to forecast in crayfish growth in in order to develop a well suit ANNs model for prediction and obtain an accurate prediction for decision making. Therefore, data of crayfish was collected and the analysis pro-
cess carried out by Matlab R2015a application using the neural network toolbox. The neural network framework for the some metric data prediction was developed with the minimum error. The fisheries industry is able to conduct prediction process with the framework and make a better decision based on the result in order to reach their goal.

**Keywords**

Artificial neural networks, crayfish, fisheries industry, traditional methods, modern methods, Matlab.

1 **Introduction**

Terms such as; “Digital Revolution”, “Industrial Revolution”, “Industry 4.0” conceptualize the same meaning: “Technological Revolution”. Technological Revolution aims improving human abilities with cyber-physical systems, creating factories based on artificial intelligence (AI), making interactions among objects and also with human-beings and providing decisions based on data processing. Researchers addressing interdisciplinary fields, experts have deep knowledge in wide-range of branches and collaboration facilities between them have utmost importance in the course of revolutionizing technology. Industry 4.0, 4th industry revolution, is the project of encouraging industrial improvements based on computer science and equipping industry with state-of-the-heart technology. AI is the most significant tool for extracting information from data and for making decisions. At this point, in fishery industry applying modern techniques related to AI instead of conventional methods is gaining importance. Nowadays thanks to high computer technology human-beings are trying not only to resolve unsolved problems but to contribute novel approaches. From this point of view, the idea enabling intelligent machines in 1980s evolved and improved with ANNs in 1990s. In particular ANNs, a branch of AI, attracted interests of various academics and researchers. ANNs provide generalized learning based on training process (Bon and Hui 2017). Thus, ANNs has non-linear structure. Besides, ANNs outperform conventional methods in terms of performance measures and they can detect non-linear relations without any hypothesis (Türeli et al. 2011;
Benzer 2015; Benzer and Benzer 2015; Benzer et al. 2015; Benzer and Benzer 2016; Benzer et al. 2016; Benzer et al. 2017; Benzer and Benzer 2017; Benzer et al. 2017; Benzer and Benzer 2018). Furthermore, ANNs enables using infinite variables. Companies that encounter difficulties while decision-making processes are to develop appropriate and well-planned solutions to maintain their existing situation and to forecast events in the future. Aim of prediction is not only to forecast their statutes in the future but to take measures against problems that do not currently exist. Stoke and growth problem has also the same aim. In terms of sustainability of any business, prediction has invaluable importance. Predictions supports business managers to make decisions parallel to company objectives. Predictions are forecasts to reveal unclear events' occupations, duration and impacts. Product managers occasionally deal with predictions on request forecasts prepared by (or with) marketing functions. However, managers use relational predictions to forecast payments of raw materials, to plan human powers and to decide on stock level. Thus, they can serve customers in better conditions, use capacity of their companies efficiently, and also enhance stability (Sharda and Patil 1992; Kaastra and Boyd 1996). Conventional statistical methods provide prediction of requests after analyzing past request status, factors affecting requests and economic indicator relations. Forecasts about the future is implemented using statistical methods that examine past events. Some of the most prominent statistical methods in prediction are given as follows; regression method, correlation method, curve fitting method, time series analysis method, moving averages method (Tekin 2008). Regression and von Bertalanffy are among the conventional methods used in Fishery Industry. Box – Jenkins Methods (AR-MA Model, ARIMA Model, and Simulation Model), fuzzy logic and artificial neural networks can be listed as modern estimation methods. Even structure and properties of ANNs are specific for problem, it is observed that performance results of ANNs are higher than that of conventional data processions methods. With the structure of the ANNs and the feature of imitating the intuition ability of human-beings, companies use ANNs in almost every vital decision-making process nowadays. Information systems are one of the main pillars of the information society and clearly show that machines can interpret, prioritize, solve problems, produce solutions to
complex problems that computers can not solve under normal conditions, perceive and prioritize events. With the concept of Industry 4.0, a rapid digital transformation is triggered in communities. In this context, it is obvious that the possible developments are examined that digital domination makes one feel more and more in industrial life at any moment itself, at the same time it leads to important developments in the social sense. Digitization is great importance when considering the big data, intelligent robots, simulation, vertical and horizontal system organization, internet of objects, cyber security, cloud, joint production and enriched reality. In terms of data, information, knowledge, understanding and comprehension, Industry 4.0 has emerged as a strategic step in the direction of businesses. Environmental sustainability, product variety, branding by increasing the competitiveness in international markets and some kind of IT support including all kinds of classical and modern computing approaches are gaining importance in terms of digitalization in aquaculture. Also it will be accelerated by automating the production, processing and distribution chain by transforming the obtained data into decisions (Dopico et al. 2016). In the aquaculture industry, there will be no innovation without interdisciplinary work, it will not be possible to produce value-added ideas in complex socio-technical fields through various interdisciplinary collaborations and the engineers should be equipped with the skills they have adopted modern approaches to provide interdisciplinary thinking and access to excellence. In this study, effects of ANNs on predicting statistical growth in fishery industry are investigated. Besides comparisons with conventional method are performed.

2 Methodology

2.1 Study area

The Lake Yeniçaga is located in in west Black Sea region of Turkey (40° 46' 45" N, 32° 01' 33" E), within the borders of the city Bolu and in the north of the town Yenicağa (Fig. 1). Lake Yenicağa is a shallow eutrophic freshwater lake with maximum depth of 5.2 m (Saygı and
Demirkalp 2004), 989 m above sea level, and covers surface area of about 260 ha (Kılıç and Becer 2013).

The study area (Yeniçağa Lake).

2.2 Data collection

Crayfish (*Astacus leptodactylus*) shows a widespread distribution within inland waters of Turkey. It was the most important inland water product between 1970 and 1985. However, there was a dramatic decrease in its population due to the crayfish plague, which was recorded in Turkey in 1984 (Furst 1988; Baran and Soylu 1989; Rahe and Soylu 1989). In Turkey, crayfish production was 7936 tonnes in 1984. It dropped to 1565 tonnes in 1987 and 320 tonnes in 1991 (TÜİK 1984–1991). Furthermore, there have been some fluctuations in crayfish production in the last 25 years. Production was 324 tonnes in 1992, which increased to nearly 1500 tonnes in 1998. While production was 1372 tonnes in 1999, it reached 2317 tonnes in 2004. However, it diminished to 816 tonnes in 2007, 1030 tonnes in 2010, 609.6 tonnes in 2011, 492 tonnes in 2012, 532.1 tonnes in 2013, 582 tonnes in 2014, 532 tonnes in 2015 and 544 tonnes in 2016 (TÜİK 2018). Crayfish samples were
collected from Yeniçağ Lake. During the study, 455 crayfish specimens (260 females and 195 males) were caught between 2015 and 2016. The total length (TL), total weight (TW), carapace length (CL), carapace width (Cw), abdomen length (AL) and abdomen width (Aw), chela length (ChL) and chela width (Chw) of each specimen were measured. The parameters related to length and width were measured with a digital calliper to the nearest 0.1 mm, while the weight related ones were measured to the nearest 0.01 g, and sex determination was carried out for each specimen (Rhodes & Holdich 1979). The crayfish obtained from the lake were immediately transported to the laboratory. Sex, maturity, mating, spawning and hatching statuses were recorded during the study. Sex and length composition, the average length and weight, and the length-weight relationship for each sex and combined sexes were determined.

2.3 Length–weight relationship (LWR) equation

LWR equation is a traditional method used for the determination of the growth features of populations. From the collected samples; sex and length composition, the average length and weight weight, and the length–weight relationship for each sex and combined sexes were identified. The relationship between length (L) and body weight (W) for nearly all species of fish can normally be represented by the "length-weight relationship" following equation:

\[ W = aL^b \]

Where W is the body weight of fish (in g), L is the length (in cm) and 'a' and 'b' are constants. The parameter 'b' (also known as the allometry coefficient) has an important biological meaning, indicating the rate of weight gain relative to growth in length or the rate at which weight increases for a given increase in length. If b is equal to 3, isometric pattern of growth takes places, if b is not equal to 3, then allometric pattern of growth takes places, it may be positive if it is greater than 3 or negative otherwise (Ricker 1973). The q and b constants could be esti-
mated from linear functions. However, many functional relationships observed in fishery biology such as length-weight relationship are not linear. Fortunately, such curvilinear functions can often be transformed into linear functions by taking the logarithm or the natural logarithms of both sides:

\[ \ln W = \ln a + b \ln L \]

2. 

\[ \log W = \log a + b \log L \]

3. 

This equation is equivalent the regression equation:

\[ y = a + b \cdot x \]

4. 

This mean that; \( y \) is equivalent to \( \ln W \), \( a \) which represents the \( y \)-intercept (the point where the line crosses the \( y \) axis) of the regression line is equivalent to \( \ln a \), \( b \) is the slope of the line, and \( x \) is equivalent to \( \ln L \).

2.4 Artificial Neural Networks (ANNs)

ANNs are computational systems that simulate biological neural networks and can be defined as a specific type of parallel processing system based on distributional or connectionist methods (Andrews et al. 1995; Hopgood 2000).

Artificial Neural Networks (ANNs) are used in three basics methods:

– As biological nervous system models and intelligence.
– As real time adaptive signal processing controllers implemented in hardware for applications such as robots.
– As methods of data analytic.
In several years of artificial neural models (ANNs) network has developed to predict. There are three featured steps in developing an ANNs based solution:

- Scaling or data transformation.
- Definition of Network architecture as in Fig. 2, when the number of hidden layers, the number of nodes in each layer and connectivity between the nodes and set, learning algorithm construction in order to train the network.

![Diagram of Artificial Neural Networks model](image)

**Fig. 2. Artificial Neural Networks model diagram**

That contain of an input layer, a series of hidden layer, an output layer and connections between them. Nodes in the input layer represent possible influential factors that affect the network output and have no computational activities, while the layer of output contains one or more nodes that produce the output of network. Hidden layer may consist a large number of hidden processing nodes. A feed-forward back-propagation network propagates the information from the input layer to the output layers, compares the network output with known target, and propagates the error term from the layer of output back to the layer of input, by using a learning mechanism to adjust the biases and weights. ANNs are simulations of biological nervous systems using mathematical models. They are networks with simple processor units, interconnections, adaptive weights and scalar measurement functions (e.g., summation and activation functions) (Rumelhart et al. 1986). ANNs mathematical expression is seen in Fig. 3. Y is the neu-
ron’s output, x is the vector of inputs, and w is the vector of synaptic weights.

![Biological neuron](image1.png)

![Artificial neuron](image2.png)

Fig. 3. Biological and Mathematical explanation for ANNs design

In case of biological neuron information comes into the neuron via dendrite, soma processes the information and passes it on via axon. In case of artificial neuron the information comes into the body of an artificial neuron via inputs that are weighted (each input can be individually multiplied with a weight). The body of an artificial neuron then sums the weighted inputs, bias and “processes” the sum with a transfer function. At the end an artificial neuron passes the processed information via output(s). Benefit of artificial neuron model (Krenker et al. 2011) simplicity can be seen in its mathematical description below:

\[
y(k) = F \cdot \left( \sum_{i=0}^{m} w_i(k) \cdot x_i(k) \right)
\]

Where:
- \(w_i(k)\) is weight value in discrete time k where i goes from 0 to m,
- \(x_i(k)\) is input value in discrete time k where i goes from 0 to m,
- \(F\) is a transfer function,
- \(y_i(k)\) is output value in discrete time k.

As seen from a model of an artificial neuron and its equation (5) the major unknown variable of our model is its transfer function. Transfer function defines the properties of artificial neuron and can be any mathematical function.
2.5 Normalization

The supervised learning method trained with the network structure (Back-propagation Networks) will be used to solve problems in this study. The transfer function (6), \((VN)\) is normalized data, \((VN)\) is data to be normalized, \((V_{min})\) is the minimum value of the data, \((V_{max})\) is the maximum value of the data) mostly used a sigmoid or a logistic function, gives values in the range of \([0,1]\) and can be described as (normalization):

\[
V_N = 0.8 \times \left( \frac{V_R - V_{min}}{V_{max} - V_{min}} \right) + 0.1
\]

2.6 Estimation Accuracy Validation

For this research, the Mean Absolute Percentage Error (MAPE) is used for estimation accuracy. MAPE is defined as:

\[
MAPE = \frac{1}{n} \sum_{i=1}^{n} \left( \left| \frac{Estimated_i - Actual_i}{Actual_i} \right| \right)
\]

Comparisons can be made with more than one method by MAPE, because it is easy to interpret with its relative measurements. The smaller the values of MAPE, the closer are the forecasted values to the actual values.

\[
MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{e_i}{Y_i} \right| \times 100
\]

MAPE is the preferred error measure of the software measurement (MATLAB) researches.
2.7 Statistics

The MAPE benchmark refers to forecast errors as a percentage, and can therefore negate the disadvantages that may arise when correlating models developed for examines with different values. These features of MAPE are considered to be superior to those of other evaluation statistics. The MAPE results were assessed according to literature (0%–10%: Very Good, 10%–20%: Good, 20%–50%: Acceptable, 50%–100%: Wrong and Faulty) (Witt and Witt 1992; Lewis 1982).

The coefficient correlation ($R^2$) calculated by the LWR regression model was 0.971. When the coefficient correlation ($R^2$) was evaluated in both ANNs and LWR model, the results of ANNs were better, although they did not seem close to each other. It is evaluated that comparing the MAPE values together with $R^2$ values can give a healthy result (Gentry et al. 1995).

2.8 Data Editing for MATLAB

Neural Network Toolbox of MATLAB was used for the ANNs calculations. This study was performed on 540 crayfish (270 females and 270 males) caught between 2015 and 2016 in Uluabat Lake. The data were divided into three equal parts: training, validation and test sets. The Matlab functions were used for “training”, “testing”, and “validation”. They were used randomly; 70% in training, 15% in testing, and 15% in the validation of the crayfish.

3 Literature Review

It is well acknowledged that Astacus leptodactylus is of great element in the food webs of freshwater habitats and their examination provides advantageous information on the comprehensive water systems (Hogger 1988; Momot 1995; Nyström 2002; Füreder et al. 2003). The crayfish, which is examined as eutrophic water scavengers, is one of the aquatic creatures with high nutritional and economic values. Therefore, it has long attracted interests in scientific research (Holdich and
Crayfish (*Astacus leptodactylus*), is a common species distributed throughout Europe, Middle East and Eastern Russia (Harlioglu 1996, Gutierrez-Yurrita et al. 1999; Souty-Grosset et al. 2006). It can be found in 27 countries around the world (Skuradal and Taugbol 2001; Parvulescu et al. 2012; Azari et al. 2014; Azari et al. 2015).

*A. leptodactylus* is naturally and widely distributed in freshwaters throughout Turkey (Harlioğlu 2004; Harlioğlu and Harlioğlu 2005; Yuskel and Duman 2011; Bolat et al. 2011; Bök et al. 2013; Aydın et al. 2015; Benzer et al. 2015; Benzer and Benzer 2015; Demirol et al. 2015; Aksu and Harlioğlu 2016).

Length-weight relationships (LWR) is a widely used method, namely, in fish biology, ecology and fisheries studies. It is widely used in the determination of fishery measurement when sampling large species, mostly because of the difficulty and time required to record weight in the field (Andrade and Campos 2002).

LWR for fish are predicted using the average length and weight (Mendes et al. 2004; Tosunoglu et al. 2007). The LWR describes the correlation mathematically between the length and weight of the fish as well as the estimated values (Beyer 1991) of its length and weight. LWR are beneficial for the conversion of length equations to weight for use in stock calculation models (Lindqvist and Lathi 1983; Deval et al. 2007) and in predicting stock biomass with narrow sample (Verdiell-Cubedo et al. 2006). These results also let scientists make identifications on morphological properties among species or among populations of the same species from various habitats (Moutopoulos and Stergiou 2002; Etchison et al. 2012). Critically, LWR were used to inform on the condition of freshwater samples and to evaluate whether somatic growth was isometric or allometric (Ricker 1973). The prediction of the relationship parameters between a and b can explain the connection regarding ecological events and life history. Environmental causes may affect crayfish growth by feeding and food resources. Length-weight values may probably demonstrate the differences in growth that may be correlated with environmental stress across the species (Westman and Savolainen 2002; Olsson 2008). The most frequently researched dimensions for crustaceans are carapace length, body length, total length, body width, and wet weight (Primavera et al. 1998). Differences in length between individual body parts are used to
demonstrate the morphological changes between the male and female crayfish species (Lindqvist and Lahti 1983). These differences are also utilized in determining crayfish populations, its relative growth, comparing the populations of the same species, the morphology of crayfish species and the systematic assignment of crayfish (Lindqvist and Lahti 1983; Skurdal and Qvenild 1986; Gillet and Laurent 1995). The dimensions may be favorable to be able to convert into the desired length values when only one of the other length measurements is known and the LWR may be used to predict length from weight (Tosunoğlu et al. 2007). ANNs has been used in biology and in different disciplines of fisheries rather than in sciences (Tureli Bilen et al. 2011). Exercises of ANNs has included forecast the fish species distributions (Maravelias et al., 2003), fish predicting in a river (Mastrorillo et al., 1997), predicting macro invertebrate diversities (Park et al. 2003), population of aquatic insects (Obach et al. 2001), modeling freshwater fish (Joy and Death, 2004), fish population modeling (Benzer et al. 2016; Benzer and Benzer 2016). There are many publications on management information systems approaches in fisheries, biology and similar research areas (Fish et al. 1995; Lek and Guégan 1999; Olden and Jackson 2001; Teles et al. 2006; Goethals et al. 2007; Cabreira et al. 2009; Sholahuddin et al. 2015; Rocha et al. 2017; Ouali et al. 2017). Compared to traditional methods, ANNs has supported better conclusions in the evaluation of future data (Suryanarayana et al. 2008; Tureli Bilen et al. 2011). For limited values, the normality and their independence from the predicted values, ANNs is asserted to be an excellent model which gives excellent predictions. ANNs is also recorded to have accomplishment compared to linear regressions (Sun et al. 2009). Besides, ANNs is more favorable for its speed and flexibility (Brosse et al. 2009).

4 Results

There were about 57.14 % females, 42.86 % males (260 female, 195 male). The female: male ratio was found to be 1:0.75 for the general population. The length and weight (minimum-maximum) of the crayfish were 89–163 mm and 15.82 – 105.60 g. The average length and weight of samples were 122.154 ± 18.10 mm and 49.09 ± 19.38 g for
male, 118.17 ± 15.50 mm and 42.04 ± 14.82 g for females and 118.98 ± 16.81 mm and 45.06 ± 17.07 g for the combined sex, respectively (Table 1). We organized the length-weight relation formulation data as a TL-TW, CL-ChL, CL-AL. Total length total weight relation (TL-TW) for the crayfish in Yeniçağa Lake were found as $W = 0.12949911L^{2.3258}$ for females, $W = 0.18113315L^{2.2176}$ for males and $W = 0.14162875L^{2.3010}$ for both sexes. The carapace length chela length relations (CL-ChL) for the crayfish in Yeniçağa Lake were found as $W = 1.31828102L^{0.9788}$ for females, $W = 2.21471042L^{0.7544}$ for males and $W = 1.48781344L^{0.9378}$ for both sexes. The carapace length abdomen length relations (CL-AL) for the crayfish in Yeniçağa Lake were found as $W = 1.02962529L^{0.8497}$ for females (Table 2 and Fig. 4).

Table 1. Some metric properties for crayfish data

<table>
<thead>
<tr>
<th>Metric Species</th>
<th>Sex</th>
<th>Median ± Sx</th>
<th>Min – Max</th>
<th>t test</th>
</tr>
</thead>
<tbody>
<tr>
<td>TL</td>
<td>♀</td>
<td>118.17 ± 15.57</td>
<td>89–150</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>122.15 ± 18.13</td>
<td>89–163</td>
<td></td>
</tr>
<tr>
<td></td>
<td>♂♀</td>
<td>119.87 ± 16.81</td>
<td>89–163</td>
<td></td>
</tr>
<tr>
<td>TW</td>
<td>♀</td>
<td>42.04 ± 14.44</td>
<td>15.82 – 80.0</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>TW</td>
<td>♂</td>
<td>49.09 ± 19.38</td>
<td>18.01 – 105.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>♂♀</td>
<td>45.06 ± 17.07</td>
<td>15.82 – 105.6</td>
<td></td>
</tr>
<tr>
<td>CL</td>
<td>♀</td>
<td>57.21 ± 8.6</td>
<td>42–75</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>CL</td>
<td>♂</td>
<td>61.89 ± 11.51</td>
<td>40–90</td>
<td></td>
</tr>
<tr>
<td></td>
<td>♂♀</td>
<td>59.22 ± 10.2</td>
<td>40–90</td>
<td></td>
</tr>
<tr>
<td>AL</td>
<td>♂</td>
<td>45.51 ± 7.3</td>
<td>25–60</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>AL</td>
<td>♂♀</td>
<td>45.40 ± 6.93</td>
<td>25–60</td>
<td></td>
</tr>
<tr>
<td>ChL</td>
<td>♂</td>
<td>73.09 ± 13.83</td>
<td>45–130</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>ChL</td>
<td>♂♀</td>
<td>91.59 ± 27.45</td>
<td>15–155</td>
<td></td>
</tr>
</tbody>
</table>

Sx: Standard deviation

Table 2. Some metric properties for crayfish data

<table>
<thead>
<tr>
<th>Species</th>
<th>Sex</th>
<th>Relationship</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>TL – TW</td>
<td>♀</td>
<td>$W = 0.12949911L^{2.3258}$</td>
<td>0.975</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>$W = 0.18113315L^{2.2176}$</td>
<td>0.964</td>
</tr>
<tr>
<td></td>
<td>♂♀</td>
<td>$W = 0.14162875L^{2.3010}$</td>
<td>0.968</td>
</tr>
<tr>
<td>CL – ChL</td>
<td>♂</td>
<td>$W = 1.31828102L^{0.9788}$</td>
<td>0.994</td>
</tr>
<tr>
<td></td>
<td>♂♀</td>
<td>$W = 2.21471042L^{0.7544}$</td>
<td>0.974</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>$W = 1.48781344L^{0.9378}$</td>
<td>0.980</td>
</tr>
<tr>
<td></td>
<td>♂♀</td>
<td>$W = 1.02962529L^{0.8497}$</td>
<td>0.995</td>
</tr>
<tr>
<td>CL – AL</td>
<td>♂</td>
<td>$W = 1.46177399L^{0.6201}$</td>
<td>0.994</td>
</tr>
<tr>
<td></td>
<td>♂♀</td>
<td>$W = 1.31682998L^{0.6947}$</td>
<td>0.994</td>
</tr>
</tbody>
</table>
Pearson correlation coefficient is a dimensionless measure that determines a linear relation between two variables. Its value varies from -1, when there is a perfect negative linear relation, to +1, when there is a perfect positive linear relation. The closer this value to zero, the smaller is the degree of linear relation. From the Pearson correlation coefficient, many other statistics are calculated, such as partial correlation, direct and indirect effects between variables in track analysis, and canonical correlation (Sari et al. 2017). Thus, the precision of these statistics depends on accuracy of the estimate of Pearson’s correlation coefficient. In the present study, Table 3 showed that there is no negative pearson correlation between all parameters. Apart from these results, TW – TL, ChL – TL, AL – TL, CL – TW have a high correlation.

Fig. 4. LWR relations for TL-TW (Yeniçağa Lake).

Table 3. Pearson correlation coefficients between metric characteristics.

<table>
<thead>
<tr>
<th></th>
<th>TL</th>
<th>TW</th>
<th>CL</th>
<th>ChL</th>
<th>AL</th>
</tr>
</thead>
<tbody>
<tr>
<td>TL</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TW</td>
<td>0.850</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CL</td>
<td>0.955</td>
<td>0.831</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ChL</td>
<td>0.648</td>
<td>0.703</td>
<td>0.683</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>AL</td>
<td>0.905</td>
<td>0.742</td>
<td>0.760</td>
<td>0.497</td>
<td>1.000</td>
</tr>
</tbody>
</table>

All correlation is significant at the 0.01 level.

If we examine the example problem in question as a multi-layer neural networks; the following objectives will be achieved.

- With a single, suiciently large hidden layer, it is possible to represent any continuous function of the inputs with arbitrary accuracy,
- As a consequence, given a particular learning problem, it is unknown how to choose the right number of hidden units in advance,
- We need to consider multiple output units for multi-layer networks.

Let \((x, y)\) be a single sample with its desired output labels \(y = \{y_1,...,y_i,...,y_M\},\)
The error at the output units is just \( y - hW(x) \), and we can use this to adjust the weights between the hidden layer and the output layer.

A term equivalent to the error at the hidden layer, i.e. the error at the output layer is back-propagated to the hidden later.

This is subsequently used to update the weights between the input units and the hidden layer.

A multilayer feed-forward neural network was used for the ANNs. The following three steps will be carried out for this.

1. Update the weights between the hidden and output layers.
   - Let \( E_{rr_i} \) be the i-th component of the error vector \( - hW(x) \)
   - Define \( \Delta_i = E_{rr_i} x g'(in_i) \)
   - The weight-update rule becomes \( W_{j,i} \leftarrow W_{j,i} + \alpha x a_j x \Delta_i \)

2. Back-propagate the error to the hidden layer.
   - The idea is that the hidden node \( j \) is “responsible” for some fraction of the error \( \Delta_i \) in each of the output nodes to which it connects.
   - Thus the \( \Delta_i \) values are divided according to the strength (weight) of the connection between the hidden node and the output node
     \[ \Delta_j = g'(in_j) \sum_i W_{j,i} \Delta_i \]
   - Again, this is similar to weight-updates in perceptrons:
     \[ W_{k,j} \rightarrow W_{k,j} + \alpha x a_k x \Delta_j \]

A schematic representation of a typical ANNs was shown in Fig. 2. Fig. 5 illustrates graphical presentation of the fit between the actual and predicted values. Performance of the ANNs between forecast values for TL TW was seen in Fig. 6.

Fig. 5. Relationship between of artificial neural networks for TL-TW (Yeniçağa Lake).

Fig. 6. Performance of artificial neural networks for TL – TW (Yeniçağa Lake).

Fig. 7 shows the distribution of fish data collected from the Yeniçağa Lake by total length (TL) and total weight (TW). Fig. 8 shows the distribution of the actual data with estimation (estimation) data for the
results of the regression on learning, validation and test clusters in Matlab.

Fig. 7. Distribution of fish data collected for TL – TW (Yeniçağa Lake).

The average absolute error and average error squares of error functions used in both training and test data are calculated with Matlab coding. In the training data MAE 0.1585, RMSE 0.2122; in the test data, MAE was found to be 0.2158 RMSE 0.2689. The actual values of the fishes obtained from nature (Yeniçağa Lake), as seen in Fig. 4, are well predicted.

Fig. 8. Actual and predictive data

The values observed, ANNs and length-weight relation data are presented in Table 4. The observed data, which is collected from the
Yeniçağa Lake, were presented according to the gender of group with length and weight. The calculated data observed from the artificial neural networks, length-weight relations. Table 4 were prepared for comparison of data of the crayfish in Yeniçağa Lake with length-weight relation and ANNs method.

Table 4. Observed and calculated values for ANNs, length-weight relation

<table>
<thead>
<tr>
<th>Type (1) – (2)</th>
<th>Sex</th>
<th>ACTUAL DATA</th>
<th>FORECAST</th>
<th>MAPE (%)</th>
<th>LWR</th>
<th>MAPE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>TL (1) TW (2)</td>
<td>Female 11.81</td>
<td>42.04</td>
<td>11.99</td>
<td>43.59</td>
<td>12.01</td>
<td>40.43</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Male 12.21</td>
<td>49.09</td>
<td>11.99</td>
<td>46.78</td>
<td>12.50</td>
<td>46.59</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All 11.98</td>
<td>45.06</td>
<td>11.99</td>
<td>45.58</td>
<td>12.23</td>
<td>42.99</td>
</tr>
<tr>
<td>CL (1) ChL (2)</td>
<td>Female 5.721</td>
<td>7.310</td>
<td>5.807</td>
<td>7.407</td>
<td>1.505</td>
<td>3.29</td>
</tr>
<tr>
<td></td>
<td>All 5.922</td>
<td>8.103</td>
<td>5.910</td>
<td>8.190</td>
<td>0.214</td>
<td>1.84</td>
</tr>
<tr>
<td></td>
<td>Female 5.721</td>
<td>4.552</td>
<td>5.807</td>
<td>4.570</td>
<td>1.505</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>Male 6.190</td>
<td>4.526</td>
<td>6.065</td>
<td>4.537</td>
<td>2.023</td>
<td>0.252</td>
</tr>
<tr>
<td></td>
<td>All 5.922</td>
<td>4.541</td>
<td>5.909</td>
<td>4.540</td>
<td>0.214</td>
<td>0.015</td>
</tr>
</tbody>
</table>

5 Discussion

Environmental factors such as behavior, foraging efficiency, feeding and the availability and quality of food resources might widely influence variation in morphometric traits (Lindqvist and Lahti 1983). Crustacean growth is affected by the environmental conditions by influencing molt intervals and incremental rises in length and weight. In fishery studies, the relationship between bodies length – weight is an essential and extensively used equation and the simplest parameter to measure is the fish length. Crustaceans experience different stages in their life history which are defined by different length-weight relationships. The parameter b is characteristic of species and usually does not show a significant change throughout the year, unlike the parameter, which may change on a daily basis, seasonally, between different environments, water temperature and salinity, gender, availability of food,
diversity in the number of specimens analyzed, as well as in the observed length ranges of the species caught (Tesch 1971). The morphological differences are used in determining the growth characteristics of the freshwater crayfish population, comparing populations of the same species with different regions and classifying freshwater crayfish systematically (Harlioğlu 1999). The calculated LWR is model dependent; as a result, model selection uncertainty may be quite higher in certain data sets. Ignoring model selection uncertainty may cause substantial overestimation of the precision and estimation of the confidence intervals of the parameters below the nominal level. This uncertainty has serious implications, e.g., in the case of comparing the growth parameters of different crayfish populations. The average lengths and weight of the males were higher than the females in this study. It was generally found that TL and TW of all sex was longer and weight than that of all the literature (Table 5).

Table. 5 Comparison of crayfish parameters in different locations.

<table>
<thead>
<tr>
<th>Referee</th>
<th>Sex</th>
<th>TL</th>
<th>TW</th>
<th>Regression parameters</th>
<th>Sex ratio (♀/♂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harlioğlu (1999)</td>
<td>♀</td>
<td>106.79</td>
<td>-</td>
<td>0.00159</td>
<td>2.52</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>108.14</td>
<td>-</td>
<td>0.00093</td>
<td>2.67</td>
</tr>
<tr>
<td>Harlioğlu and Harlioğlu (2005)</td>
<td>♀</td>
<td>103.29</td>
<td>32.17</td>
<td>-</td>
<td>2.11</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>101.81</td>
<td>33.07</td>
<td>-</td>
<td>2.51</td>
</tr>
<tr>
<td>Eğirdir Lake</td>
<td>♀</td>
<td>104.54</td>
<td>29.19</td>
<td>-</td>
<td>2.66</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>100.47</td>
<td>29.34</td>
<td>-</td>
<td>2.72</td>
</tr>
<tr>
<td>Iznik Lake</td>
<td>♀</td>
<td>105.93</td>
<td>19.36</td>
<td>-</td>
<td>2.22</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>104.76</td>
<td>20.17</td>
<td>-</td>
<td>3.66</td>
</tr>
<tr>
<td>Balık et al. (2005)</td>
<td>♀</td>
<td>92.88</td>
<td>24.19</td>
<td>0.00002</td>
<td>3.06</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>89.07</td>
<td>21.85</td>
<td>0.0003</td>
<td>2.94</td>
</tr>
<tr>
<td>Demirköprü Dam Lake</td>
<td>♂</td>
<td>90.18</td>
<td>25.43</td>
<td>0.00001</td>
<td>3.27</td>
</tr>
<tr>
<td>Berber and Balık (2006)</td>
<td>♀</td>
<td>89.07</td>
<td>21.85</td>
<td>0.0003</td>
<td>2.94</td>
</tr>
<tr>
<td>Manyas Lake</td>
<td>♂</td>
<td>82.12</td>
<td>19.57</td>
<td>0.0003</td>
<td>2.98</td>
</tr>
<tr>
<td>Berber and Balık (2009)</td>
<td>♀</td>
<td>80.28</td>
<td>20.62</td>
<td>0.0003</td>
<td>2.96</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>78.05</td>
<td>21.92</td>
<td>0.0002</td>
<td>3.03</td>
</tr>
<tr>
<td>Apolyont Lake</td>
<td>♀</td>
<td>-</td>
<td>-</td>
<td>0.00003</td>
<td>2.96</td>
</tr>
<tr>
<td></td>
<td>♂</td>
<td>-</td>
<td>-</td>
<td>0.00003</td>
<td>2.97</td>
</tr>
<tr>
<td>Deniz et al. (2013)</td>
<td>♂</td>
<td>-</td>
<td>-</td>
<td>0.00007</td>
<td>2.78</td>
</tr>
<tr>
<td>Inland water in Turkey</td>
<td>♂</td>
<td>-</td>
<td>-</td>
<td>0.00001</td>
<td>3.21</td>
</tr>
<tr>
<td>Eğirdir Lake</td>
<td>♂</td>
<td>-</td>
<td>-</td>
<td>0.00001</td>
<td>2.71</td>
</tr>
<tr>
<td>Hirfanli Dam Lake</td>
<td>♂</td>
<td>-</td>
<td>-</td>
<td>0.000008</td>
<td>3.28</td>
</tr>
<tr>
<td>Keban Dam Lake</td>
<td>♂</td>
<td>-</td>
<td>-</td>
<td>0.00005</td>
<td>2.42</td>
</tr>
<tr>
<td>Porsuk Dam Lake</td>
<td>♂</td>
<td>-</td>
<td>-</td>
<td>0.000005</td>
<td>3.38</td>
</tr>
<tr>
<td>Benzer et al. (2015)</td>
<td>♀</td>
<td>108.71</td>
<td>28.64</td>
<td>0.00220024</td>
<td>2.02</td>
</tr>
<tr>
<td>Mogan Lake</td>
<td>♂</td>
<td>102.93</td>
<td>32.49</td>
<td>0.00095247</td>
<td>2.22</td>
</tr>
</tbody>
</table>
Some researchers have indicated that the females have a larger size than the males (Benzer and Benzer 2018; Benzer et al. 2015; Aydin et al. 2015; Balik et al. 2005; Berber and Balik 2006), while some researchers have indicated that male females are longer than female females (Harlioğlu 1999; Berber and Balik 2009; Benzer and Benzer 2016). In some studies, it is stated that females are heavier than males (Berber and Balik 2006; Aydin et al. 2015), and some studies indicate that males are heavier than females (Benzer and Benzer 2018; Benzer et al. 2015; Benzer and Benzer 2016; Balik et al. 2005; Berber and Balik 2009). It was found that b values for male and female were lower than the values found in the study by Harlioğlu (1999), Harlioğlu and Harlioğlu (2005) (Eğirdir and İzник) for female, Benzer et al. (2015), Aydin et al. (2015), Benzer and Benzer (2015), Deniz et al (2013) (Eğirdir, Hirfanlı, Keban and Porsuk). It was found that b values were higher than the values found in the study by Benzer et al. (2015) for all individuals and Harlioğlu and Harlioğlu (2005) (Eğirdir, İzник and Hirfanlı – male) for only males (Table 5). The differences may result from the environmental factors, food, density of the population and the selectivity of the traps or fykenets used in the studies. For example, male crayfish were found heavier than females in a previous study. This disparity is said to be a result of the increasing development of the male chela with sexual maturity; however, the chela of the females remain isometric during their life (Romaire et al. 1977). Furthermore, males were found rougher and more thick-set than females in another study (Skurdal and Qvenild 1986). The TL – TW relationship, which shows the estimate power of the developed ANNs, was found to be 0.90297 as the r² (for all individuals) values. Success is considered high when r² values are between 0.95 – 1 (Ekici and Aksoy 1993). The coefficient
correlation ($r^2$) calculated by the LWR regression model (for all individuals) was 0.968. When the coefficient correlation ($r^2$) was evaluated in both ANNs and LWR model, the results of LWR were better, although they did not seem close to each other. The calculated SSE and MSE value for actual data, ANNs, length-weight relations are given in Table 6. It is evaluated that comparing the MAPE values together with $r^2$, SSE and MSE values can give a healthy result (Gentry et al. 1995).

Table 6. SSE and MSE values for actual data, ANNs, length-weight relations

<table>
<thead>
<tr>
<th></th>
<th>Actual data</th>
<th>ANNs</th>
<th>Length-weight Relations</th>
</tr>
</thead>
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<tr>
<td><strong>Length</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>381.78</td>
<td>233.57</td>
<td>28105.12</td>
</tr>
<tr>
<td><strong>SSE</strong></td>
<td>381.78</td>
<td>233.57</td>
<td>28124.96</td>
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<tr>
<td><strong>MSE</strong></td>
<td>2.74</td>
<td>1.68</td>
<td>3.29</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>12307.66</td>
<td>201.50</td>
<td>202.33</td>
</tr>
</tbody>
</table>

When MAPE results of length-weight relation and ANNs were compared, it was found that MAPE value of the forecast of ANNs was 0.164 and 0.750, and the value of length-weight relationship was 2.620 and 2.488 for length–weight of all genders. ANNs gives better results than length-weight relation (Table 4). In the literature, it is reported that ANNs MAPE ratios are low (Tureli Bilen et al. 2011; Benzer and Benzer 2016; Benzer et al. 2015, 2016, Benzer and Benzer 2018). The most important result of this research is that it is done with artificial neural networks instead of the traditional approach methods used in businesses administration of fisheries thus providing the necessary environment for decision makers to make decisions more easily and quickly. By using the developments in the field of informatic in prediction approaches, plans will be made more comfortable and easier for the coming years, without forcing the populations existing in the fishing industry. Especially in the European Union countries, it is evaluated that the use of information software and hardware tools can be used more effectively and that inventory control and product efficiency can reach maximum levels through the use of modern fisheries. Taking into consideration that timing, effort and cost are the three most important elements of a successful project management, the results obtained with modern predict methods will lead to making healthier decisions based on case evaluation reports in business. Modern methods of pre-
dict will gain competitive advantage when judged to be more difficult in case of uncertainty. With the industrial revolution of the industry 4.0, it will be possible to automate all kinds of business sectors faster and less costly by using modern methods. In this paper, the use of the neural networks approach was examined for regression problem with the aim of analyzing the level of relationships between length and weight variables in Yeniçağa Lake by using the crayfish.

6 References


Reference


Harlioğlu, M. M. Comparative biology of the signal crayfish, Pacifastacus leniusculus (Dana), and the narrow-clawed crayfish, Astacus leptodactylus Eschscholtz (Doctoral dissertation, University of Nottingham). 1996.


7 Key Terms

<table>
<thead>
<tr>
<th>Artificial neural networks</th>
<th>crayfish</th>
<th>Decision</th>
<th>Growth</th>
</tr>
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<tr>
<td>Traditional methods</td>
<td>Fisheries industry</td>
<td>Artificial intelligent</td>
<td>Lake</td>
</tr>
<tr>
<td>Modern methods</td>
<td>Matlab</td>
<td></td>
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</tr>
</tbody>
</table>

8 Questions for Further Study

Describe the principal steps in the planning phase. What are the major deliverables?
**Compare** modern methodologies and traditional methodologies. **What** does normalization mean in artificial neural networks? **How** do error comparisons be made in artificial neural networks?

**9 Exercises**

In the fisheries industry, you can use the traditional methods for the samples taken from ecosystems. Find the growth models and draw growth curve. What do you say? 

In the fisheries industry, you can use the modern methods (artificial neural networks) for the samples taken from ecosystems. Find the growth models and draw growth curve. What do you say? **Compare** the traditional methods and modern methods (artificial neural networks).

According to the error rates, which method gave better results. What do you say about ecosystem? 

**Artificial** neural networks can be used in other areas of the industry, discuss.

**10 Further Reading**


Would the Benefits Created by Industry 4.0 Via Innovations Set the Consumers Free of Planned Obsolescence?

Learning Objectives

Once you have mastered the materials in this chapter, you will be able to:

– Discuss the enabler technologies of the fourth industrial revolution.
– Understand the effects of the fourth industrial revolution and planned obsolescence on profitability.
– Identify the effects of Industry 4.0 on economy, individuals, society, and government.
– Explain the applications of planned obsolescence.
– Understand the conveniences that the digital revolution brings to our lives.

Chapter Outline

While the third industrial revolution is not experienced in many countries of the world; the fact that the rich and powerful countries have undergone the fourth industrial revolution, and that the increasing inequalities between them and within the country are more important for the future of humanity. The innovations introduced by Industry 4.0 offer humanity the opportunity to move to another world, which could not have imagined until 15 years ago. The question of what these opportunities are and how they can be used to great effect by human beings are examined by many scientists and business people. In this chapter, whether the idea of making production in order to profit in the context of the wild capitalism, especially the planned obsolescence,
will change in the face of the innovations brought by Industry 4.0 is discussed. First of all, the terminology of Industry 4.0 is defined and nine pillars of Industry 4.0 are listed. Then, its effects on the economy, individuals, society and government are examined. Afterwards, the definition and application of planned obsolescence is presented. In the conclusion part of the chapter, the situation of whether Industry 4.0 would eliminate the negativity of planned obsolescence is discussed.

Keywords
Industry 4.0, Fourth Industrial Revolution; Planned Obsolescence, Digital Revolution; Technology Revolution, Nine pillars

1 Introduction

1.1 Definition and Evolution of Industry 4.0

The term Industry 4.0 was coined by the German Federal Government as a paradigm shift from centralized to decentralized smart manufacturing and production. Germany Trade and Invest (GTAI) further adds that Industry 4.0 refers to the technological evolution from embedded systems to cyber-physical systems (CPS) – technologies that bring the digital and physical worlds together to create networked world in which intelligent objects communicate and interact with one another. Industry 4.0 represents the fourth industrial revolution which we are currently experiencing, following in the footsteps of the first revolution (Industry 1.0), which happened in the 18th century and was linked to mechanical production and water/steam power; the second (Industry 2.0), took place at the beginning of the 20th century and characterized by mass production made possible by the use of electricity; the third (Industry 3.0), happened in the mid of 20th century and characterized by computers and the internet. Smart products are an inherent part of this industrial revolution. These products are embedded with sensors, identifiable components, and processors which carry information and knowledge to convey the functional guidance the cus-
tomers and transmits the uses feedback to the manufacturing system (Qin et al., 2016). Main objectives in Industry 4.0 generally are automation, production or productivity improvement and process improvement, specifically are innovation and transition to new business models and revenue sources with information and services. Industry 4.0 will change the competitiveness of companies and regions, change traditional production among customers, suppliers, and producers to customized production, besides changing the relationship between human and machines and inevitably increasing efficiency and productivity on the way to its enabler technologies. The nine pillars of Industry 4.0, the enabler technologies, will transform isolated and optimized cell-type production into an interconnected autonomous production flow where the technologies can communicate and cooperate amongst and across each other (Vaidya et al., 2018). Changing the relationship between humans and machines, industry 4.0 have different meanings for different individuals. For customers, Industry 4.0 offers more customized products and services that meet their needs. On the other hand, for employees, Industry 4.0 means new training needs due to the shifting demands for workforce enabled by new technologies. Computer Integrated Manufacturing (CIM) was the most prominent concept of integration of industry. CIM system is the integration of production technology, communication and computer equipment that is installed in the organizational unit of the enterprise but it can also be observed as a mark of quantity of business partners in the observed companies (Hozdić, 2015). CIM and Industry 4.0 are mainly separated from each other in terms of human role in production environment and flexibility in production. Industry 4.0 has an important role of human worker in performing the production whereas CIM considered workerless production (Thoben et al., 2017).
2 Nine Pillars of Industry 4.0

2.1 Autonomous Robots

Using robots in manufacturing is not new, robots have been deployed for executing routine and repetitive tasks, requiring sophisticated programming for setup and implementation, while lacking the agility to easily adjust operations. As autonomous robots become handling more complex jobs, set up times are decreasing, they require less supervision, and they are able to work safely together with humans and learn from them. The benefits are expanding as autonomous robots become capable of working throughout the day with more stable levels of quality and productivity, performing tasks that humans cannot, should not, or do not want to do. Some benefits of autonomous robots in manufacturing as follows:

- Reduced error rates
- Improved safety for employees in risky jobs
- Increased efficiency and productivity

For example, Kiva offers robots that automate the picking and packing process at large warehouses. According to a note published by Deutsche Bank, Kiva robots have cut operating expenses of Amazon by about 20%, which is roughly $22 million in cost savings for each fulfillment center (Kim, 2018).

- Increased revenue by customer satisfaction
- Enhanced employee value through focus on strategic work instead of ordinary tasks

For instance, drones are useful when managing inventory scattered across different locations because they can recognize products that are out of place and product counts. Also, drones can be flown directly up to the shelves to scan barcodes which is much more efficient than having someone riding up and down on a forklift doing the same job.

Autonomous robots can vary, from robotic process automation to flying vehicles with artificial intelligence (AI), considerably in size, ability, mobility, intelligence, and cost. Autonomous robots can recognize and
learn from their surroundings and make decisions independently. With AI and automation being more integrated into industry, problem solving and learning analytics will make robots more responsive with minimal human feedback. Facial recognition software is making leaps in detecting movements in eyebrows, eyelids, retina and lips; through these sensors, combined with audio recognition software that recognizes changes in tone, pitch, and volume, autonomous robots can detect frustration, urgency, or approval, and in turn, adjust actions to modify behavior based on live interactions (Deloitte, 2017).

2.2 Big Data and Analytics

Through analysis of the increased quality and quantity of data collected from technologies like IIoT, robotics, digital twins, additive manufacturing and augmented reality, real-time decision-making is supported. Without regard to the industry in which it is used, indubitably the world of devices is becoming much more connected that it becomes a source of data and information for industrial intents. By creating scenarios that are complex to imagine even today, the potential uses for data once analyzed within its definite industry of origin can be augmented when data from various fields are associated. According to Forrester’s definition, big data consists of four dimensions:

- Volume is simply defined as the large data-sets consisting of terabytes, petabytes, zettabytes
- Velocity is the speed of increase in big data volume and its relative accessibility
- Variety is used to define the different data types, categories and associated management of a big data repository
- Value is the extracting knowledge from vast amounts of structured and unstructured data without loss, for end users (Sivarajah et al., 2017).

Big data analytics includes statistical algorithms, what-if analysis powered by high-performance analytics systems, and complex applications with components like predictive models, can be evaluated as advanced analytics. By using big data analytics, manufacturers are able to uncov-
er new information and identify patterns that provide improved processes, increased supply chain efficiency and identified variables that effect production. Some use cases of big data in manufacturing are as follows:

- **Improved processes**
  For example, a biopharmaceutical company, used big data analytics company’s project team assessed process and identified nine parameters that had a direct impact on vaccine yield. By modifying target processes the company was able to increase vaccine production by 50 percent resulting in savings between $5 and $10 million annually (Auschitzky et al., 2018).

- **Enhanced Quality Assurance**
  Using big data for predictive analytics Intel was able to significantly reduce the number of tests required for quality assurance. It resulted by saving $3 million in manufacturing costs for a single line of Intel Core processors (Bertolucci, 2018).

- **Customized Product Design**
  Using big data analytics Tata Consultancy Services was able to analyze the behavior of repeat customers. The outcome is critical to understanding how to deliver goods in a timely and profitable manner (Burgess, 2018).

- **Machine Maintenance**
  Information can constantly be collected from machines to help organizations in determining when and how intense a specific machine maintenance is required by using sensors. With big data analytics manufacturers can keep track of their machines by continuously analyzing and discover how to improve the efficiency of them.

### 2.3 Simulation

Simulation is an acceptable tool for evaluating and predicting the performance of complex probabilistic systems that are analytically intractable. Rapid growth in computing power and simulation optimization have made the usage of simulations possible to optimize the design and operations of systems precisely. However, the arrival of Indus-
try 4.0 has brought changes to the simulation modelling. The Industry 4.0 paradigm requires modelling of manufacturing and other systems via the virtual factory concept and the use of advanced AI (cognitive) for process control, which includes autonomous adjustment to the operation systems (self-organization) (Rodič, 2017). The new simulation modelling paradigm is best inferred by the concept of digital twin. The concept of digital twin was firstly presented by Grieves at one of his presentation about PLM in 2003 (Grieves, 2014). A digital twin can be defined, fundamentally, as an evolving digital profile of the historical and current behavior of a physical object or process that helps optimize business performance (Parrott & Warshaw, 2014). Unlike traditional simulation modellings, digital twin provides connectivity and integration in a far-reaching information system, richer models that return more realistic and holistic measurements of unpredictability, and construction and modification of models data-based to the highest degree. It is in the list of Gartner’s Top 10 Strategic Technology Trends for 2019. In the context of Internet of Things (IoT), the concept of digital twin has become economical to implement. According to Thomas Kaiser, SAP Senior Vice President of IoT: “Digital twins are becoming a business imperative, covering the entire lifecycle of an asset or process and forming the foundation for connected products and services. Companies that fail to respond will be left behind.” Increased collaboration of digital twins and IoT enables data driven decision making, automated business processes, and creating new business models. For example, IoT keeps data flowing which links digital twins to real-world objects. Thus, prediction of the physical counterpart’s performance analysis, answering to changes are provided. Stara, Brazil-based tractor manufacturer used digital twins to create new business models. With the wealth of IoT sensor data, the company launched a new profitable service that provides farmers with real-time insight detailing the optimal conditions for planting crops and improving farm yield. Farmers have reduced seed use by 21% and fertilizer use by 19% through Stara’s guidance (Ohnemus, 2018). Another example of company winning with digital twin technology is Kaeser, a U.S. manufacturer of compressed air products. To date, the company has cut commodity costs by 30% and on-boarded 50% of major vendors using digital twins (Ohnemus, 2018). The company used digital twins to change from sell-
ing products to selling services. Instead of installing equipment at a customer’s site and leaving operation to the customer, Kaeser maintains the asset throughout its lifecycle and charges fees based on air consumption rather than a fixed rate. A digital twin network enables the company to monitor the condition of its equipment around the clock and measure customer air consumption. Real-time asset data helps Kaeser ensure equipment uptime and charge an accurate amount of money each billing cycle.

2.4 System Integration

Integration (revolutionary short value chain) and self-optimization (to improve beyond the theoretical boundaries therefore to become better as expected) are two major mechanisms on the production side (Schuh et al., 2014). Some integration examples from real life are as follows:

– Vertical Integration (Kenton, 2018):
  Apple Inc. manufactures its custom A-series chips for its iPhones and iPads and custom touch ID fingerprint sensors. In 2015 opened a laboratory in Taiwan for developing LCD and OLED screen technologies and paid $18.2 million for a 70,000 square foot manufacturing facility in North San Jose. These investments allow Apple to move along the supply chain in a backward integration, giving it flexibility and freedom in its manufacturing capabilities.

– Horizontal Integration (Tarver, 2018):

– Facebook, looking to strengthen its position in the social sharing space, saw the acquisition of Instagram as an opportunity to grow its market share, reduce competition and gain access to new audiences. All of these things came to pass, resulting in a high level of synergy.

– End to End Integration (Kenton, 2018):
  In the petroleum industry, transport and logistics companies offer customers flexible and cost-effective end-to-end services, from order planning to inventory monitoring, loading and transportation, to delivery. This includes supplying fuel and lubricants to service stations, aviation fuel to airports and bitumen to the asphalt industry.
Companies, departments, functions, and capabilities will become more cohesive through Industry 4.0, as cross-company, universal data integration networks evolve and enable truly automated value chains (Rüßmann et al., 2018). The paradigm of Industry 4.0 is essentially outlined by three dimensions (Stock & Seliger, 2016):

- **Horizontal Integration across the entire value creation**
  Describes the cross-company and company-internal intelligent cross-linking and digitalization of value creation modules throughout the value chain of a product life cycle and between value chains of adjoining product lifecycles (Stock & Seliger, 2016).

- **Vertical Integration and networked manufacturing systems**
  Describes the intelligent cross-linking and digitalization within the different aggregation and hierarchical levels of a value creation module from manufacturing stations via manufacturing cells, lines, and factories, also integrating the associated value chain activities such as marketing and sales or technology development (Stock & Seliger, 2016).

- **End-to-End engineering across the entire product life cycle**
  Describes the intelligent cross-linking and digitalization throughout all phases of a product life cycle: from the raw material acquisition to manufacturing system, product use, and product end of life (Stock & Seliger, 2016).

The full digital integration and automation of whole manufacturing processes in the vertical and horizontal dimension implies as well an automation of communication and cooperation especially along standardized processes (Erol et al., 2016).

### 2.5 Cybersecurity

With the increased connectivity and use of standard communications protocols that come with Industry 4.0, the risk of cyber threats and cyberattacks increased dramatically. The risk is expanding while connection is increasing day by day. It is estimated that 20.8 billion IoT devices will be deployed around the world by 2020 (Gartner.com, 2018). Many of these devices may be used in manufacturing facilities and production lines, but many others are expected to be in the market-
place where customers, whether B2B or B2C, can purchase and use them (Waslo et al., 2017). As a result, it is crucial for companies operating in Industry 4.0 to focus on security. Developing a fully integrated strategic approach to cyberattacks is fundamental to manufacturing value chains as they unite operational technology (OT) and information technology (IT) (Waslo et al., 2017).

According to the study conducted by Deloitte and MAPI (the study was informed by 35 executive interviews and 225 survey responses collected) about cyber risk in advanced manufacturing the six key themes and what manufacturers should do (Huelsman et al., 2016):

– Executive and board level engagement
  Set up a senior management-level committee with board member representation dedicated to issue cyber risk.
  Set up escalation criteria to include board members and review cyber breach incident management framework.

– Talent and human capital
  Set up a cross-functional team of key stakeholders in the cyber program, including IT, OT, R&D, Finance, and Risk.
  Perform regular internal phishing tests as an assessment and tool of awareness to help employees better identify these attacks when they occur.
  Implement threat, behavior and audience-based, concise learning programs with active user engagement to maximize attention and retention.

– Intellectual property
  Extensive data protection strategy, executive support, and investment of time, talent, and funding is required to protect sensitive data.
  Organizations may also need to make some strategic business decisions based on the risk tolerance.

– Industrial control system
  Create an inventory of connected devices including industrial control systems that are attached to those network segments.
  Organize a cross-functional security team that includes representatives from global information security, engineering, and operations.

– Connected products
Before releasing, make sure accessing the value-added for new connected product functionality.
Sustain an open line of communication with legal.
Determine if cyber threat monitoring and simulations or resiliency exercises are comprehensive enough to cover top cyber risks.

– Industrial ecosystem
For third-party cyber risk management up front in key contacts requirements defining. Augmenting monitoring and assurance activity over third parties could considerably reduce cyber risks.
Progressively shifting from focus on cost to a focus on value of the drivers for third-party alliance.

2.6 The Industrial Internet of Things (IIoT)

The Industrial Internet of Things (IIoT), also known as Industrial Internet, is the network of a multitude of industrial devices connected by communication technologies that result in systems that can monitor, collect, exchange, analyze, and deliver valuable new insights, which can help drive smarter, faster business decisions for industrial companies (Ge.com, 2018). The Internet of Things (IoT) means a worldwide network of interconnected and uniform addressed objects that communicate via standard protocols (Hozdić, 2015). The term IIoT is often encountered in the manufacturing industries, referring to the industrial subset of the IoT. It also goes beyond machine-to-machine since it not only focuses on connections between machines but also includes human interfaces (Lueth, 2015). While IoT and IIoT have many technologies in common, like the cloud, sensors, connectivity, machine-to-machine communications and data analytics, they are separated according to their purposes. Manufacturers worldwide are connecting their machines to the cloud and developing their own IIoT to scratch the surface of untapped potential, which promises exponential growth and enormous scalability for their business. For instance, Airbus has integrated sensors to tools and machines on the shop-floor and has given wearable technology to workers, including industrial smart glasses, designed to reduce errors and support safety in the workstation. In one process, known as cabin-seat making, the wearables en-
abled a 500% improvement (Accenture.com, 2018) in productivity while nearly eliminating errors.

While cloud computing is a major enabler of industrial transformation, edge computing is rapidly becoming a key part of the IIoT equation to accelerate digital transformation (Ge.com, 2018). Edge computing refers to a computing infrastructure that exits close to the source of data. The role of edge computing is packing more compute, storage, and analytic power to consume and act on the data at the machine location which is remarkably valuable to industrial organizations. For example, Intel CEO Brian Krzanich, estimates that autonomous cars, with hundreds of on-vehicle sensors, will generate and consume 40TB of data for every eight hours of driving. Because the sensing, thinking, and acting attributes of edge computing in this case must be done in real-time with the lowest latency to ensure safe operation for passengers and the public, it is unsafe and impractical to send that big amount of data to the cloud. The terms IIoT and Industry 4.0 are mostly used alternatively. Despite referring to identical applications and technologies these two terms have different meanings. First of all, Industry 4.0 is associated with governmental and institutional initiatives involving academic world, private businesses and the German Federal Government. Second, Industry 4.0 is mainly focused on the manufacturing sector, whereas the IIoT is much more focused on giving acceleration and empowering the approval of technologies connected to the internet over industries. Third and the last one is, that Industry 4.0 is not only about the connection of data management and assets but also the entire value chain digitization.

2.7 The Cloud

Industry 4.0 increased the need of implementation of cloud solutions since many of technologies that form the foundation of Industry 4.0, like digital twin, IIoT and big data analytics, require data sharing across companies, sites, and machines. With compute, storage and networking capabilities, cloud offers an environment to adopt new technologies. Based on service model cloud can be categorized as:
Software as a Service (SaaS) is a model which allows the clients to use and rent the applications without installing and executing it on their computer (Bokhari et al., 2018).

Platform as a Service (PaaS) delivers the services in the form of development tools, framework, architecture, programs, and Integrated Development Environments (IDE) (Singh et al., 2016).

Infrastructure as a Service (IaaS) provides computing resources such as processing or storage which can be obtained as a service (Pati-dar et al., 2012).

Anything as a Service (XaaS) is a service model that may be anything or everything as a service like Security as a Service, Communication as a Service, or Database as a Service and so on (Kumari & Kaur, 2018).

Based on a deployment models, cloud can be classified as:

- **Public Cloud**: Allows the general public to access the system and services offered by an enterprise provider (Saikia & Devi, n.d.).
- **Private Cloud**: The cloud resources and services can be accessed or used inside an organization without the restrictions of network bandwidth, security exposures, and legal requirements that using public cloud services across open, public networks might entail (Rimal et al., 2009).
- **Hybrid Cloud** is a composition of two or more clouds (private, community, or public) allowing data and applications to be shared between them while preserving their separate identities (Savu, 2011).
- **Community Cloud** is the cloud infrastructure that shared by several organizations and supports a specific community that has communal concerns (Zissis & Lekkas, 2012).

Based on recommendations from the National Institute of Standards and Technology (NIST), an ideal cloud should have five characteristics: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. Industries can use the cloud platform to run their applications, optimize their business processes, and yet gain visibility into the data and analytics that inform their next actionable insight. Some of the advantages provided to the cloud manufacturers are:
- Agility
  Cloud based systems are making it easier for manufacturers to keep up with new developments than traditional systems. They also offer the potential to increase adoption rates across sellers and customization is easier with them.

- Security
  According to The Cloud for Manufacturing report by Microsoft and Invensys (2014), cloud-based system using manufacturers do not need to grant suppliers direct access to their internal network. You can preserve your internal systems while improving your collaboration with suppliers.

- Saving
  Again according to The Cloud for Manufacturing, cloud-based manufacturing solutions can reduce up to 54% of the costs relating to IT infrastructure, maintenance and lifecycle for both new and existing operational or process improvement projects.

- Scalability
  With cloud computing, it is possible to customize your technologies depending on your needs. Based on the bandwidth demands, cloud capacity is easy to scale up or down.

2.8 Additive Manufacturing

Additive Manufacturing (AM) is the process of joining materials to make objects from 3D model data, usually layer by layer. Although the terms 3D Printing and Rapid Prototyping are casually used to discuss additive manufacturing, each process is actually a subset of additive manufacturing (GE Additive, 2018).


- Material Jetting (MJ): A print head moves back and forth on x-, y-, and z- axes to create 3D object.
- Binder Jetting (BJ): Similar to MJ, except that the print head lays down alternate layers of powdered material and a liquid binder.
Material Extrusion (ME): Material is selectively pushed out through a nozzle or orifice
Directed Energy Deposition (DED): Focused thermal energy melts materials during deposition.
Powder Bed Fusion (PBF): Thermal energy fuses a small region of the powder bed of the build material.
Sheet Lamination (SL): Sheets or foils of materials are bounded
Vat Photopolymerization (VP): Liquid polymer in a vat is light-cured

With Industry 4.0, AM technologies like 3D Printing will be widely used to produce smaller batches of customized products that offer construction advantages, such as complex, lightweight design. According to Additive Manufacturing: Strategic Research Agenda (2014) Summary of some potential benefits of AM is as follows (Tofail et al., 2018):

- Reduction of waste production
- Direct conversion of components or shapes to physical parts
- Without additional manufacturing or tooling cost, generating parts with greater customization.
- Ability to design for function rather than for manufacture
- Reduction in overall manufacturing and production development time leading to quicker transfer to market
- Production of lightweight structures enabled by flexible manufacturing
- With minimal to no additional processing, ability to direct production of a component to their final (net) or near final (near net) shape.
- Smaller operational foot-print towards manufacturing
- Great scalability
- Rather than projection-based manufacturing, on-demand manufacturing is provided.

While the focus was mostly on the consumer side, there is an example that will show 3D printing’s potential in industry. MIT have created 3D Printed graphene which is lighter than air and 10 times stronger than steel also only one atom thick (Mearian, 2017). If it can be enlarged, it could help to lightweight products such as aircraft, cars and filtration.
devices, saving huge amounts of fuel, costs and carbon emissions (Scott, 2017).

2.9 Augmented Reality

Augmented Reality (AR) is the technology that extends our physical world by adding digital information onto it. Unlike Virtual Reality (VR), AR does not create totally artificial environments to replace real with a virtual one. By adding sounds, videos, graphics, AR appears in the view of an existing environment. AR can be displayed on devices like screens, handheld devices, glasses, mobile phones, head-mounted displays involving technologies like SLAM (Simultaneous Localization and Mapping), depth tracking (briefly a sensor data calculating the distance to objects), and the following components:

- Cameras and sensors: Sending data collection of user interactions for processing.
- Processing: Measurement of speed, angle, direction, orientation in space and so on. This requires a CPU, a GPU, flash memory, RAM, Bluetooth/Wi-Fi, a GPS, etc.
- Projection: Viewing of digital content (result of processing) onto a surface.
- Reflection: To perform a proper image alignment some AR devices have mirrors to assist human eyes to view virtual images.

AR can help manufacturers provide visual, real-time information to the right person at the right place and right time. Also, this technology will lead to reduction in defects introduced during service and maintenance, and the time spent on training of new employees (Kadir, 2017). Some real-life examples on usage of AR technologies in industry:

- The Vuzix M2000AR displays content from a connected device over a video stream of real-world content, which could be perfect for managers or employees who need to access technical data or repair procedures while in fields (Neagle, 2013).
- IBM’s Augmented Reality Shopping Assistant scans shelves at retail stores and provides product information, reviews, offers and suggestions of other items customers might like.
Retailer IKEA has found that 14 percent of its customers end up taking home furniture which turns out to be the wrong size for its intended location. Therefore IKEA uses augmented reality on its catalogues to give a virtual preview of furniture in a room.

NGrain’s augmented reality app is a good investment for businesses that need to train employees on industrial equipment. Viewing a piece of equipment through an iOS device, 3D/2D graphical overlays walk the user through the steps, creating a learn by doing training experience.

3 Positive and Negative Effects of Innovations Brought by Industry 4.0

The fourth industrial revolution deeply affects all sectors and causes significant changes. These changes can be counted as the emergence of new business lines, the deterioration of traditional institutions, production, consumption, transportation, education, health and shipment. In addition to this there are notable changes in the social fields, business life, communication habits, information and entertainment style. These changes created by the technological revolution naturally force governments and institutions to change. The complexity and interdependence of this rapid and intense change in human history; all social classes of the global community, companies, governments, academics, non-governmental organizations required to work together and find the least common denominator. Thus, it has created a collective future which reflects common target and worth. The desire to create a collective future will be effective in destroying the consequences of the fourth industrial revolution because of the basics and global nature of revolution of technology’s effects on economies, people and different commercial and industrial sectors of countries worldwide. The extent and scope of the change created by the fourth industrial revolution considerably effects the speed, development and spread of innovation. Today the companies such as Uber and Alibaba which are in the limelight were not that popular until a few years ago. Smart phones and completely autonomous cars were only dreams in 2000s. Thanks to the technology revolution, activities such as calling a cab, buying a product, rendering payment, watching a movie or listening to music can be
made remotely. Similarly, smart phone, internet and many applications like this enable us to be more productive by making our life easier. Despite these developments on behalf of consumers, negative results are observed in the production and business world. The automatization which came with digitalization helps us so that we make more money with less work. The reason for this is to get the marginal cost towards zero in digitalized companies. At the beginning of the 21st century, there was a substantial decrease in the rate of labor in the gross national product of developed countries. In the economy of developing countries, the introduction of innovations brought by the technological revolution will cause companies to move towards replacing the labor force with capital. This situation shows the importance of analyzing the positive or negative effects of the fourth industrial revolution on our lives as it will cause millions of workers to become unemployed. In order to help understand these impacts, Klaus Schwab, the President of the World Economic Forum in Davos Klosters, wrote a book, which lasted for 3 months, with a very broad participation, in order to serve as a catalyst for their discussions and partnerships at the 2016 annual meeting to deal with the fourth industrial revolution. The president thought that with his book, he can create means to exchange ideas on using 4th Industrial Revolution for everyone’s benefit in Annual New Champions Meeting in Tianjin, China by convincing the partners to reach a consensus on a regulation to lean onto and hence throw disciplinary light on research, technology and commercialization studies in June 2016. We have to go deeper into the relation and ties to understand the benefits of Industry 4.0 Technology Revolution. If the progress in the technology of sensors, AI and such had not been staged, cars, trucks, drones, planes, ships and other machines would and could not have reached their current status. Namely, when drones are used together with data processing techniques, they will enable the agricultural means to use fertilizers and irrigation with higher efficiency. Due to the development of new age sensors, robots are now used not only in restricted areas but also all agricultural aspects, nursing and rehabilitating humans, house care and many other areas. In the earlier phases, they had to be programmed by specialized people but nowadays we can get software and all other information via the cloud system and hence link to other robotics networks. This, naturally, gives alarm for
future ethical and psychological relations between humans and robots. This is an area full of risks. As a result of the progress covered in digital applications, internet platforms and technologies which bind humans and things provided us notable efficiencies. Life is made easier in contemporary times because smaller, cheaper and more intelligent sensors are used in houses, city life, clothes, accessories during manufacturing processes. Another example to show the step digital evolution has reached is blockchain. Blockchain is a ledger used for and by cashiers which are programmable, cryptography safe and reliable technology and its most popular application is bitcoin concept which we call as digital money. Uber, Alibaba and Airbnb companies can be named as examples of digital evolution (Schwab, 2016). Uber, the biggest taxi company, does not have a single vehicle owned by it. The world’s biggest retail company Alibaba does not keep any level of inventory and again, the world’s biggest accommodation company Airbnb does not own any facility. The company named above get in contact with their customers via digital platforms and provide service. Innovations in genetic science present extraordinary progress. Human Genome Project, which was completed in 10 years with a budget of 2.7 billion dollars states the genome series of a human being in 1 hour for a price of 1,000 dollars (Wetterstrand, 2015). Since this Project may cause producing babies upon order in the future, it is bound to produce medical, ethical and psychological problems. Klaus Schwab provided strong financial support to the programs run by the countries which would enable new horizons and innovative technical applications and by doing this planned to incite both business and Academic environments. In addition to this, he also states that countries should take steps to direct and organize collaborations of state and private sectors to enable knowledge and human capital to be used for the benefits of human race. He advocates this argument by putting forward the inefficiency of Carnegie Mellon University research works and hence jeopardizing the contract they signed with the state and other companies after Uber Technologies transferred 40 researchers working for the university’s robotics laboratory (Ramsey & MacMillan, 2015).
3.1 Companies and Overall Economy

One of the essential elements of Technology Revolution is raising and improving talents and thus making the benefits of the companies for the better out of Industry 4.0 which are open to change and progress. The human factor to be employed for this purpose should believe and have the cultural bases for innovation, open to education and training, quick in reaching right decisions and invest in themselves for the better. What happens to companies lacking this culture may be seen by glancing at S&P 500 list and see that average life-span of such companies decreased from 60 to 18 years (Knight, 2014). To prolong the life-span of companies; they have to make use of global digital platforms in the right way and improve marketing, research and development, sales and distribution abilities by throwing more attention to speed up these services, improve their product quality and prices. Companies which feel strong currently because of their end of the year figures are bound to realize that the advantages they have by then will not and cannot sustain their power for long. They will either accept and apply the innovations brought by technology revolution and follow the line or develop new business means in their adjacent marketing environment or seek for new business areas in other sectors. All these show that companies are forced to question and analyze their existing management procedures and naturally the managers themselves and seek for new business methods and models. This requires continuous innovation. Number one factor which brings selling means to a product is correct analysis of customer requirements. Data collection is of utmost importance for this. Information sharing gets more important every day and to acquire this, data sharing is more important than investing in real estates. Colossal amounts of data and hence information acquired by big data on personal tendencies, sectoral direction, life-styles and personal behaviors of the community create highly important sources for product development projects. Efforts to make best out of these data inevitably push decision makers to continuous personal improvement and get into self-critics and thus be wide open for new developments.

Contribution of digital revolution to growth of the companies did not affect growth of global economy. Global economic growth of 5%...
till 2008, the year economic crisis commenced; decreased to 3.5% which is below the amount of post-war times. (Schwab, 2016) The striking aspect of global development is the stagnation of manufacturing. The dramatic result of this decrease was the moderation of manufacturing speed. Global productivity rate in labor and in total factors did not react positively to the progress made in technology and the exponential increase in innovation. The most important indications of long-term growth and higher life standards is productivity rate remained the same against the fact of progress made in technology and investments in innovations and there is still no satisfactory explanation to this contrast. In this context, should we agree with the technopessimism which states that the end of the positive contributions of Industry 4.0 have long been past and hence their positive effect on productivity? Another factor which corroborates this point of view is what we see in unemployment rates. Debates on the effect of technology progress on employment had started during Industry 3.0. Economist John Maynard Keynes in 1931 pointed out “Due to our discovery of means of economizing the use of labor outrunning the pace at which we can find new uses for labor” (Keynes, 1931). This viewpoint was not proved right at those times, but when we consider the infiltration depth, width and speed of Industry 4.0; plus the help provided by digital revolution, the risk of unemployment of cashiers, book-keepers and telephone operators has increasing supporters today. People opposing this view state that the rate of labor in USA Agriculture was 90% at the beginning of the century, but only 2% currently (Schwab, 2016) and that this decrease covered distance quite smoothly with minimum social deficiency and caused widespread unemployment and that effects of Industry 4.0 would decrease in time and stabilize in the future like its predecessor. In addition to all of these; since technology revolution will increase the demand on new products and services, there will be new business areas and new employment demand for them which would decrease the negative effect it. The studies on the effects caused by technology revolution show that the distance covered has got negative effects on labor force. According to the report produced by USA Economic Growth Office; innovations on information technologies and productivity raised by Industry 4.0 technologies use existing labor force by modifying the character and employment areas instead of pro-
ducing new products which would require more labor force. Economist Carl Benedict Frey and machine expert Michael Osborne realized a research in 2013 on 702 different lines of profession to being subject to automation showed that 47% of total employment in USA is under risk in the next 10 to 20-year time (Frey & Osborne, 2013). It also showed that employment will increase in high salary information jobs and innovative products and also in low-salary manual tasks but will decrease in great scale in medium salary jobs of routine, monotone and repeating processes.

3.2 Managers and Employees

Industry 4.0 brings considerable changes in relations between the managers and employees. Employees can obtain knowledge because of means provided by digital revolution and increase their communication abilities while the managers, especially state bureaucrats must be cautious in using their authority. The reason for his is that people can come together easier due to digital revolution and can put up non-governmental organizations (NGO) and by these institutions can affect the political power in great scale. Level of power reached by the employees to affect the decisions is considerably higher than before and consequently the decision makers should accept that the managing power does not flourish from the state only but also from non-governmental players and thus should build their new managing system on transparency and accountability basis. Moises Naím (2013) said “In 21st Century, achieving power is easier than using it and it is quite easy to lose”. We can deduce out of this citation that micro-power sources can restrict power of macro-power sources by the means provided by the digital revolution and the people in power may lose their potential easily. While decision makers try to adapt themselves to the new and high-speed changing medium; the employees should create political instruments in order to contribute to the decision which are bound to effect themselves. Employees have been struggling to restrict the managing power on them since Magna Carta, 1215; and the fruits of this struggle will reach its summit by this way. The techno-optimist view is summarized in here but techno-pessimists put forward that the man-
aging class may increase their auditing and controlling power on the working class by the potential provided to them through digital revolution.

### 3.3 Countries, Regions, Cities and Transnational Relations

The unlimited effects of the digital revolution require re-adaptation of cities, regions, countries and transnational relations. It is understood that USA and Western Europe will assume the locomotive power in this adaptation process, just like they did in the other industrial revolutions. However, this time also China, Russia, India and Japan will make significant contributions. The fact that whether the innovations came along with the Industry 4.0 will create further and more efficient collaboration within or among the countries shall be determinant for societies of having a better future. For this reason, countries and regions that can achieve to provide common norms in economy’s efficient sectors such as 5G communication, IoT or digital health shall be able to increase their welfare levels through the economic and financial benefits they will gain. On the other hand, countries creating their own norms, blocking the foreign competitions and limiting the foreign technology transfers in order to provide benefits for their own local producers shall fall behind with regards to increasing their social welfare due to the risk of being unable to utilize properly the benefits brought by the digital economy. In summary, the companies from countries which internalize the technological revolution by carrying out regulations facilitating innovations are becoming a center of attraction vis-a-vis the best talents in other countries. Thus, they will accomplish an increase in competitive power, just like as in the creativity factor, by easily incorporating them into their own companies. Considering the fact that the companies in question are not from economically strong countries, it is easily understood that they will take control of even a bigger portion of the world’s and venture capital. The more effects of the digital revolution on the global economy increase, the more the significance of presence of a reliable internet infrastructure increases in terms of economic development. Reliable internet is important for countries not only for their domestic transactions but also the
transnational transactions. Just like it got easier to access data through internet, big data provided enormous increase in the storage capacities. In this case, ensuring security of the personal data and company’s internal information is essential. Such a security can be accomplished by countries through gathering together and creating data rights and data protection norms. Furthermore, countries had to add a new unit called the command of cyber security into their armed forces in order to ensure the security because the countries now are using also cyberattacks to harm their enemies in addition to the classical ground and naval attacks or the air strikes. These cyberattacks sometimes target the public institutions or private companies, as well as the security units. However, ironically, these cyberattacks created a new employment area. Creation of cyber security units by the companies, just like the countries, for their own security is another line of work brought by this fourth industrial revolution. The importance of cities has significantly increased in 20th century since the population density has escalated with the industrialization. Today, more than half of the world populations is living in the cities. The accessing opportunities within the cities to the information and communication technologies which are most important bases for the fourth industrial revolution affecting the competitive power shall definitely have an impact on development of the countries and regions. Therefore, as the methods and infrastructure required for creation, collection, transfer and usage of data are developed further, a number of additional skills, such as tracking epidemics, finding efficient solutions for natural disasters, easy access by the poor to the financial opportunities and public services, and understanding immigration patterns of the sensitive populations, which will contribute to development of cities will be gained (World Economic Forum, 2015). Thus cities that became center of attraction shall make great contributions to the welfare levels of the relevant countries and regions. The biggest threat for the cities which cannot keep up with the innovations brought by the technological revolution shall be the negative effect that will be created by being helpless in the face of enormous competitive power advantage created by innovation power of the competitive power they have in terms of labor and intense production of goods and services. This may cause a serious destruction especially for developing countries and regions.
3.4 Individual and the Society

According to sociologist Manuel Castells, professor of communication and society: In all moments of major technological change, people, companies, and institutions feel the depth of the change, but they are often overwhelmed by it, out of sheer ignorance of its effects (Castells, 2014). This opinion reveals the problem of harmonization between the conventional values and values brought by the modernity. If such a harmonization is not ensured, then the tension especially between societies under deep influence of religious beliefs and values and the societies focusing more on the secular values will escalate more. Today, the main reason for the radical groups becoming so strong on a global scale is the increase of this tension. Today, starting a business in the digital economy with a less capital became possible since the robots and algorithms, which are among the innovations brought by the technological revolution, substantially replaced human beings in the production process. When the digital economy highlights efficiency of the most skilled people who are few in numbers, this will prevent the low-skilled people from benefiting from industry 4.0’s advantages and increase the inequality at the same time. The researches made show that more than half of the world’s wealth is being controlled today the richest 1% of the global population, while the other half of the global population altogether possess less than 1% of the global wealth (Credit Suisse, 2015); and the average income of the richest 10% of the population in OECD countries is approximately 9 times of the income of the poorest 10% (OECD, 2011). These facts are very important as they show us the level of inequality in the world. The study made among the OECD countries reveals that the technology is blocking income of the majority of the population also in the high-income countries, therefore such inequality is seen also in these high income countries. The high availability, low costs and geographically neutral aspects of digital media also enable greater interaction across social media, economic, cultural, political, religious and ideological boundaries (Schwab, 2016). This finding shall enable the digitalization users, especially those socially and physically isolated people, to communicate with people thinking in a similar way with them without time and distance limitations. This way, it will also provide an opportunity to contribute to the
creation of the democratic society by giving these societies formed to have an impact on the decision taking processes. The power of the digital media is also open vulnerable against and open to the malicious use by the non-state actors, especially the terror organizations. The highly efficient use of social media by ISIS to recruit soldiers into its organization is the most dramatic example of this evil-minded use. Furthermore, creation of monitoring and surveillance tools by the governments in many countries through using their economic power, which includes putting in place laws that are aiming to suppress and limit actions and freedoms of individuals groups and non-governmental organizations by means of gathering various technologies together shows us that they are trying to eliminate the democratic power of the digital media. The most superior level that the democratic systems could reach until now is the parliamentary system which applies representative democracy. Digital revolution can make great contribution to the direct democracy which used to be applied in the City-States of the Ancient Greece. However, the fact that in the Ancient Greece only the aristocrats had the right to participate in the decision-making process while the slaves were deprived of such right cause the system to be defined as semi-direct democracy. Whereas today, it can be possible to take decisions by enabling citizens to participate in referendums through digital channels and use their direct votes instead of resorting to the representation system. The fact that the election results in USA are declared within a very short period of time, which is only 30 minutes, is providing humanity an opportunity that is very hard to imagine for carrying out the direct democracy.

The various innovations brought by the industry 4.0, such as biotechnology and AI, has significant changes also on our identities as individuals which are forming our thoughts and habits like our right to privacy and development of consumption, working and relaxation patterns or our skills and abilities. Incredible discoveries such as extending lifetimes, designed babies, deletion of memories from the brain can create positive but also negative effects at the same time. Stephan Hawking and his scientist friends, Stuart Russell, Max Tegmark and Frank Wilczek (2014), state that the short-term effect of AI will depend on who is controlling it while the long-term effect of the AI will depend on whether it is controllable or not; this statement is very im-
important for indicating the danger we are facing. Another interesting research conducted by MIT’s Sherry Turkle shows us the dangers we are facing in terms of human relations. According to this study, 44% of the teenagers remain constantly online while doing sports and when in company with their friends or family. This factor designates that, due to the elimination of face-to-face interaction, these teenagers consumed by the social media will face great hardships in future while listening to each other, making eye contact and reading body language.

4 Overview of Planned Obsolescence

4.1 Definition and History of Planned Obsolescence

In industrial design and economics planning or designing a product with an artificially limited useful life, so that it will become obsolete (out of date or no longer functional) after a certain period of time is a policy named planned obsolescence (Bulow, 1986). Some other symbolic definitions of planned obsolescence:

According to Stewart (1959), planned obsolescence indicates the practice of holding back product improvements from the market until sales of existing models decline, then employing just enough improvements in new models to induce consumers to turn in their old models. It also suggests a heavy reliance on superficial product changes, styling, or prestige selling appeals to induce consumers to buy a new model before the old model is worn out. It is the execution of a policy of producing products with an unnecessarily short functional life so as to require premature replacement (Kupfelwieser et al., 2018). Packard (1960), elaborated planned obsolescence as obsolescence of function, obsolescence of quality, and obsolescence of desirability in his book of “The Waste Makers”. According to White (1969), planned obsolescence is the creation in people's minds of the belief that the economic usefulness of a product has declined well before any actual physical decline (Kupfelwieser et al., 2018). The production of goods which are less durable than would arise out of production by perfectly competitive industries (Swan, 1972). Many products are designed to have uneco-
nomically short lives, with the intention of forcing consumers to repurchase too frequently (Fishman et al., 1993). The behavior of a firm that underinvests in durability from a social-welfare standpoint (Waldman, 1996). Monopolist’s choice for an inefficiently short life for first-period products (Utaka, 2000). Brooks Stevens (1954), who coined the phrase planned obsolescence, defined planned obsolescence as instilling in the buyer the desire to own something a little newer, a little better, a little sooner than is necessary (Adamson & Stevens, 2003). Obsolescence occurs when products become “out of use” or “out of date” (Cooper, 2004). Planned obsolescence represents continuous product development promotes shorter durables replacement and disposal cycles with troublesome environmental consequences (Guiltinan, 2008). Strausz (2009) proposed planned obsolescence as an incentive device that benefits consumers. The strategy of shortening a product’s lifespan is called planned obsolescence (Rivera & Lallmahomed, 2016). Perceived obsolescence is where the users or customers of a product are persuaded to replace a functional product and/or its component because it is seen to be no longer fashionable or suitable (Amankwah-Amoah, 2017). Profit maximization by shortening the replacement cycle is the motive for planned obsolescence (Bidgoli, 2010). The additional sales revenue provided by planned obsolescence creates more than counterbalances the additional costs of research and development, and counterbalances the opportunity costs of reusing an existing product line, considered by producers following this strategy. However, this is a risky policy for competitive industries since consumers may decide to buy from competitors instead when they realized this strategy. In spite of this, some companies persist with keeping up with this policy. The first documented case of planned obsolescence is the light bulb. In 1920s lifespan of a light bulbs was 2500 h (Rivera & Lallmahomed, 2016). While technology made it possible to produce more durable light bulbs, Phoebus cartel (1924–1939) formed by companies such as Osram, Phillips, General Electric, and others to control light bulbs market by limiting the lifespan of light bulbs to 1000 h (Kessler & Brendel, 2016). In 1920s, thanks to Henry Ford automobile market reached saturation. Head of General Motors Alfred P. Sloan Jr. saw an opportunity in this inertia and suggested annual model-year design changes to convince the car owners to buy a new car each year, and
named the strategy as dynamic obsolescence (Grattan, 2016). During the Great Depression, planned obsolescence was presented among the scenarios of resolving crisis. As a result, companies put artificial expiry dates on products in order to encourage consumers to buy more or renew their products (Kuppelwieser et al., 2018). In a paper named Ending the Depression Through Planned Obsolescence (London, 1932) “Furniture and clothing and other commodities should have a span of life, just as humans have,” is written. “They should be retired, and replaced by fresh merchandise. It should be the duty of the State as the regulator of business to see that the system functions smoothly.” During the 1950s to the 1960s, nylon stockings for women had a big success since they were sturdy and resistant (Rivera & Lallmahomed, 2016). Based on the fact that they were long lasting, nylon stockings were modified to tear more easily so that they had to be replaced. Even today nylon stockings do not last more than three or four uses. Seed industry is affected by planned obsolescence of plant breeding. Since plant varieties are easy to reproduce and multiply, and genetic characteristics are heritable, enabling a seed to replicate itself, producers of genetic information face a problem in inducing farmers into regular replacement purchases (Rangnekar, 2002). As a result, the durability of varieties reduced to force farmers buy seeds for every season.

4.2 Types of Planned Obsolescence

In order to obsolete products in a planned way, there are couple of techniques developed by manufacturers and marketers. According to Packard’s definition of planned obsolescence, there are three main ways that products can be made obsolescent. They are obsolescence of function, obsolescence of quality and obsolescence of desirability. However, the process of obsolescence is not limited to these methods. Social, cultural, technological and political factors (such as technology innovation; variation in customer demands; change in existing legislation; social pressures; advancement of knowledge; inflation of currency; civil unrest or conflict of interests; etc.) can also drive obsolescence (Butt et al., 2015).
4.2.1 Obsolescence of Function

An existing product becomes outmoded when a product is introduced that performs the function better (Packard, 1960). Obsolescence of functions is a strategy of shortening the product lifetime before it is released to the market, by manufacturing a product less durable than could have been manufactured or manufacturing a product with a specific technology rather than with another rapidly available technology that would have made the product more durable (Orbach, 2004). Fragile batteries and the ability to easily get damaged are the results of the short life span of smart phones and some other electronic devices. Before 1990s, most households were filled with bulky, heavy tube televisions, entertainment centers, as a result, were constructed to accommodate their weight and size (Kenton, 2018). Today, most households are filled with sleek, lightweight flat-screen televisions, rendering the old entertainment centers functionally obsolete (Kenton, 2018).

4.2.2 Obsolescence of Quality

When it is planned, a product breaks down or wears out at a given time, usually not too distant (Packard, 1960). The light bulb is a good example of this type. The famous Centennial Bulb is still burning in its 117th year of illumination. In addition, this light bulb is being watched with a security camera and several cameras have been obsolete during the time it burned. Manufacturers sometimes make replacement parts either unavailable or so expensive that it makes the product uneconomic to repair. By making replacement parts unavailable or so expensive that repairing the product becomes uneconomic, manufacturers force customers to buy a new device. Sealed batteries, for example, make for a thinner product than one that can be upgraded or fixed, while tamper-proof screws can be safer (Khaleeli, 2015).

4.2.3 Obsolescence of Desirability

In this situation a product that is still sounds in terms of quality or performance becomes worn out in our minds because a styling or other change makes it seem less desirable (Packard, 1960). The General Motors example is well suited for this type of obsolescence. Once the pub-
lic is persuaded that the style is important element, obsolescence in the mind simply become created by shifting to another style. Thus, this type of obsolescence is also called psychological obsolescence. Industries as fast as fashion are ideal for leading the way in planned obsolescence of desirability. Smart phones can be counted as the product of that kind of industries. For example, Samsung and Apple respectively launch the new versions of their mobile phones every year in the spring and late summer.

5 Conclusions

Will the capitalists give up the planned obsolescence – which is being applied today by the companies with a collective agreement despite the fact that it was not enacted by the government, and which aims to make more profit by targeting to shorten the life cycles of the goods – against the innovations brought by Industry 4.0? The digital revolution has made significant contributions to companies in collecting and analyzing data so that they can develop more customized products. At the production stage, technologies such as 3D printers, robots and AI, which have been used by Industry 4.0, have brought the production phase to a new level. This situation caused the decrease in production costs and quality, and also caused a decrease in the sales prices of the products.

For instance, in the light of the information above, let us look at the situation of a product at the market whose price went down with Industry 4.0. Does the fact that the production has been accelerated and therefore the price of the product has been decreased, and that the product may be found in greater amounts and cheaper than the demand of the people, will this increase the profit expected by the producer? Naturally, the producer’s expectation of a profit increase is not realized in market economy conditions. Because, the producer, who sell products with planned obsolescence, can sell more product with for less money under the favor of the benefits came with brought by Industry 4.0; would make a gain in the short term. Even though it had helped to make a gain in the short term, the producer would lose money in the long term. As it is explained above, economic growth has lost
its positive effect on productivity after a certain period of time. This negative effect occurred even in a situation where the capitalists did not give up the planned obsolescence. As technology pessimists stated; it is a complete dream to wait for the capitalists to abandon the planned obsolescence by themselves, as it will increase inequality between countries as well as between people. In such a case, the prevention of planned obsolescence remains to be regulated by the authorities. In a world ruled by capitalism, when the effects of the capitalist class on government are considered, such an event does not seem possible. Considering the American writer Edward Abbey’s words “Growth for the sake of growth is the ideology of the cancer cell,” the idea that the technological innovations introduced by Industry 4.0 bring prosperity to a small minority, not to the whole” of humanity gains importance.

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### Key Terms

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<tr>
<th>Autonomous Robots</th>
<th>Big Data Analytics</th>
<th>Simulation</th>
<th>System Integration</th>
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<td>Cybersecurity</td>
<td>Industrial Internet of Things (IIoT)</td>
<td>The Cloud</td>
<td>Additive Manufacturing</td>
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<td>Augmented Reality</td>
<td>Innovation</td>
<td>Planned Obsolescence</td>
<td>Industry 4.0</td>
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Questions for Further Study

Which business segments in a company can undergone the most and the least transformation as part of Industry 4.0?

How can supply chain management benefit from Digital Twin?

What measures can be taken against firms and manufacturers which are found to be engaged with planned obsolescence?

What are the future impacts of Industry 4.0 on logistics management?

Exercises

Please describe the benefits of each pillar of Industry 4.0 and their effects on profitability.

Please compare and contrast the types of planned obsolescence and identify their effects on economy.

Which segment of society can benefit from innovations introduced by Industry 4.0? Why?

Further Reading


Industry 4.0 and Big Data Literature Review

Learning Objectives

The objectives of this chapter are introducing the concept of Industry 4.0, examining the concept of Big Data and showing the studies done in various sectors. You will be able to carry out to belows:

- You will learn the process of the Fourth Industrial Revolution.
- You will be informed about the basis of Industry 4.0.
- You will learn the big data concept that comes with Industry 4.0.
- Learn the components of Big Data.
- You will see the practices and studies on big data, economic, production, service, IT sectors.

Chapter Outline

In a constantly evolving world, people are always trying to access existing information and Innovate new products from existing information. The new process, referred to as Industry 4.0, has a structure that will completely change the relationship between production and consumption. It describes the production systems that adapt to the changing needs of the consumer instantly and the automation systems that are in constant communication and coordination with each other. Smart Factories include intelligent machines and systems that perceive their business needs with sensors and communicate with other remote production tools via the Internet and capture the production knowledge they need in the cloud systems. Along with the increase in data sources, the amount and diversity of the data is also increasing. This situation, which gives new dimensions to the use of data in the enterprises, has resulted in new business opportunities and usage areas in different sec-
tors. In this study, between 2013–2018; wide literature research in sectors that are economical, production, service, information.

Keywords
Big Data, Industry 4.0, Literature

1 Introduction

The concept expressed as Industry 4.0 is defined as the ability of machines to manage themselves and their production processes without the need for human power. It refers to technological development of cyber-physical systems from embedded systems. Industry 4.0 defines the organization of technology-based production processes that independently communicate with each other in the value chain. It is a mirror image of how production would be shaped in the future. The Fourth Industrial Revolution has emerged in the industry, in general, when machines start to direct themselves and their production processes without the need of human power (EBSO 2015). There were three major industrial revolutions until the return of what we were in (Can and Kiyamaz 2016). The first three industrial revolutions have brought mechanization, electricity and information technology (IT) to human production (Jian et al. 2016). These three industrial revolutions were aimed at increasing productivity in production (Can and Kiyamaz 2016). When the customer who bought only the existing product in the 1960s came to the 2000s, the change of the wishes and expectations caused the production processes of the companies to become more complex (Sayer and Ulker 2014). Finally, the development of cyber technologies and the integration of the entire industry value chain into digital ecosystems has contributed to the emergence "Industry 4.0". The first reference to this industrial revolution was introduced at the Hannover Industrial Technology Fair in 2011 (Bartevyan 2015). According to Kagermann, Industry 4.0, with the intelligent monitoring and control system it provides, predicts that production will be more controllable, more efficient, faster and more economical (ICV, 2015). Based on the concept of Industry 4.0; (Brettel et al. 2014; Siemens Report 2015) that all units involved in the industrial production process
are able to reach each other in a timely manner, with all relevant data being available in real time. Industry 4.0 is a collective term that encompasses many modern automation systems, data exchanges and production technologies. The most distinguishing elements of Industry 4.0 can be grouped under three headings (Schwab 2016); velocity, volume and variety, the effect on the system. This new process involves a structure that will completely change the relations of production and consumption. On one side, the production systems that adapt to the changing needs of the consumer are instantly defined, while on the other side the automation systems which are in continuous communication and coordination with each other are described (Sinan 2016).

This study covers big data applications and researches by reviewing literature in the field of economics, production services and information systems. The concept of Industry 4.0 is introduced, the concept of big data is examined and its components are emphasized, and finally a literature review covering the years 2013–2018 on sectors categorized by activity areas is presented. In the conclusion, the findings of the literature review are presented.

2 Big Data

Big data; it includes a number of methods for revealing hidden patterns from different, complex, and big data sets (Hashem et al. 2015). Big data format is large enough to fit into a single server, used for data that is not configured or configured (image, video, email, transactional data, and social media interactions, etc.). This data is constantly flowing in a static data warehouse and cannot be analyzed by conventional methods (Davenport 2014). The ever-increasing Internet-based mass of data interacts with the economic and social environment. Numerous people, companies and public institutions collect, produce and publish daily information on the internet. As a matter of fact, recent research has played an increasing role as a data provider to explain, model, publish and predict the socialization of the Internet (Blazquez and Domenech 2018). Big data includes data sets beyond the storage, management and processing capacity of programs. With big data, the vast majority of things that were never measured, hidden, analyzed, and
shared in the past have begun to be verified (Mayer-Schönberger and Cukier 2013). The three basic items (3V) of the big data are "volume, variety and velocity" (Hurwitz 2013). Volume (Volume refers to the size and size of the data (Arslantekin and Doğan 2016)), Velocity (Velocity means that the data can be acted in real time (Cackett 2013)), Variety (Diversity means sources of big data and more unstructured data (Iafrate 2015)). Two additional characteristic components have been added with the increase in awareness in the area. These; Veracity which provides a useful data set after the data has been edited to be analyzed (Mayer-Schönberger and Cukier 2013), Value (Value, the material value that the data reveals (Manyika et al. 2011)). Big data can be defined based on large volumes of large volumes produced, captured and processed at high speed (Laney 2001). The concept of big data first appeared in August 2000 in Seattle with a statement at the 8th World Econometrics Congress, but earlier studies on this concept are included in the literature. Wal-Mart developed a Retailed-Link system in the 1990s to record every product it sold, Oren Etzioni used the Internet to build MetaCrawler, the first search engine in 1994, Amazon.com’s algorithm for processing and analyzing large volumes of data for book sales forecasts in 1998 with the beginning (Mayer-Schönberger and Cukier 2013) and the emergence of methods such as data mining for exploring information from data warehouses coincides with the same years (Shi 2014).

![Big Data Component](https://doi.org/10.5771/9783828872301)

Figure 1: Big Data Component
2.1 Literature Review

With the constantly evolving internet, increasing access to new data sources and the possibilities offered have become to the concept of electronic commerce. By reaching a large number of people and developing new marketing strategies, it is possible to market the products economically and in the shortest time. With mobile technology, safe trading and payment tools have become more secure and reliable. New product recommendations, personal shopping, retailing, marketing have been investigated through the effect of big data. There are also studies on communication resources and financial resources such as stocks and real estate. Consumer analysis and the related economic activities are at the center of big data. In real time the effects of consumer resources and multinational shopping and human behaviors in the financial are changing day by day and researches are increasing. Table 1 presents a literature review of economics sectors such as e-commerce and finance sectors between 2013–2018.

Table 1: Literature Review in Economics

<table>
<thead>
<tr>
<th>Sector</th>
<th>Year</th>
<th>Author</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-COMMERCE</td>
<td>2013</td>
<td>Mayer-Schönberger and Cukier</td>
<td>In a study on the application of big data, Walmart and amazon.com have been recognized as pioneers</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>Siegel</td>
<td>In his work, he suggested that companies who want to present new products to their customers through their personal purchases are using large amounts of data. In addition, about one third of Amazon.com's sales; It has been noted that about four-thirds of Netflix's orders were made as a result of these recommendations.</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>Mora-bitio</td>
<td>In his work, IBM's personal shopping consultation aimed to move one step further. By combining artificial intelligence and the possibilities of big data, it is not only giving users advice on selected products related to their shopping, but also aims to develop an application that makes estimates of what they need.</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>Erevelles et al.</td>
<td>It has created a conceptual framework to better understand the impact of the data on various marketing activities and they have used resource-based theory.</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Lee et al.</td>
<td>In California, they worked with a comprehensive survey dataset to explore the effects of personal perception and character on the frequency and environment of shopping.</td>
</tr>
<tr>
<td>Year</td>
<td>Author(s)</td>
<td>Summary</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-----------</td>
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<td></td>
</tr>
<tr>
<td>2017</td>
<td>Matzand Netzer</td>
<td>Interview-based Customer survey provides data integration using Bayesian Networks.</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>Hureet al.</td>
<td>Multi-channel shopping value (SV); It has been empirically tested with SV model based on a multi-channel SV model. A mixed method design combining quantitative and qualitative methods in a mixed mode has been adopted.</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>Chen and Laz-er</td>
<td>He has done a study that examines the relationship between tweets and stock movements and a model that can make meaningful inferences.</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>Du et al.</td>
<td>He has presented a study on the current practices of big data centers in the field of real estate development and marketing in China in terms of real estate businesses. The application, big data problems have been analyzed and possible solutions have been proposed.</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>Morabito</td>
<td>He analyzed the data by correlating the estimated data with the other variables in the market.</td>
<td></td>
</tr>
</tbody>
</table>

Developments in Internet technology has accelerated the development of artificial intelligence and large data by increasing the volume of production data. Big data provides the opportunity for today’s smart production transformation by supporting accurate and timely decision making. With dynamic competitiveness and changing global market opportunities, firms have to adapt to the dependencies and complexities of growing production networks. The application of big data increase the speed of decision-making, therefore takes away the complexities of production. When the studies are examined, it will be beneficial to reduce the costs of monitoring the current situation in the production and effective use of forecasting information. In the literature; by using radio frequency (RFID) technology the manufacturing process is followed. A layered architectural framework is purposed for error estimation in data analysis. Work on data analysis in smart production and planning has been done. Big data technologies are applied in the production area to facilitate decision-making. Table 2 presents a literature review for the production sector between the years 2013–2018. Table 3 presents a review of literature on health and education between the years 2013–2018. Much of the work done in the field of health seems to be based on using real-time imaging to monitor patients, to access information, and to provide confidentiality. Investigations into the follow-up of infectious diseases such as H1N1 and HIV virus and cancer treatment are available. In addition, studies of data analysis and effects of drugs on patients have been examined. It is observed that the work done in the field of health for the big donation is
increasing day by day. The studies are increasing in the direction of the security of the medical devices, patient tracking systems and personal information.

Table 2: Literature Review in Production Sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Year</th>
<th>Author</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODUCTION</td>
<td>2015</td>
<td>Pries and Dunnigan</td>
<td>Data obtained from radio frequency identification (RFID) technology is used in areas such as automotive, manufacturing, logistics and security services.</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>Golzeret al.</td>
<td>Big Data techniques has been defined in the design and operation of global production networks, underlining the decision makers’ data access patterns, the way in which required data structures and design scenarios are addressed. This approach can be applied to various decision-making processes related to interrogation, analysis and interaction with a general manufacturing system in manufacturing.</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Ji and Wang</td>
<td>It has introduced a big data analysis based error estimation approach that includes local data, local network data and cloud data for floor planning in stores.</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Zakiet al.</td>
<td>Research has been conducted on how big data-consumption goods industries can facilitate redistribution of production andthey proposed a conceptual framework</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Khakifroozet al.</td>
<td>Bayesian inference and Gibbs methods were applied to enhance intelligent production over complex semiconductor production data. The proposed approach is an empirical work and has been approved by simulation.</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Sorokaet al.</td>
<td>Reported some of the results of the first exploratory research on the manufacture of SMEs in the United Kingdom. Redistributed Production focused on major customer analysis.</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>Moktadir et al.</td>
<td>The existing knowledge body has been examined using the Delphi-based Analytic Hierarchy Process (AHP) to remove the obstacles that the Big Data Analysis (BDA) could create on data from five Bangladeshi manufacturing companies.</td>
</tr>
</tbody>
</table>

On-the-job learning in the field of education focuses on online learning. There is a lack of practice in education based on big data and analysis. It is anticipated that this field will be increased in a short time.
<table>
<thead>
<tr>
<th>Sector</th>
<th>Year</th>
<th>Author</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEALTH</td>
<td>2015</td>
<td>Germano</td>
<td>Pharmaceutical companies have established a large data analysis department to better analyze drug-patient interactions. His work has facilitated research on his own markets as well as producing better medicines.</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>Young</td>
<td>It focuses on big data to be protected from HIV. The analysis of the social media network suggests that the HIV tracking system can be established. It is stated that with big data, there will be a chance of early intervention and new ideas can be produced to follow the disease.</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>Xie et al.</td>
<td>Some issues and potential solutions in the System Pharmacology Modeling (SPM) using big data technology and analytics have been addressed. The simultaneous development of high-yielding techniques, cloud computing, data science, and semantic networks suggests that SPM can be foldable, accessible, interoperable, reusable, reliable, interpretable and actionable.</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Celestie et al.</td>
<td>It addresses the clinical workflow that can manage the transition of big eHealth Data from medical devices to a Cloud NoSQL storage system. In addition, the clinical workflow for managing the large robotic rehabilitation data sets of Italy Institute has been taken into account.</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Abouelme-hdi et al.</td>
<td>The big data being applied to the healthcare sector have explored security and privacy issues. Current data privacy and security have discussed users’ accessibility.</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Mendelson</td>
<td>It summarizes the needs and possible solutions to the problems of collecting and using personal health data that are not legally prohibited by third parties.</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Manogaranet al.</td>
<td>A big database of information management systems has been proposed to monitor patients and make accurate clinical decisions. The proposed information system includes Electronic Health Record (EHR), Medical Imaging Data, Unstructured Clinical Notes and Genetic Data.</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>Chen</td>
<td>In Taiwan Health Industry, they have proposed a hybrid strategy for following the Tibbian institutions, using the Net Relationship Map (NRM) and the DEMATEL method.</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>Melie-Garcia</td>
<td>Within the Human Brain Project, they have proposed a methodology using Multiple Linear Regression (MLR) and Bayes over Distributed Big Data.</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>Chung</td>
<td>The main features of large brain network data providing statistical difficulties have been researched. Certain topological constraints focus on statistical approaches and models that we can use effectively.</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>Fessele</td>
<td>Oncology defined big data and data science in nursing care. In order to promote quality and high-value cancer care, it has recommended that standardized data sources be created to support the acquisition of meaningful and comparable predictions.</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>Mehta and Pandit</td>
<td>By examining the research on Health Care in developing countries, they found that the large data analysis is a lack of information in real world use.</td>
</tr>
</tbody>
</table>
It has been examined how big data oriented tools change the pedagogical decision making structure of schools. It has also been shown how the fundamental aspects of America's educational initiative have changed.

Graduate education has proposed for data-centric learning pedagogy. The four-pronged approach emphasizes that data science education is different from today's postgraduate education, but not in a single curriculum.

By using the big data approach, it aimed to discover innovative design for innovative online learning in Higher Education.

In table 4, between 2013 and 2018, a survey of the literature on the social sciences sectors and presented. It is seen that majority of the studies are on social media communication and simultaneous transportation. In addition, critical factors for employees working in social media based work environments and institutional development practices are included. The demographic structure of a certain area was studied with big data and studies based on accessing climate and socio-ecological effects with big data were found.

Table 4: Literature Review in Service Sector–Social Science

<table>
<thead>
<tr>
<th>Year</th>
<th>Author</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>Weichselbraun et al.</td>
<td>In the study on opinion mining and emotional analysis, data collected from Amazon (electronic and software) and IMDB (comedy, crime and theater) were evaluated.</td>
</tr>
<tr>
<td>2014</td>
<td>Mahyoub et al.</td>
<td>In the text mining study, Inspired by Wordnet, arabic sensitivity dictionary was created.</td>
</tr>
<tr>
<td>2015</td>
<td>Shin and Choi</td>
<td>In Korea, socio-ecological effects of big data processing have been investigated.</td>
</tr>
<tr>
<td>2015</td>
<td>Gandomi and Haider</td>
<td>It has been emphasized that analytical methods for efficiently analyzing heterogeneous data in large quantities should be developed. It has been argued that it will become an important research area thanks to the increase in mobile applications.</td>
</tr>
<tr>
<td>2016</td>
<td>Gleaser et al.</td>
<td>Income estimates have been made from Google Street View imagery in New York City. It has been stated that other regions that have not yet been measured for income can be estimated.</td>
</tr>
<tr>
<td>2016</td>
<td>Bello-Orgaz et al.</td>
<td>Big data technologies, machine learning algorithms and social network applications have been examined to provide effective data mining and new methodologies.</td>
</tr>
<tr>
<td>2016</td>
<td>Su et al.</td>
<td>They have proposed a new architecture using content-centric mobile social networking.</td>
</tr>
<tr>
<td>2016</td>
<td>Williams et al.</td>
<td>They analyzed crime and disorder from social media data.</td>
</tr>
</tbody>
</table>
They analyzed the advantages, disadvantages and difficulties of publishing the Australian government’s data as open data.

Using big data (qualitative and quantitative data) in social media, it has identified critical factors for employee participation. Laboratory and decision-making tests into the evaluation method.

To make time consuming calculations and large data analysis easier, Climate Spark recommends.

They used the social network analysis approach, which shows six points in management issues, to perform the Large Data Analysis.

Table 5 presents a survey of the literature for the service sectors such as tourism, energy, management and logistics between 2013–2018. The work done in the field of tourism has shown that the big question is to analyze customer satisfaction, to facilitate access to firms in the sector and to increase interest. Scientific calculations have been made in the field of energy, big data analysis and power systems and energy consumption. In the field of management, there have been studies to analyze firm performance processes and complex data. When we look at the logistics sector studies, it is observed that the focus is on the value created by large firms and on the analysis of supply chain.

Table 5: Literature Review in Service Sector–Tourism, Energy, Logistic

<table>
<thead>
<tr>
<th>Sector</th>
<th>Year</th>
<th>Author</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOURISM</td>
<td>2015</td>
<td>Benjellounet al.</td>
<td>Some of the registered customers of tourism sector companies, climate, transportation prices and web sites visit information collected. Thanks to this data, they have offered personal vacation offers to their customers.</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>Xiang et al.</td>
<td>They aimed to measure the experience and satisfaction levels of hotel guests. They analyzed the classification and statistical relationship with the data they obtained from Expedia.com.</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>Li et al.</td>
<td>Tourism problems have been analyzed with different kinds of data such as online text, photos, GPS, mobile transport data.</td>
</tr>
<tr>
<td>ENERGY</td>
<td>2018</td>
<td>Niemiet al.</td>
<td>While the data are being analyzed, architectural improvements, cloud technologies have been dealt with in order to maintain energy efficiency. Green big data project aims to increase the productivity of CERN computing.</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>Akhavan-HejaziandMohsenian-Rad</td>
<td>They have studied structures and methods related to large data analysis in the field of power systems.</td>
</tr>
</tbody>
</table>
Table 6 presents a literature review of the software sector from 2013 to 2018. The system of calculating, processing, collecting and storing data has been examined and accurate and reliable data sharing platforms have been presented. Data storage systems use Hadoop technology. In business management, business intelligence, the whole data life cycle is examined and big data analysis and architectural structure are proposed.

**Table 6: Literature Review in Information Sector–Software**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Year</th>
<th>Author</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOFTWARE</td>
<td>2013</td>
<td>Hurwitz</td>
<td>In the study, he describes companies that implement and turn big data into benefits: Google, IBM, Oracle, Microsoft, Cloudera, SAS Institute, Teradata.</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>Mayer-Schönbergeran dCukier</td>
<td>Google has been identified as a pioneer in the use of large data sets, and it has been stated that a large number of firms have come to a large extent from using data.</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>Gursakal</td>
<td>He mentioned big data applications. The study stated that Google collects and processes about 24 petabytes of data a day from many different sources or from smartphones GPS devices.</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>Corte-Real</td>
<td>Based on strategic management theories (dynamic capabilities and knowledge-based view), a theoretical model was introduced to understand how and why specific Business Intelligence and Analysis...</td>
</tr>
<tr>
<td>Year</td>
<td>Author(s)</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-----------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>Ackerman and Angus</td>
<td>It has conducted a large data study to visualize spatial and temporal IP mobility in large cities.</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>Elragal</td>
<td>In the study, it was stated that a strong platform could be established by combining enterprise resource planning and large data.</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>Hashem et al.</td>
<td>In the context of big data and cloud computing, it examines the relationship between large data storage systems and Hadoop technology by examining 5 cases. The importance of the Map Reduction algorithm is also emphasized, as it provides information about large data storage systems.</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>Qian et al.</td>
<td>Attribute reduction algorithms have been dealt with as a topic. Using Map Reduce, large data is better scaled and efficiently processed.</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>Dong et al.</td>
<td>Proxy re-encryption algorithm is proposed for secure data storage, data use, data destruction operations in a semi-reliable large data sharing platform.</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>Samuel et al.</td>
<td>A prototype called Intelligent Privacy Manager (iPM) has been created for sharing privacy of multimedia data securely and for determining privacy policies.</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>Yin and Kaynak</td>
<td>A large data analytical architecture has been proposed using a large-scale analytical (Bosch Car Multimedia – Braga) and its practical difficulties have been addressed. In the study, the entire data life cycle from summarization to analysis was handled taking into account the different data processing speeds that may be present in the real world of a plant (batch flow or flow).</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>Arslantek-inand-Doğan</td>
<td>Examples of the use of big data technologies and Methods in the world and in awareness-raising companies are given.</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>Karim et al.</td>
<td>In this study, data collection, visualization data processing, and cloud technologies were processed to determine major data management issues.</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>Ramakrishnan et al.</td>
<td>In his work, Hadoop discusses the design and performance of the Azure Data Warehouse (ADSL) architecture, which supports Distributed File System (HDFS) and Cosmos semantics.</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>Smithset al.</td>
<td>Numerical and categorical data calculations and techniques for identifying interfaces with the human reasoning linguistic domain have been proposed.</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>TorrecillaslandRomo</td>
<td>The role of statistical data such as data collection, storage, preprocessing, and visualization emerged from big data was discussed.</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>Smith and Nichols</td>
<td>Human neuroimaging studies have been discussed with a large number of data.</td>
<td></td>
</tr>
</tbody>
</table>
Table 7 provides a review of the literature on electronic and security sectors between the years 2013–2018. In the field of electronics, there are studies examining the application of data streams in electrical and wireless devices. Possible threats are presented in studies that examine the security of big data sets.

Table 7: Literature Review in Information Sector–Electronic and Security

<table>
<thead>
<tr>
<th>Sector</th>
<th>Year</th>
<th>Author</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELECTRONICS</td>
<td>2016</td>
<td>Baccarellet al.</td>
<td>By developing a self-configurable integrated computing platform, it enables simultaneous processing of large data streams from mobile and wireless devices.</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>Guet al.</td>
<td>Large data technologies have been proposed to solve the management problem of electronic devices.</td>
</tr>
<tr>
<td>SECURITY</td>
<td>2015</td>
<td>Jinet al.</td>
<td>It offers a four-step life cycle framework for big data, specifying security threats and attacks for each.</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>Salleh and Janczewski</td>
<td>In the context of large data security and confidentiality, it emphasized not only the technological deficiency but also the organizational culture and its environmental impacts.</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>Kobusinska et al.</td>
<td>The fingerprint tool has been developed and fingerprint reliability is underestimated.</td>
</tr>
</tbody>
</table>

In this study, studies on the use of big data in various sectors between 2013–2018 are discussed. 78 studies are categorized and presented according to the sector in which they are located. Table 8 shows Literature Review all sectors in big data.

Table 8: Literature Review All Sectors in Big Data

<table>
<thead>
<tr>
<th>Year</th>
<th>e-Commerce</th>
<th>Finance</th>
<th>Production</th>
<th>Health</th>
<th>Education</th>
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### 3 Conclusion

The proposed framework and researches for storing and streaming the data show that it is mostly the work of the software sector. Thirteen studies in the field of health services have been identified and it has been observed that the studies have increased towards recent years. Most of the work is productivity analysis. RFID applications are largely included in education sector and industrial activities. More studies can be presented considering the analysis approaches of unconfigured data. The number of studies conducted on energy management systems and electronics are expected to increase. In the health sector, big data applications are mostly focused on patient follow-up and clinical practices. But, more techniques can be presented by investigating the methods to be used to ensure the patient’s privacy. It is expected to focus on producing effective solutions for big data confidentiality and security scalability in healthcare. There are 12 studies conducted on social science and social network analysis to this date. The number of studies conducted are insufficient numbers on such in-depth fields and are forecasted to increase in the following years. The number of studies in education, electronics, and energy are less than the number of studies in logistic. In the education field, more researches and studies on innovative approaches to online learning and teaching systems are expected in the coming years.

### References


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**Key Terms**

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<th>Smart Production</th>
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<th>Industrial Revolution</th>
<th>Software</th>
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<td>Simultaneous Data Sharing</td>
<td>Data Storage System</td>
<td>Data Mining</td>
<td>Security</td>
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<td>Reliable Data Sharing</td>
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Questions for Further Study

In what field did the first big data come out? Give information about its development.  
Examine the benefits and threats of big data during the transition to Industry 4.0.  
What is the importance of security on data storage and sharing when big data is analyzed in software sector? What measures can be taken in terms of information security and protection?  
What steps should be taken on a sectorial basis to make big data more useful? What are the concepts that come with Industry 4.0 in these steps?

Exercises

You work at the bank. In your sector, there are fraud attempts due to intensive money movements. In order to locate the fraud attempts, you would want to know where the customers are and know what kind of communication source is being used along with the type of transaction. However, for this reason, information security is only monitored and the customer’s key movements are insufficient. What do you do?  
You work in a human resources department in a company that offers software programs to customers. You keep all the data of different customers. You have the wage information of the people who work different sectors that based on their titles. Would you use the analysis of these remuneration policies as suggestions in the remuneration process of other companies? What do you think about reliability?  
Think you’re working in the e-commerce sector. What strategies would you implement with the diversity component of the big data in your system?  
To what extent do you think big data will benefit educational practices? Does it have appropriate components for improving learning in schools and lessons?
Further Reading


About the Chapter Contributors

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Prof. Erkollar is a Professor for management information systems. His research expertise includes management information systems, industry 4.0 and the factory of the future, production management, technology management, modelling of business systems and simulation. Some of his recent publications include 'Flextrans 4.0 – Smart Logistics for Smart Cities', 'Industry 4.0: Big Data Revolutions require Smart Technologies' and 'Sustainable Cities Need Smart Transportation: The Industry 4.0 Transportation Matrix'. He is an author/editor of several books, more than 200 refereed papers, and an editorial board member of 13 international journals. Dr Erkollar is the editor of the international EBM Series.

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