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İsmail İyigün
Ömer Faruk Görçün *Editors*

Health 4.0 and Medical Supply Chain

Springer

Accounting, Finance, Sustainability, Governance & Fraud: Theory and Application

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Editors

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İsmail İyigün, Ph.D.
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About the Editors

Dr. İsmail İyigün has been working as a lecturer at Edirne Vocational School of Social Sciences at Trakya University since 2006. His current research areas are marketing, logistics, and supply chain management. He worked at the Uzunköprü Vocational School in Marketing Program at the same university from 1995 to 2005. He graduated from Gebze Technical University Ph.D. Programme on Business Administration from in 2016. The title of the Ph.D. thesis is the effects of sales and logistics competencies on the relationship continuity in supply chain and corporate governance: an application in logistics enterprises. Logistics 4.0 and customer relations, technology and industry 4.0, big data usage, transportation systems. His articles and conference papers have been published on prestigious academic platforms. In 2022, he was the editor of the book Logistics 4.0 and Future of Supply Chains Dr. İyigün teaches supply chain management, physical distribution systems, logistics information systems selling techniques, and basic marketing courses in Trakya University's and Kadir Has University's Logistic program. He is married and has two children.

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Part I
Introduction Chapter

Chapter 1
Introduction

İsmail İyigün and Ömer Faruk Görçün

Abstract Using high technologies for producing health services can assist in providing more satisfactory healthcare services, as it can help diagnose and decide on treatment. It can help to increase the quality of auxiliary health services, such as health logistics, supplying medical substances and drugs, and healthcare waste disposal. The present book suggests new and unprecedented ways to understand the central concept of health 4.0 and its emerging technological implementations. For this aim, the book's authors examined technological implementation used or will be used in the healthcare industry. They synthesized the information concerning these technologies and their abilities and benefits to health professionals and patients in the present industry. After the introduction section, given the scope, concept, and future of health 4.0 in detail, examined the new tools for distribution management in the health industry. As a well-known fact for scholars and practitioners dealing with the health industry, distribution operations, a significant part of the logistics activities, play a crucial role in producing and providing successful health services.

Keywords Health 4.0 · Health · Healthcare industry · Health logistic · Technology utilization

1.1 Introduction

Our world is changing speedily, and all traditional things and habits are becoming a part of history. Today, most of us cannot think of starting a day without high-tech coffee machines providing various types of coffee to us by touching a small button. That is a very minor and straightforward example. Technological transformation not

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only influences companies and substantial supply chains but also is largely influenced by the strong wind of change arising from technological revolution as a natural result of the industry 4.0 process.

Today, the healthcare industry is in this digital transformation, and most physicians cannot decide on a treatment that will be applied to a patient without test results from high-tech diagnosis devices. Moreover, many emerging technologies, such as the internet of things, big data, cybersecurity systems, and artificial intelligence, draw attention to the healthcare industry. Health industry practitioners try to find the best solutions to apply these technologies to produce more qualified health services.

The health system is encountering many difficulties, including producing health services is becoming more costly and employing adequate health specialists is a big problem. Furthermore, managing the healthcare system is challenging, as it is an ever-growing huge-scale system. Even worse, it has become gigantic in today's conditions, and it is impossible to manage such a system without using high technological instruments and implementations. On the contrary, these challenges are the primary motivation for improving healthcare services with the help of advanced and emerging technologies.

Although these attempts are still at the starting point, they are promising efforts to improve the quality of the healthcare service provided to people. In addition, new emerging technologies are changing business strategies and models in the healthcare industry. Due to high technological instruments, patients have become a significant and determinative component and stakeholder of the health systems. In the past, while only patients demanded health services from healthcare institutes and hospitals, all people (even if they were healthy) wanted to get healthcare services from these institutes to keep their health. It causes an increase in the number of people demanding healthcare services and makes it difficult to produce satisfactory services for each person.

Using high technologies for producing health services can assist in providing more satisfactory healthcare services, as it can help diagnose and decide on treatment. Furthermore, it can help to increase the quality of auxiliary health services, such as health logistics, supplying medical substances and drugs, and healthcare waste disposal.

The present book proposes new and unprecedented ways to understand the central concept of health 4.0 and its emerging technological implementations. For this purpose, the book's authors examined technological implementation used or will be used in the healthcare industry. They synthesized the information concerning these technologies and their abilities and benefits to health professionals and patients in the present industry. By keeping the requirements and curiosity of the readers in mind, each technology with the potential to apply in the healthcare industry is investigated by the authors in different chapters.

After the introduction section, given the scope, concept and future of health 4.0 in detail, Dördüncü examined the new tools for distribution management in the health industry. As a well-known fact for scholars and practitioners dealing with the health industry, distribution operations, a significant part of the logistics activities, play a crucial role in producing and providing successful health services. Even more, producing health services without a well-designed and operated health logistics system is impossible. The author demonstrates the importance and impacts of the improved distribution system for all stakeholders of the health system, such as health professionals, patients, pharmaceutical warehouse companies, pharmacies, and drug stores, by keeping the new requirements of the industry in the era of industry 4.0.

Healthcare institutes' financial performance and efficiency are critical for creating a sustainable health system. Many works in the literature focus on the financial indicators of hospitals and healthcare institutions. However, few of them present a new point of view concerning the healthcare industry's compatibility with the requirements of the digital transformation age with respect to the industry's financial performance. Çanakçıoğlu attempted to fill this gap with excellent efforts and presented the financial performance of the healthcare industry with the help of a new and unprecedented approach that considers ratio analysis.

Pharmaceutical warehouses play critical and vital roles in the era of industry 4.0, as hospitals cannot hold a massive volume of inventory. Moreover, healthcare professionals in hospitals try to produce health services. They have no time for organizing logistics and warehousing operations, as it is complicated and laborious, and only professional companies can overcome this problem with higher efficiency and lower costs. Tutam focused on this problem to present logical and reasonable solutions and examined the future of pharmaceutical warehousing in healthcare supply chains.

In the next chapter, Özan successfully investigated the implementation of artificial intelligence and big data analytics in the healthcare industry. He examined the first age of these emerging technologies and presented their performance in monitoring and producing solutions for health problems. Also, he presents a comprehensive insight into the functions of these instruments in the future. This chapter can be fruitful and beneficial for readers dealing with the new technologies and their implementation opportunities in the present industry.

Also, Alakaş and Eren present a detailed investigation concerning the utilization of artificial intelligence in the treatment processes and diagnosis of various diseases. They claim that this technology can assist healthcare professionals in taking precautions against spreading many types of pandemics.

Today, robotics is a promising technology for the healthcare industry, and they operate many surgical operations in many countries. Furthermore, operating surgeons can manage such surgeries from a distance with small devices, which are the same as joysticks. According to the authors dealing with the surgery robots, they operate over seven million surgical operations in various countries, and their error ratio is meager compared to the surgeons. Aydınocak presents comprehensive evaluations concerning the functions of robotics in the healthcare industry. She assesses the potential of these technological instruments in the present industry.

It is a well-known fact for all healthcare professionals that avoiding the spreading of diseases is the main aim and strategy of the healthcare industry, and treatment is the last ditch for the professionals in the hospital. Hence, long-term people monitoring is required to produce effective preventative health care. Big data analytics can help to monitor the individual continuously. Gür and Tamer examine the implementation of big data analytics in the health industry.

Kolcu and Kolcu presented a successful evaluation to understand health 4.0 and its future. They defined the scope and concept of health 4.0 and demonstrated the historical roots of technology utilization in the healthcare industry from the past to the present. In the final section of the chapter, the authors tried to show the future of the healthcare industry based on their and scholars' dealing with the technology utilization in the present industry estimations.

In the next chapter, Küçükönder and Görçün conducted an examination to present a systematic literature review of the studies dealing with the healthcare industry by using various decision-making approaches.

İyigün assesses the impacts of the well-designed and operated transport chain on the performance of the health industry. He focuses on the new opportunities and dimensions concerning medical substances and materials transportation. This chapter provides a new point of view on transportation operation by considering the requirements of the healthcare industry and claims that transport service providers should improve their transport operations with speed, agility and effectiveness. Also, using technological instruments in transportation operations can assist practitioners in improving the quality of transport operations for health transportation companies.

In the last chapter, Dalkıran examined the interactions and connections between the tourism & hospitality industry and the health sector. She focused on the various types of operations in both industries and indicated that there are meaningful correlations between both sectors and that any development can simultaneously influence both tourism and health industry.

We hope that the book comprehensively dealing with health 4.0 and emerging technologies, which are still used or have the potential to apply in the present industry, will be fruitful and beneficial for scholars who work on this subject and practitioners in the healthcare industry. Although it has many precious benefits and contributions to the existing literature, it is possible to overlook some issues related to health 4.0, as this subject is pervasive and almost endless. In future works, various authors can fill these gaps, and this book can be accepted as the basis for health 4.0 and advanced technology utilization in the healthcare industry.

Lastly, we would like to thank all authors for their invaluable contributions, efforts, and information spent preparing this book. Also, we are appreciated to Editors and Professor Kıymet Çalıyurt for their valuable and constructive contributions and recommendations.

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Part II
Manageral Issues in Health 4.0 and Medical Supply Chain

Chapter 2
New Tools for Distribution Management in Health Industry

Hazar Dördüncü

Abstract The usage area of distribution methods in the healthcare industry is diverse and vast. Essentially, various elements of the distribution systems are used until the patient leaves the institution at the end of the recovery period, supplying the drugs necessary for the treatment, the health and hygiene equipment to be used for surgical intervention when necessary, and the storage of the equipment and the reverse logistics that will be formed as a result of the treatment period are included in the management processes of health care. Consistency and efficiency are being sought to conduct a qualified and convenient healthcare service for the patients. Thus, new tools are being established to comprehend the challenges and requirements that the developing industry of healthcare needs.

Keywords Healthcare industry · Distribution management · Supply chain management · Reverse logistics · Healthcare

2.1 Distribution and Supply Chain Management in the Healthcare Industry

Healthcare industry includes a vast number of distribution and supply processes. Ensuring timely and cost-effective service in the healthcare industry are the most challenging aspects. Thus, efficient managerial skills are vital for enabling the sufficient network of supply chain and distribution services. Since the essential focus on the healthcare industry is providing the services to patients in a cost-effective and convenient way without compromising the quality standards. The overall processes are discussed to be essential along with the challenges in the study of de Vries et al. (1999). The further challenges such as the technological requirements and need for developed IT infrastructures are covered in Pfhol et al. (2015). Through these

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diverse challenges, the term "Industry 4.0" covers the integrated processes including the technological advances.

Challenges and the potential cost optimizations are expected to be managed by the relevant technologies in the industry 4.0 era of supply chain management and distribution services. Dynamic and flexible approaches to the digitalizing industry (Geisberger and Broy 2012), come along with new ways and tools to ease the challenges of healthcare industry needs. One of the key techniques in the new era practices is the Business Intelligence (BI) techniques and its applications to better analyze and optimize the data collected in the healthcare system via machine to machine (M2M) communication (Zaus and Choi 2014). The BI techniques are offering tools to analyze, automate, and integrate the healthcare service process while optimizing the cost and possible human-based errors, especially in the decision-making processes where the timing is very crucial.

Real-time communication that is sustained with the smart and digitalized technologies under the branch of BI techniques brings the physical world and data from various sources together. These techniques are making the processes "smarter" in the way that they aid the management periods. Disruptive innovations in the smart logistics and smart healthcare management (Chang 2017), utilizes the network created among the connectable devices. Internet of Things (IoT) are recalled for the network that is created with smart devices that can communicate such as sensors, RFID tags, and health devices. Li et al. (2011) studied the smart communities in the context of IoT. The potential opportunities in the healthcare organizations are aiming to use this network to extend the market boundaries, reduce the space and energy usage, and meet the forecasted supply chain and manufacturing timing in the healthcare supply chains and distributions (Manavalan and Jayakrishna 2019). Location tracking and monitoring for deliveries, temperature sensing and monitoring, and stakeholder alert systems are highly integrated into the embedded healthcare systems through IoT.

2.2 Procurement and Purchase Management

Hospitals are labor-technology-intensive organizations that provide healthcare services to the community 24 h a day, 7 days a week. To provide health services in an uninterrupted, effective, and efficient manner in hospitals, a wide variety of materials, devices, and services are needed besides the health personnel. The healthcare industry ensures the placed orders through the new tools of Industry 4.0 to be able to fulfill the management operations from the manufacturer to the distribution to the end user. With industry 4.0, the existing system will be redesigned in accordance with digital transformation phenomena by providing end-to-end integration of the digital technologies required by the hospital into the traditional model.

Procurement and purchasing medical supply chain management process made with the delivery of the goods or services that begin when the need arises. Procurement and purchasing medical chain processes in business begin with the establishment of the enterprise and throughout the life of the enterprise, at different times, types and sizes consists of repeated operations.

The process of "Purchasing and Medical Supply Chain Management" in health enterprises can be explained under the following headings:

1. Emergence, determination, or notification of need
2. Determination of the characteristics of the goods or services to be provided (technical preparation of the specification)
3. Preliminary market research (determination of approximate cost)
4. Determination of procurement procedure (determination of tender procedure)
5. Preparation of documents related to supply; necessary specifications, contract, etc. (tender preparation of the document)
6. Obtaining the purchasing permit from the authority (obtaining the tender approval)
7. Establishment of purchasing commission (establishment of tender commission)
8. Announcement of the procurement process (tender notice and tender document seen by those concerned)
9. Getting offers from vendors
10. Evaluation of offers and decision on purchasing
11. Notifying the purchase decision (tender result) and making the contract
12. Delivery of goods, services, or works
13. Inspection and acceptance procedures of delivered goods or services
14. Fulfillment of obligations/payment transactions
15. Logistics management operations
16. Stock management operations
17. Supplier/subcontractor performance evaluation
18. Planning for new needs (Fig. 2.1).

2.3 Medical Device/Equipment Management

The automation of the healthcare industry comes along with the real-time communication provided via the M2M communication and BI technologies to deliver the most accurate service to the end users. BI solutions and the technologies include a robust integration of healthcare devices with the cyber systems. This integration is the so-called cyber-physical systems (CPS). Conceptually, "cyber" derives from the scientific discipline known as cybernetics (cybernetics), which focuses on communication and control over living beings and machines. In the 1940s, the concept of "cyber" was generally used to describe control processes based on information technologies, computers, and the Internet (Bradley and Atkins 2015, p. 23,023). In the Industry 4.0 process, computer, communication, and control technologies support

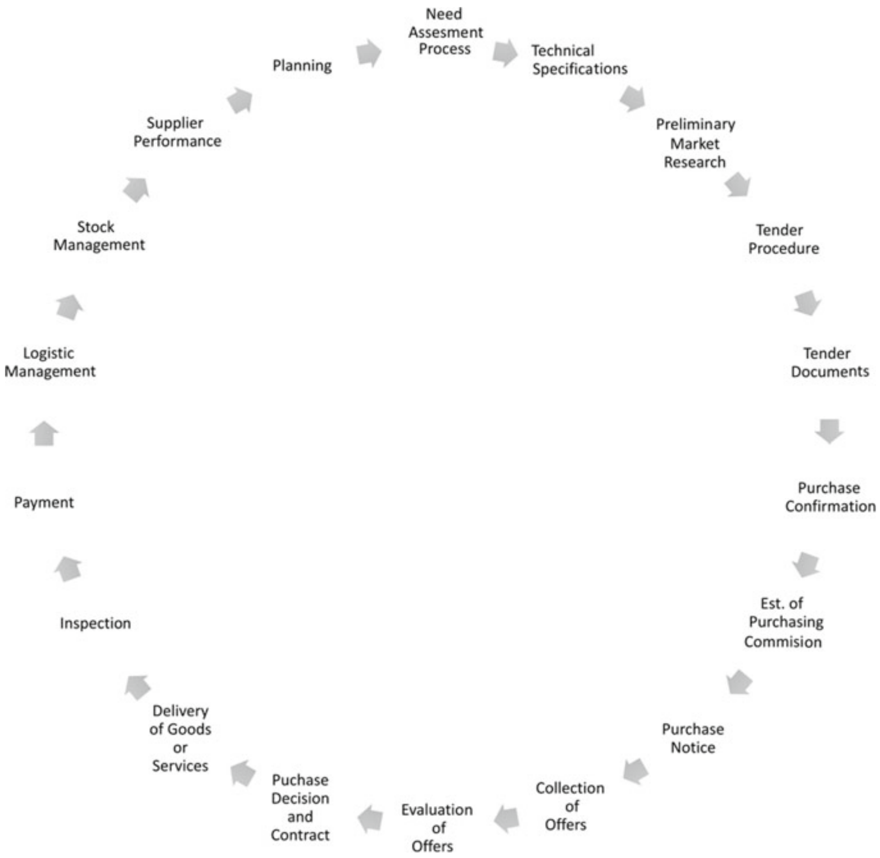

Fig. 2.1 Purchasing and medical supply chain management (Atasever 2019, p. 14)

developments in real-time sensing, dynamic control of large-scale industrial systems, information services and product life cycle management.

Keeping accurate inventory information is not the end of the HTM process. Instead, inventory serves as input to many different activities within the HTM cycle (Fig. 2.2).

2.4 Warehouse Management

Distribution in the healthcare industry harnesses vast data that can be analyzed while it necessitates security, privacy, and sensitivity in the management. These features not only include the timely and right management of the healthcare products but also, are related to the patients' vulnerable information. Rather than a regular warehouse management, healthcare related warehouse management requires more attention to

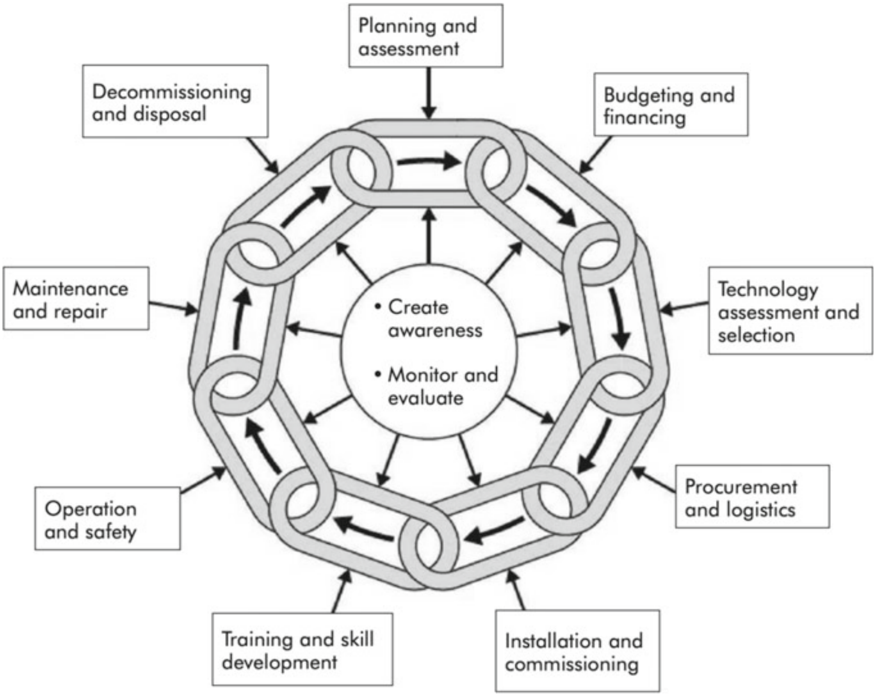

Fig. 2.2 Health care technology management cycle

prevent the possible health risks toward the patients. Besides, the possible threats such as eavesdropping, authentication protocols, and long periods in the healthcare supply chain system are disparate than the other industries and new tools for alleviating these threats would need robust technological, real-time support (ref).

2.5 Stock Management

The purpose of stock control in hospitals is to ensure that materials are constantly available in the warehouse, to minimize investments in stocks, to use the workforce effectively, to reduce transportation and logistics costs and to improve the quality of care with less stock. Hospitals must develop a stock control method depending on their stock policy, service type, financial situation, and other factors. Whether the demand for the goods in stock is dependent or independent is an important feature that determines the method that can be used to plan and control stocks. Some of these methods are; the visual control method, tickler method, and click sheet control method.

2.6 Pharmaceutical Management

Various technologies have been adopted to ensure the secure services in the ever-growing market of pharmaceuticals. Supply chain and distribution solutions in the pharmaceutical management has been coupled with the digital tracking applications. Falsifications and counterfeiting are being prevented with the aid of the IoT and blockchain technologies including RFID, sensor and such solutions to have a robust inhibitor for the possible insecurities and errors during the distribution and SCM. Blockchain technology is (Clauson et al. 2018). To reduce medication errors, hospitals may choose to implement barcode-assisted medication administration. Using this approach, healthcare professionals scan the barcodes on the packaging of the drug to be administered, on the patient's wristband, and on their ID badge, to rule out any preventable medication errors. As this information is recorded automatically, time-consuming paperwork is reduced.

2.7 Usage of Radio Frequency Identification (RFID) in the Health Industry

RFID, is a technical term created by using the initials of the words Radio Frequency IDentification and can be briefly explained as identification with the radio frequency technique.

RFID is the name given to technologies that use radio waves for the automatic identification of different materials. RFID technology is the basis for a new coding system, as well as helping businesses to solve the problems they face in controlling their supply chains and is caused by the lack of information in the supply chain. The difference with the barcode system is that in the barcode system, the information flow is bidirectional whereas in RFID it is unidirectional. In RFID technology, people and objects can be identified automatically with radio waves. The way how RFID works are represented in Fig. 2.3.

RFID enables the tracking of medical devices and fixtures. It allows whether the necessary actions (for example, disinfecting the device) are carried out during the use of the device. The RFID system allows seeing where a device is in real time, whether it is in use, and whether it is suitable for use in the hospital.

2.8 Usage of Barcode and Data Matrix in the Health Industry

Two types of barcode systems are used for consumption units, EAN-13 and EAN-8. If the surface of the product and package is too small to receive the reading marks for 13-digit numbers and it exceeds 25% of the surface on which it will be printed, the

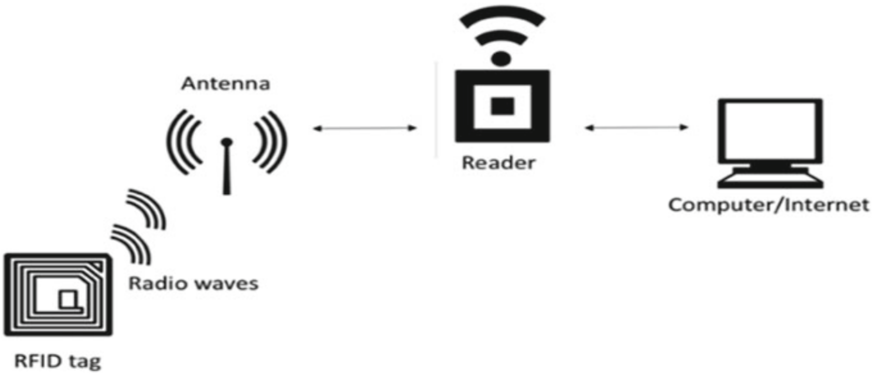

Fig. 2.3 Working principle of RFID (Thomas et al. 2017)

Fig. 2.4 Barcode and QR

8-digit barcode system (EAN-8) is used. The first three digits of a 13-digit barcode system form the country code. The 4-digit numbers after the country code show the company code that is the owner of that product.

Unlike conventional one-dimensional barcodes (consisting of lines), QR type barcodes are a type of barcode with a matrix structure consisting of white and black squares or rectangles. The advantage of QR code type barcodes is that they can contain more data than conventional 1D barcodes. With the implementation of barcode and QR, time losses and errors in inventory management of drugs and materials have been reduced to a minimum, and with barcode and QR technology, the same drug is not written to the stock records more than once, and the reordering of the drugs in the warehouse is prevented (Fig. 2.4).

By using the barcode and QR technologies, the dose applied to the patient is actively followed, and it is also possible to automatically order the products whose stocks are decreasing. Thus, the cost of holding excess inventory is reduced. At the same time, with this technology, the auto-warning mechanism is activated before the expiration date of the products.

2.9 Healthcare Waste Management and Reverse Logistics

The waste created out of the health care and medical processes is called as healthcare waste (HCW). These wastes include hazardous components (infectious, pathological, sharps, chemical, pharmaceutical, cytotoxic, and radioactive) (WHO 2018). Thus, HCW needs to be taken care of with specific attention. Healthcare waste management (HCWM) requires consideration of sustainability issues. Grose and Richardson (2013) examined the procurement and supply chain activities to better understand the benefits of sustainability in HCWM.

Precise location tracking and predictive analytics for the vehicle location and timing estimations are specially used for the temperature-sensitive and perishable healthcare products. Cloud technology along with the predictive analytics under BI technologies, aims to minimize wastage. The remote tracking and monitoring via IoT, cloud, and data analytics tools can leverage the supply chain process for health care and prevent shortages (Yang et al. 2011).

Reverse logistics (RL) and reverse supply chain (RSC) are adopted mostly in the new tool applications for wastage management. Missing products and timely deliveries are tracked with sensor-embedded systems (Ilgin and Gupta 2011).

Reverse logistics includes various methods that are also valid in supply and distribution logistics, as well as special methods for reverse logistics. These can be listed as follows (Dyckhoff 2004, pp. 164–165).

- **Collection** covers all activities related to the collection of waste, which is usually dispersed within the production area.
- **Separation** involves the division of waste into smaller volumes for different treatments.
- **Transport and transfer** cover the transportation of wastes to places where disposal or reuse operations are to be carried out.
- **Storage** takes place before transportation and transfer or before it is processed into waste. Storage is mainly used for the collection of waste quantities from transport and processing activities, where the highest efficiency will be achieved. The capital allocated to inventories is not as high as it is in traditional storage activities since wastes are of no value or are of low value.
- **Processing** covers the processes of making wastes reusable or harmless to nature.

2.10 Recycling Stages of Hospital

The following stages are followed in the recycling of hospital waste (Kayar 2015, p. 48):

Stage 1: The products used in hospitals for various reasons are collected in containers according to the type of waste and delivered to licensed companies and local municipalities.
Stage 2: The collected wastes are separated according to their characteristics.
Stage 3: Recyclable wastes are made reusable with the appropriate recycling method.
Stage 4: Non-recyclable wastes are destroyed by incineration or burial without harming the environment.
Stage 5: The recovered products are offered for resale in the markets.

The autoclave and sterilization process is applied to the reusable materials specified by the Ministry of Health in the hospital in accordance with the instructions before they are reused.

2.11 Conclusion

Cutting healthcare supply chain costs allows people to access pharmaceutical products and medical devices more affordable. In addition, patient safety increases with improved opportunities thanks to developing new technologies. In addition to these benefits, productivity has been increased with the newly developed technology and newly used distribution channels in the health sector. Thanks to the new software, disease control has been increased, health records have been stored in a digital environment and zero waste policy has started to be developed in the health sector.

In addition, technology has made it easier than ever to both access treatment and communicate with professionals. As a result, technology has certainly had a huge impact on various fields in medicine and health. This book chapter has shared just a few of the ways technology and new distribution systems are making health care easier and more efficient for everyone involved. As technology continues to advance, the healthcare industry will continue to be affected even more.

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Chapter 3
An Assessment of the Financial Performance of Hospital Services Sub-Sector in Turkey by Ratio Analysis Method

Mustafa Çanakçıoğlu

Abstract The present study made use of the sector balance sheets of "Q-861 Hospital Services Sub-Sector" for the years 2015–2020, which was recently published by the Central Bank of the Republic of Turkey (TCMB), which maintains the largest financial data on the hospital services sub-sector. The 6-year time period above was selected for the purposes of the study on the grounds that TCMB published the most up-to-date sector balance sheets for the said timeframe. The present study also aimed to investigate the financial structure of the hospitals operating in this sector in Turkey prior to the COVID-19 pandemic across the world. In general, ratio analysis, parametric, and non-parametric methods are used to measure the performance levels of hospital enterprises. The present study employed ratio analysis, a financial analysis method to assess the performance levels thereof. The financial performance of the sector was assessed in the study using 15 criteria, including liquidity, financial, activity, and profitability ratios.

Keywords Financial management · Financial performance · Hospital management · Turkey · Ratio analysis

3.1 Introduction

The increase in the world population and especially the high rates of elderly in the general population, the desire to benefit from health services, and different diseases that emerge due to altered environmental and ecological conditions have caused an ever-increasing demand for health services each day. Furthermore, along with the fact that the technologies used in diagnosis and treatment are expensive, there have been changes with regard to extent of the need for hospital services due to the COVID-19 epidemic since 2019. While the said increase in demand turned the healthcare

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services into one of the largest sectors in the world, the scarce resources in provision of services, on the other hand, increased the significance of the financial structures of hospital services. The concept of service has been systematically and technically studied since the 1700s, and the service notion is embodied in different forms in almost every field as a result of people's interaction and relations with each other (Sayım and Aydın 2011).

Healthcare service is defined as a permanent system organized in certain healthcare institutions and organizations across the country with an aim to achieve objectives that vary by the needs and requests of the society with the help of different types of healthcare professionals, and thus to carry out the activities intended for preventive and curative health care of the individuals and the society (Bozkurt 2020). Whereas the healthcare services sector is a concept used to classify economic units that produce goods and services to cure, prevent, rehabilitate, and provide palliative care for patients and diseases (Gül 2020). Hospital activities, as one of the human healthcare activities classified within the scope of "human health and social service activities" in the United Nations International Standard Industrial Classification (ISIC) guide, cover all general and special hospital activities (United Nations 2008). Hospitals within the health system are service enterprises that provide society with various healthcare services and assume important tasks in the generation of a healthy society. These organizations are a part of the country's economy and constitute a large service industry (Özkan 2003).

As of 2020, there were a total of 1,534 hospitals in Turkey, of which 900 were state hospitals, in addition to 68 universities and 566 private hospitals (T.C. Sağlık Bakanlığı Sağlık Bilgi Sistemleri Genel Müdürlüğü 2021). The incentives offered by the government to the healthcare sector in recent years played an important role in the development of enterprises in this sector. In addition, thanks to the rapid merger and acquisition activities in the sector in recent years, healthcare institutions in the sector tended to generate chain enterprises (Karadeniz 2016). In this respect, the TCMB data included both general hospitals and specialized hospitals providing healthcare services. For example, the 2020 data were obtained upon consolidation of the financial statements from a total of 2,613 businesses operating in the sector. Certain numerical information about the structure of those companies in the sector is given in Table 3.1, and the balance sheet structure of the sector is given in Table 3.1.

An analysis of the tabulated financial structure of the sector in Table 3.2 indicates that the current assets of the sector have increased in the last 12 years. Nevertheless, the said increase in current assets was less compared to the increase in short-term debts between 2015 and 2020. The fact that the fixed assets have decreased over the years, albeit slightly, is indicative of the fact that the investments in fixed assets in the sectorial companies have also decreased. Notwithstanding the above, it is possible to suggest that those enterprises adopted a correct borrowing policy given the slight increase in long-term liabilities and the fact that constant capital is higher than the total percentage of fixed assets in most years. The difference was paid by short-term debts in the 2017 and 2018 periods when the said percentage distribution was

Table 3.1 Statistical data on businesses in the sector

Scale distribution	Number of companies	Number of companies (%)	Number of employees	Number of employees (%)	Active total (%)	Equities (%)
Micro	1,995	74.8	2,586	1.31	8.4	7.5
Small	164	6.3	3,278	1.43	3.6	3.4
Medium	217	8.3	31,559	18.80	8.9	9.3
Large	277	10.6	191,165	83.62	79.1	79.8

Source TCMB Sectorial Statistics (2020)

insufficient. Nevertheless, it is a fact that the rate of current assets in these two years was lower compared to the rate of short-term debts.

In light of those statistics, the rapid increase in the number of private health institutions in recent years and the structural changes in the healthcare sector have escalated the competition in the sector and reduced the profit margins. The narrowed profit margins as a result of fierce competition inflicted major controversies on the part of private hospitals (Karadeniz 2016). As a result of those structural developments in the sector, the results of the ratio analysis method have become increasingly important with each day to analyze and interpret both the performance of the healthcare companies over years and how they compare to other companies in the sector. Accordingly, the main purpose of the present study was to assess the financial performance of the Turkish hospital services sub-sector. Therefore, the study used the ratio method to analyze the financial statements of the "Hospital Services Sub-Sector" as published by the Central Bank of the Republic of Turkey (TCMB) between the years 2015 and 2020. In the context thereof, first, the asset and resource structure of the sector was reviewed and then the liquidity, financial structure, activity, and profitability ratios of the sector were calculated.

Although not frequent use across the public and private healthcare institutions in Turkey, the United States (US) Healthcare sector started to use the ratio analysis as early as the 1940s. Today, all the US healthcare institutions employ this method in the scope of financial management (Atlı and Demir 2017).

3.2 Literature Review

Upon a literature review, it was seen that there were relevant studies, which investigated the financial performance of different sectors with reference to the sectorial balance sheets released by TCMB. The relevant studies in the literature investigated the tourism industry (Karadeniz et al. 2016, 2017; Koşan and Karadeniz 2014), hospitality and food services industry (Karadeniz et al. 2011, 2015a), healthcare sector (Karadeniz 2016; Aydemir 2018), energy sector (İskenderoğlu et al. 2015, 2017), food and textile industries (Öğünç 2018; Mazman İtik 2021), the construction

Table 3.2 Percentage analysis of the hospital services balance sheet

	2009 (%)	2010 (%)	2011 (%)	2012 (%)	2013 (%)	2014 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)
Asset structure												
Current assets	35.0	38.3	36.9	36.2	37.1	38.8	39.8	39.1	41.2	43.8	38.3	44.8
Fixed assets	65.0	61.7	63.1	63.8	62.9	61.2	60.2	60.9	58.8	56.2	61.7	55.2
Liability structure												
Short-term debts	29.1	31.3	32.6	35.8	35.1	37.7	37.6	39.7	42.6	46.6	37.9	40.0
Long-term debts	24.1	23.7	28.2	25.8	30.3	29.0	32.1	33.4	32.7	27.8	32.9	32.7
Equity	46.9	45.0	39.3	38.4	34.6	33.3	30.3	26.9	24.7	25.6	29.2	27.3
Number of companies	669	861	964	1210	1836	1797	1853	1887	2008	2302	2537	2613

Source TCMB Sectorial Statistics (2020) industry (Çalış 2013), forest products industry (Akyüz et al. 2015), transportation industry (Kurtlar 2021), land and sea freight transport industry (Dursun and Erol 2012; Karadeniz et al. 2015b; Deran and Erduru 2018; Doğan 2020; Beller Dikmen 2021), paper products industry (Karadeniz et al. 2021), trade sector (Şahin 2021), and manufacturing industry in general (Demirci 2017; Kazak 2018).

Whereas, relevant studies on the healthcare sector, which used the ratio analysis, generally focussed public (Saraçoğlu et al. 2012; Özer 2012; Dayı and Akdemir 2013; Ercan et al. 2013; Korkmaz and Güney 2013; Avcı 2014; Alparslan et al. 2015; Çam 2016; Gazi et al. 2016; Sonğur et al. 2016; Alper and Biçer 2017; Bülüç et al. 2017a; Çil Koçyiğit and Kocakoç 2019; Kakilli Acaravcı and Gazi 2019; Yiğit and Bayrakcıoğlu 2020; Ekinci and Bakır 2021) and private sectors (Özgülbaş et al. 2008; Gider 2011; Akca and Somunoğlu İkinci 2014; Ardıç and Köşkeroğlu 2014; Bülüç et al. 2017b; Bıçakçı et al. 2018).

Along with the aforementioned studies, there are studies on the healthcare sector, which used the TCMB balance sheet data for the purposes of ratio analysis. The said studies included a review of factors effective in the financial performance of 797 private hospitals using ratio and trend analysis (Özgülbaş et al. 2008) and periodic reviews of the financial performance of the hospital services sub-sector in Turkey spanning 2011–2013 (Karadeniz 2016), 2013–2015 (Aydemir 2018), and 2009–2019 (Yiğit 2020) periods. The most recent study analyzed the financial statements of the sector for the period of 2012–2014 based on the DuPont financial analysis technique (Karadeniz and Koşan 2017).

3.3 Method and Dataset

The TCMB classifies the sectors in Turkey pursuant to the NACE (Nomenclature générale des Activités économiques dans les Communautés Européennes), a pan-European classification system, which allows statistical classification of economic activities across the European Union. The TCMB makes data from a number of companies in respective sectors available to researchers. The globally accepted International Standard Industrial Classification (ISIC) activity classification by the United Nations (UN) is taken as a basis for the intercountry comparison of domestic commercial and industrial activity data. Based on the NACE classification system, which was intended for use by the EU member states, the hospital services cover short and long-term hospital activities and the activities of specialized hospitals (Karadeniz 2016).

In the present study, ratio analysis was used to measure the performance of hospital enterprises. The first study in the literature, which aimed to measure the financial performance of hospitals using the ratio analysis, was conducted by Choate and Tanada in 1979 (Aydemir 2018). The ratio analysis in the present study employed 15 financial performance assessment criteria, including liquidity, financial, operating, and profitability financial ratios. Those financial ratios were selected among the most frequently utilized criteria by previous studies upon literature review. The TCMB balance sheet and income statement data (Türkiye Cumhuriyeti Merkez Bankası 2020) and the codes, names, and formulas of those selected ratios as calculated using Microsoft Office Excel software are given in Table 3.3. Furthermore, the information as regards which authors used the selected criteria in previous studies is given in Table 3.4.

Table 3.3 Criteria and formulas

Liquidity ratios	
Current ratio	Current assets/short-term liabilities
Liquidity (acid test) ratio	(Current assets—inventories)/short-term liabilities
Cash ratio	(Liquid assets + securities)/short-term liabilities
Financial structure ratios	
Total liabilities/total assets	(Total liabilities/total assets)
Short-term liabilities/total assets	Short-term liabilities/total assets
Tangible fixed assets (net)/equity ratio	(Tangible fixed assets (net)/equity)
Operation rates	
Receivables turnover ratio	Net sales/average commercial receivables
Asset turnover ratio	Net sales/average total assets
Profitability ratios	
Return on equity	Net profit (loss)/equity
Return on assets	Net profit (loss)/total assets
Operating profit margin	Operating profit (loss)/net sales
Net profit margin	Net profit/net sales

Table 3.4 Previous studies, which used the selected criteria

Criteria	Resources used
Current ratio	47; 7; 14; 49; 8; 35; 45; 41; 32; 42; 51; 38; 55
Liquidity (acid test) ratio	47; 7; 14; 45; 49; 8; 35; 41; 32; 42; 51; 38; 55
Cash ratio	47; 7; 14; 55; 49; 45; 41; 32; 42; 51; 38
Total liabilities/total assets	47; 7; 14; 55; 38; 49; 8; 35; 45; 41; 32; 42; 51
Short-term liabilities total assets	47; 7; 14; 55; 49; 35; 41; 32; 42; 51
Tangible fixed assets (net)/equity ratio	47; 32
Receivables turnover ratio	47; 7; 14; 55; 49; 8; 41; 32; 42; 51; 38;
Asset turnover ratio	47; 7; 14; 38; 49; 45; 41; 32; 42; 51; 38
Return on equity	47; 7; 14; 55; 38; 49; 8; 35; 41; 32; 42; 51
Return on assets	7; 14; 49; 8; 35; 45; 41; 32; 42; 51; 38;
Operating profit margin	47; 7; 14; 49; 45; 41; 32; 42; 51
Net profit margin	47; 7; 14; 49; 35; 45; 8; 41; 32; 42; 51; 38

3.4 Results

This part of the study is spared for the ratio analysis method used for assessing the financial performance of the hospital services sub-sector (Table 3.5).

A review of the liquidity ratios, which measured the current assets of the hospital enterprises and their ability to pay their short-term debts, indicated that there was a tendency of decrease in current ratio, acid-test ratio, and cash ratio during the 2015–2018 period, which increased in 2019 and 2020 compared to the previous year. While the current ratio, provided a general measurement of the ability of enterprises to offset short-term liabilities with their current assets, it also offers important information about the sufficiency of net working capital. In the reference frame thereof, while the adequacy of net working capital decreased until 2018, there was an increase after 2018. A review of the risk of hospital enterprises as regards their ability to offset their short-term debts should include an assessment, which uses the acid-test ratio and the cash ratio combined. The acid-test ratio, which measured the current assets and short-term debts of enterprises other than their stocks, also decreased until 2018, similar to the current ratio, and increased in 2019 and 2020 compared to the previous years. The fact that the size of stocks in the balance sheet of the healthcare enterprises was relatively low compared to the manufacturing industry or commercial enterprises accounts for the close results of the current ratio and acid-test ratio in the hospital enterprises.

The cash ratio, which is another liquidity ratio that complements the current ratio and acid-test ratio, measures the ability to offset short-term liabilities using cash and cash equivalents. Accordingly, the ability of hospital enterprises to offset their short-term liabilities with liquid assets and securities decreased until 2018, as was the case with the current ratio and acid-test ratio, and thereafter increased compared to the previous year. Upon assessment of the three ratios combined, they moved in the same direction over the years. The main reason for the foregoing was that the ratio of short-term liabilities over the total resources of hospital enterprises was on an upward trend until 2018, and then decreased. The sector averages indicated that 38% of the total resources were provided by short-term liabilities in 2015, while the same rate increased to 47% in 2018. In other words, hospital enterprises financed almost half of their total assets by means of short-term borrowing in 2018. This is an extremely risky situation with regard to the ability of hospital enterprises to offset their short-term obligations. Nevertheless, the fact that the same ratio decreased to

Table 3.5 Ratio analysis method used for assessing the financial performance of the hospital services sub-sector

Liquid ratios	2015	2016	2017	2018	2019	2020	Arithmetic mean
Current ratio	1.06	0.98	0.97	0.94	1.01	1.12	1.01
Liquidity (acid test) ratio	0.91	0.84	0.83	0.80	0.82	0.93	0.86
Cash ratio	0.21	0.13	0.16	0.11	0.17	0.25	0.17

Table 3.6 Financial structure ratios

Financial structure ratios	2015	2016	2017	2018	2019	2020	Arithmetic average
Total liabilities/total assets	0.70	0.73	0.75	0.74	0.71	0.73	0.73
Short-term liabilities/total assets	0.38	0.40	0.43	0.47	0.38	0.40	0.41
Tangible fixed assets (net)/equity ratio	1.08	1.22	1.30	1.12	1.08	1.05	1.14

Table 3.7 Operation ratios

Operation rates	2015	2016	2017	2018	2019	2020	Arithmetic mean
Receivables turnover ratio	4.35	4.28	4.47	4.86	5.40	5.30	4.78
Asset turnover ratio	0.79	0.76	0.74	0.76	0.86	0.83	0.79

38% in 2019 and that it was 40% in 2020, is indicative of positive developments with a view to the liquidity risk of enterprises compared to 2018 (Table 3.6).

A review of the distribution of financial resources of hospital enterprises suggested that approximately 73% of the total financing resources were ensured by means of borrowing, while 27% by equity capital. The fact that businesses finance only 27% of their total assets by equity capital, indicated that the sectorial enterprises followed a debt-based financing policy and therefore they were at a relatively higher financial risk. While the ratio of total liabilities to total resources was 73% on average during the 2015–2020 period, there was no general trend by year. The high rate of borrowing in the sector would on the one hand increase the financial risk due to borrowing, and therefore, the total risk of the enterprises, and on the other hand, it would directly affect the financing expenses and profitability of the enterprises. The increase in financing expenses would increase the degree of financial leverage of the enterprises, and as a result, the volatility in the net profit of the enterprises would increase vis-à-vis the change in the operating profit.

While the rate of short-term liabilities in total resources had a trend of increase during the 2015–2018 period, the same decreased in 2019 and 2020. The increase in short-term debts in total resources negatively affected the ability of enterprises to offset their short-term debts and had an adverse effect on the liquidity ratios, as mentioned above.

The ratio of tangible fixed assets over equity increased between 2015 and 2017 compared to the previous year, while the same decreased during the 2018–2020 period. The fact that the said ratio was above 1 in all the years within the scope of the study indicated that not all the tangible fixed asset investments could have been financed by equity. The reason is the low equity of hospital enterprises, as mentioned above (Table 3.7).

The receivables turnover ratio, which showed the average number of times that hospital businesses make over or collect their commercial receivables, tended to increase during the 2015–2020 period. In other words, the collection period of the receivables of the enterprises tended to become shorter. This is an extremely positive development for the ability of enterprises to obtain cash from their main activities. Concurrently, the same reduced the risk of commercial receivables of businesses turning out to be bad debt and positively affected their profitability. It shows that the receivables management process worked well and collection losses were low.

The asset turnover rate, which measured how effectively or efficiently the total assets of hospital enterprises were used, decreased during the 2015–2017 period, but increased after 2017. This was indicative of the fact that the efficiency of the activities of the sectorial enterprises vis-à-vis their total investments, decreased until 2017 and increased thereafter. In general, an increase in the asset turnover ratio positively affects the profitability and liquidity of the enterprises. Therefore, the years 2019 and 2020 presented a better outlook compared to the previous periods. The increase in this ratio in those years meant that the hospital units, including outpatient clinics, clinics, operating rooms, delivery rooms, intensive care, and laboratories as well as medical systems, including Magnetic Resonance Imaging (MRI), Computed Tomography (CT), and Angiography inter alia were used efficiently and effectively (Table 3.8).

A review of the profitability ratio of the equity of hospital enterprises indicated that the average return on equity was negative in 2016 and 2018, and positive in the other four years. During the six-year period in question, the return on equity was at the highest level in 2020. In the said year, the return on equity was 7.4%. In other words, the sectorial companies earned TL 7.4 net profit on average for every TL 100 of equity capital. Given that the inflation rate (Consumer Price Index—CPI) in Turkey was 14.60% in 2020, the profitability remained below the inflation rate, even in 2020, when the hospital enterprises had the highest profitability. The fact that most of the hospitals in Turkey were controlled by the public sector and were not profit-oriented accounted for this low rate.

The return on assets ratio, which indicated the net profit as the percentage of the total assets, was negative in 2016 and 2018, and positive in the other years. The reason why the return on assets and return on equity ratios were negative in 2016 and 2018 and positive in other years was that the net profit of the period was included in the share of both ratios. The reason why the return on equity ratio of the sectorial

Table 3.8 Profitability ratios

Profitability ratios	2015	2016	2017	2018	2019	2020	Arithmetic average
Return on equity	0.007	−0.050	0.020	−0.059	0.025	0.074	0.003
Return on assets	0.002	−0.013	0.005	−0.015	0.007	0.020	0.001
Operating profit margin	0.067	0.062	0.062	0.070	0.076	0.105	0.074
Net profit margin	0.003	−0.019	0.007	−0.021	0.009	0.027	0.001

enterprises was extremely low as well as the return on assets ratio was even lower was that a significant part of the total assets of the enterprises was financed by means of borrowing and therefore the equity was low compared to the total debts.

Despite the low operating profit margin, which showed how much operating profit was obtained from the net sales of the hospital enterprises, it was positive in all the years in question. The increase in the operating profit margin was positive for the profitability of the enterprises especially in 2018, 2019 and 2020. There was a continuous increase in the operating profit margin in the sector since 2017. Upon analysis of the income statement with an aim to figure out the reasons for the said increase, the increase in net sales in the sector in those years was higher compared to the increase in operating expenses and cost of sales. The decrease in the ratio of Operating Expenses to net sales over years is the most important evidence for the foregoing.

The net profit margin of the hospital enterprises is extremely low compared to the operating profit margin. So much so that despite the operating profit margin being positive in 2016 and 2018, the net profit margin was negative. This is because of the fact that foreign exchange losses, financing expenses, and extraordinary expenses and losses in the sector were high in each period upon detailed analysis of the respective income statement items.

3.5 Conclusion

The present study, which aimed to investigate hospital enterprises from a financial point of view, used the ratios produced from the financial statements of the years 2015–2020. Accordingly, the liquidity, operating efficiency, financial structure, and profitability of the enterprises were reviewed based on the average data from Hospital Services Sub-Sector.

The ability of sectorial businesses to pay their short-term debts is low. The change in short-term debts by years accounted for the change in the current ratio, acid-test ratio, and cash ratio of enterprises by year. The fact that it had a high share in the short-term total resources, put the enterprises at a relatively high liquidity risk. Healthcare enterprises may mitigate the liquidity risk by restructuring their short-term debts in the form of long-term debts.

The hospitals generally adopted a high-risk financing strategy and used equity to a lower extent. The fact that the borrowing rates were above the generally accepted standards, indicated that the sectorial enterprises were predominantly financed on a borrowing basis. As regards the use of liabilities, the rate of short-term borrowing was higher compared to long-term borrowing. Accordingly, the risk of financial distress due to the inability of the sectorial enterprises to offset their debts was very high. Therefore, sectorial enterprises strengthen their equity capital and act a little more cautiously in the use of liabilities. In the meantime, it should be noted that the use of equity above the standards was likely associated with an increase in the cost of capital.

Profitability rates are important indicators for the assessment of financial performance. In that respect, even though the other indicators of the hospitals were not at a level to suggest a financial failure, the profitability of the hospitals was not at the desired level. The sector incurred losses, especially in 2016 and 2018. The main factor that would affect the profitability of hospitals is the costs and funding expenses associated with service provision. Especially in 2018, there was an increase in those two factors combined with foreign exchange losses, which adversely affected the financial performance of the sector.

In light of the results of the present study, it can be suggested that the sector should pay attention to liquidity ratios, keep their costs under control, follow a tighter receivables collection policy, and review their borrowing strategies in order to maintain high financial performance. In addition, they should hold continuous financial analyses with an aim to increase resource efficiency. Furthermore, the fact that the profitability was low although the sector did not have poor financial indicators, is indicative of hospitals' need for professional financial managers and further insight into financial management.

The 2015–2020 period was selected as the subject of research with an aim to investigate the financial structure of the sector prior to the COVID-19 pandemic and thus contribute to the post-pandemic studies. In other words, the study aimed to contribute to the financial performance analyses based on the TCMB data intended for the assessment of hospitals' performance in the pre-pandemic, pandemic, and post-epidemic periods.

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Chapter 4
Pharmaceutical Warehousing 4.0 in Healthcare Supply Chain

Mahmut Tutam

Abstract Over the last decade, many countries have suffered from supply chain disruptions for different products because of the ever-increasing global problems with devastating financial and social consequences. In response, most companies revisit their just-in-case supply chain strategies and shift them to just-in-case models. As a result, warehouses acting as barriers to unexpected circumstances have become more crucial than ever in human history. Apparently, warehousing plays an essential role in any industry but a critical role in health care because of the possible results of any instability and lateness in pharmaceutical deliveries. Different from conventional warehouses, thousands of pharmaceuticals are received, stored, and preserved in pharmaceutical warehouses (pharmahouses) under special storage, handling, temperature, ventilation, and lighting conditions. Moreover, with the increasing older population and chronological or pandemic diseases, thousands of pharmaceuticals are delivered daily to patients, healthcare providers, or pharmacies. Therefore, recent technological advancements are continuously adopted by pharmahouses to cope with the ever-increasing conditions and demand. This chapter presents the history of pharmahouses and their transformation from primitive cellars or storerooms to intelligent facilities.

Keywords Healthcare supply chain · Pharmaceutical warehousing 4.0 · Information and communication technologies · Robotics · Intelligent systems

4.1 Introduction

Health has been the most valuable asset for humankind throughout history. Regardless of time or region, people have spent their time and wealth to gain health. Apparently, wealth and health are connected so improvements in health will increase the wealth

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of an individual or a nation and vice versa (Tiainen 2018). Therefore, health has become a key focus for policymakers or governments, and a notable percentage of Gross Domestic Product (GDP) has been allocated to healthcare expenditures. As a result, the global health expenditure reached 8.3 trillion dollars composing 10% of the worldwide GDP (World Health Organization 2020). Increasing annually by 2.4%, global spending on health is anticipated to expand to $18.28 trillion by 2040 (Dieleman et al. 2016), causing a significant burden development of countries (Kaya and Demir 2021). By the end of the day, different strategies must be developed by policymakers or governments to reduce health expenditures by enhancing the efficiency and effectiveness of their health services. These include strategies to empower the health industry to bring more reachable, flexible, scalable, reliable, sustainable, high-quality, agile, and cost-effective health services because more pandemic diseases will occur in the future (Daszak et al. 2020; Gill 2020).

In addition to the governmental strategies, new inventions introduced by industrial revolutions push companies in the health industry to revisit their systems continuously and undertake significant changes in their processes. Therefore, most health companies are rushing to adopt new technologies required for industrial transformation in their organizations to strive in a competitive business environment and provide better, faster, and more cost-effective health services. The first industrial revolution is regarded as the transition from human power to water- or steam-powered mechanical systems. The second industrial revolution is powered by electromechanical systems and refers to the change from individual production to mass production. With the advent of electronic, computer, and robotic technologies, the third industrial revolution is materialized based on automated and autonomous systems. The latest industrial revolution (Industry 4.0, abbreviated to I4), but not the last, redesigns all industries by integrating recent advances in information and communication technologies.

The I4 pushes all industrial fields to move from traditional computerized systems to cyber-physical systems. As with other industries, most sectors in the health industry have experienced profound revolutions by the extension of the concept I4 and the adoption of its principles. Accordingly, new concepts are coined to reflect the history of revolutions in each sector, including but not limited to Health 4.0 (Ferrer-Roca and Méndez 2012; Khelassi et al. 2019), also known as Healthcare 4.0 (Chanchaichujit et al. 2019; Rehman et al. 2019; Tortorella et al. 2020), Medicine 4.0 (Wolf and Scholze 2017), Hospital 4.0 (Faramondi et al. 2019; Unterhofer et al. 2021), Surgery 4.0 (Feußner and Park 2017; Tang et al. 2019), Medical 4.0 (Javaid and Haleem 2019), Pharma 4.0 (Ding 2018; Hariry et al. 2020; Inuwa et al. 2022), and Pharmaceutical Warehousing (hereafter Pharmahousing) 4.0. By analogy with I4, the 4.0 paradigm simply conceptualizes the alteration of each concept in the health industry toward cyber-physical systems.

Healthcare 1.0 refers to the physical visit to small clinics, and patients seek care from clinicians after a physical diagnosis process (Li and Carayon 2021). With the advent of electromechanical systems, Healthcare 2.0 enables to use of different types of technologies for health services in large and more centralized hospitals (Chen et al. 2020). Adopting information technologies to health services, Healthcare 3.0, results in transferring all manual operations to computers and remotely caring for patients (Hathaliya et al. 2019). I4-driven technologies such as Artificial Intelligence, Big Data Analytics, Blockchain, Cloud Computing, and the Internet of Things introduce Healthcare 4.0 (Paul et al. 2021) by connecting patients, healthcare providers, locations, equipment, etc., to provide a more decentralized, virtualized, and dynamic environment (Al-Jaroodi et al. 2020).

With the adoption of I4-driven technologies into healthcare services, all devices and service providers can be connected to create a continuous flow of information for a better service structure. Following the health conditions of individuals with mobile applications or remote connections, healthcare systems evolve from a hospital- or doctor-centric model to a patient-centric model (Afferni et al. 2018; Thuemmler and Bai 2017). As a result, diagnosis or treatment of various diseases can be performed remotely for each patient, and actions can be taken immediately. Moreover, some intelligent systems can follow essential health measures and independently perform complex tasks without human intervention for detection and prevention. As a result, the service quality can be increased by improving the decision process while accomplishing a faster health service by taking advantage of advanced technological systems. Nevertheless, the cost of health services can be decreased dramatically.

All the current and emerging technologies to detect, diagnose, monitor, and treat diseases are integrated by Medicine 4.0 (Ioppolo et al. 2020). Collaborating with intelligent patients, Hospital 4.0 enhances patients' knowledge of their health conditions and allows healthcare providers to make better decisions (Afferni et al. 2018). Assisting the surgical team in using emerging technologies, Surgery 4.0 smoothen surgical operations and eliminates mistakes by developing excellent communication between devices, instruments, and human users (Feussner et al. 2017). Using modern technologies based on interconnected devices, Medical 4.0 enables the development of better medical devices, the introduction of healthcare delivery concepts, and the faster improvement of pharmaceuticals (Haleem et al. 2022).

Pharmaceuticals have existed from the earliest stages of humanity's existence, and their importance in our lives is becoming more critical than ever as the elderly population increases and more pandemic diseases are expected. Accordingly, the global pharmaceutical market is projected to show a compound annual growth rate of 8% and reach 1,700.97 billion dollars by 2025 (The Business Research Company 2021). Therefore, the 4.0 paradigm inherited from Industry 4.0 takes serious attention from the pharmaceutical academy and industry. While academic studies primarily focus on integrating and optimizing digital systems for pharmaceutical services, industrial companies look for opportunities to accelerate the adoption of I4-driven technologies into their pharmaceutical systems.

Pharma 1.0 represents the transformation from the derivation of small-scale medical materials by hand-operated tools to the production of commercial-scale medical materials by mechanical materials (Anderson 2005). Pharma 2.0 enables manufacturers to mass-produce pharmaceuticals by using electromechanical systems (Arden et al. 2021). Pharma 3.0 reduces human intervention in most processes and provides more effective production systems with the help of computer electronics'

(Prajwal et al. 2020). Pharma 4.0 is characterized by an integrated manufacturing control strategy, including big data, interconnectivity, collaborative robotics, artificial intelligence, and cloud computing (Kumar et al. 2020).

In addition to implementing Pharma 4.0 principles, pharmaceutical companies are still struggling with managing logistics, warehousing, and transportation costs (UPS 2015). Therefore, most pharmaceutical companies tend to focus on operations in pharmaceutical warehouses (hereafter pharmahouses) because the quality of patient care depends on the punctuality, accuracy, safety, and reliability of pharmaceutical deliveries. Typically, products are received, processed if necessary, stored, protected in pharmahouses, and eventually transferred to healthcare providers. Representing one of the most regulated industries, pharmahouses require large spaces, costly material and protection fees for complying with legislation rules, as well as specialized and trustable labor. Most importantly, sensitive or personal information must be protected when data is recorded, analyzed, and reported for all processes.

In accordance with the 4.0 paradigm, the revolution of pharmahouses is classified into four stages, as shown in Fig. 4.1. Using water- or steam-powered mechanical systems in primitive pharmahouses can be considered the first revolution (Pharmahousing 1.0). With the transition from small-scale storage to large-scale storage, the second revolution (Pharmahousing 2.0) represents the storage of mass-produced pharmaceuticals in more structured warehouses using electromechanical systems. Employing different computer and information systems in pharmahouses brings the third revolution (Pharmahousing 3.0) with the usage of automated or autonomous systems. The final revolution (Pharmahousing 4.0) integrates all advanced information and communication technologies in pharmahouses to transform them into intelligent facilities.

This chapter is organized into three chapters. Details of revolutions from human power to mechanical, electromechanical, information, and cyber-physical systems are discussed in the following section. The summary and conclusion are formulated in the last section.

4.2 Revolution of Pharmahousing

The usage of pharmaceuticals can trace its origin to the early history of human beings. Early civilizations used leaves, mud, or clay to stop minor bleeding (Wensel 2017). In addition to the instincts of early humans, the effects of natural remedies derived from plants, animals, and minerals on diseases were recognized by watching the behaviors of animals or neighboring tribes (Wensel 2017). Ancient people had faith in the existence of Gods or supernatural forces for conditions they did not understand (Bastian et al. 2019). Moreover, it was common to believe that diseases originated from breaking moral codes (Wensel 2017). Therefore, spirituals or magical practices were presumed to cause health problems because of the entrance of destructive creatures into the human body. Correspondingly, treatment methods for health problems were a combination of cultural, ethical, medical, and ritual ceremonies, known as

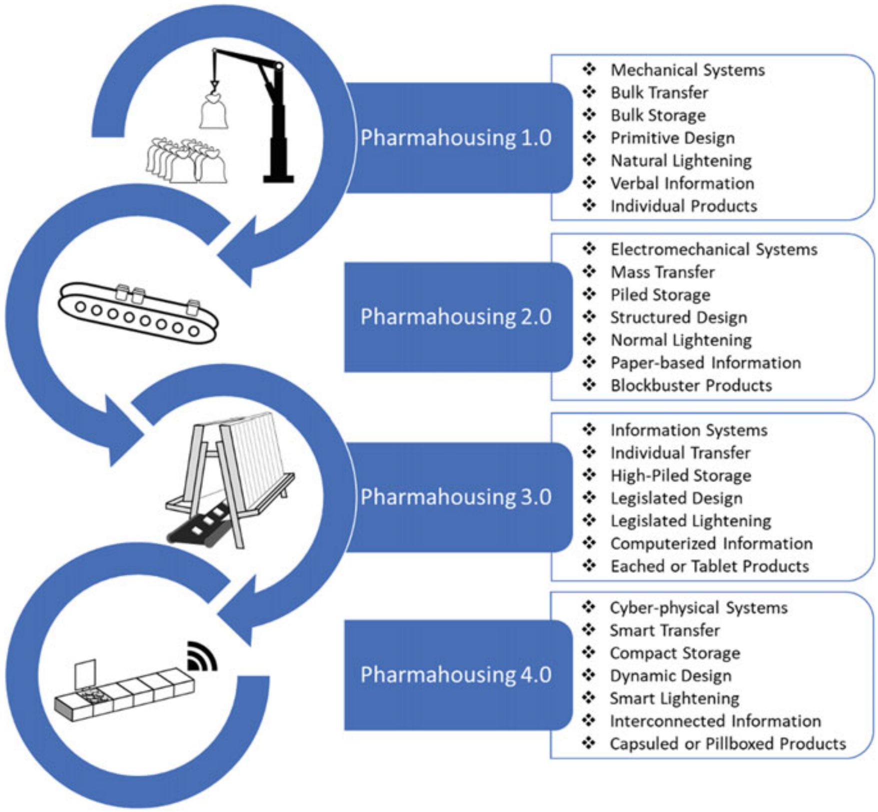


Fig. 4.1 Four revolution stages for pharmahousing

medical rituals (Koştı et al. 2021; Welch 2003). Medical rituals were conducted by shamans, tribal healers, witch doctors, or medicine humans, who were connected to supernatural forces and provided healing for diseases (Koştı et al. 2021). Throughout the rituals, singing or chanting with dancing was used to cast out the destructive creatures, in addition to giving pharmaceuticals by mouth or applying ointments to a part of the skin.

Hunter-gatherers traveled from one place to another because of the limited amount of natural resources in a specific area. Moreover, they stored surpluses of what was hunted-gathered from different regions to use throughout the year, especially during seasonal scarcity. Coping with resource availability in a region and resource variability in time, medical remedies used in rituals were critical to being preserved because of their healing value. Therefore, storage pits were used to protect resources as underground storage areas (Sakaguchi 2009).

With the transition to nomadic life, people began to live in villages and cultivate domestic plants, some of which were used to treat diseases. Over time, humans learned more about plants in limited clinical trials (Davidson 1983). The results of the experiments were recorded in cuneiform tablets, pictograms, or monographs (Wensel 2017). Including detailed information about medicines from plants, animals, and minerals, different collections of information sources (Materia Medica) appeared and served as the primary sources for modern medicine (Majno 1991; Wu 2005). Living a nomadic life restricted the mobility of humankind to specific regions, say villages or cities. Therefore, the population increased dramatically in some areas. As a result, the spread of diseases among human beings increased. Moreover, the domestication of animals and commercial activities between regions also contributed to the transmission of diseases. Hence, exchanging information on how to treat diseases and the need for medical remedies were accelerated.

As a result of moving to residential areas, the accessibility of medical remedies from different regions was limited. Therefore, remedy or cosmetic preparers, called pasisu, appeared by selling medical products on particular streets (Kremers et al. 1986). Over time, demand for medical remedies increased, and the trade between regions accelerated. Another reason for the trade growth between regions was the common belief that medical remedies brought from a distant place in the Far East (considered a paradise) were more effective with curative powers (Hancock 2022; Nam 2014). Therefore, many remedial products were transferred between regions, countries, and even continents via transfer roads such as the Silk Road, Spice Routes, Amber Road, etc. With the increasing trade volume, medical remedies were stored in drug storehouses (Apotheca), grain houses, or armamentariums. Preparing prescriptions and being in charge of the storehouse of medical remedies, humans believed in trusted apothecaries and considered them representatives of gods (Anderson 2018).

With the rise of polypharmacy, multiple medical remedies were used in a single formula to develop pharmaceuticals, resulting in the need for more medical remedies. Therefore, unique rooms in horreas or bazaars were designated for storing and preparing pharmaceuticals. The Horrea Piperataria (or Piperiana or Piperatica) was not used only to store pharmaceuticals but also to sell them to the public (Cassius 1917; Platner 2015; Rickman and Rickman 1971). As illustrated in Fig. 4.2, early versions of storerooms were structured under a floor of around three meters (Palombi 2019) to stabilize the temperature and humidity level of stored medical remedies or pharmaceuticals (Cheung 2021). Over time, pharmahouses were composed of parallel storerooms equipped with raised floors, including windows and doors. Different types of packages, ceramic containers (dolia or pithoi), wicker baskets, or bales (pondo or collo) were used to transfer or store pharmaceuticals (Ashtor 1980, 1982; Cheung 2021; McLaughlin 2014). Moreover, pharmahouses representing the wealth at that time were built near the regional center, ideal places for doctors who had all medical remedies for preparing pharmaceuticals (Palombi 2019).

With the industrial revolutions, the structure of pharmahouses has become increasingly mechanized, electromechanized, automized, and ultimately autonomized. Additionally, pharmahouses have transformed from just storage places for medical remedies to intelligent facilities in which the integrity of customers is preserved, and legislation rules by the Food and Drug Administration (FDA) or the European Medicines Agency (EMA) are applied. Moreover, the temperature, ventilation,

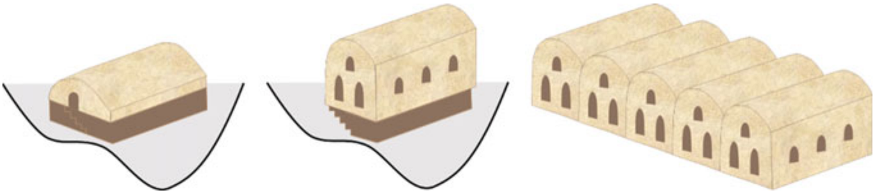


Fig. 4.2 Evolution of pharmahouses

and lighting conditions are monitored continually and adjusted to optimal levels. As a result, recent technological advances have paved the way for transforming pharmahouses into better, faster, and more cost-effective facilities.

4.2.1 Pharmahousing 1.0

The first revolution of pharmahouses was mainly characterized by the transition from human power to mechanical power by mechanizing pharmaceuticals' handling and storage operations. As a result of the advances in medical practices, people's interest in pharmaceuticals increased. Moreover, the number of pharmaceuticals produced increased significantly (small-scale production) with the invention and usage of the pill machine (pill roller). Therefore, pharmahouses became essential facilities, and technologies inherited from Industry 1.0 were adopted to operations in pharmahouses to deal with the increasing interest and production volume for pharmaceuticals.

Large-sized bales were densely packed and transferred rather than moving pharmaceuticals in small packages, containers, or baskets. The employment of large-sized bales in pharmaceuticals' storage and handling operations resulted in the need for relatively large storage areas and more power to load/unload cellars or ships. However, transferring products in bulkage was difficult, labor-intensive, time-consuming, and expensive. Therefore, water- or steam-powered crane systems (see Fig. 4.3) were used to lift heavy bales and locate them on top of each other.

There was not any specific design or structure in pharmahouses. Bales of pharmaceuticals were stored on the floor and located on top of each other if necessary. Space utilization was low because stacking large-sized bales vertically on each other could cause the stacks to topple over. Moreover, pharmahouses were designed to use daylight or gas lighting, generating heat and pollution. In general, locations of pharmahouses were chosen close to the city center or central roads.

Due to limited information about diseases, people believed what they heard about pharmaceuticals in public. Therefore, widespread stories were used to increase sales. All storage and handling operations in pharmahouses were organized by one individual, either the manager or the owner. Therefore, the manager or owner was in

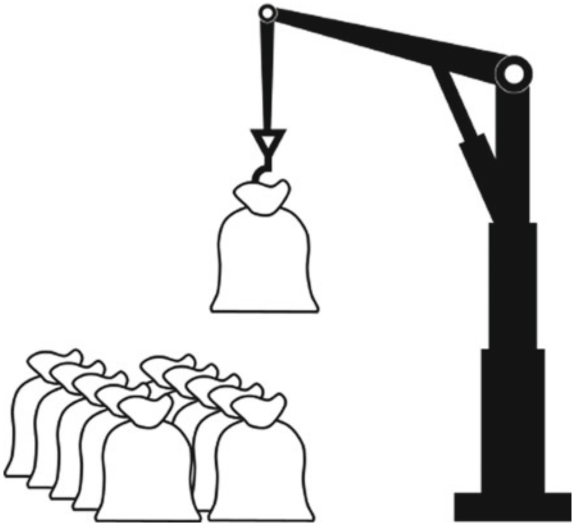


Fig. 4.3 Crane system

charge of all activities in a pharmahouse and knew all information about pharmaceuticals, patients, sales, etc. Moreover, worker and job assignment decisions were made by the same individual. The variety of pharmaceuticals was not much because of the limited knowledge and clinical trials.

4.2.2 Pharmahousing 2.0

Using mechanical systems powered by electrical energy (electromechanical systems) was marked the second revolution for pharmahouses. Therefore, the transition from water- or steam-powered machines to electrical machines revolutionized the industry and enabled the enormous expansion of transportation and communication systems, resulting in the eccentric movement of people, products, and information. As a result, more efficient and faster machines reduced operation costs, requiring less human and mechanical power. Moreover, installing assembly lines in facilities paved the way for mass production. Therefore, some facilities are devoted explicitly to producing larger volumes of pharmaceuticals.

Advanced machine tools allowed people to mix more medical remedies, which proved more effective in treating diseases. Moreover, the availability of papers and newspapers to promote pharmaceuticals increased awareness, resulting in more attraction toward pharmaceuticals. As a result of the mass production of pharmaceuticals, handling and storage operations became more critical. With the appearance of professional cover or package systems, conveyor systems (see Fig. 4.4) were used to transport more compact and straight-shaped packages. Moreover, the excessive

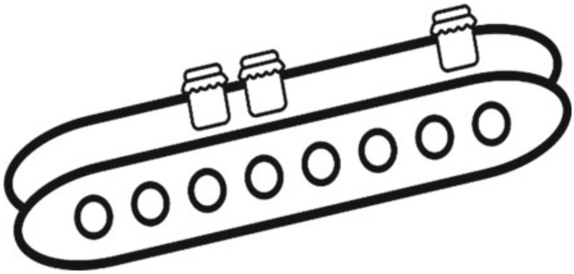


Fig. 4.4 Conveyor system

pharmaceuticals were transported to other regions with the effective use of rivers and the installation of more railroad connections.

Pharmahouses became more specialized and structured because of the increase in steel production. Therefore, packages were stored in vertical directions by installing small-scale racking systems; hence, space utilization increased. More medical remedies were used in producing pharmaceuticals. The requirement of different conditions for pharmaceuticals changed the layout of pharmahouses. Electrical lighting improved the working conditions.

People started to show interest in pharmaceutical companies due to the pharmaceutical industry's developments based on clinical trials. Moreover, pharmaceutical companies took advantage of papers to give more information about pharmaceuticals and advertise their success in treating diseases. Paper-based management systems were adopted to manage pharmahouses effectively. Therefore, a hierarchical management structure was embraced by assigning responsibilities to workers in the ranks. Despite the increasing variety of pharmaceuticals, blockbuster (more demanded) products were mainly stored in pharmahouses.

4.2.3 Pharmahousing 3.0

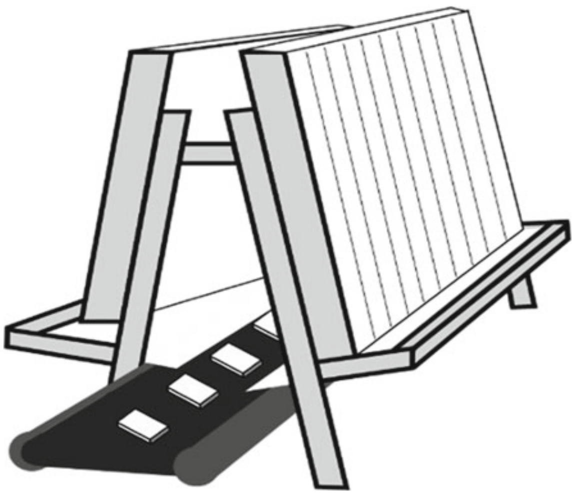
The third revolution of pharmahouses enabled the shift from electromechanical systems to information systems with the adoption of digital computing and communication technologies. More specified and preventive pharmaceuticals were produced, changing the focus from treating patients to protecting humans in healthcare systems (Sargutan 2005). Moreover, computerized systems for tomographic images enabled doctors to recognize disease occurrences and take action for disease prevention or early treatment. With the advances in diagnostic technologies, people physically visited doctors' offices more frequently and were given prescriptions to use pharmaceuticals daily. Moreover, phenomenal growth was observed in the pharmaceutical industry due to the discovery of pharmaceuticals derived from chemical substances in laboratories, and the variety of pharmaceuticals increased dramatically. The increasing demand for personal care or cosmetic products also contributed to the growth of the pharmaceutical industry.

As a result of the enormous increment in the variety of pharmaceuticals, the storage and handling operations became the main problem in pharmahouses. Moreover, blister packaging was introduced with the launching of contraceptives to aid women in taking the pill (Zedler et al. 2011). Therefore, blister packaging boxes were picked from cartons (each-picking or piece-picking). Notably, picking each box from racks and preparing them for delivery led to labor-intensive and time-consuming operations. Reducing human power, automated systems were employed in pharmahouses, such as A-frame module systems (see Fig. 4.5), mini-load automated storage and retrieval systems, etc. Therefore, space utilization, throughput rate, safety, and security were increased. Following the growth of cities, more pharmahouses were established near city centers to facilitate and accelerate the distribution of pharmaceuticals.

Complying with FDA requirements, pharmahouses were built with a more organized structure. The size of a pharmahouse was determined to allow enough space for operations and dirt accumulation. With the growing range of pharmaceuticals, the area of pharmahouses increased dramatically. Moreover, the layout of the pharmahouse was designed to provide enough temperature, ventilation, and lighting control. Designated sites were devoted to poisons, addictive or quarantining pharmaceuticals, requiring security from unauthorized entries. Additionally, transporting pharmaceuticals required high care to ensure safety and security.

With the advent of computer technologies, most information in pharmahouses was transferred to computer systems. Moreover, necessary conditions were monitored and adjusted by using information and communication technologies. A centralized computer took the responsibility to manage all operations effectively by using Warehouse Management Systems. Therefore, the inventory was tracked in real time to optimize the inventory level. Moreover, the efficiency of workers was increased by providing accurate order and location information in addition to optimally solving

Fig. 4.5 A-frame



picking, batching, or routing problems. With the continuous improvement in the pharmaceutical industry, the variety and the number of pharmaceuticals sharply increased.

4.2.4 Pharmahousing 4.0

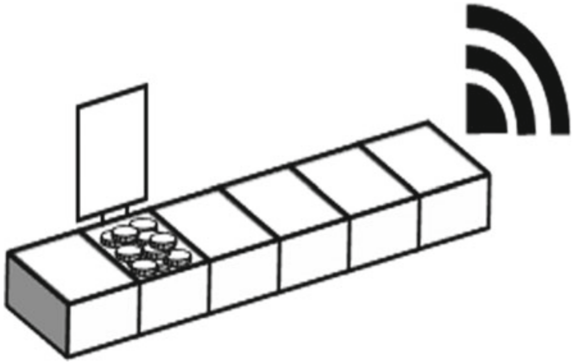
The final revolution in pharmahouses is still ongoing by employing cyber-physical systems and paving the way for digital transformation. Most advanced information and communication technologies continue to be integrated into any stage of storage and handling operations. A tremendous amount of data has been collected to perform the necessary analytics and generate actionable information. Moreover, the real-time monitoring of pharmaceuticals is enabled with cloud computing technologies, and artificial intelligence is employed for the decision-making of operations. Therefore, pharmahouses have gone from traditional warehouses to more complex, intelligent, and interconnected facilities.

In recent decades, people's shopping behavior has changed significantly because of the frequent occurrence of pandemics. People have switched to online shopping rather than going to crowded pharmacies. As a result, some companies have started delivering pharmaceuticals to their customers with legislative permission. Accordingly, the FDA has created a campaign to educate customers about the dangers of online purchasing and how to purchase pharmaceuticals safely in online pharmacies (FDA 2020). Following the big boast in e-commerce, thousands of pharmaceuticals are placed and delivered daily to patients, healthcare providers, or pharmacies. With the growing range of pharmaceuticals, increasing costs, and introduction of legislation rules, pharmahouse managers are compelled to invest in more intelligent, complex, and robotic systems which provide flexibility, space utilization, and 24/7 service. What's more, the increasing older population and chronological or pandemic diseases, in addition to the rising need for personalized pharmaceuticals, will accelerate the employment of more robotic solutions in pharmahouses.

Preventive diagnosis and the application of medical solutions have become more critical than ever before. More importantly, personalized or precision medicine is improved by tailoring disease prevention and treatment depending on people's genes, environments, and lifestyles (FDA 2018). Therefore, storing personified pharmaceuticals will require a more dynamic pharmahouse structure. Moreover, monitoring temperature, ventilation, and lighting conditions will be necessary to become an FDA- or EMA-approved and certified pharmahouse (Fig. 4.6).

Controlling the micro-level of the system will raise space and energy problems. Therefore, more compact and energy-efficient pharmahouses will be designed. Recently introduced mobile and dynamic systems are expected to increase the productivity and accuracy of pharmaceuticals delivered. For instance, combining automated picking with a robotic picker and using vision-based detecting algorithms will improve handling time (Piccinini et al. 2013). Moreover, artificial intelligence

Fig. 4.6 Smart pill-box



will be used to determine future demand and make necessary changes in the layout of pharmahouses. The progress at every stage of the storage or handling operations will be monitored; hence, unwanted situations or consequences will be prevented.

4.3 Conclusion

This chapter provided the history of pharmahouses and their transformation journey from primitive cellars or storerooms to intelligent facilities. With the aging and increasing global diseases, people have become more dependent on pharmaceuticals. Moreover, people's shopping behavior has changed significantly due to recent advances in information and communication technologies. Therefore, most pharmaceutical companies focus on more agile and sustainable solutions in response to global advancements and challenges. Pharmahouses take a more critical role in human history than ever before by providing a buffer role in the supply chain operations and supporting faster delivery for customer satisfaction.

In accordance with I4-driven systems such as Industry 4.0, Pharma 4.0 or Medical 4.0 etc., the revolution in pharmahouses become a reality in four stages. In the first revolution of pharmahouses, human power was replaced by water- or steam-powered mechanical systems. Therefore, more medical remedies were produced, transported, and stored. With the usage of electromechanical systems, the second revolution materialized and resulted in an eccentric movement of people, products, and information. In the third revolution, the use of computer systems paved the way to adopt digital computing and communication technologies in pharmahouses. Therefore, more tractable and controllable systems were developed. Eventually, all advanced information and communication technologies are continuously adopted into pharmahouses to cope with the ever-increasing conditions and demand.

With the advancement of pharma, medical, healthcare, and hospital systems, there is a great possibility that we will witness pharmahousing 5.0 in the not-too-distant future. By Industry 5.0, human well-being will become more critical than ever before. Future technologies such as remotely triggered pharmaceutical treatments will redesign not only health systems but also pharmahouses.

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Part III
AI and Big Data in Health 4.0 and Medical Supply Chain

Chapter 5
Internet of Things (IoT) Technologies and Implementation in the Healthcare Industry

Mustafa Ozan

Abstract Internet of Things (IoT) technology, an essential part of the technological revolution emerging in the era of Industry 4.0, has become a critical success factor for almost all industries. Aside from its destructive effects in various industries, it presents new opportunities and advantages. Also, the healthcare industry is a critical sector using high-tech devices and equipment compared to many traditional industries. In today's conditions, producing a health service without using these devices and technological equipment is impossible. All health staff need to diagnose using these technological instruments to start treatment. Furthermore, dependency on technology in the health industry continues to increase with each passing day. Therefore, understanding these technologies and creating logical and reasonable solutions is an essential task for practitioners in the health industry. By keeping these requirements in mind, the current paper systematically evaluates the Internet of things technology and its implementation in the current industry.

Keywords Health industry · Internet of things · Destructive technologies

5.1 Introduction: Definition and Historical Development

The concept of the "Internet of Things/IoT/IoT", one of the technological developments that emerged in the last years of the twentieth century and started to enter all areas of our lives, has embraced our lives without us realizing it, supporting the first predictions. Its story began in 1991 with a coffee machine shared by a group of academics working in the computer laboratory of Cambridge University in the building where they worked. According to the story, it started with the fact that the coffee machine was upstairs, and the academics working downstairs designed software to see if there was coffee in the coffee machine before going upstairs to get

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Fig. 5.1 Image of the coffee machine (*Source* https://en.wikipedia.org/wiki/Trojan_Room_coffee_pot)

coffee. According to the software they prepared, the camera they put in front of the coffee machine took three images of the coffee machine every minute and transferred them to the computers of the academicians over a network simultaneously (Fig. 5.1). Thus, academics could see from their desks whether the coffee machine had coffee or not. Established by academics, this system was transferred to the web in 1993 and used until 2001 (Kutup 2011).

The coffee machine in Fig. 5.2 and the camera that displays it and transfers it to computers was the first example of the IoT. After this early application, the concept of the "Internet of Things" was first used in the study prepared by Kevin Ashton on behalf of Procter & Gamble company in 1999. In his study, Kevin Ashton explained the benefits of the RFID (Radio Frequency Identification) system in the supply chain and recommended its use (Kutup 2011).

After this development, the rapid spread of internet infrastructure with developing new technologies and the introduction of new technological intelligent devices (smartphones, tablets, smart wristbands and wristwatches, smart glasses, smart white goods, etc.) into our lives have led to the IoT reaching every area of our lives. Today, the IoT is in our lives in many areas; from water heaters to cars and buildings, to illuminating, heating, or cooling the house, also opening and closing the door while away from home, tracking daily sleep time, heart rate, blood pressure and even the amount of oxygen in the blood via smartwatches and wristbands, starting the car and heating and cooling the interior of the car before even getting in, and many others that we have not yet counted. The IoT has been defined as the connection of objects,

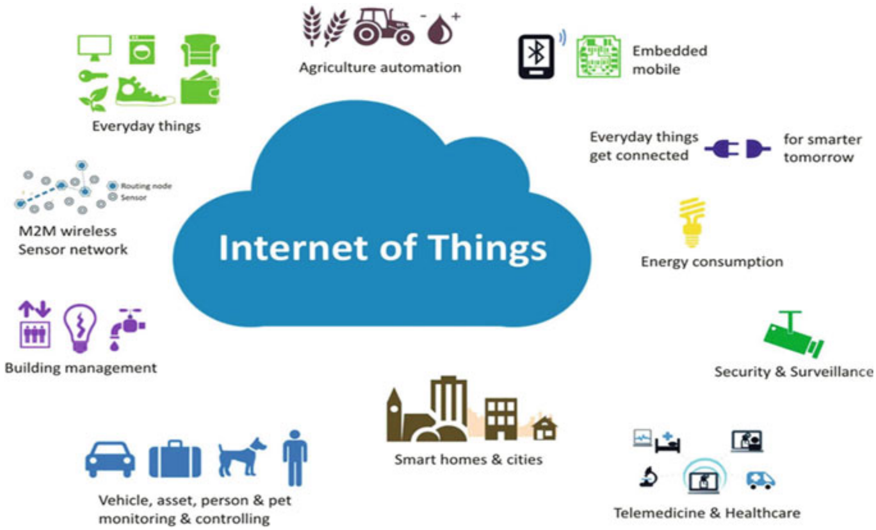

Fig. 5.2 Usage areas of the Internet of things (*Source* Aktaş et al. 2016, p. 43)

which come into our lives more and more with each passing day, through the Internet, data transfer, and control of their functions.

The IoT can be defined as a system of wireless, interrelated, and interconnected digital devices that can collect, distribute, and store data over a network without requiring human-to-human or human-to-computer interaction (Höller et al. 2014). This situation means that the spreading speed of the IoT technology increases and the scale of the data produced is getting bigger and bigger. Beyond this, in parallel with the significant development and transformation observed in artificial intelligence and network technologies, it is deduced that IoT technology may be a future development element of social life (Çark 2020, p. 1250). Even though the scope of the concept of the IoT is so vast, different definitions will inevitably emerge.

The International Telecommunication Union (ITU) defines the IoT as "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies" (ITU 2005).

Belissent, on the other hand, defines the IoT as "an environment which takes advantage of information and communication technologies to realize essential system elements and services for a public transformation, city utilities, city administration, public health and safety and more" (Belissent 2010).

In the final report of his project, CASAGRAS defined the concept of the "IoT"; "It is a global network infrastructure that connects physical and virtual objects by leveraging data capture and communication capabilities. This infrastructure includes current and emerging Internet and network developments (CASAGRAS 2009). It will offer the ability to identify, sensor, and connect specific objects as a basis for the development of standalone collaboration services and applications. They will be characterized by highly autonomous data capture, event transmission, network connectivity, and interoperability".

SAP has defined the IoT as "a world where physical objects are seamlessly integrated into the information network, and physical objects can become active participants in business processes" (SAP).

ETP EPoSS defines the IoT as "a network created from things/objects with identities, virtual personalities working in smart areas, and social and environmental contexts to connect and communicate with users using smart interfaces" (ETP EPoSS).

The IoT technology was defined as a worldwide network created by uniquely addressable things/objects which can communicate with specific protocols (Kutup 2011). It often refers to scenarios where network connectivity and computing capability extend to objects, sensors, and everyday items that are not usually considered computers, allowing these devices to generate, exchange, and consume data with minimal human intervention. We can also briefly define the IoT as; "a global network of uniquely addressable, interconnected objects based on standard communication on the Internet". Thanks to this network, smart wireless identifiable devices can interact with the environment seamlessly, communicate and make our lives easier.

When we look at the estimations made by international organizations in the last five years about the developing and rapidly growing IoT and the point reached, we can better understand the future and size of this market. For example, according to Cisco's estimations in 2015, it was predicted that there would be more than 24 billion internet-connected devices by 2019 (Cloud and Mobile Network Traffic Forecast 2015). In 2013, Morgan Stanley predicted 75 billion connected devices by 2020 (Danova 2013). Looking further and raising the risks, Huawei, in 2015, predicted 100 billion IoT-connected devices by 2025 (Global Connectivity Index 2015). When the number of devices connected to the internet network is so high, its economic potential will be high in parallel. In this regard, McKinsey Global Institute predicts that the financial impact of IoT on the global economy will be between \$3.9 and \$11.1 trillion by 2025 (Manyika et al. 2015). Although the variability between these forecast numbers makes the forecasts questionable, it cannot overshadow the growth rate of the IoT.

The historical development of the IoT is directly linked to the development of the Internet network. To briefly summarize the history of the Internet, the Internet was first established by the United States Department of Defense as Advanced Research Projects Agency Network (ARPANET) to provide defense communications. In 1981, ARPANET began to connect to more advanced networks due to development work. On January 1, 1983, they announced that every device connected to the ARPANET network should accept the Communication Control Protocol. With this protocol, the foundations of the Internet began to be laid. After a while, studies were carried out on extensions that determine the identity of websites. Since 1990, there have been years when digital networks have gained speed. However, this development marked the end of ARPANET and NFSNET activity. Later, the network known as "www", which came from the Swiss city of Cern, entered our lives. During this period, companies began to acquire domain names and share information about themselves on the network. The next stage is where companies (amazon.com, eBay, etc.) that do marketing over the Internet emerge. Parallel to this, there were developments such as chatting and video calling on the Internet at first (Kutup 2011). Subsequently, the emergence of blogs and social media platforms (Facebook, Twitter, Youtube, LinkedIn, etc.) and developments in smartphone technology made the Internet more popular. After all these developments, the last point reached is the IoT. We are now connected to the Internet in every field, from the daily tools to the systems that instantly monitor our health through remote access. In this context, the IoT is the latest point of this ever-accelerating change and transformation in internet technology.

5.2 Future of the IoT

The point reached by computer and internet technology, which continues to develop exponentially, is far beyond the predictions when computers and the Internet were first used. The correct conclusion we can make from this can only be: "Twenty years from now, it will be far beyond our present projections". The developments in recent years, when the IoT has become widespread and entered the lives of ordinary people, are dizzying. For example, the data about our health, which is transferred to the network via the smart wristband or smartwatch we wear, can be observed by our doctor, and even in case of unusual developments that may occur in body functions (excessive increase or decrease in blood pressure, excessive increase or decrease in blood sugar, excessive increase or decrease in body temperature, etc.), the system gives a warning. Although there are many different predictions about where the developments in internet technology will take humanity, we do not know which of them will come true.

5.3 Communication Technologies Used in the IoT

IoT uses connection types such as Wireless Hotspot such as Wireless Fidelity (Wi-Fi), Near Field Communication (NFC), Radio Frequency Identification (RFID), Short-range Radio Frequency (RF) such as Zigbee and Bluetooth, Wireless Personal Area Networks (WPAN) and wide area networks such as GPRS, GSM, LTU, and 3G-4G-5G for network connection (Çark 2020, p. 1252).

5.4 Usage Areas of the IoT

The IoT, defined as the Internet 4.0, is in our lives in all areas of life, from agriculture to industrial production, from domestic life to city life, from scientific studies to the world of entertainment, from the diagnosis of diseases to the training of athletes. The usage areas and functions of the IoT are given in Table 5.1 (Rose et al. 2015).

Table 5.1 Usage areas of the Internet of things

Usage areas	Usage functions
Human Devices attached to or contained in the human body	Devices (wearable and digestible products) for monitoring and maintaining human health and wellness; disease management, increased fitness, higher productivity
House Buildings where people live	Home monitors and security systems
Business Life Areas where consumers are engaged in trade	Stores, banks, restaurants, arenas—everywhere consumers think and buy; self-checkout, in-store offers, inventory optimization
Workspaces Areas where white-collar workers work	Energy management and security in office buildings; enhanced productivity, including remote workers
Factories Standardized production environments	Places with repetitive work routines, including hospitals and farms; operating efficiencies, optimizing equipment usage and inventory
Means of transport Systems inside vehicles	Vehicles, including cars, trucks, ships, aeroplanes and trains; condition-based maintenance, usage-based design, pre-sales analytics
Cities Urban environments	Public spaces and infrastructure in urban settings; adaptive traffic control, smart meters, environmental monitoring, resource management
Upstate Areas between (and outside) urban environments	External uses include railroad tracks, autonomous vehicles (out-of-town destinations) and flight navigation; real-time routing, linked navigation, shipment tracking, etc

5.5 Use of the Internet of Things in Healthcare

Along with the increase in the population in the developing world, its aging has started to be insufficient in the number of hospitals and beds everyone can benefit from. The fact that the patients stayed in the hospital for a long time for their treatment to be carried out under surveillance caused a substantial financial burden. The possibility of accessing the information obtained through the sensors, which emerged because of technological developments via wireless networks, paved the way for these services to be provided outside the health institution. IoT sensor types have different functions from each other. In healthcare, the pulse sensor is used to measure the heartbeat, the electrocardiography (ECG) sensor to monitor the heart rate, the body temperature sensor for measuring acute febrile diseases, and the oxygen sensor to determine the level of oxygen in the blood. Recently, with the development of technology, smart wristbands and watches and acceleration sensors for falling, running, shaking, and walking are also used for instant situation detection (Akleylek et al. 2020). This situation has supported health institutions in terms of easing the workload. While long-term treatments in health institutions cause physiological, psychological, and social problems for the patient, thanks to the IoT, the hospitalization time is shortened, and the problems experienced by the patient can be reduced due to the lengthy hospitalization. With the ever-developing technology, the collection of physiological data from patients receiving treatment (ECG, EEG, pulse, blood sugar, etc.) or the physical data of the environment they receive the treatment (temperature, humidity, light, etc.) is now possible with minimizing their effect on the daily life of the individual by taking into account the comfort of the user. Today, as seen in Fig. 5.2, physiological data obtained from patients using Wireless Body Area Networks (WBAN) were primarily taken for tracking purposes. With the sensors that can be dressed or placed on the patient's body through the technology used, the people's physiological data can be collected without causing pain to the patient and while the patient continues his daily routine. The most crucial benefit of this situation for the patient is that the limitation of movement disappears, and the desired measurements can be made regularly without the patient's preference (Fig. 5.3). Thanks to the infrastructure of the IoT technology, chronic diseases can be monitored remotely, and measurements can be shared with physicians and patient relatives full time, and with this, undesirable situations caused by diseases can be intervened immediately (Aktaş et al. 2016, p. 38).

5.6 The Conveniences of the Internet of Things

The IoT makes daily life more comfortable for people. Accessing information from any device connected to the Internet, anywhere, at any time, makes people's lives easier. Easy access and transfer of data packets produced by devices using IoT technology over the network saves time, effort, and money. The easy transfer of data

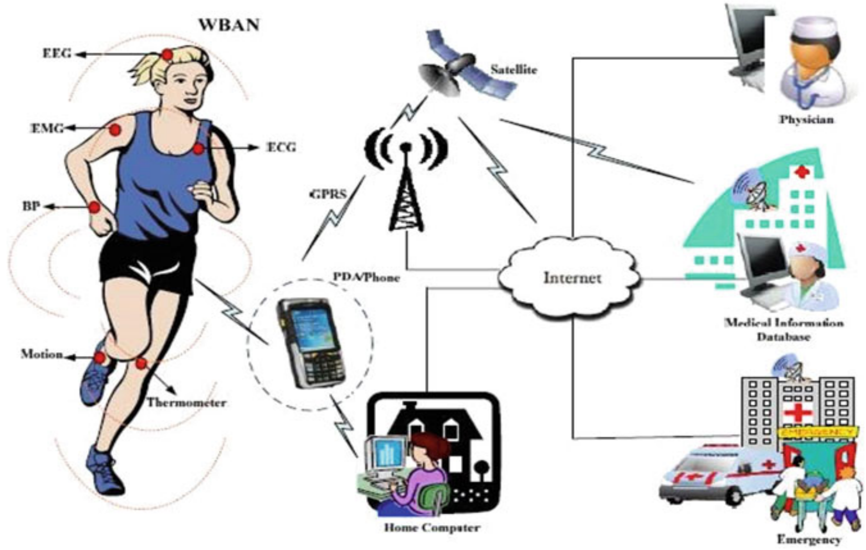

Fig. 5.3 Wireless Body Area Networks (WBAN) (*Source* Aktaş et al. 2016, p. 45)

packets over the network saves time and money. As explained in detail above, it has many benefits for human health. With remote and instant controls, the treatment of diseases becomes easier. It also has many benefits, such as increasing efficiency in production, transportation, use of energy resources, and remote monitoring and control in energy production.

5.7 Concerns About the Internet of Things

Although the benefits of the IoT to human life are many, some problems that may occur during the provision and use of this convenience and comfort cause concern. There will always be the possibility of hackers infiltrating the motion-sensitive camera system you put in to ensure the security of your home. Again, consider that the data collected about your health is captured and changed by hackers. In addition to such significant disruptions, less harmful disruptions may also be experienced. Let us say the sensors in your refrigerator notify you over the network when you are out of fruit juice while you are shopping and you buy fruit juice. The same message will go to your partner, who will also get fruit juice. In this case, you will get an extra pack of fruit juice. Again, any vulnerability in any of the devices used in a system established over the IoT will affect all devices connected to this system. Another concern and one of the current problems are the difficulties arising from the incompatibility between devices produced by different manufacturers in different countries since there is not yet an international standard for the IoT.

In addition to these, although it seems to have been overcome with cloud technology, for now, it should not be forgotten that the difficulties that can be experienced in storing the considerable amount of data produced over the IoT and in requesting the desired information from this vast data pool called big data in a short time.

5.8 Conclusion

As a result, although the potential consequences of IoT technology are significant, there are some potential challenges ahead of this vision, especially in the security field. These difficulties; include privacy, interoperability, standards, legal, regulatory and rights issues, and the inclusion of emerging economies in this system. The IoT encompasses a complex and evolving set of technological, social, and policy considerations among various stakeholders. The IoT is now in our lives in different areas, and the process continues. In this process, there is a need to reduce the risks, overcome the difficulties and maximize the benefits of the IoT. In the last sentence, we can say that "it is one of the biggest technological developments that make people's lives easier despite some risks" about the IoT.

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Chapter 6
Using Artificial Intelligence in Health and Medical Supply Chains

Hacı Mehmet Alakaş and Tamer Eren

Abstract In the supply chain, strategic and tactical decisions are taken to ensure the correct flow of raw materials and products from the raw material to the end user. These decisions are supported by using various methods in the sub-stages of the supply chain such as demand forecasting, creation of the supply network, supplier selection, production and distribution planning, and inventory management. Among these methods, the use of artificial intelligence has been increasing in recent years. Artificial intelligence techniques are one of the important tools used to support decisions in the supply chain, as before and after the pandemic. In this study, the need for artificial intelligence techniques in supply chain decisions in the post-pandemic period in the health sector was evaluated. The sub-stages of the supply chain were evaluated according to the determined criteria, and it was determined for which sub-stage the development of artificial intelligence techniques was more important. The analytical network process method was used to prioritize the sub-stages according to the criteria. Evaluations about which method should be used in which sub-stages according to the prioritization are also presented in the study.

Keywords Supply chain · Artificial intelligence · Analytical network process · Decisions in supply chain · Post-pandemic conditions

6.1 Introduction

Today, with the development of the internet and transportation opportunities, people can easily access products and services, and therefore consumption has increased. Due to this increase, companies have to meet the demands of their customers faster. Firms adopt a holistic approach that covers both supply and sales transactions in order

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to increase the speed of supply. Supply chain management has emerged in order to ensure the integrity of operations. Supply chain management is a management approach that coordinates suppliers, manufacturers, dealers, and retailers in the most effective and efficient way in order to meet the targeted customer service level at the lowest cost, to produce and distribute goods in the right amount, at the right place, and at the right time (Karakoç et al. 2020). One of the most important application areas of this approach, which is widely used in production and service systems, is health.

Although supply chain applications in health systems are similar to other sectors, the most important difference is that any disruption affects human and public health. The recent COVID-19 outbreak is a good example of this effect. Many countries could not reach even the most easily accessible health and hygiene materials. Diplomatic problems have arisen between the countries due to the supply of materials (Sood et al. 2022). In order to ensure the sustainability of the health supply chain in the recent period, managers should be operationally supported with various software both in the processing of data and decision process. One of the most preferred methods for accelerating decision processes is artificial intelligence techniques that use human thinking, evaluation, and decision-making abilities.

Artificial intelligence, is a scientific study and the product that emerges in this form, that covers many fields such as computer engineering, neuroscience, philosophy, psychology, robotics, and linguistics, and examines subjects such as computer software, robot design which exhibit behaviors specific to human intelligence such as perception, reasoning, thinking, learning, comprehension, intuition, and design. Artificial intelligence has recently come to the fore with industry 4.0. Artificial intelligence is also used in the health sector in diagnosing diseases, estimating the epidemic, determining the rate of spread of the epidemic, determining the effect of the epidemic on public health, solving problems such as personnel scheduling and inventory management (Sood et al. 2022).

There have been changes that started with COVID-19 and caused major disruptions in the supply chain of the world. It has affected both the flow of production and the availability of necessary materials in many sectors from food to automotive, from electronics to health system. At the same time, large price increases were experienced in products. One of the most important sectors affected by all these extraordinary conditions is the health sector. Supply chain management is even more important because the health sector has a direct impact on the sustainability of human life and the provision of better living conditions. In this study, the use of artificial intelligence in the health and medical supply chain is discussed, taking into account the conditions of the post-pandemic period. Considering the supply chain operations, it has been researched which operation requires more artificial intelligence. In this research, first of all, criteria were determined by considering the advantages of artificial intelligence. Supply chain operations were evaluated according to these criteria and it was determined for which operation the development of artificial intelligence techniques should be considered first. The weights of the criteria were calculated using the fuzzy analytical hierarchy process (AHP) method. By using these criterion weights, the operations are ranked with the PROMETHEE method.

6.2 Supply Chain Operations and Healthcare Applications

In the supply chain, there are a number of operations carried out in the process from raw material to the customer. Some of these are carried out periodically, while others are carried out in certain time periods. Operations carried out in the supply chain will be discussed in this section.

Supply chain network design: The most strategic decision of a supply chain is to determine the network design. Because the network structure will directly affect many operational decisions such as determining the chain costs, determining the facility locations, determining the product flow, choosing the warehouse location, choosing the demand forecasting method, and choosing the supplier. For this reason, companies should first decide on the supply chain network design with appropriate techniques or methods (Sharma et al. 2022). The effective design and management of components such as hospitals, pharmacies, warehouses, and manufacturers, which will be in the network structure of health supply, is an important decision problem in the supply chain.

Supplier selection: The effective and efficient operation of a supply chain is directly related to the continuity of the flow between the elements of the chain. One of the most basic elements of the supply chain is suppliers. The harmonious and effective work of suppliers, both within themselves and with other companies, affects the performance of the chain (Sharma et al. 2022). For this reason, the suppliers to be included in the chain should be selected using appropriate numerical methods. The proposed methods should adapt to changing conditions or create solutions by defining the conditions. The use of artificial intelligence techniques in supplier selection can achieve these goals.

Green Supply Chain Management: There is a lot of energy and resource consumption in supply chains, from design to management. The resources, consisting of electricity, natural gas, and scarce resources are obtained in a way that does not harm the environment and nature, show the green sustainability of supply chains (Sharma et al. 2022). In the health sector, the resources needed in all processes from the production of drugs to the delivery of them to the appropriate points must be obtained from green alternatives.

Inventory planning: One of the most important purposes of supply chains is to respond quickly and flexibly to customer demand. In cases where demand rates are variable, it is not always possible to meet all demand directly with production quantities on time and in the required amount. For this reason, an effective inventory management is needed in supply chains in order to provide demand flexibility (Sharma et al. 2022). In order to ensure uninterrupted and continuous supply of drugs or treatment equipment in health systems, especially in emergencies, stock management should be supported by artificial intelligence techniques. Thus, it may be possible to prevent interruptions in a learning structure.

Demand planning: Demands act as catalysts to activate operations in a supply chain. Effective demand planning and forecasting will directly affect the performance of all operations in the supply chain (Min 2010). For this reason, demand planning emerges as an initial decision in supply chain management. Artificial intelligence algorithms that can evaluate changing situations and make consistent forecasts are needed in demand forecasting.

Production planning: The performance of manufacturers, which is an important element of supply chains, is a factor that directly affects network performance. Ensuring full compliance with the demand plan will only be possible with an effective production plan. For these reasons, production planning and control emerge as a vital decision problem in supply chains. It is seen that an important application area of artificial intelligence techniques is production planning (Dash et al. 2019). It has many applications such as scheduling, resource planning, and personnel planning. As in other sectors, effective planning of the production of healthcare materials and equipment emerges as an important decision problem in healthcare sector supply chains (Sharma et al. 2022).

Reverse logistics: One of the performance indicators of supply chains is the capacity to follow the status of the products produced after the end consumer's use. This is possible by designing the flow in the supply chain network design in a way that allows the flow to flow not one way but two way, that is, the reverse. In reverse logistics, after the supply chain has flowed toward the customer, a number of items from the chain must be recovered. These items can be information or products such as customer requests, fault information, technical service information, products to be recycled, and waste (Wilson et al. 2022). Items such as unused medicines, waste medicines, defective tools, and equipment in health supply chains can be considered as a contribution to the supply chain of reverse logistics.

Warehouse management: Another important policy that supply chains implement to meet demand is warehouse management. Decisions such as warehouse location selection, variety and number of warehouses, and warehouse size are strategic decisions for the continuity of the supply chain (Nemati et al. 2002). In terms of healthcare supply, the need to store drugs and treatment equipment is a factor that will directly affect the supply chain.

Distribution network planning: The distribution network is the system in which the items such as warehouse, route, point of sale, etc., are defined in the process from the dispatch points of the products to the delivery points in logistics (Oral et al. 2022). The problem of delivering the products produced in the supply chain to the desired point is also a decision problem that is very difficult to solve (Min 2010). Especially in the case of a sudden developing product need in the health sector, it is expected to respond quickly to the need in the supply chain. The solution to this problem is possible with an effective distribution network planning.

Recycling management: Not only the management but also the recycling of the wastes generated as a result of the use of the products delivered to the customers are indicators of the performance of the supply chains. Recycling of materials is possible by incorporating recycling facilities into the supply chain design (Wilson et al. 2022). These facilities are generally considered as recycling facilities and biowaste facilities. Many of the biological wastes generated in the health sector can be reused after sterilization. Therefore, recycling management emerges as a very important decision support problem.

Waste disposal: The increasing global population has led to great increases in demand in supply chains, as well as an increase in waste. How waste will be collected and disposed of is also important for the protection of the environment. The effective management of especially medical wastes in the health sector will positively affect the performance and green sustainability of the supply chain.

Sales Management: Sales in every sense is the delivery of a manufactured product to the customer. It is necessary to determine suitable channels for sales and to provide suitable conditions for the delivery of the product to the customer (Min 2010). In the health supply chain, especially the products must be delivered to the customer under certain conditions. Therefore, effective sales management will directly affect the overall performance of the supply chain.

Outsourcing: Outsourcing is one of the most common ways to perform some activities or services in supply chains more efficiently, more effectively, faster, and at lower cost. In outsourcing, it is very important to make decisions such as choosing a vendor, choosing an activity or a service. Considering the diversity of materials and drugs in the health supply chain, it is inevitable that some activities are outsourced.

Facility Layout: In order to provide an effective production system, the facility should be established in the most appropriate place and the facility layout should be done in accordance with the production structure. The general purpose of the facility layout is to reduce the number of required machinery and equipment and material movement (Petri and Yuqiuge 2021). Making the materials to be produced in the health sector in an efficient facility will affect the supply chain performance. In addition, both facility location selection and facility layout are important decision problems for healthcare organizations.

6.3 Methods

In this study, fuzzy analytical hierarchy process and PROMETHEE methods were used. The calculation steps of the methods are given in this section.

6.3.1 Fuzzy Analytical Hierarchy Process

The analytical hierarchy process method is known as a multi-criteria decision-making method that is widely used to determine criterion weights in the decision-making process. In the AHP method, the decision problem is displayed in a three-level hierarchical structure. The first level includes the purpose, the second level includes the criteria that affect the decision, and the third level includes alternatives.

After determining the purpose of the decision problem, pairwise comparisons are made for the second and third levels of the hierarchical structure. As a result of the comparisons, the weights of the criteria and the scores of the alternatives are determined. In comparisons, a 1–9 severity scale is used. Expert opinions are used in the comparison process. However, experts may not be able to express their opinions with numerical values due to their limited knowledge and skills. In these cases, uncertainty situations can be overcome by making use of fuzzy set theory instead of exact sets in the creation of the comparison matrix (Liu et al. 2020). The steps of the fuzzy AHP method are listed as follows (Chang 1996).

Step 1: A suitable pairwise comparison matrix is created with fuzzy numbers.
Step 2: The pairwise comparison matrix is normalized.
Step 3: The weight vectors of the decision criteria are obtained.
Step 4: The score values are determined by comparing the alternatives.

6.3.2 PROMETHEE Method

The PROMETHEE method is a MCDM method developed by Brans and De Smet (2016) and consists of two basic stages, namely PROMETHEE I and PROMETHEE II (Yazıcı et al. 2021). The PROMETHEE method determines the order of decision points with partial ranking (PROMETHEE I) and full ranking (PROMETHEE II). The main difference from other MCDM methods is that the evaluation criteria take into account their internal relationship (Bedir and Eren 2015).

The first step of the PROMETHEE method is the creation of the initial matrix containing numerical values, in which the alternatives are evaluated according to the criteria. In order to apply the method, the criterion weights and the preference functions of each criterion must be known to compare the alternatives. Preference functions can be accessed from Yazıcı et al. (2022).

The steps of the PROMETHEE method are given in Fig. 6.1 (Dağdeviren 2008).

6.4 Prioritization of Healthcare Supply Chain Operations Based on AI Need

Artificial intelligence techniques are used to facilitate and support the decision processes of the operations carried out in the health and medical supply chain. In this study, “Artificial intelligence techniques should be developed primarily for which of these operations?” research question has been addressed. This application will be discussed in this section.

Step 1: Creating the data matrix

Step 2: Define preference functions for criteria.

Step 3: Determination of common preference functions based on preference functions.

$$P(a,b) = \begin{cases} 0 & , f(a) \leq f(b) \\ P[f(a) - f(b)], & f(a) > f(b) \end{cases} \quad (1)$$

Step 4: Determination of preference indices for each alternative, taking into account the common preference functions.

$$\pi(a,b) = \frac{\sum_{i=1}^{k} w_i P_i(a,b)}{\sum_{i=1}^{k} w_i} \quad (2)$$

Step 5: Identifying positive ($\emptyset^+$) and negative ($\emptyset^-$) advantages for alternatives

$$\emptyset^+(\alpha) = \sum \pi\,(a,x) \qquad x = (b,c,d,\ldots\ldots) \quad (3)$$

$$\emptyset^-(\alpha) = \sum \pi\,(x,a) \qquad x = (b,c,d,\ldots\ldots) \quad (4)$$

Step 6: Identify partial priorities with PROMETHEE I.

Equation 5, 6, and 7 are given so that alternative a is preferred to alternative b.

$$\emptyset^+(a) > \emptyset^+(b) \text{ ve } \emptyset^-(a) < \emptyset^-(b) \quad (5)$$

$$\emptyset^+(a) > \emptyset^+(b) \text{ ve } \emptyset^-(a) = \emptyset^-(b) \quad (6)$$

$$\emptyset^+(a) = \emptyset^+(b) \text{ ve } \emptyset^-(a) < \emptyset^-(b) \quad (7)$$

Equation 8 The case where alternative a has no advantage over alternative b

$$\emptyset^+(a) = \emptyset^+(b) \text{ ve } \emptyset^-(a) = \emptyset^-(b) \quad (8)$$

Equation 9 and 10 The situation where alternative a cannot be compared with alternative b

$$\emptyset^+(a) > \emptyset^+(b) \text{ ve } \emptyset^-(a) > \emptyset^-(b) \quad (9)$$

$$\emptyset^+(a) < \emptyset^+(b) \text{ ve } \emptyset^-(a) < \emptyset^-(b) \quad (10)$$

Step 7: Set exact priorities with PROMETHEE II.

$$\emptyset(a) = \emptyset^+(a) - \emptyset^-(a) \quad (11)$$

Fig. 6.1 PROMETHEE method steps

6.4.1 Criteria for Evaluation of the Need for AI Techniques of Operations

Artificial intelligence is widely used in decision mechanisms. Artificial intelligence is also used to support decisions at various stages in the supply chain. Criteria have been determined in order to evaluate the operations that should be given priority in the use of artificial intelligence techniques in the processes of the supply chain. The criteria can be explained as follows.

Strategicity of decisions (SD): Decisions are divided into three groups according to the time dimension as operational, tactical, and strategic. Since the time period is shorter, it can be easier to make operational and tactical decisions. However, the time dimension in strategic decisions is long and uncertainties are also higher. Therefore, analysis with artificial intelligence techniques is needed in making these decisions. Artificial intelligence is needed for operations where strategic decisions are taken in the evaluation of supply chain operations in the health and medical sector.

Necessity of taking decisions quickly (DQ): The supply chain is one of the systems that is most rapidly affected by changing situations. For example, an accident in the Suez Canal caused a disruption in the supply chain as it prevented the passage of ships. The disruption of materials procured from different countries, especially China, during the COVID-19 process has similarly caused interruptions in the supply process. In the health sector, there may be a need to make quick decisions in cases such as epidemics and natural disasters. Another effect is that companies need to make quick decisions to seize opportunities. It is necessary to analyze the situations arising from these and similar events quickly and take decisions. It is possible to take decisions faster by using the analysis and inference mechanisms of artificial intelligence techniques.

Flexibility (Flex.): Adaptation to customer demands and variable demand quantities is expressed by flexibility. The high variability in the health sector also highlights flexibility. Artificial intelligence techniques are also used for the establishment and execution of a flexible supply chain.

Data size of operations (DS): Artificial intelligence techniques are preferred due to the size of the input data used in the operations in the supply chain. Analysis of big data is an important area of artificial intelligence (Khanzode and Sarode 2020).

Variability of operational data (VD): Variability is a factor that complicates the management and analysis of all systems. The variability of data such as demands, production times, qualitative and quantitative quality values, lead times, costs, and sales prices in the supply chain are the factors that make it difficult to make decisions. Artificial intelligence is an important tool used to evaluate the factors that cause variability. Artificial intelligence techniques are preferred because they allow the identification of possible situations and the analysis of variability (Khanzode and Sarode 2020).

Uncertainty of operation data (UD): One of the most important aspects for the effectiveness of an artificial intelligence algorithm is the awareness of the input data. However, in the developing world, uncertainties arise because the data is affected by many factors such as political situations, market needs, consumer behaviors, and the expectations of generations. While making predictions for uncertain situations, scenario analysis, etc., are made and one of the tools used for this purpose is artificial intelligence techniques (Khanzode and Sarode 2020).

Impact on supply chain sustainability (IoS): Today, one of the biggest factors that provide competitive advantage is sustainability. As in many areas, sustainability has become one of the important performance parameters in supply systems. In the health sector, supply should be provided continuously so that operations are not disrupted. Any disruption in the health sector has a higher impact on human and social life. It causes situations such as interruption of diagnosis and treatment and inability to perform surgeries.

Impact on human and public health (IoH): The most important impact of supply chain operations in the health system is its impact on human and public health. Therefore, when evaluating operations in terms of the use of artificial intelligence, its impact on human and public health should also be taken into account.

6.4.2 Calculation of Criterion Weights with Fuzzy AHP

The criteria were compared using linguistic expressions by five academics who are experts in the field of supply chain. The fuzzy numbers given in Table 6.1 were used for comparison. The matrix obtained as a result of the comparison of the criteria with each other is given in Table 6.2. The criteria weights were obtained by applying the data from Table 6.2 and the Fuzzy AHP steps.

The criteria weights are given in Table 6.3. The most important criterion is the strategicity of decisions. Two other important criteria are “uncertainty of operation data” and “flexibility.” The two criteria with the lowest weight were determined as “necessity of taking decisions quickly” and “impact on human and public health.”

Table 6.1 Fuzzy numbers used in comparison

Definition	Fuzzy triangular scale
Equally important	(1, 1, 1)
Weakly important	(2, 3, 4)
Fairly important	(4, 5, 6)
Strongly important	(6, 7, 8)
Absolutely important	(9, 9, 9)

Table 6.2 Pairwise comparison matrix of criteria

	SD	QD	Flex	DS	VD	UD	IoH	IoS
SD	(1, 1, 1)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(1, 1, 1)	(9, 9, 9)	(2, 3, 4)
QD	(0.5, 0.33, 0.25)	(1, 1, 1)	(0.5, 0.33, 0.25)	(0.17, 0.14, 0.13)	(0.25, 0.2, 0.17)	(0.5, 0.33, 0.25)	(2, 3, 4)	(0.17, 0.14, 0.13)
Flex	(0.5, 0.33, 0.25)	(2, 3, 4)	(1, 1, 1)	(2, 3, 4)	(2, 3, 4)	(0.5, 0.33, 0.25)	(4, 5, 6)	(2, 3, 4)
DS	(0.5, 0.33, 0.25)	(6, 7, 8)	(0.5, 0.33, 0.25)	(1, 1, 1)	(0.5, 0.33, 0.25)	(2, 3, 4)	(4, 5, 6)	(0.25, 0.2, 0.17)
VD	(0.5, 0.33, 0.25)	(4, 5, 6)	(0.5, 0.33, 0.25)	(2, 3, 4)	(1, 1, 1)	(0.5, 0.33, 0.25)	(4, 5, 6)	(2, 3, 4)
UD	(1, 1, 1)	(2, 3, 4)	(2, 3, 4)	(0.5, 0.33, 0.25)	(2, 3, 4)	(1, 1, 1)	(4, 5, 6)	(2, 3, 4)
IoH	(0.11, 0.11, 0.11)	(0.5, 0.33, 0.25)	(0.25, 0.2, 0.17)	(0.25, 0.2, 0.17)	(0.25, 0.2, 0.17)	(0.25, 0.2, 0.17)	(1, 1, 1)	(0.25, 0.2, 0.17)
IoS	(0.5, 0.33, 0.25)	(6, 7, 8)	(0.5, 0.33, 0.25)	(4, 5, 6)	(0.5, 0.33, 0.25)	(0.5, 0.33, 0.25)	(4, 5, 6)	(1, 1, 1)

Table 6.3 Criteria weights

Criteria	Weight
Strategicity of decisions	0.26
Necessity of taking decisions quickly	0.04
Flexibility	0.15
Data size of operations	0.10
Variability of operational data	0.13
Uncertainty of operation data	0.18
Impact on human and public health	0.03
Impact on supply chain sustainability	0.11

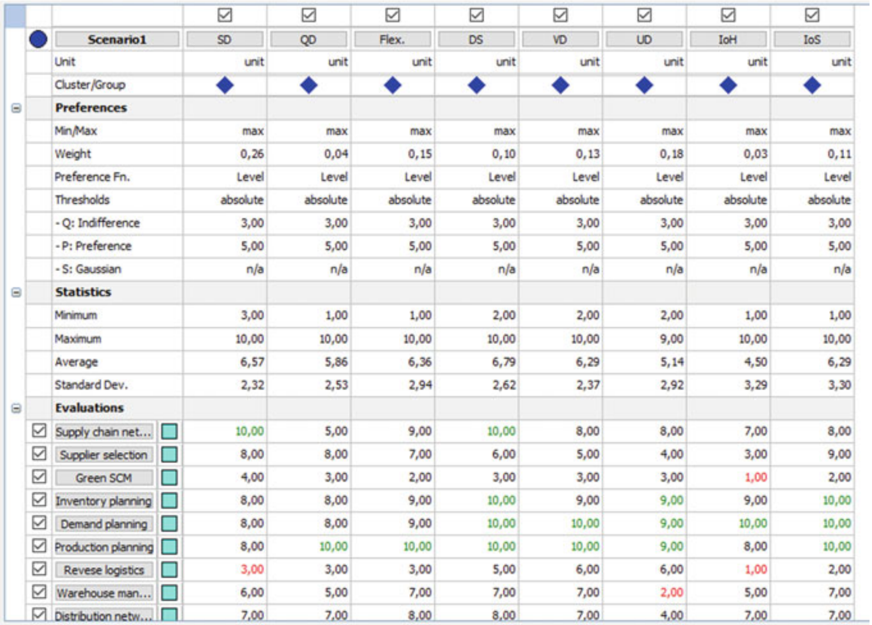
6.4.3 Ranking of Operations with the PROMETHEE Method

The operations are scored on the basis of each criterion, according to a 1–10 scale (Table 6.4). Operations were scored by five academicians who are experts in the supply chain and ranked with the PROMETHEE method. In the PROMETHEE method, the level function is used as a preference function. Rankings were obtained using the Visual PROMETHEE program. The data entry screen of the program is given in Fig. 6.2 and rankings are given in Fig. 6.3. Figure 6.4 shows the superiority of operations to each other.

According to the ranking, production planning, demand planning, and inventory planning operations are in the first three places. For the development of artificial

Table 6.4 Criterion scores of operations

	SD	QD	Flex	DS	VD	UD	IoH	IoS
Supply chain network design	10	5	9	10	8	8	7	8
Supplier selection	8	8	7	6	5	4	3	9
Green SCM	4	3	2	3	3	3	1	2
Inventory planning	8	8	9	10	9	9	9	10
Demand planning	8	8	9	10	10	9	10	10
Production planning	8	10	10	10	10	9	8	10
Reverse logistics	3	3	3	5	6	6	1	2
Warehouse management	6	5	7	7	7	2	5	7
Distribution network planning	7	7	8	8	7	4	7	7
Recycling management	4	4	2	5	4	2	1	1
Waste disposal	3	1	1	2	2	2	1	1
Sales management	8	8	8	7	7	9	2	8
Outsourcing	5	8	6	4	5	2	1	5
Facility layout	10	4	8	8	5	3	7	8



Scenario1	SD	QD	Flex.	DS	VD	UD	IoH	IoS
Unit	unit	unit	unit	unit	unit	unit	unit	unit
Cluster/Group								
Preferences								
Min/Max	max	max	max	max	max	max	max	max
Weight	0,26	0,04	0,15	0,10	0,13	0,18	0,03	0,11
Preference Fn.	Level	Level	Level	Level	Level	Level	Level	Level
Thresholds	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute
- Q: Indifference	3,00	3,00	3,00	3,00	3,00	3,00	3,00	3,00
- P: Preference	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics								
Minimum	3,00	1,00	1,00	2,00	2,00	2,00	1,00	1,00
Maximum	10,00	10,00	10,00	10,00	10,00	9,00	10,00	10,00
Average	6,57	5,86	6,36	6,79	6,29	5,14	4,50	6,29
Standard Dev.	2,32	2,53	2,94	2,62	2,37	2,92	3,29	3,30
Evaluations								
Supply chain net...	10,00	5,00	9,00	10,00	8,00	8,00	7,00	8,00
Supplier selection	8,00	8,00	7,00	6,00	5,00	4,00	3,00	9,00
Green SCM	4,00	3,00	2,00	3,00	3,00	3,00	1,00	2,00
Inventory planning	8,00	8,00	9,00	10,00	9,00	9,00	9,00	10,00
Demand planning	8,00	8,00	9,00	10,00	10,00	9,00	10,00	10,00
Production planning	8,00	10,00	10,00	10,00	10,00	9,00	8,00	10,00
Revese logistics	3,00	3,00	3,00	5,00	6,00	6,00	1,00	2,00
Warehouse man...	6,00	5,00	7,00	7,00	7,00	2,00	5,00	7,00
Distribution netw...	7,00	7,00	8,00	8,00	7,00	4,00	7,00	7,00

Fig. 6.2 Visual PROMETHEE program data entry screen

intelligence techniques, researchers should first focus on these areas. These three operations are the ones most affected by changes in demand in the supply chain.

Production planning includes planning activities to be done during the production of both materials and services. The irregularity of activities such as examination, surgery, and treatment in the planning of health services increases the uncertainty in the supply chain. For this reason, planning has taken the first place in terms of the development of artificial intelligence techniques. The most important factor affecting the planning activity is demand forecasting. If the forecasts are made consistently, the planning activities will be as consistent. However, it is difficult to forecast because the demands of health services are affected by seasonal effects, human mobility, and extraordinary situations such as pandemics and disasters. Demand management has also been at the top due to these effects and should be considered together with planning activities.

Inventory management is another important operation to ensure that health services are not interrupted. Inventory management is difficult in all industries. However, considering the impact of lack of materials on human life in the health sector, the importance and difficulty of inventory management can be better understood. Stock policy affects many operations of the supply chain such as factory location, customer service level, distribution planning, and warehouse management. Therefore, there is a need for artificial intelligence algorithms to be developed for a good inventory management. Supply chain network design is another prominent operation. Due to COVID-19, one of the problems experienced in the health sector, PROMETHEE Flow Table

Rank	action	Phi	Phi+	Phi-
1	Production planning	0,4102	0,4102	0,0000
2	Demand planning	0,3978	0,3978	0,0000
3	Inventory planning	0,3768	0,3768	0,0000
4	Supply chain network	0,3686	0,3715	0,0030
5	Sales management	0,2776	0,2913	0,0137
6	Facility layout	0,1184	0,2242	0,1057
7	Distribution network	0,0917	0,1550	0,0634
8	Supplier selection	0,0411	0,1547	0,1135
9	Warehouse	0,0043	0,1082	0,1039
10	Outsourcing	-0,1866	0,0436	0,2302
11	Revese logistics	-0,3606	0,0332	0,3937
12	Recycling management	-0,4490	0,0000	0,4490
13	Green SCM	-0,4889	0,0000	0,4889
14	Waste disposal	-0,6015	0,0000	0,6015

Fig. 6.3 Ranking of operations

both on the supplier side and the end consumer side, was the inability to deliver the materials to the desired places on time. Companies made new connections and sought alternative suppliers to overcome this problem. They aimed to develop the supply chain network in terms of both production and logistics and ensure continuity in material supply. Interruptions in the supply chain were prevented with the development of the supply network.

Among other operations, facility layout, distribution network design, supplier selection, and warehouse management emerged as the second group. Researchers can prioritize developing artificial intelligence techniques in these areas as well. Since these operations have high scores from the criteria of strategicity of decisions, data size of operations, flexibility, and variability of operational data, they are in the second group according to the level of importance. Other operations, although important in the supply chain, received the lowest score in terms of the development of artificial intelligence techniques. This is due to the fact that operations are for the efficient use of resources rather than the execution of the supply chain.

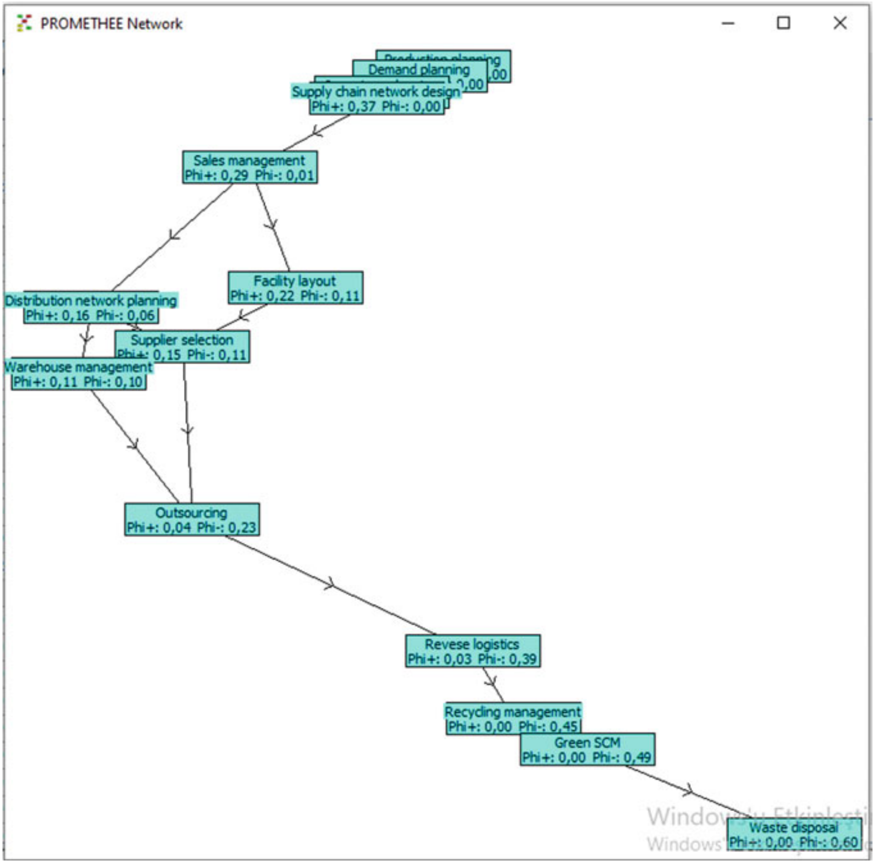


Fig. 6.4 The superiority of operations

6.5 Conclusion

In this study, the need to develop artificial intelligence techniques in the decision processes of operations was evaluated on the use of artificial intelligence techniques in the health and medical supply chain. Operations in the supply chain were taken as alternatives and criteria for evaluation were established. Fuzzy AHP method was used to determine the weights of these criteria. The PROMETHEE method was used in ordering the operations.

The most important criteria are strategicity of decisions according to the fuzzy AHP results. This criterion has a high score as it reflects the decisions in supply chain operations. Similarly, the flexibility criterion has a high score. In addition, the criteria of uncertainty of operation data and variability of operational data, which are determined by taking into account the advantages of artificial intelligence in data analysis, have also emerged as high-weight criteria.

When the alternatives were evaluated, production planning, inventory planning, demand planning, and supply chain network design were at the top. They dominate other operations because of the higher scores they get from the criteria with high weight. Developing new methods for these operations by researchers will contribute more to the health and medical supply chain. In order for the supply chain to be carried out uninterrupted in the health sector, these operations should be handled as a priority and decision models should be developed.

As future studies, studies can be carried out to deal with each of these operations separately and match them with artificial intelligence techniques. In addition, operations can be evaluated using different MCDM methods.

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Chapter 7
Robotics Systems and Healthcare Logistics

Ezgi Uzel Aydınocak

Abstract Including waste management, warehousing, inventory management, equipment maintenance, sanitation, and transportation, healthcare logistics has focused on providing more innovative and value-added services in recent years. Therefore healthcare services should be examined and aligned with the objectives of the entire healthcare supply chain to meet the needs of both individuals and organizations. This will help to improve the supply chain performance so that reflects on the patient outcomes. Lack of efficient storage areas, increasing wages/salaries, and some activities that are conducted by healthcare employees manually are the priority areas that require solutions. According to studies in the field of health logistics, supply chain activities take more than the time spent on patient care. In addition, the logistics activities that have to be done manually by the health personnel leave a negative impression on the patients. Based on these, healthcare logistics should be improved in order to decrease the level of fatigue of healthcare personnel and create more time to interact with patients. Serving various tasks and purposes in many business sector, robots are preparing to become one of the most important technological innovations for healthcare industry. Nowadays, the robotics community is largely focused on developing the next generation of service and social robots. It is predicted that the use of robots in diagnostics, surgery, rehabilitation, patient care, disinfection and cleaning, medicine and food distribution, vital signs measurement, disease prevention, and disease management will increase performance in healthcare services. Among these, robots providing disinfection and logistics services are predicted to have the shortest-term impact.

Keywords Healthcare industry · Robotics technology · Hospital logistics · Robotics in health industry · Autonomous mobile robots

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7.1 The Role of Robots in Healthcare

Robots, which have been used in the healthcare industry for a while, have expanded the range of services over the last five years and have become important assistants for doctors, nurses, caregivers, and patients in hospitals and care facilities. Both economic and social advantages provided by robot systems, which have been used in many branches of the industry for years, have also been noticed in the health sector and a rapid usage prevalence has been gained.

Robotic Industries Association (RIA) defines a robot as it is "*a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or other specialized devices through various programmed motions for the performance of a variety of tasks*." Robot technology has been helping people in the industry since the 1940s to perform many tasks, from the simplest to the most complex. Nowadays, robots are accepted as an important technology that can make a significant contribution to world health and economy (Camarillo et al. 2004). Medical robots appear in different forms to serve a variety of purposes, tasks, and applications in the medical/health and social care fields. It is constantly growing, from robots used in surgery and rehabilitation to robots designed to work in hospitals/nursing homes, and personal robots helping patients and elderly people.

Application areas of robotics can be classified under five main fields (Jovanovic et al. 2021):

- **Robotics Response in Diagnostics**

This type of robot allows healthcare personnel to monitor the patient from a safe distance, decrease the processing time, and provide standardization. These types of robots contribute to three important areas (Jovanovic et al. 2021). The first of these is the autonomous operation of some equipment, such as endoscopy devices or examination tables. The second is robotic laboratory setups that can assist with automated processing of samples taken. The last one is in the field of using robots for remote control of machines or visible participation in remote events by utilizing virtual reality technology. The best examples of this are communicating with patients by monitoring their temperature, pulse, and respiration remotely. Robots of this type are helpful in the early diagnosis of diseases. However, despite their rapid development, most of these systems are not yet mature enough to be adopted.

- **Robotics Response in Interventions/Surgical Robots**

The first robots to appear in this field were robots that contributed to surgical operations through robotic arm technologies in the 1980s (Camarillo et al. 2004). In this way, surgeons no longer need to touch the inside of the patient with their hands during an operation. This, in turn, contributes to the reduction of traumas that may occur after surgery in patients and to a shorter recovery period. Today, surgeons can comfortably control a robot remotely. Therefore, Satava (1999) and Ballantyne and Moll (2003) said laparoscopic surgeries are a revolution in the use of surgical robots. In addition to laparoscopic operations, developing surgical robots are also successfully used in interventions such as colonoscopy and endoscopy.

One of the biggest advantages of robots used in surgical operations is their ability to perform an operation repeatedly and without errors. In this way, human errors are also avoided. In fact, unlike the robots used in other branches of industry, most of the robots used in the health field can work with humans. For example, after the use of robots in factories, minimizing interaction with humans and reducing the workforce are concerned, while health robots work together with humans, thus increasing reliability.

Surgical robot investments have increased in recent years. Firms tend toward different product groups in their investments. For example, the da Vinci System, one of the well-known general surgery robot systems, focuses on surgical operations in the fields of urology, bariatrics, and gynecology, while Stryker's MAKO System is used in orthopedic surgery (Fig. 7.1).

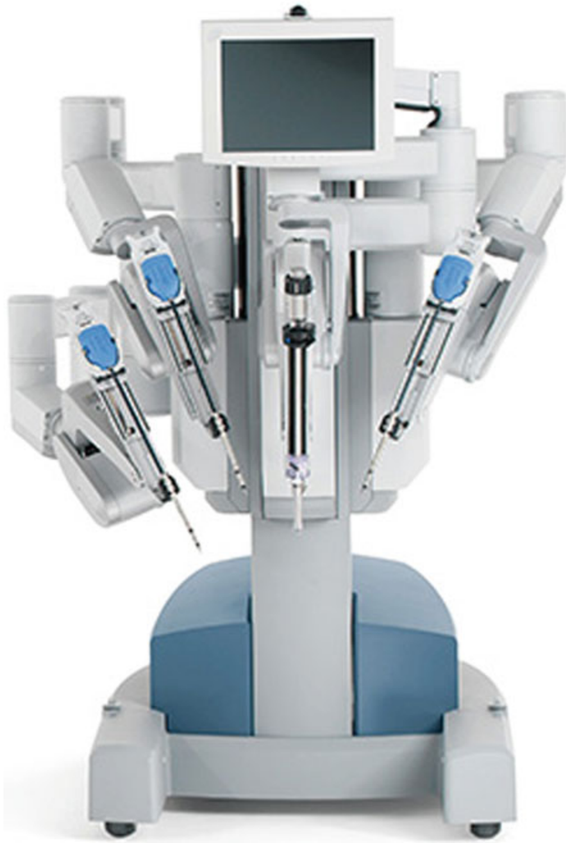

Fig. 7.1 About the da Vinci Surgical System (*Source* davincisurgery.com. https://www.uchealth.com/services/robotic-surgery/patient-information/davinci-surgical-system/)

Fig. 7.2 MAKO—robotic-arm assisted surgery (*Source* Stryker.com. *Video 2* Watch knee replacement using the MAKO Robotic arm [https://www.youtube.com/watch?v=FiLf4KGd494])

The Da Vinci Surgical System is the first robotic surgery platform to be used commercially in laparoscopic surgery in the United States in 2,000. To date, more than 1 million patients have undergone this procedure (Fig. 7.2).

After all these years since the use of robots in surgical operations, robot technology has proven itself successful in this field, and thanks to developing technologies, for example, with the use of artificial intelligence in robot technology, the capabilities of health robots have increased in many fields, especially data analytics.

- **Robotics Response in Rehabilitation/Exoskeletons**

Rehabilitation is a kind of a care that supports the recovery, protection, or development of physical, mental, or cognitive abilities needed daily for any reason. Patients with severe infections, chronic pain, loss of muscle mass after surgery, or long stay in intensive care units, especially patients who have experienced various injuries, burns, bone fractures, or traumatic brain injury need rehabilitation. Therapy robots are the most common robots we see in this area. These robots are devices that allow patients to practice. The first robot known in this field was MIT-Manus which was developed at the Massachusetts Institute of Technology and is known for providing support to stroke patients (Hidler et al. 2005).

Physical therapy performed by robots helps patients to adapt to physical movements easily, so that they can do more activities, and as a result, data on the patient's development can be obtained. With therapy robots, special exercise programs can be planned for patients, and even patients can be served at their homes.

In addition to therapy robots, exoskeletons can be counted among the robots serving in this field. An exoskeleton is a device that can be worn to support the body as a person recovers from an event such as an injury or to enhance existing biological capacities (Fox et al. 2019). With this device, which works thanks to electric motors, the limbs gain strength and endurance in their movements. Exoskeleton robots work with sensors placed on the skin to detect electrical signals in the human body and

Fig. 7.3 The World's First Wearable Cyborg "HAL"—Cyberdine (*Source* Cyberdine.jp. *Video 3* Cyberdyne build robots and exoskeletons—BBC Click [https://www.youtube.com/watch?v=UffBS1uKJdE&t=2s])

respond to joint movements. One of the known exoskeleton robots, including spinal cord injuries and strokes, is Cyberdyne's Hybrid Assisted Limb (HAL) exoskeleton (Fig. 7.3).

The invention of the Cyborg-type Robot was awarded the Invention of the Twenty-First Century Award by the Japan Institute of Invention and Innovation in 2009. Hybrid Assistive Limb (HAL) is the world's first technology to improve, support, enhance, and regenerate the physical functions of the harvester according to their purpose. Because of this feature, it is also called "Wearable Cyborg™."

- **Robotics Response in Support of Patients/Care Robots**

The first robots in this field were developed by focusing on the simple needs of patients. Today, however, they can serve much more complex activities in patient care. For example, in the early days, they only helped patients to get in and out of bed, but today they manage the time of taking medication and provide services in areas such as blood collection and body temperature measurement. By carrying out simple and repetitive activities such as these, they save hospital staff time and allow them to provide more qualified and personalized service. Patient care robots are a suitable alternative for places where there is a shortage of healthcare personnel. For example, Japan is increasing its investments in this field by anticipating the personnel shortage in the future, and products such as Robear Japanese are being developed to serve this field in RIKEN and Sumitomo Riko research institutes. Toyota and Honda companies have been working in this field for many years.

Robots that provide physical care to patients as well as social support have begun to be developed. The purpose of these robots is to meet the emotional needs of patients in hospitals or nursing homes, especially the disabled or elderly. For example, there are robots that allow patients placed in isolation during the COVID-19 pandemic to communicate with their family members or have entertainment elements (Fig. 7.4).

The robot named ROBEAR is a care robot that is used to transport patients, for example, that can lift the patient from the bed to a wheelchair. The latest version has emerged as RIBAII (Fig. 7.5).

Fig. 7.4 The ROBEAR Robot (*Source* Riken.jp. *Video 4* ROBEAR: The experimental nursing care robot [https://www.youtube.com/watch?v=0LaVwDmLDLw])

Fig. 7.5 PARO Therapeutic Robot (*Source* Parorobots.com. *Video 5* PARO therapeutic robot [https://www.youtube.com/watch?v=2ZUn9qtG8ow])

PARO is an interactive robot developed by AIST, which is well known in the Japanese industry. It was developed based on the benefits of treatments with animals. The purpose of this robot is to relieve the stress of both patients and their caregivers. It entered the Guinness Book of World Records as the World's Most Healing Robot. Paro was developed to socialize with people and help them emotionally heal.

- **Robotics Response in Support of Healthcare Professionals/Hospital Robots**

It can be said that robots in this field basically have two purposes. The first is to increase the motivation of the employees by reducing their fatigue by undertaking routine activities that waste time, do not have high added value, and steal the qualified time to be allocated to the patient; another is to protect the health of employees by reducing the risk of infection transmission to frontline healthcare personnel. When we look at the content of the first purpose, it is seen that there are activities such as distribution of drugs, collection of samples, and transportation of beds.

Thanks to the delivery robots serving in this field, drug distribution, sample collection, and medical supplies deliveries are made easily. These robots are technically capable of autonomous navigation and mapping. In addition, they have very high mobility with their cameras and sensors. An example of this type of robot is Aethon's TUG autonomous mobile robot (Dahl and Boulos 2013). In addition, companies that already produce medical equipment in this field, as well as iRobot (MIT Technology Review 2012), for example, have started to produce this type of robot for hospitals.

Finally, Xenon (Song et al. 2020) company has also designed a robot for the disinfection of devices, equipment, operating rooms and patient rooms used in hospitals, and ambulances that provides a great added value in terms of workforce.

Robots serving in this field will be discussed in more detail in the next section.

7.2 Logistics Robots in Healthcare/Hospital Logistics Robots

As mentioned before, many robots used in the healthcare industry reduce the workload of healthcare professionals, thus allowing them to focus on other services that provide value. If we look at logistics in terms of other sectors, it is known that efficient planning and execution of many logistics activities such as transportation, warehousing, inventory management, etc., provide many economic benefits. According to the main purposes of logistics, the requested product/materials should be distributed to the user at the required place, time, form, quality, cost, and without damage. This also applies to hospital operations within the framework of health. For example, a hospital needs to plan for optimal distribution and stocking of medicines, medical equipment and supplies, biological samples, medical waste, and even bed linen. Many of these activities are carried out by health personnel, and for a 500-bed hospital, it is almost 850 man-hours per year. In addition, the physical transportation of materials is often carried out with equipment that the personnel have to push manually, which both take the valuable time of the personnel and cause physical and moral fatigue (Gao et al. 2021). Therefore, supporting these intra-hospital logistics operations, which we can also describe as the hospital supply chain, by establishing a well-planned logistics system and automation will provide positive returns in terms of hospital management, hospital staff, and patient satisfaction.

Hospitals contain warehouses where many health equipment, medical supplies, food products, cleaning and care materials, laundry, and waste are stored (Landry and Philippe 2004; Rivard-Royer et al. 2022). Hospital personnel provide a continuous flow of these materials from these storage areas to the places needed in their daily routine. In addition, the management of stocks, the planning of orders, and distribution cause very high logistics costs for the hospital. These costs correspond to approximately 46% of the total costs of a hospital. Looking at the distribution, 27% of this is spent on materials and equipment, while 19% goes to the workforce (Chow and Heaver 1994). Moreover, the amount spent on the workforce does not go to those who are directly related to logistics, but also to health workers. In a way, health personnel other than logisticians have to take a role in the logistics operations of a hospital, which steals the time that the health personnel will allocate to the patients.

Hospital logistics operations need to make cost optimization just like in other sectors. Although there are many innovative solution alternatives in this regard, the recent development of robot technology will help to quickly eliminate the problems in this field.

As mentioned before, different types of robots are used in the health sector, which cause fewer errors and help the operations to be carried out safely, quickly, and economically. It has been realized that robots used in the healthcare field are not limited to surgeries and surgical operations anymore. Many different types of robots developed aim to support healthcare workers by carrying out logistics operations within the hospital. Responsible for executing logistics operations, these robots can clean patient rooms and help distribute supplies such as medicine, food, and sheets.

According to the research of Lappalainen (2019), the logistics services that robots can provide in the hospital are as follows: central storage service, instrument maintenance service, and catering service to care units.

- **Robots in Central Storage Service**

The service expected from robots in this area is the efficient management of direct distribution of all kinds of materials from the shelf systems in the warehouses in the hospital in order to meet the needs of the patients. Under normal conditions, the operations that the hospital staff will carry out during working hours can be carried out 24/7 with the use of robots. In addition, these uninterrupted operations increase the usage rates of robots and facilitate the return on investment.

- **Robots in Instrument Maintenance Services**

As stated above, uninterrupted distribution from the warehouses to the relevant units is only possible if the device maintenance and repair processes are carried out on time. Repair-maintenance robots are of great importance in the efficient execution of hospital logistics. The fact that robots working in this field can provide service 24 h a day and 7 days a week creates a great added value for the hospital. In case of a malfunction, the robots intervene more quickly than the technical personnel and put the devices back into use, preventing delays and making a positive contribution to patient satisfaction. Moreover, the level of trust and cost savings it provides are other advantages.

- **Robots in Catering Service to Care Units**

There are sensitive points in the food service provided in the hospitals. First, ensuring food safety is only possible with uninterrupted and error-free cold chain logistics operations. In addition, it is a great responsibility to provide food service not only for the patients, but also for the whole hospital personnel. It is a critical task to distribute the right food to the right people on time, and thanks to robots, errors are reduced and the right menu is distributed to the right unit at the right temperature.

Apart from these three service areas, there is one separate service area of robots that provide logistics support in hospitals.

- **Robots in Cleaning Service**

Every year, there are approximately 37,000 deaths in Europe and approximately 100,000 deaths in the United States due to hospital-acquired infections (Ahmed et al. 2020). Especially during the COVID-19 pandemic, the importance of disinfection was once remembered and the use of robots used in this area has increased. According to the data of IFR World Robotics 2020: Service Robots, the sales of this type of service robot increased by approximately 20% in 2019. One of the most important reasons for this is that 99.9% of microorganisms can be destroyed within 10 min by using these ultraviolet disinfection robots.

Besides, ultraviolet disinfection robots, autonomous mobile robot scrubbers are also popular in hospital cleaning services. The COVID-19 pandemic has created a high awareness of cleanliness in hospitals and has led to a change in cleaning protocols. For example, the need for additional cleaning, sanitation, and disinfection multiple times a day has been revealed, revealing the inadequacy of cleaning personnel. So the emergence of autonomous robots that can take over cleaning jobs is revolutionary. In addition, such robots can determine the realization rate of the key performance criteria determined for the cleaning operation. This provides performance measurement and increases visibility. For example, a heat map of the square meters of the cleaned areas can be used to measure the satisfactory completion of the work or a video recording of the process can be taken. In addition, robots provide users with ideas by preparing reports at the end of the work.

Based on this context, different types of robots with its examples that have been involved in the logistics operations of hospitals in recent years will be explained below.

7.3 Types of Robots in Hospital Logistics

It has been observed that the technology behind the robots used in hospitals and serving in the field of logistics is mostly based on autonomous transport systems. When such autonomous systems are mentioned, automated guided vehicles (AGVs) come to mind first. However, in recent years, autonomous mobile robots (AMRs) have started to replace the AGV technology. Below, first of all, information about AGVs will be given, then AMR technology will be explained, and examples of robots that are frequently used today will be presented.

7.3.1 Automated Guided Vehicle (AGV) Systems in Hospitals

AGVs are a technology that has been used for material distribution in hospitals since the 1980s (Landry and Philippe 2004). AGVs are a system that emerges in large, fixed installations where repetitive, consistent material deliveries are made by movement through a predetermined set of routes in a facility. The use of AGVs in hospitals provides significant convenience in daily routine operations and helps healthcare personnel focus on their core business. In general, AGVs provide transportation of medical supplies, drugs, meals, and laundry from warehouses located in the basement of the hospital via elevators (AGV Network). Each AGV is programmed according to its respective distribution needs and moves within the hospital accordingly. For example, it provides efficiency in moving food from the kitchen to the patient rooms, then returning empty trays to the kitchen, managing trash cans, moving laundry, moving sterile supplies, and transporting medicines and other supplies. In this way, an increase in patient care service quality, efficiency in operations, and a decrease in costs are achieved. Thanks to AGVs, many jobs outside the job description of the health worker are eliminated. It is observed that the financial return of the investment is met in approximately 5–6 years (Landry and Philippe 2004). Despite all their advantages, AGVs are limited to following a fixed route and only performing the same delivery task throughout their service life. When a change is desired, an excessive cost may be encountered (Fig. 7.6).

The EVOcart™ Oppent-branded Automated Guided Vehicle is a tool used in hospital logistics services (for example, laundry, waste, sterilization, pharmacy, and transportation of general supplies and medical trolleys).

Fig. 7.6 EVOcart™—AGV system at Acıbadem Maslak Hospital (*Video 6* EVOcart™—AGV system at Acıbadem Maslak Hospital [https://www.youtube.com/watch?v=epeSHuSFNrs]. *Source* Oppent.com.tr)

7.3.2 Autonomous Mobile Robotics (AMRs) in Hospitals

The limited mobility of autonomous guided vehicles (AGVs), the inability to bypass the obstacles and enter the rooms, especially due to security and space concerns, impede in hospital logistics operations, AGVs are gradually being replaced by more flexible and more cost-effective systems called as autonomous mobile robotics (AMRs). They are small in size. Therefore, they can carry lower volume materials. Its small size provides an advantage by not creating traffic at peak times. AMRs can perceive the changes and make the necessary updates automatically. Also, AMR uses data from cameras and onboard sensors and laser scanners. Also, with its advanced software it can perceive its surroundings and choose the most efficient route to the target. It works completely autonomously and can navigate around obstacles in front of it. In this way, it supports the efficient distribution of the material flow (Oitzman 2021).

When AMRs are compared with AGVs, they can only follow simple programming instructions. They have a structure that requires installation before they can move. In addition, even AGVs can understand obstacles in their way, but they cannot move until the obstacle is removed. In contrast, AMR requires simple software installations and it can operate different tasks in different places (Table 7.1).

In this context, AMRs are more intelligent than AGVs. Also, one of the other differences between an AGV and an AMR is AGVs are all-wheeled vehicles while AMRs come in a variety of motion configurations.

Table 7.1 Comparison between the characteristics of automated guided vehicles and autonomous mobile robots

	AGVs	AMRs
Capacity load	1–500 kg	1–100 kg
Speed	1–2 km/h	3–4 km/h
Services provided	Transportation	Transportation, collaboration, assistance, etc.
Service points	Fixed pick and delivery points	Flexible pick and delivery points
Navigation	Fixed guided path	Autonomous in a predefined zone
Cost	Less expensive	Can be expensive in some cases
Best feature	Carry extreme payloads	Can follow humans around a facility in a “follow me” application
Work best in…	Well-defined conditions and applications such as material handling	Work best in applications in unstructured environments such as security, deliveries, person to goods and goods to person intralogistics

Source Adapted from Fragapane et al. (2020) and Oitzman (2021)

7.3.3 Examples of AMRs Used in Hospital Logistics

Logistics departments in hospitals are responsible for a number of supporting streams, including bed-linen logistics, medication distribution, blood management, sample transport, patient transport, cleaning, laundry services, food distribution, surgical instrument management, medical management aids, waste management, and postal services. Therefore, the use of robots in these intensive operations is increasing day by day. Accordingly, the logistics robot market expects a growth of approximately 23.7% CAGR until 2025 (Globe Newswire 2022).

In this section, robots known to be used in various logistics operations within the hospital will be introduced.

7.3.3.1 AMRs Used for Transportation of Materials

These types of robots are embedded solutions that enable the autonomous transport of materials to support nurses. These robots support the 24/7 flow of supplies in hospitals. It is designed to support logistics operations in six different areas. First of all, they work to reduce the responsibilities of nurses in logistics activities. They work with nurses to manage medicines, meals, consumables, and test kits. The second area is the transport of drugs. The main goals here are to safely transport drugs to where they are needed. They automate deliveries traditionally made via pneumatic tubes or manual couriers. The third area includes laboratory operations. Thanks to these robots, it provides controlled sample input–output with unique pin code application to the relevant departments. The fourth area is food service. These robots ensure that the meals are delivered to the patient floors and then the dirty trays are returned. The fifth area is waste management. The robot helps to dispose of wastes safely with an automatic discharge system. It is an important feature to be able to do this job, especially during non-working hours. The last area is about laundry. These robots provide scheduled delivery of linens to care units. Thus, the officers do not need to do this job.

Some examples of this kind of robots are provided below:

- **Tug by Aethon**

One of the robots known as the Tug robot is Aethon. Tug was developed by the American company Aethon and distributed by a Finnish distributor. Aethon mobile robots perform delivery and transport tasks in hospitals to give hospital healthcare workers more time to focus on patient care. It ensures the safe delivery of medicines and laboratory samples and the transportation of materials such as meals, linens, and environmental services. It is known to reduce the cost per delivery by up to 80% (Lappalainen 2019) (Fig. 7.7).

Fig. 7.7 The Tug robot by Aethon (*Video 7* Aethon Tug Robot [https://www.youtube.com/watch?v=MLZMAW9lqXE&t=12s]. *Source* Aethon.com)

- **Moxi by Diligent Robots**

Moxi robot was developed by Diligent Robotics in 2017. Especially after the COVID-19 pandemic, its distribution increased. Just like Aethon, Moxi is involved in the distribution of materials, delivery of samples, and collection and distribution of laundry. Moxi is a robot with social intelligence, mobile manipulation, and human-guided learning. It has handles for picking up supplies and a mobile base for moving around. Moxi can complete all the operations itself without any assistance.

Moxi Robot was first used in 2018. This robot also handles the stocking of materials, delivery of blood samples, and updating of patient records (Thomas 2021) (Fig. 7.8).

7.3.3.2 AMRs Used for Cleaning and Disinfection

Manual cleaning and disinfection in large and risky areas such as hospitals is difficult and can cause errors. Centers for Disease Control (CDC) estimates that Hospital Acquired Infections (HAIs) account for an estimated 1.7 million infections and 99,000 associated deaths each year (Business Wire 2020). Especially with the COVID-19 pandemic, the importance of hospital cleaning has increased and of course this has brought extra workload to the staff. For this reason, many technology companies have seen the opportunity for disinfection and cleaning of hospitals and

Fig. 7.8 Moxi by Diligent Robotics (*Source* Diligentrobots.com. *Video 8* "Moxi" the robot that supports nurses—Diligent Robotics [https://www.youtube.com/watch?v=Pdm0hix7OiI])

have developed autonomous robots for this work. Based on these reasons, the disinfection robot market is expected to record a CAGR of approximately 36.4% by 2025 (Globe Newswire 2021).

Examples of the most commonly known disinfection robots are given below.

- **UVD Robot by Blue Ocean Robotics**

Blue Ocean Robotics is an autonomously moving UVD robot designed for hospital disinfection. The robot, which won the IERA innovation award in 2019 and the European Professional Service Robots Product Leadership award in 2020, uses UV technology to prevent the spread of viruses, bacteria, and other harmful microorganisms in the environment (Fig. 7.9).

- **SESTO HealthGUARD by SESTO**

The robot named SESTO HealthGUARD, developed by SESTO, can work in hospitals for 24 h, and can work autonomously and eliminate 99.9% of all kinds of viruses, bacteria, and other harmful microorganisms. With maneuverability and obstacle avoidance, SESTO can define and plan tasks with a tablet or laptop computer. It is known that the robot cleans an area of 100 m^2 in approximately 45 min (Fig. 7.10).

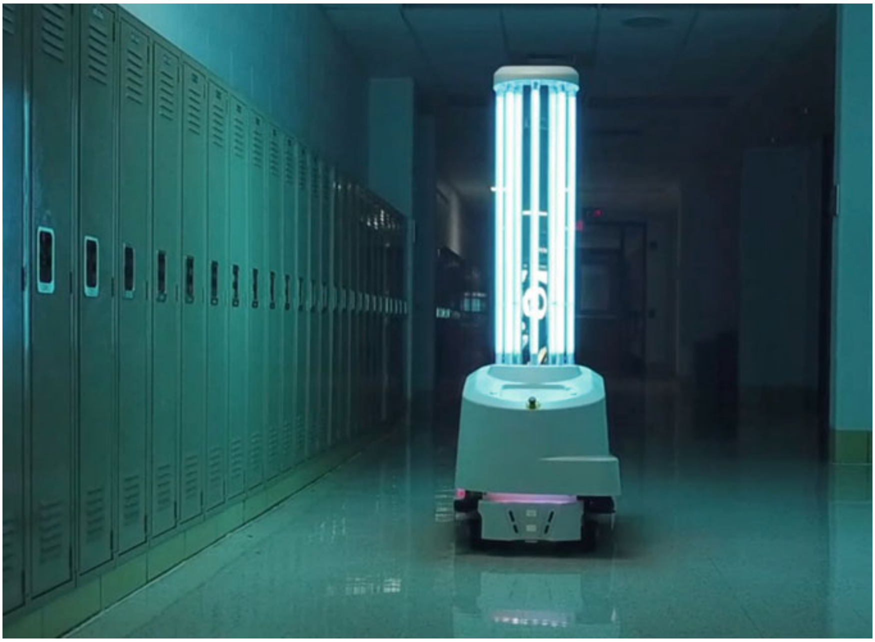

Fig. 7.9 UVD Robot by Blue Ocean Robotics (*Source* Business Wire. *Video 9* UVD Robots [https://www.youtube.com/watch?v=ljUFyrDa8Is&list=PLAyjTBWIhqZF1qB6Jbj7I75IkAYAxr8UW]. *Source* Blue Ocean Robotics)

7.4 Conclusion

The world population is increasing. In particular, the increase in the elderly population causes the density of health services in all countries. As in every field, the use of technology in the field of health is working on new designs that will help employees spend their time correctly.

The health sector has experienced concentration in hospitals, especially after the COVID-19 pandemic, and it has been determined that health workers are insufficient at one point. Moreover, although the number of personnel is sufficient, the importance of securing the health of the personnel during the pandemic periods has been understood.

Robot technology, which has been in our lives for a long time, has been available in the health sector since the 1980s, but after the COVID-19 pandemic, many technology companies working in this field increased their studies on robots to be used in the hospital service robots.

The use of robots in diagnosis and surgical interventions has proven its worth for a long time. However, increasing population, growing hospital capacities, and low number of personnel draw attention to hospital logistics. Just like in other sectors, there are many logistics activities in hospitals where it is essential to ensure efficiency.

Fig. 7.10 SESTO HealthGUARD by SESTO (*Video 10* Disinfect your HEALTHCARE facility with SESTO HealthGUARD [https://www.youtube.com/watch?v=QWt8bP_Iczw]. *Source* Sestorobotics.com)

There are areas that need to be optimally planned and executed, such as the storage and distribution of various materials, maintenance and repair of equipment and devices, and cleaning. The efficient execution of this type of logistics activities, which has a negative impact on hospital costs, will contribute positively to the satisfaction levels of both hospital management, health personnel, and patients.

Logistics activities carried out in hospitals are time-consuming. In addition, most of these activities have to be undertaken by health personnel other than the relevant personnel. As such, the valuable time of the health personnel, who are already insufficient in number, is allocated to non-duty workers instead of patients. This situation directly affects patient satisfaction negatively.

Considering all these, the design of robot technology in hospitals in a way that contributes not only to diagnosis and surgery but also to logistics activities has come to the fore, and many technology companies working in this field have introduced new robots to the market. Many robots have started to take charge in the market in order to reduce the stress on the employees, to protect the health of the employees, to provide service to the patients at all times, to make a more efficient hospital management by reducing the hospital costs, and to satisfy the patients at the end of the day. It is estimated that these technologies, which are only at the beginning of the road, will be used more intensively in health services in the future.

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Chapter 8
Big Data and Its Implementation in Health Industry

Şeyda Gür and Tamer Eren

Abstract The concept of big data is defined as the data obtained in large quantities and the information formed by their processing. From the perspective of the health sector, the concept of big data consists of data such as patients' health histories, medical examination records, and treatment processes. For these data to be transformed into meaningful information, methods and analyses must be done correctly and robustly. Technological tools should be used for efficient management and analysis of big data. At the same time, with the development of technology, tools, and applications that accelerate the processes in terms of the health sector have started to be developed. From the point of view of hospitals, a new environment has begun to be created for operating rooms, which are one of the most important units among income and expense items. In these environments, which are referred to as the concept of the hybrid operating room, many different specialities are practiced. In these environments, simultaneous imaging, biopsy diagnosis, and operation are provided by surgeons and their teams. For this reason, big data are created at once. Information is created, in which these data are simultaneously processed and used in the operation process. For all stages, there is big data consisting of the patient's medical history, medical, and clinical data in terms of patient health. The systematic storage, analysis, processing, and use of these data when necessary is of critical importance for patient health. This importance is increasing even more for hybrid operating rooms. To carry out operations in these environments, it may be necessary to use this information in scheduling processes. The operating room scheduling concept is the schedules that are optimally prepared for the most efficient use of operating rooms. While there are already many uncertainties for operating rooms, these uncertainties increase for operating rooms used as hybrids, and the use of huge amounts of data revealed here can directly affect the efficiency of the created charts, thus the process of these environments. In this study, the importance of big data concept for scheduling processes in

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hybrid operating rooms will be discussed. It will be examined how the data obtained in hybrid operating rooms where many operations are performed in the same area will affect the efficiency of the scheduling processes.

Keywords Big data · Hybrid operating rooms · Scheduling · Operating room scheduling · Efficiency

8.1 Introduction

With the advancement of technology, the development of new technological tools and the use of these tools in various sectors have become increasingly common today. From the point of view of the health sector, at the beginning of the nineteenth century, processes such as patient records and care processes were recorded manually in health systems. Today, with technology, the digitization of this data, which has become a pile of paper and is constantly being lost and deleted, has accelerated (Bause et al. 2019). While integrating digital technologies into the health sector, some situations should be considered such as not reducing the quality of service and keeping the costs at an optimum level (Al-Jaroodi et al. 2020). Focusing on these points, it is aimed to increase efficiency in care services with faster and more effective coordination in practice. Technological innovations and the systematization of medical data in digital environments are among the biggest revolutions in health systems.

The concept of big data is among the phenomena that have been heard frequently with technology in recent years. Big data is defined as the analysis and classification of large amounts of data, especially obtained in large enterprises, and its transformation into a meaningful and processable form. The most important point is to make the most useful data available. It is also of great importance that this data, which has become the most simple and useful in businesses, is used in the right place and at the right time. Analyzing the relationships between data obtained from many places and classifying them is among the functions of big data. Analyzing the relationships between data enables more effective and robust decisions in decision processes. This process basically includes the building models in the collected data, and by changing these models with each incoming data, how the results are affected can be monitored. The concept of big data, which is used in many fields, makes a great contribution to the improvement of health services for the health sector, and thus to human health. The big data-driven healthcare industry includes the analysis of a large number of medical records and images that can help in the early diagnosis of disease and the development of new drugs (Aceto et al. 2020).

In addition to the real-life applications of the big data concept, many researchers are working on this subject in the literature. Looking at the studies, there are studies on the potential application areas of the big data concept. For example, Hajjaji et al. (2021) examine current trends, data architectures, and challenges in these application areas in building smart environments. As a result, he mentions that the integration of big data technologies can provide very important opportunities for the protection and improvement of natural resources. Ageed et al. (2021) examined approaches to storage in big data. Li (2021), on the other hand, investigated the application of machine learning techniques for big data analysis in the health sector. Raut et al. (2021) analyzed the supply chain links of enterprises with big data analysis and made analysis to improve their operational capabilities. In another study on the supply chain, Lee and Mangalaraj (2022) examine the features developed for advanced supply chain functions with big data analysis. Naeem et al. (2022) mention the difficulties for today's businesses, such as analyzing, classifying, and visualizing large amounts of collected and complex data. The study includes the features of big data, current problems, opportunities, and trends. Papadopoulos and Balta (2022) carried out big data and analyses on climate change in another big data study that found another application area. Looking at the studies in the literature, the concept of big data takes place in many different sectors and fields. The existence of the data produced in each passing second and the analysis of their complexity are made possible with the development of technology. With the increasing population and the aging population, there is an increasing demand for the health sector. In this case, it causes inefficiencies in health services. Such demand also leads to the creation of large amounts of data. This causes inefficiencies to increase and the system to malfunction when this amount of data cannot be controlled. In this study, the importance of the concept of big data in the health sector is mentioned. Especially surgical areas are one of the most important units for hospitals. The data obtained in these units directly affect the health status of the patients. For this reason, the concept of big data is especially important in the planning made for these units in operating rooms. In this study, the importance of the concept of big data for the health sector and surgical fields will be mentioned.

The study consists of four parts. In the second part, after mentioning the concept of big data that has developed in the health sector, in the third part, the concept of big data for operating rooms, which is one of the most important units of hospitals, will be mentioned. In the last section, the results will be mentioned.

8.2 Big Data in the Health Sector

The increase in the demand for the health sector with each passing day causes an increase in the data obtained. This makes the analysis of the data difficult. With the development of technology, the emergence of concepts such as big data has facilitated the analysis and classification of large amounts of data. Today, the increasing use of real-time data collection and tools such as big data and artificial intelligence shows the point reached in the health sector. Thus, a new vision was created by starting the digitalization era in the health sector. Hospitals have switched to a patient-oriented approach that provides the best care with technology-based changes in their organizational structures. With this approach, technology offers patients the personalization of healthcare services. To achieve this personalization, patient data must be systematically stored, analyzed, and classified (Al-Jaroodi et al. 2020).

The impact of these technologies in the health sector has begun to spread over a wide area. The effects of technology are seen in diagnosis and treatment processes, treatment monitoring, drug applications, imaging processes in operation processes, patient–doctor relations, and pricing. The data that increases exponentially with the technology reflected in these areas is also of special importance. To respond quickly to the demand for general public health in possible disaster situations such as increasing population, old age rates or pandemics, it is tried to develop a system using these technologies (Thuemmler and Bai 2017). It is necessary to provide quality healthcare services for patients with these technologies and to improve the efficiency and performance of the general system.

Considering the innovations and developments reflected in the health sector, it is possible to experience improvements in planning and resource allocation with a more detailed analysis of the processes operating in the current system. It is possible to monitor the patient remotely with smart equipment, to analyze the data of remotely followed patients in the system with big data, and to easily access these data by the physician, thus accelerating the decision-making services in the treatment processes and increasing the efficiency of the service provided (Singh 2018). It is also possible to make predictions for future needs by performing data analysis of equipment and resources with proactive maintenance programs. Thanks to all these and similar applications, the costs encountered in the care and treatment processes can be reduced and both operational and service efficiency can be increased. The special care provided to the patient and the use of big data will enable access to the patient's previous records, healthcare professionals, and disease diagnoses, and the patient's condition over time can be monitored by analyzing these data. Thus, when needed, improvements in treatment processes can be increased by taking into account the previous data. The main purpose of the use of big data in the health sector is to perform processes such as data processing and data storage to monitor patient health remotely or in the hospital (Dash et al. 2019). Since the system processes in hospitals are very long and complex, the slightest mishaps or delays can have direct effects on patient health. Therefore, collecting, observing, and examining the data, which is constantly changing, increasing, and having a fast flow in the process, is very important in terms of patient health and the value chain. It is a difficult process to control this data flow, and at this point, technological tools such as the internet of things (IoT) and big data, which are reflected in the health sector, simplify and accelerate system processes at the same time (Sevinç 2018; Khanra et al. 2020).

Health managers should collect, organize, and store the inputs of each stakeholder within the health systems while integrating technology into their strategic policies. The management and evaluation of these data are among the subjects of the new strategies developed. At this point, it is necessary to determine the unique characteristics and needs of each department of the hospitals correctly. It is important to remember that even if there is data collected in a single unit, it includes all other units. Therefore, patients' data should be shared quickly and easily with all healthcare professionals in different departments. In this value chain established within the hospital, the added or updated data belonging to the patient in any department must be updated in a synchronized manner to maintain the correct information flow in the database. With this established value chain, huge amounts of data are collected. It is very important to make these data meaningful and to use them at the right time and in the right place. Thanks to technological tools and big data, the data obtained directly with patient monitoring devices can be used to facilitate operations, provide the information needed by the staff instantly, optimize operational programs, and improve patient flow. In the long term, it is possible to use these collected data to create proactive action plans in the health sector and to develop future steps (Mukherjee and Singh 2020; Tortorella et al. 2020).

This technology, which has many benefits, also has difficulties that may be encountered. For this technology, difficulties such as lack of trained healthcare personnel, equipment costs, initial investment costs, ability to respond to the increasing demand for high-quality service, data privacy, data security, legal issues, complexity and size of the value chain created, standardization, competition in healthcare providers may be encountered. In addition to these, increasing design complexity, power to support services, security and privacy issues are among the issues to be considered. It is very difficult to create the desired technology model in applications, so detailed and robust analyses of existing processes are required for this. At this point, big data comes into play. With big data, it is possible to prepare the system by presenting information that has been transformed into meaningful with the correct analysis of the large amount of data collected on the process (Tortorella et al. 2020).

The health sector should have a continuous control mechanism while minimizing the errors encountered while incorporating innovative technologies into its systems. This mechanism created by bid data will increase the probability of being successful in producing solutions to the errors encountered by learning the process at the same time while processing the data it receives. Health administrators have begun to understand the importance of gaining the ability to capture this vision created by technology. Therefore, while health managers invest in technology, they aim to increase the level of satisfaction in the services offered to patients, while aiming to both reduce costs and increase efficiency in the performances achieved.

8.3 The Concept of Big Data for Operating Rooms

Operating rooms are one of the most important units in income and expense items for hospitals. Considering that 30% of the patients who come to the hospitals undergo an operation, it is seen that the plans prepared for these units are of great importance. Technological innovations reflected in the health sector have made great progress in a short time. This situation allowed improvements that made great contributions both to patients and surgeons (Gür et al. 2019).

When we look at technology for patients in the health sector, innovations such as reductions in hospital stays and waiting times for operations, less risk of complications, follow-up of treatment processes, and personalized treatment are seen. For surgeons, there are benefits such as simulation systems to reduce risk in operations, and artificial intelligence screens that reflect the results of the next step during the procedure. In addition, when we look at the other innovations made for operating rooms, it is seen that robotic systems are becoming widespread. Surgical robotic systems provide more dexterity and sensitivity with advanced imaging modules (Hirides and Hirides 2018). In addition, with increased visualization, the control of the operations can be provided more. Tools such as big data have emerged for the analysis of the increasing amount of data produced by all this technology. With big data analysis, it is possible to collect data instantly on the patient during the operation and convert them into meaningful information to establish a structure that feeds them back to the surgeon. Robotic technology, developed and widely used to assist surgical processes, is the reflection of modern medicine today, and these systems have a unique data capacity and computing power (Wickramasinghe et al. 2021).

In the operating rooms, there are three different processes, namely pre-operative, operational, and post-operative processes, and the environments in which these processes are experienced. Each environment has its characteristics and basically aims at the successful completion of the patient's operation and ensuring patient satisfaction. In all these three processes, treatment processes started to be recorded with the effect of digitalization. Before the operation, a system is developed by collecting the consent forms obtained from the patients in case of any risk in the electronic environment. At this stage, security systems are created to protect the personal information collected. The analysis of all these data is also carried out using big data. Thus, it has become possible to increase the effectiveness and efficiency of surgical procedures. Operating rooms, which are among the most important units of the health system, require optimum use of resources. It is very difficult to respond to the ever-increasing demand because of the uncertainties in the structure of the unit. Prolonged patient queues on the waiting list reduce the satisfaction rate of these patients, and indirectly, there is an increase in costs due to waiting. For this reason, the planning to be made in the operating rooms is important in terms of reducing costs. These plans, which are often made manually in hospitals, encounter many disruptions and changes. This causes the process to be delayed. These processes, which are carried out manually with technology, have begun to be carried out in the digital environment. The important point here is to create plans that offer solutions to the capacity problems experienced in the operating rooms. Both the technology used in the operation processes and the general process of the patient bring along a lot of data flow. Since the operation processes are of critical importance, it is necessary to ensure that the correct information is reached in the planning made in these units. Data generated from innovations such as robotic technology used during operation can also be converted into useful information for planning when properly analyzed. Because situations such as operation times and complications are information that should be taken into account when planning (Huh 2020).

The most important issue for operating rooms is to obtain direct and rapid information about the patient and the surgical procedure. To achieve this, it is possible with a systematic analysis of large amounts of data collected before. This information should be easily accessible to the medical team when urgent action is required. It is especially important to have easy and direct access to the big data analysis system established for this information flow, which is necessary for the monitoring of the vital functions of the patient (Agnoletti et al. 2013). Looking at the literature, the number of studies examining technological innovations such as big data in operating rooms has been increasing in recent years. Although the number of studies is still very small, it is a subject that is the focus of attention of researchers. Especially since the efficient use of operating rooms has great effects on costs, the use of all necessary tools for this is encouraged. With the slow spread of robotic technologies in surgical applications, it is seen that there are great improvements in the operation processes. It is stated that as the tangible benefits increase, the distrust resistance established against these technologies is gradually breaking down. When patients start to get better results, their satisfaction levels are increased with benefits such as faster recovery processes, easier access to information, and personal treatment processes. Considering the studies in the literature in which technological innovations such as big data are used for operating rooms and scheduling activities for these units, Amrollahibiouki and Beauregard (2021) and Meng et al. (2022) touched upon the continuous improvement of health services and mentions the need to optimize the operating room care with the large amounts of data obtained. Looking at the literature, no study was found in which innovations such as big data were applied in the operating room scheduling process. Bartek et al. (2019) mentioned that the efficiency of scheduling with machine learning can be increased and they developed a model for this. Large amounts of data produced during operation processes give clues about how operating rooms should be used. Collecting data on how the processes are progressing and preparing charts in which these are taken into account in the future allows more realistic and robust charts to be obtained. Because operating rooms have a lot of uncertainty due to their structure. The charts affected by these uncertainties are never completely suitable for real life. Big data technology, on the other hand, should be used as an opportunity to produce charts that are closer to this reality. It is possible to obtain more robust and effective results when data collection and analysis of previous processes are inputs for charts. Spangenberg et al. (2018) also mentioned a similar point in their study. They mentioned that it is important to make decisions based on the current situation in the operating room scheduling and based on this information. They pointed out that the large amounts of data at hand should be used in decision systems and they developed a data-driven model.

In addition, a new concept for operating rooms has been mentioned in the literature recently. These units, which are referred to as hybrid operating rooms, have been widely used for many specialities. In these units, biopsy, imaging, diagnosis, and surgery can be performed in the same environment (Singh 2016; Drevets et al. 2019; Jin and Liu 2022). In other words, some of the pre and post-operation processes for operating rooms were combined in the same environment. The construction of these units, which are designed as a large area considering the presence of personnel working for each process, is quite costly. However, since most needs can be met in the same mirror, specialities such as neurology and general surgery have been preferred (Berazaluce et al. 2019; Drevets et al. 2019; Jin and Liu 2022). Considering that the amount of data produced by each process is high, it is known that large amounts of data are formed in the system formed by these units. Here, it is very important to analyze these data quickly and to make them meaningful and usable for the next stage. At this point, big data analysis will greatly benefit this complexity. Operations performed in hybrid operating rooms include high procedural accuracy and less operating time, and also avoid the risky situations encountered during transport between operating rooms (Jin and Liu 2022). The importance and even the difficulty of the plans and schedules made for the optimum use of these units have increased even more. It is necessary to prepare plans and schedules by considering many processes at the same time. For this decision-making process, the current situation should be audited and the large amount of data collected should be analyzed. It is possible to obtain more effective and robust results from the charts prepared by performing these analyses with big data technology.

8.4 Conclusions

In the past years, storing and processing data, which has an important place in the health sector such as patient records, patient care charts, and operating room charts were very laborious and costly processes compared to today. However, in the twenty-first century, transferring medical data to digital media, storing and processing these data, together with the latest opportunities brought by technology, are revolutionary in the health sector and have an important effect on practicality. In treatment processes where speed and safety factors are particularly important, the advantages of technology are utilized with personalized treatments specific to each patient. The processing of large amounts of data resulting from all these, making them meaningful and using them in the right places clearly shows the importance of the concept of big data. The data must be transferred at the right time, in the right place, and the right information to the appropriate people. Because the optimum level of this communication directly affects the patients and their treatments. With these innovations, processes have started to be made more practical, especially in operating rooms, which have the highest share among the income and expense items of hospitals. The developed technological applications and innovations aim to improve the system and increase satisfaction rates by providing more accurate and personalized treatment to the patients.

The most important way to increase efficiency in operating rooms is possible by optimizing the scheduling made in these units. The use of data created by technological activities in these processes will ensure that the plans are more accurate. The development of processes needs to integrate the developing technological applications into hospital activities for the sustainability of the efficiency to be achieved.

In this study, the place of the big data concept in the health sector has been analyzed. The convenience of data storage, processing, and interpretation provided to various health institutions in different aspects is also conveyed in this study. The importance of big data analysis in operating rooms, which is one of the most important units of hospitals, has been mentioned. It has been concluded that big data provides a lot of convenience in the planning of patient and surgeon circulation in the operating rooms, in the process steps such as treatment processes and in making the right applications at these stages. It is recommended that in future studies, it will be beneficial to integrate big data into more specific issues in operating room scheduling.

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Part IV
Future and Decision Making of Health 4.0 and Medical Supply Chain

Chapter 9
Health 4.0

Mukadder İnci Başer Kolcu and Giray Kolcu

Abstract The goal of Industry 4.0 is to strengthen the manufacturing sector by utilizing digitalization. Health 4.0 is a term used to describe the digital change occurring in the sector of health in parallel with Industry 4.0. Smart health, mobile health and mobile health applications, wireless health, e-health, online health, telehealth or telemedicine, digital medicine, health informatics, medical information technology, pervasive health, and health information systems and applications are all discussed within the context of Health 4.0. The goal of Health 4.0 is to provide improved, value-added, and cost-effective healthcare to patients while also improving the healthcare industry's efficiency and productivity. "Natural language processing, deep learning, and virtual reality" have been recognized as three critical technologies for Health 4.0 which have the potential to produce applications that will have a significant influence on healthcare services. Despite the numerous studies on the quality of health care and service provision, it is difficult to clearly reveal the quality due to intangibility, heterogeneity, and simultaneity in health services and health care. Consequently, using the Industry 4.0 strategy, Health 4.0 is a remarkable approach with a lot of promise to improve the quality of health services and health care. Health 4.0 has the ability to assist in the transition of the health sector from a reactive and cost-per-service-centered system to a value-based one that monitors outcomes and supports proactive prevention, according to the article. Novel designs and researches that have completed the PUKO cycle, have a widespread effect, and have an influence on large populations and data sets can be recommended in Health 4.0 integration. With these designs and researches, Health 4.0 will improve and become an actuality.

Keywords Health 4.0 · Quality · COVID-19 · Virtual Reality · Medical Education

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9.1 Introduction

The goal of Industry 4.0 is to strengthen the manufacturing sector by utilizing digitalization. Internationalization, increased competitiveness, resource changes, and the need for flexible production via real-time data usage have rendered computer-aided production (Industry 3.0) insufficient, necessitating digital transformation, which includes horizontal–vertical and end-to-end integration with the Internet of Things (Sony et al. 2022). Industry 4.0 design ideas strive to link the physical and virtual worlds in real time. To that aim, it focuses on how advanced Information and Communication Technologies (ICT), data science, and artificial intelligence (especially machine learning) are being used in manufacturing, factory automation, supply chain management, and logistics (Piccarozzi et al. 2018). Medical applications have long been regarded as the driving force behind scientific and technological progress in human history (Quy et al. 2021). Academics have gotten wind of technical advancements in Industry 4.0, and Health 4.0 is a digital transformation in the sphere of health that runs concurrently with Industry 4.0 (Sisodia and Jindal 2021). From the past to the present, there have been paradigm transformations in health systems that have had a direct impact on service delivery and quality of care. Health 4.0 refers to the shift and transition in health in today's world as a result of the fourth industrial revolution, also known as Industry 4.0 (Jayaraman et al. 2020). In a study evaluating the main determinants of the health system's capacity to respond to the results of the fourth industrial revolution, it was conducted research on the adaptability of the health system is still in its early stages, and that human capital, financial resources, and legal regulations have been the most important health determinants of the adaptive capacity for the fourth industrial revolution (Ćwiklicki et al. 2020).

In this sense, technological transformation in health is assessed in four categories. After superstition and belief in witchcraft, the time from the Hippocratic Oath (fifth century BC) to the Renaissance (1600 AD) was known as Health 1.0, and it comprised physician-oriented, organized training of physicians as well as documentation of treatments and interventions. It was a time when information is only flowing one way. Health 2.0 represents the foundation of modernization, the germ theory of disease, and the era of vaccine and antibiotic discoveries. It is regarded as an introduction period to e-health. It has associated with Web 2.0. Health 3.0 is defined as a combination of "modern" human technology. The use of systematic reviews and meta-analysis in evidence-based medicine demonstrates a comprehensive understanding of natural sciences in medicines, physical instrumentation technologies, and chemical therapy, as well as a focus on public health with applicable health policy. Health Mobile social networking applications are the most popular 3.0 applications.

9.2 What is Health 4.0?

Health 4.0 is a concept derived from Industry 4.0, which represents the fourth industrial revolution and encapsulates Industry 4.0's main ideas. Health 4.0 is similar to Industry 4.0 in that it encourages the use of cutting-edge technologies in healthcare. By delivering value-centered service, it delivers real-time monitoring. Intelligent machines drive this approach, giving them access to vast amounts of data and allowing them to make judgments without the need for human participation. Smart health, mobile health and mobile health applications, wireless health, e-health, online health, telehealth or telemedicine, digital medicine, health informatics, medical information technology, pervasive health, and health information systems and applications are all discussed within the context of Health 4.0. (Herrmann et al. 2018). Machine intelligence drives this concept, giving them access to vast amounts of data and allowing them to make judgments without the need for human participation. Smart health, mobile health and mobile health applications, wireless health, e-health, online health, telehealth or telemedicine, digital medicine, health informatics, medical information technology, pervasive health, and health information systems and applications are all discussed within the context of Health 4.0 (Herrmann et al. 2018). Electronic medical data as well as imaging methods are of relevance to today's healthcare industry. For processing this data, the "Internet of Health Things (IoHT), medical Cyber-Physical Systems (medical CPS), health cloud, health fog, big data analytics, machine learning, blockchain, and smart algorithms" are creatively integrated and used. Health 4.0 offers the healthcare business a bright new future. Health 4.0 is transforming the healthcare business, thanks to networked electronic health record systems, artificial intelligence, invisible user interfaces from wearables, and real-time data with improved analytics (Bause et al. 2019). Health 4.0 aspires to increase healthcare service quality, flexibility, productivity, cost-effectiveness, and reliability while also improving the patient experience. This system integrates and uses the internet of health objects, medical cyber-physical systems, health cloud, health fog, big data analytics, machine learning, blockchain, and smart algorithms.

9.3 Purpose

The goal of Health 4.0 is to provide sophisticated, value-added, and cost-effective healthcare services to patients while also improving the healthcare industry's efficiency and productivity (Al-Jaroodi et al. 2020). Health 4.0 transforms the healthcare business model by enhancing interactions among patients, stakeholders, infrastructure, and value chain participants. This move is expected to improve the quality, flexibility, productivity, cost-effectiveness, and reliability of health services while also improving patient satisfaction.

9.4 Advantages, Disadvantages, and Limitations

One of the benefits of Health 4.0 applications is that they can consistently and effectively examine data (Bause et al. 2019). It can help you find areas where you can improve and make better selections. Health 4.0 design concepts, according to the company, help with chronic disease management, rare disease management, and the rapid evolution of smart pharmaceuticals (Thuemmler and Bai 2017). Because of improvements in Industry 4.0, such as the internet of things, mobile networks, cloud computing, and artificial intelligence, Health 4.0 is able to connect the patients and healthcare providers (Loeza-Mejía et al. 2021).

In the realm of health, trust relationships between health managers, health workers, and patients are utilized to develop and implement policies and recommendations. One of the disadvantages of Health 4.0 applications is that the information and communication technologies supporting it have the potential to disrupt this analog relationship in numerous dimensions (Guckert et al. 2022).

When the constraints of Health 4.0 applications are assessed, it is clear that the major objectives are set and that talks on advanced prospective health applications are held (Al-Jaroodi et al. 2020). Health 4.0 now faces numerous ethical, technical, safety, and legal problems (Loeza-Mejía et al. 2021). It is feasible to design diverse software for Health 4.0, but one of its major drawbacks is that it requires subject-matter expertise and that projects take a long time. Furthermore, sufficient results in skill acquisition were not reached in a comparative study with face-to-face training utilizing a VR application built for cardiopulmonary resuscitation training, and it is claimed that more research is needed (Nas et al. 2020).

9.5 Health 4.0 and COVID-19

The COVID-19 period has provided an ideal setting for discussing Health 4.0 applications. The Health 4.0 approach garnered attention due to the sharing of experiences and solutions peculiar to this time period (Baser et al. 2021; Kolcu et al. 2021). The COVID-19 pandemic has highlighted the need to improve healthcare services in order to reduce the risk of transmission and foster a collaborative environment, even if it is done remotely, and the potential of Health 4.0 in preventing transmission, improving diagnosis, promoting virtual learning environments, and providing remote services has been mentioned in this context (Loeza-Mejía et al. 2021).

The global COVID-19 pandemic has put a lot of pressure on all healthcare services, particularly in the field of health data. There were issues accessing health care for people who did not have an urgent priority, for example, due to the possibility of coronavirus transmission. This complaint, which should be addressed as quickly as possible, built up over time, and many academics have begun to work on telemedicine applications. Doctors have limited face-to-face contact with their patients due to concerns about the spread of the new coronavirus, and as a result, non-emergency patients are frequently denied medical care, potentially resulting in long-term health problems. This phenomena is also mentioned as a possible COVID-19 drawback.

9.6 Areas of Use

"Natural language processing, deep learning, and virtual reality" have been recognized as three critical technologies for Health 4.0, all of which have the potential to build applications that will have a significant influence on healthcare (Müschenich and Wamprecht 2018). Applications are made in a variety of sectors in relation to these technology. Health 4.0, according to Loeza-Mejía et al. (2021), can be used in epidemics, diagnostic recommendations, supporting virtual learning settings, and delivering remote services (Loeza-Mejía et al. 2021).

Deep learning algorithms are used for ECG diagnosis in Health 4.0 applications. These apps provide perspective into two areas. The first is the possibility of employing deep learning for less invasive and less costly diagnosis in a situation where ECG recordings are usually taken in clinical settings. The second is the use of artificial intelligence to evaluate ECG records sent via wearable devices. In a related study, a new system architecture was presented to improve patient health monitoring during surgical procedures (Arpaia et al. 2020).

Virtual reality (VR) is a significant part of the Health 4.0 vision. It allows achieving the Health 4.0 vision and displaying the Health Metaverse's two-decade (2000–2020) pre-life map easier (Liu et al. 2022). Although virtual reality is a high priority in healthcare, there is limited data on VR-assisted therapy regimens at a macro level. Some studies point to a possible blueprint for future therapeutic VR use in Health 4.0 applications (Liu et al. 2022). Although research on educational motivation and effectiveness is ongoing, it is advised that it should be evaluated in terms of the educator–student relationship of trust (Guckert et al. 2022). In 2016, Erlangen and Lilly Germany University Hospital collaborated on a project to improve doctors' and medical students' rheumatology education (Kleyer et al. 2017). Süleyman Demirel University Faculty of Medicine is working on a project to employ medical education in virtual reality applications. VR is seen as a viable acquisition tool in the knowledge, skills, and attitudes of health learners in this research.

9.7 The Impact of Health 4.0 on the Healthcare Quality

Despite the fact that there is a great deal of study on the quality of health care and service delivery, it is a challenging process to clearly show the quality due to intangibility, heterogeneity, and simultaneity in the service area (Endeshaw 2021). As a result, multidimensional models that allow for this evaluation have been developed.

Technology has a direct impact on the quality of health care in areas such as communication and relationships between clients/patients and service providers, as well as its contribution to the achievement of goals in service delivery (ease and accessibility opportunities created in diagnosis, treatment, rehabilitation, and follow-up processes) (Abidova et al. 2020).

Furthermore, patients' perceptions of material and intangible environmental quality, quality perception in managerial and operational management, and quality perception in support services are all areas that are influenced by technology and indirectly affect the quality of health care and service (Dagger et al. 2007; Nimlyat and Kandar 2015). A recent systematic review study assessed the implications of Health 4.0 on healthcare quality by analyzing the articles through this multidimensionality (Sony et al. 2022). As a result, Health 4.0 was used to assess interpersonal, technological, environmental, and managerial quality aspects in health care. Many various aspects will positively enhance the relationship and communication between patients and healthcare providers when Health 4.0 practices and their impact on interpersonal interactions and communication quality are reviewed, according to published studies. Despite the fact that it may appear unattainable for digital transformation to have a good impact on human–human connection, it is vital to foresee and evaluate these pathways. First and foremost, it is critical to comprehend the current state of the connection between healthcare providers and their patients/clients. The large number of people who want to benefit from health service delivery in today's world, combined with the relative inadequacy of healthcare workers, results in increased workload in working conditions. Due to the increased workload, healthcare personnel are unable to meet patient/client expectations, as well as maintain fractured communication among themselves, resulting in their personal well-being being jeopardized. Although patient-centered team-based treatments and interprofessional collaboration in the area of presenting health have been proposed as alternatives to this dilemma, their adoption rate is questionable. Patients might be delighted by acquiring more information in the interaction as a result of technological advancements (Singh and Dey 2020). Patients' usage of ICT and online or mobile applications can have a positive impact on the development of connections and satisfaction since it makes service delivery more sustainable and accessible (Wu 2018). Furthermore, approaches such as data mining in the layout of the content of the programs that enable this remote access can be used to create unique content designs that directly address the needs of the patient/client/family. For example, in the most difficult areas like medication consumption information and interactions (Anand et al. 2016, 2018; Sabaté and Diego 2021). Again, "chatbots," which are commonly employed in health service delivery, and robots meant to give social care, or "humanoids" with the name of special literature, can provide tailored, transparent, sustainable, and accessible communication with patients (Bates 2019; Howick et al. 2021; Mierzwa et al. 2019; Schüssler et al. 2020). Artificial intelligence is also used to create empathic and caring robots for health care (Tripathi et al. 2021). It is now manufactured in technical instruments that utilize the Internet of Emotional People (IoEP), an approach developed specifically for this purpose, in which human emotions are perceived and personalized designs are created using artificial intelligence (Han et al. 2021). This process can be used to provide people with friendly and emotionally connected technologically supported health services, as well as for healthcare providers to conduct emotional assessments of patients, clients, and family members, and to improve communication and relationships in the healthcare setting. Today, thanks to the use of technology, a group of patients/clients/family groups in the field of health receive support without wearing out the system. So it can be said that technology has a significant and positive impact in areas such as providing patients with the emotional support they require from health providers in direct and interactive settings such as the management of complex cases (cases that are disrupted due to time constraints, or cases where human–human relations are required instead of technology, or cases that require more empathic, compassionate solutions) (Kerasidou 2020). In light of this, it is plausible to assume that "implementation of healthcare 4.0 will increase the interpersonal aspect of healthcare service quality" (Sony et al. 2022). When evaluating the impact of Health 4.0 on service delivery, it has been suggested that mastering fundamental algorithms will give you an advantage in avoiding human-specific errors and will help you develop preventative health services with artificial intelligence on public health (Basheer et al. 2021). Artificial intelligence and data mining are examples of technological approaches that have helped physicians with follow-up process as well as diagnosis and treatment processes (Wehde 2019). In complex settings, Health 4.0 makes it easier to collect and use data (Al-Jaroodi et al. 2020). It is possible to assert that the use of technology results in positive outcomes in the individualization of treatments, as well as in the production of personalized medicine and biological-based products, robotic-directed surgical treatments, and estimating personalized plans using simulation-based applications (Croatti et al. 2020; Madni et al. 2019; Sharma and Bhardwaj 2021). Furthermore, it has been shown that patient and disease information is shared globally and effectively used even in global occurrences, as as the COVID-19 pandemic, in determining risk factors that will negatively affect public health or in the management of global epidemics.

Patients' perceptions of environmental quality will improve in a patient care center or hospital equipped with Health 4.0 opportunities, and faster, more cost-effective, and definitive service delivery can be planned as individualized procedures can be applied both in outpatient and daily treatments during their hospital stay (Jayaraman et al. 2020). Furthermore, designs have been developed that can take regular blood pressure measurements, monitor status-behavior, and drug intake, particularly in the elderly and needy, or, more broadly, predict changes in the environmental conditions that patients are exposed to and intervene in negative factors (Gerg n.d.; Jayaraman et al. 2020). In light of these findings, it is predicted that Health 4.0 will contribute positively by paving the way for administratively planning patient care centers/hospitals at the micro level, institutional/national health service delivery at the meso level, and global health service delivery at the macro level, all while utilizing appropriate resources.

9.8 Conclusions and Suggestions

In the realm of Health 4.0 applications, there are numerous design studies on artificial intelligence (Beam and Kohane 2016; Dante et al. 2021, 2022). Experiments on artificial intelligence applications in health worker training using the Health 4.0 method have been conducted in our country (Baser et al. 2021; Filiz et al. 2022; Karaca et al. 2021; Kolcu et al. 2021). Since Health 4.0 applications are a relatively new subject, the majority of studies in the literature are letters to the editor, meta-analyses, mini-reviews, experimental studies, and preliminary studies (Guckert et al. 2022; Loeza-Mejía et al. 2021; Nas et al. 2020; Quy et al. 2021). In the majority of these studies, it is stated that additional research with other patterns and designs is required.

Finally, Health 4.0 is a promising approach with a lot of potential in the Industry 4.0 space. Health 4.0 has the ability to assist in the transition of the healthcare business from a reactive and cost-per-service-centered system to a value-based one that monitors outcomes and supports proactive prevention, according to the article (Bause et al. 2019). Despite the fact that the basic principles have yet to be released, it is advised that application developers establish a service-oriented middleware framework in order to produce applications under the Health 4.0 umbrella (Al-Jaroodi et al. 2020). It is advised in Health 4.0 integration to prepare designs and studies that have completed the PDCA cycle, have a wide impact, and impact large populations or data sets. Health 4.0 is an area that these concepts and plans have the potential to progress.

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Chapter 10
Healthcare 4.0 and Decision-Making Techniques in the Health Industry: A Systematic Literature Review

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Abstract The current study examines the state-of-the-art literature on using MCDM frames to solve various evaluation problems faced in the health industry. As is known, the health industry has a highly complicated and dynamic structure. Moreover, the requirement to use advanced technology in almost all phases of the treatment process makes it challenging to handle these assessment problems faced in the healthcare industry. Also, these requirements make evaluation and selection processes more complicated for practitioners, as they produce many complicated uncertainties aside from existing ambiguities. Therefore, the health industry is one of the promising fields of application for scholars dealing with decision-making approaches and proposing a new methodology. The authors applied a systematic literature review approach to determine the gaps and key research themes and synthesize the findings. The study concludes with recommendations about the research framework to help the authors carry out future works on this issue.

Keywords Health industry · MCDM · Systematic literature review · Technology

10.1 Introduction

Industry 4.0 and emerging advanced technologies such as artificial intelligence, machine learning, the internet of things, Big Data, robotics, and 3D printing technologies have severely and significantly affected manufacturing industries by forcing these industries for digital transformation. Aside from manufacturing industries, they

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have caused crucial transformations in the healthcare industry. Today, the healthcare industry has become dependent on advanced technology on a vast scale. Diagnosing and starting a treatment process has become almost impossible for a doctor without diagnosis devices, electronic health record applications, and other technological health instruments. The number of magnetic resonance imaging tests demanded by health staff proves this situation (Smith-Bindman et al. 2008; Barucci and Neri 2020). Therefore, today's healthcare services cannot be compared with the traditional healthcare service depending on doctors' evaluations and experiences. From this perspective, today's healthcare industry is defined as healthcare industry 4.0 (Larrucea et al. 2020).

Besides, these advanced technologies, essential to improve health service quality, also represent a significant research field requiring collaboration and integration (Hsu et al. 2021) among several industries. Thus, when both the dynamic and complex structure of the health industry and its requirement to collaborate with many industries are considered, it is clearly understood that existing complexities are the main factors which make it challenging to handle selection problems faced in the healthcare sector. In addition, many conflicting criteria, variables, and criteria exist in assessment processes that require robust and practical evaluation approaches providing decision support to the practitioners in the health industry. Therefore, the health industry is a promising and good field of application for scholars proposing new methodologies and dealing with decision-making approaches.

The current study was carried out in two different frames in this respect. First, the previous studies dealing with industry 4.0 and technological implementations in the health industry have been examined; secondly, the previous works focusing on selecting technology and technological devices using decision-making tools have been evaluated. For this purpose, Web of Science academic databases was reviewed using keywords such as healthcare industry 4.0, technology selection, MCDM, decision, and device selection. The collected previous works were classified into two main groups: healthcare industry 4.0 and decision-making applications in the health industry.

From this perspective, the researchers identified some research questions to evaluate the previous works existing in the literature with a systematic point of view. These research questions are presented as follows:

1. What are the new technological implementations emerging in the health industry in the era of Industry 4.0?
2. What Are the Prevalent Trends and Research Topics Concerning the Solution to the Decision-Making Problems Faced in the Healthcare Industry?
3. Which decision-making approaches are the decision-making frames commonly used to evaluate the advanced health technologies and applications in the health industry in recent years?
4. What Methodological Frames Are Implemented to Handle the industry's Selection of Technological Health Devices?

The authors took in and handled 177 papers in these research questions' framework by examining the scientific databases. These papers are relevant to the decision-making approaches used in the health industry. The authors determined several key themes from the existing literature. First, the authors carried out previous studies and noticed that decision-making problems are complex and affected by uncertainties. Hence, the papers presented lately have preferred to use the fuzzy approach more than those presented in the past. Secondly, decision-making problems are mainly encountered when practitioners evaluate digital and technological devices. It proves that technology usage has increased in the health industry. Hence, technology usage and the dynamic structure of the industry increase the suitability for digital transformation. These findings can help practitioners make more rational and logical decisions about digital transformation in the current field. In addition, there are some theoretical and managerial gaps in the literature. Significantly, the authors presenting the previous papers preferred to apply the classic version of the fuzzy sets (FSs), but these FSs may not be sufficient to produce practical and robust solutions due to their structural problems and drawbacks that cannot meet the requirements for handling the complex uncertainties (Garg 2016; Janková and Dostál 2021). In this context, the study concludes with recommendations about the research framework to help the researchers conduct future research on this issue.

10.2 The Research Framework

This study evaluates the previous literature research under two categories, Health 4.0 and decision-making in the health industry, with a systematic point of view. Within this scope, a methodological framework consists of two phases to identify the previous works relevant to both headings. The methodological frame is demonstrated in Fig. 10.1.

As is clearly understood from Fig. 10.1 that keywords for two review processes were identified; then, the scientific database was reviewed detailed and carefully. In the second phase, papers that will be examined within the scope of the study were selected, and these studies were classified in the aspect of their features (i.e., authors, years, journals, research topics) by examining them with a systematic framework. Finally, it has been aimed to present current trends concerning research frames in the health industry. Consequently, details for the previous works are presented below.

10.3 The Previous Works Related to Healthcare 4.0

As a result of a comprehensive and detailed literature review examining the scientific databases, 21 papers are available in the existing literature. While 14 papers were published in scientific journals, six were presented as conference proceedings, and one study was published as a book chapter. When these studies were evaluated, the first relevant paper was published in 2017. Hence, healthcare 4.0 is a new subject in the literature, requiring much research and studies to fill the existing gaps. Most

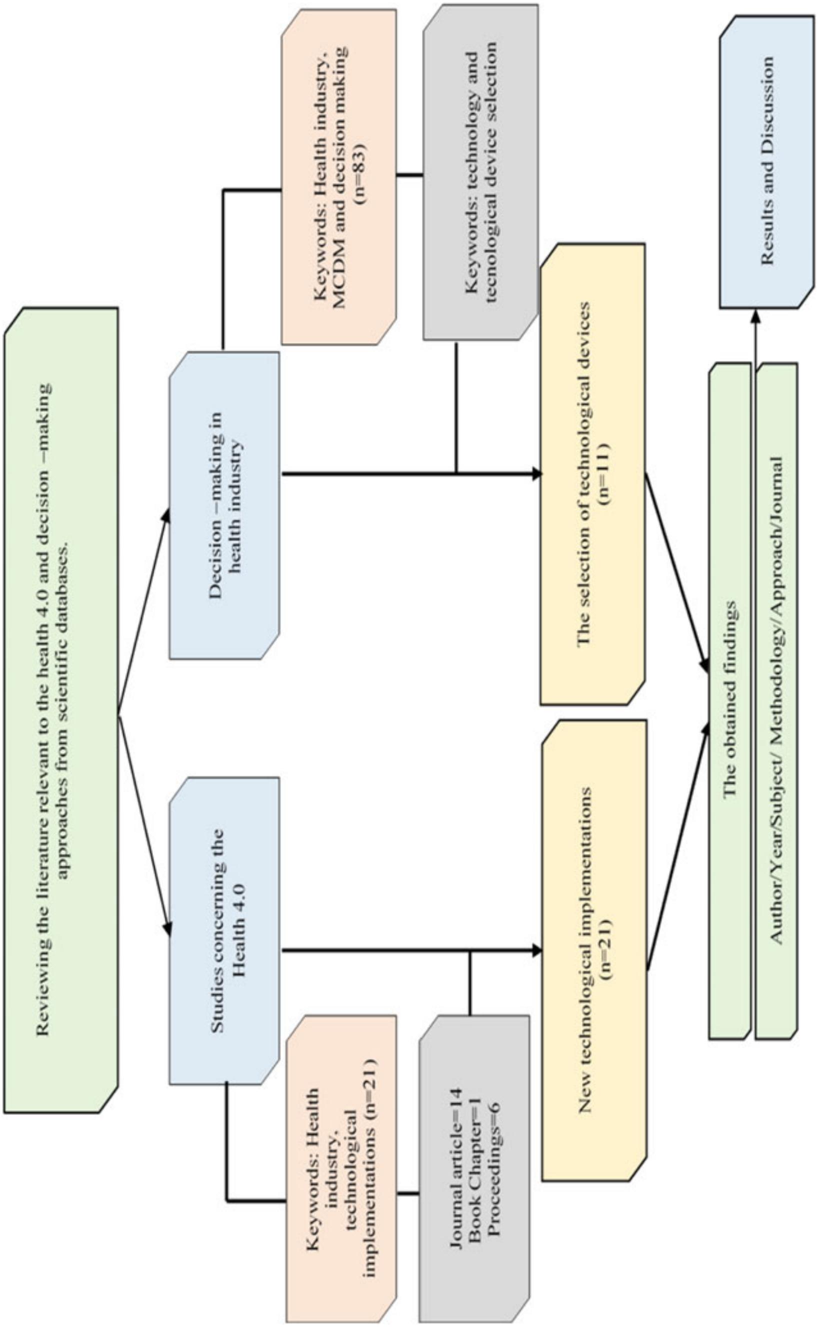

Fig. 10.1 Illustration of the research framework

studies deal with new technological implementations emerging with industry 4.0 in the health industry. Wan et al. (2019) proposed a production mode based on a newly planned intelligent manufacturing plant architecture for pharmaceutic production.

Manogaran et al. (2017) suggested a secure Industrial Internet of Things (IoT) architecture to store and process scalable sensor data (big data) for healthcare applications. According to the authors, collecting real-time data about individuals through these technological instruments can help reduce fatal results related to human health. Pace et al. (2019) proposed a novel architecture suited for human-centric applications in the emerging healthcare industry. Larrucea et al. (2020) examined the national health system by considering the advanced technologies emerging in the era of industry 4.0, and they proposed an extended version of the healthcare industry architecture reference model. Celesti et al. (2019) examined the implementation of advanced technologies such as Cloud Computing, Edge Computing, the Internet of Things, and Big Data Analytics Applications for the healthcare industry 4.0.

Roy et al. (2019) suggested a new scheme that provides combined fine-grained access control over cloud-based multi-server data and a provably secure mobile user authentication mechanism for Healthcare Industry 4.0. Kumari et al. (2018) proposed a three-layer patient-driven healthcare architecture for real-time data collection, processing, and transmission. Deshmukh et al. (2019) evaluated the mobile cloud mod's role in sharing and analyzing the detailed patient data record in the health sector, and they tried to show access control of cloud-based server information. Fu et al. (2019) emphasized the significance of intelligence devices in collecting data in the era of industry 4.0. Also, they introduced a photochemical dongle working with a smartphone. Dautov et al. (2019) suggested a hierarchical data fusion architecture by focusing on IoT networks based on the health industry.

Pimentel et al. (2021) compared interoperable healthcare information systems and proposed a minimum set of requirements for prospective interoperable healthcare information system architectures compliant with the industry 4.0 design principles.

Guo et al. (2021) indicated that an algorithm could provide an efficient framework to reach reliable and productive results concerning data based on encrypted medical imaging by proposing a closer neighbor algorithm. Barone et al. (2021) examined the requirements for an original combination of descriptive and inferential statistics to obtain more reliable information from diagnosis devices. Mars et al. (2019) evaluated how the Internet of Things (IoT) can be better used in the healthcare industry and analyzed the motivation of IoT technology usage in the current industry. Ren et al. (2021) proposed a high-efficiency heterogeneous medical data fusion framework (HMDFF) for multimodal and heterogeneous data in the medical field based on a data lake to solve the fragmentation of multimodal data storage and enable hybrid queries for further data analytics services.

Similarly, Mahmud et al. (2020) investigated the application management strategies in Fog computing and reviewed them in terms of architecture, placement, and maintenance. Bin Habib and Tasnim (2020) examined the implementation of machine learning in the healthcare industry and indicated that the application could help reduce chronic diseases. Benis et al. (2021) investigated the effectiveness of digital health applications and pointed out that it is required to increase digital health literacy among individuals to provide effectiveness in the healthcare industry. Calvaresi et al. (2021) presented a real-time multi-factor (RT-MAS) model for developing intelligent systems, a critical and essential subject in the health industry. Krishankumar et al. (2022) proposed a decision model based on the EDAS approach to evaluate providers of cloud systems for the health industry.

10.4 The Previous Works Related to Technological Device Selection in the Healthcare Industry

According to Mardani et al. (2019), the health industry has critical importance in improving human life quality, citing a paper presented by Omrani et al. (2018). Due to the sector's dynamic structure causing complicated uncertainties, they also concurred with some authors (Clemen and Reilly 2014; Reddy et al. 2014; Ren et al. 2017) that making the right and optimal decision is difficult in the industry. So indeed, practitioners in the health industry must make optimal decisions because mistakes made in decision-making are nonrecoverable, as they directly affect human life and health. Hence, decision-makers are under high pressure because they encounter precarious and irreversible situations in the decision-making process. Also, highly complicated uncertainties increase this pressure, making it more challenging to produce logical and reasonable solutions.

Although many papers deal with decision-making problems in the health industry, the latest studies have increasingly focused on decision-making problems in selecting technologies and technological devices used in the healthcare industry. When a comprehensive literature review is performed from well-known scientific databases using keywords such as health industry, MCDM, and decision-making, 83 papers in the literature have been observed. When some keywords, such as technology and technological devices, are added, the number of papers is reduced to 11.

Many previous works related to technology selection in the industry mostly preferred the classical and fuzzy versions of the AHP technique. Some authors examined technologies used for waste management by using this approach (Brent et al. 2007; Karamouz et al. 2007; Hsu et al. 2008; Karagiannidis et al. 2010). Most of these papers used the extension of the AHP technique based on the classical fuzzy sets.

The number of papers dealing with technologies used in the healthcare industry by using MCDM frames from 2014 to 2022 has observed that 83 papers are in the existing literature, and the number of papers has regularly increased year by year until 2020. In 2021, an amount reduction was recorded in the number of papers. The numbers of the papers published year by year are presented in Fig. 10.2.

There are two papers published in 2014. Liu et al. (2014) evaluated selecting the best treatment technology for healthcare waste using the MULTIMOORA method based on interval 2-tuple linguistic variables. Ahmadi et al. (2014) examined selecting the appropriate computerized medical information systems in the healthcare industry

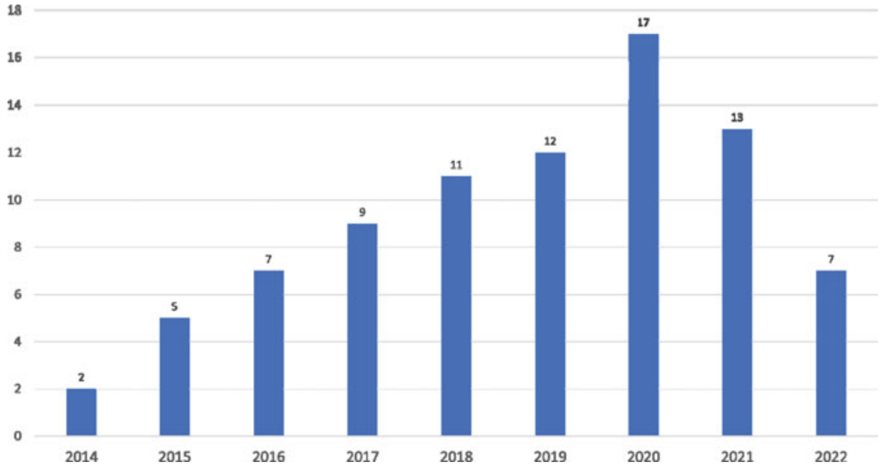

Fig. 10.2 The number of papers dealing with technological instruments selection with decision-making tools from 2014 to 2022

by applying the fuzzy TOPSIS and AHP combination. Next year, Jamshidi et al. (2015) developed an algorithm for evaluating risk priority for healthcare devices and equipment by considering static and dynamic risk factors with the help of Neural Networks (NNs). Janani and Kumar (2015) examined the barriers resisting the sustainable wireless sensor networks strategy in the healthcare industry by applying the AHP technique. Irwin and Peacock (2015) developed a decision support system, namely Health technology assessment (HTA), to help decision-makers responsible for allocating healthcare resources.

Öztürk et al. (2017) evaluated alternatives related to the health technology assessment by identifying nine criteria with the help of the AHP technique. (Liou et al. 2017) proposed applying the DEMATEL technique to improve the electronic health record, an innovative implementation. Lohan et al. (2017) examined location-based health services, namely e-health applications, using the AHP technique.

Next, Karatas et al. (2018) assessed the health-related technologies by applying the fuzzy DEMATEL approach, combining four widely used MCDM methods: fuzzy AHP, fuzzy TOPSIS, fuzzy VIKOR, and goal programming. While Xiao (2018) evaluated the healthcare waste treatment technology selection in uncertain environments using fuzzy decision-making approaches, Hinduja and Pandey (2018) assessed this decision-making problem with the help of an integrated approach consisting of fuzzy AHP, ANP, and the DEMATEL. Enaizan et al. (2018) examined electronic health record applications by applying a hybrid MCDM approach consisting of the TOPSIS and the AHP. Wu et al. (2018) evaluated the radio frequency identification (RFID) technology alternatives for the health industry with the help of the DEMATEL-based ANP (DANP) approach.

When the papers published lately are evaluated, it has been noticed that most of them dealt with selecting health devices such as MR, MRS, PA–MR, and fMR.

Using these devices has increasingly become more critical and vital in treatment processes. Accordingly, selecting the appropriate healthcare devices has become a significant and severe task for practitioners in the current industry, as these machines are expensive and require advanced information about operating these devices. In addition, existing uncertainties and complex situations in the healthcare industry increase the attention of scholars trying to develop novel decision-making approaches as a unified field of implementation.

Büyüközkan and Göçer (2019) proposed an intuitionistic fuzzy Choquet integral (IFCI) approach to evaluate the smart medical device selection process in a group decision-making environment. These authors tried a decision-making technique, namely interval-valued intuitionistic fuzzy (IVIF) with the VIKOR approach to assessing the selection of smart medical devices (SMDs) of wearable vital sign sensors under different evaluation criteria (Büyüközkan and Göçer 2018).

Kundu et al. (2021) suggested a group decision-making model based on fuzzy sets, and they tried to identify the most appropriate alternative by applying the proposed model based on the integration of the MARCOS and PSI techniques to the selection of the proper Magnetic resonance devices (MR) in private hospitals. Abdel-Basset et al. (2019) proposed a novel approach, an extended version of TOPSIS based on combining neutrosophic using bipolar numbers, to evaluate the intelligent medical devices (SMDs) alternatives.

Shbool et al. (2021) assessed medical devices for the healthcare industry using a hybrid model consisting of the AHP and ELECTRE methods. They tested the proposed model in a case study designed for selecting the Ultrasound machine in a gynaecology clinic based in the Kingdom of Jordan. Tadić et al. (2014) examined the medical device suppliers considering many criteria with the help of the fuzzy TOPSIS approach. Banerjee et al. (2020) introduced an extended, compartmented Bonferroni aggregating operator called an epsilon PMB operator (εPBM) and presented its implementation to the medical device selection.

Jalalabadi et al. (2021) examined breast implant preferences between US and European surgeons regarding size, shape, and surface texturing and indicated that differences between breast implant preferences could affect the selection of medical devices. Marešová et al. (2016) examined the correlation between wrong device selection and loss or profit by applying the Drummond and O'Brien methodology, which explicitly determines the content of direct and indirect costs in health services. Tolga et al. (2020) proposed a comprehensive TODIM approach based on the finite interval type-2 (FIT2) Gauss fuzzy numbers to evaluate the medical device selection.

Annapureddy et al. (2020) assessed selecting an implantable cardioverter-defibrillator (ICD) or cardiac resynchronization therapy-defibrillator (CRT-D). The authors conducted this study as an experimental study using real-life data collected from 4,435 physicians curing 145,900 patients in the last two years.

10.5 Results and Discussion

When both the previous papers dealing with medical device selection by using decision-making approaches and the papers focusing on healthcare 4.0 and advanced technological implementations are evaluated in general, it has been observed that the number of papers has increased in the literature year by year. It shows that these subjects' importance has continued to increase for practitioners in the field of health and scholars working on subjects such as the healthcare industry, industry 4.0, advanced technological implementations, and decision-making approaches. Significantly, studies dealing with technology usage in the healthcare industry have shown notable increases in the late years. The details of the previous studies are presented in Table 10.1.

Table 10.1 The previous studies and their details

Authors	Year	Subject	Methodology	Journal
Omrani et al.	2018	Hospital efficiency	Fuzzy clustering cooperative game DEA	Expert Systems with Applications
Clemen et al.	2014	Selection problems	Decision tools	Book chapter
Reddy et al.	2014	Prioritizing public health guidance topics	AHP	Public Health
Ren et al.	2017	The hierarchical medical system in China	Intuitionistic fuzzy MCDM	Information Sciences
Brent et al.	2007	Healthcare waste management systems	AHP	European Journal of Operational Research
Hsu et al.	2008	Selection of infectious medical waste disposal firms	AHP	Waste Management
Karagiannidis et al.	2010	Thermal processing of infectious hospital wastes	A multi-criteria assessment of scenarios	Waste Management
Karamouz et al.	2007	Hospital solid waste management	Qualitative analysis	Waste Management
Liu et al.	2014	Healthcare waste treatment technology	I2TL MULTIMOORA	Waste Management
Ahmadi et al.	2014	Electronic Medical Record Adoption	Fuzzy Multi-Criteria Approaches	Review of Contemporary Business Research
Jamshidi et al.	2015	Replacement of medical devices	A fuzzy risk-based framework	Proceedings
Janani et al.	2015	Sustainable wireless sensor network	Evaluation	Resources Policy

(continued)

Table 10.1 (continued)

Authors	Year	Subject	Methodology	Journal
Irwin et al.	2015	The value of orphan medicinal products	Multi-Criteria Decision Analysis	Regulatory Rapporteur
Öztürk et al.	2017	Health Technology Assessment	AHP	Value in Health
Liou et al.	2017	The electronic health record	A hybrid MCDM model	Sustainability
Lohan et al.	2017	Location-based services analysis	AHP	Multi-Technology Positioning
Karatas et al.	2018	Health technology assessment	Integrated MCDM	European Journal of Industrial Engineering
Xiao	2018	Healthcare waste treatment technologies	D Numbers	Engineering Applications of Artificial Intelligence
Hinduja et al.	2018	Healthcare waste treatment alternatives	Integrated decision support framework	Int. Journal of Computational Intelligence Systems
Enaizan et al.	2018	Article in Health and Technology	Evaluation	Book chapter
Wu et al.	2018	Adopting an RFID system in nursing care	DEMATEL-ANP	Proceedings
Büyüközkan and Göçer	2019	Smart medical device selection	Intuitionistic fuzzy Choquet integral	Soft Computing
Büyüközkan and Göçer	2018	Smart medical device selection	IVAIF VIKOR	Advances in Intelligent Systems and Computing
Kundu et al.	2021	Medical device selection in private hospitals	Integrated fuzzy MCGDM methods	Journal of the Operational Research Society
Shbool et al.	2021	medical device selection	Integrated MCDM approach	Cogent Engineering
Tadić et al.	2014	Ranking of medical device suppliers	Fuzzy TOPSIS	Journal of Intelligent and Fuzzy Systems
Marešová et al.	2016	Costs of inguinal hernia repair	Evaluation	Therapeutics and Clinical Risk Management
Tolga et al.	2020	Medical device selection	Fuzzy TODIM method with FIT2 Gaussian fuzzy number	Engineering Applications of Artificial Intelligence
Annapureddy et al.	2020	Device Selection in ICD Implantation	Evaluation	Journal of the American Medical Association

As seen in Table 10.1, this subject is new, and scholars have been interested in this issue lately. The first paper was published in 2017. Then, only one paper was presented in 2018. In the following years, the number of papers increased. Significantly, the number of papers reached the highest value, and seven papers were published this year. Therefore, the attention of scholars on this topic is promising, and the relevant literature has continued to grow each year. It is significant for practitioners because the accumulation of information about this issue can help healthcare decision-makers make more courageous decisions for digital transformation. Although the number of papers has increased, this increase is not at a satisfactory level for the industry. Hence, it is required to do much research and studies about the healthcare industry 4.0, decision-making, and technology utilization to fill the existing gaps.

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Chapter 11
New Dimensions in Health Medical Material Transportation

İsmail İyigün

Abstract The transportation of medical materials is a critical issue in terms of the development of the health sector and the quality of the services it provides. Today, the transportation of medical products to various regions of the world or end users within a country's borders is becoming increasingly important. In this context, it is seen that new solutions have been put forward in the transportation of medical products with the emerging needs and developing technology. In this context, both the logistics and medical product sectors and scientists are trying to develop new solutions in this field. This study aims to examine the new solutions introduced in the transportation of medical products. A literature study and academic studies in this field were examined in this context. As a result of the study, it has been observed that drones provide advantages with a short response time compared to other vehicles, especially in last kilometer deliveries. In addition, it has been observed that drones successfully deliver medical products to points where access is difficult.

Keywords Medical material · Transportation · Modes · Drone

11.1 Introduction

The transfer of health medical materials to different regions or end users in the health sector is becoming increasingly needed daily. Especially the pandemic processes experienced in recent years have revealed the importance of this need. In this context, it has been observed that the transportation sector has started to look for new solutions in the transportation of health medical materials. On the other hand, it is seen that technological developments offer opportunities for new solutions in the transportation of health medical materials. In the context of these developments, it is observed that both medical product companies and the logistics sector and scientists are working on new approaches. In this context, new approaches to transportation of

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health medical materials were investigated in this study. Studies investigating new solutions for the transportation of health medical materials have been scanned, and new prominent approaches have been put forward.

11.2 Supply Chain Management in Health Care

Supply chain management effectively manages supply chain activities and relations to increase customer value and achieve sustainable competitive advantage (Bozarth and Handfield 2008). Supply chain management integrates supply chain partners and coordinates material, money, and information flow to meet customer demands in desired conditions (Stadtler and Kilger 2005). In this context, logistics activities include planning, designing, implementing, and managing material flows (Pan and Pokharel 2007).

The primary purpose of health sector organizations is to provide high-quality service to patients. Factors such as the supply cost of the needed products and the intense competition in the health sector lead health institutions to develop new methods to provide services at low costs without compromising patient care standards (Callender 2007). However, healthcare organizations face challenges such as complex business processes, efficient use of resources, and increasing service quality. Because of all these situations, applying supply chain management principles, which enable institutions to be managed with a holistic perspective in the health sector, is considered an important issue (Vries et al. 1999).

Businesses operating in production sectors continuously make an effort to increase their income and reduce their costs. Manufacturing and retail businesses have made significant progress in supply chain management, thanks to the new technologies and automation systems they use for product quality, business processes, and supply chain management applications. Manufacturing and retail industries see supply chains as a competitive advantage. In these sectors, supply chain management is handled at the strategic level. The improvement of supply chain management performance has increased profit margin and competitive advantage in these sectors (Smith 2002). However, the healthcare industry has not been able to keep up with the progress other industries have shown in supply chain management (Callender 2007). Health sector experts state that the health sector supply chain management practices are a decade behind compared to other sectors. Allocating the necessary resources to improve supply chain management processes in the healthcare industry has not been one of the industry's priorities until recently. Among the reasons why the health sector cannot implement supply chain management practices at the desired level is the concern that cost reduction efforts will reduce service quality and human life (Jarrett 1998).

Another factor that hinders the effective management of the health sector supply chain is its enormous and complex structure. In addition, it is thought that in the health sector, unlike the production sector, customer demand cannot be predicted, so the order calendar cannot be followed (Jarrett 1998). In this context, one of the most critical factors that cause complexity in the health sector supply chain is the high number of suppliers and product diversity. For this reason, it is thought that reducing the number of suppliers will provide significant benefits due to the price decreases due to the increase in the purchase amount (Smith 2002).

Other issues that hinder healthcare supply chain management are (Burns 2002):

i. Shortening of product life cycles due to constantly developing technology,
ii. Expensive products preferred by doctors,
iii. Difficulties in estimating disease types, frequencies, and duration of treatment,
iv. Difficulties in estimating the products needed for treatment,
v. The products do not have standard codes,
vi. Lack of capital required to build the IT infrastructure to support supply chain management activities,
vii. Health employees do not have enough supply chain management training and knowledge,
viii. Inadequate top management support.

It is believed that if these obstacles are overcome, it will be possible to reduce costs and improve health services through supply chain operations. In this context, due to the increasing pressure to reduce healthcare costs, reduce waste, prevent medical errors, improve service quality, and increase operational efficiency, more importance has been given to supply chain management in the healthcare industry in recent years (Byrnes 2004).

It is observed that a wide variety of products are transferred within the scope of the supply chain in the health sector. These include medicines, medical health products, patient transfer, service transfer, and other products. Transportable health services and products are given in Table 11.1 (John 2022).

Table 11.1 Health medical products and services which can be transported

Domain	Health medical products
Medical Products	Pharmaceuticals Over-the-Counter Products Cosmetics
Patient Transport	Emergency Non-emergency Mental Health Transport Intensive Care Patient Transport
Non-medical Transport	Mailroom Services Event Covers Medical Repatriation Services Courier Services
Other	Incubator Transport Mobile Treatment Facilities

Source John (2022)

11.3 New Dimensions in Health Medical Material Transportation

11.3.1 Aero Medical Transportation

Transport of medical health materials includes transferring medical products such as blood products, blood samples, vaccines, medical equipment, test kits, and medical aid. These products are generally transported by land. However, nowadays it is also transported by air transport. For this purpose, aeroplanes and helicopters are used (Yanagawa et al. 2018). The speed factor usually comes to the fore when transporting health medical materials. As commonly known, the fastest mode of transport is air transport (Viitanen 2018).

For this reason, Aeromedical transportation comes to the fore in transporting health products. This concept can be defined as transporting patients, organs, tissues, blood, medical supplies, or personnel by plane or helicopter. This method is used when there is no need to waste time or land transportation methods are not applicable. It can be used as the primary mode for transporting some medical products that need to be transported in a short time, especially blood and organ transfer (Government of India 2016).

Air transport of health products starts with the transfer of the shippers from the storage area to the airport. Then, the products are transferred to the airport of the destination region by air. Deliveries can be made to the buyer's storage area (consignee) in the target region or end users in different modes (Transco Cargo 2016). One important issue here is keeping the products in the right ambient conditions (temperature, humidity, etc.) during this transfer process. On the other hand, it should be ensured that the products are not damaged during the transfer process. One of the most critical issues is that the transfer is carried out quickly (Viitanen 2018). An example of the distribution process in question is shown in Fig. 11.1 (Transco Cargo 2016).

Here, it is essential to transport health medical materials in suitable conditions and quickly. Especially for some products, it is imperative to provide a cold chain system. For example, the transportation of vaccines during the COVID-19 pandemic is an example. Efficient, safe, and timely delivery of vaccines from the point of origin to the point of consumption requires a challenging effort. Because the availability of vaccines for infected patients is a matter of life and death, cold chain air transportation has become essential in this context. For example, vaccines may have storage and transportation requirements at temperatures ranging from −8 °C to +2 °C or + 8 °C (IATA 2021). In this context, air cargo industries have fulfilled a crucial task in realizing the rapid and safe transportation of COVID-19 vaccines (Dai et al. 2021). It has been understood that air transport provides advantages in the rapid delivery of vaccines without losing their qualities. The role of the airline industry in the urgent delivery of vaccines to different geographies during the COVID-19 pandemic process is significant and has significantly contributed to the timely delivery of vaccines to many COVID-19 patients (Demir et al. 2021).

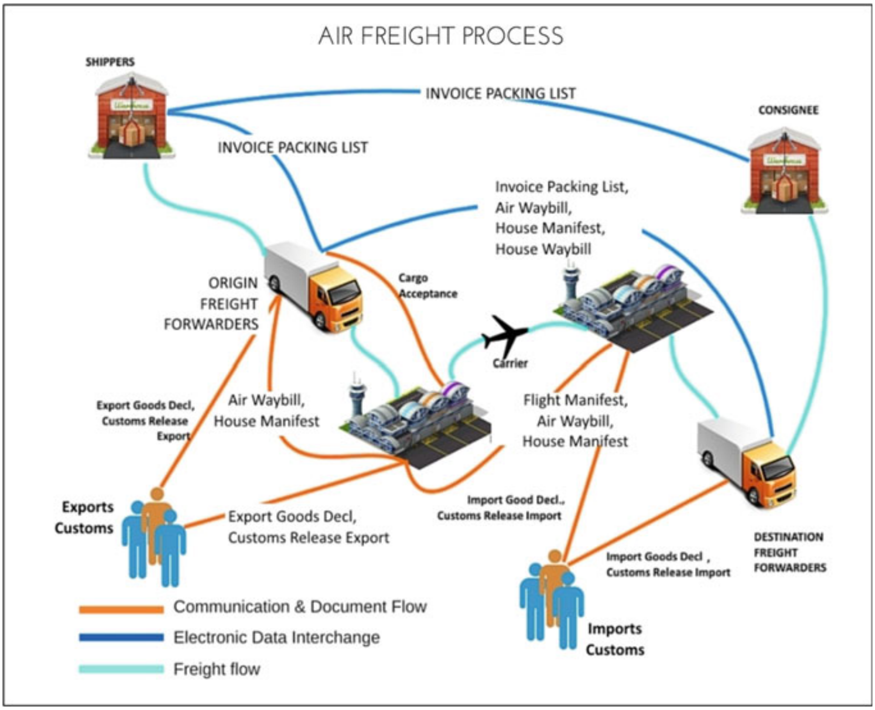

Fig. 11.1 Sample of air freight Cargo process of medical products (*Source* Transco Cargo 2016)

11.3.2 Drones and UAVs

In addition to planes and helicopters, depending on the developing technology, it is seen that drones and uncrewed aerial vehicles are also used to transport Health medical materials (Laksham 2019). Using these tools contributes to overcoming complex geographies, reducing carbon emissions, and ensuring cost-effectiveness (Balasingam 2017; Goodchild and Toy 2018). In this context, it is observed that drones, unmanned aerial vehicles, and helicopters are frequently used to transfer medical products. For example, in Italy, during the COVID-19 outbreak, it has been stated that using UAVs for the transfer of personal protective equipment (PPE) and automatic external defibrillators (AEDs) reduces the risks of infection (van Veelen et al. 2020). On the other hand, using drones in natural disasters or accidents where there are obstacles in road traffic provides an advantage in terms of the continuity of the transfer (Yakushiji et al. 2020).

As seen in Table 11.2, air transport of health products by drones and UAVs is becoming increasingly common (Scott and Scott 2017; Zaliani 2020; Xavier et al. 2021; Salas de Armas et al. 2021; Yakushiji et al. 2020).

Scott and Scott (2017) published a study on the transportation of health products by crewless aerial vehicles. In this study, automatic external defibrillators, drug

Table 11.2 Vehicles used in health medical product transportation

Vehicle	Place	Purpose
Drones	Canada, Caribbean, Haiti, USA, Nepal,	Delivering medical supplies after the disasters
	Netherlands	Delivering the Automated External Defibrillator (AED) to heart-attack victims
	Tanzania	Delivery of medicines to an island (60 km from the mainland) in Lake Victoria
	Malawi	Delivering the HIV testing kits
	Japan	Transportation of blood transfusion products by multicopters
	South Africa	He was addressing the pre-analytical phase of the laboratory logistic loop in remote areas
	Rwanda, Ghana	Delivering blood, vaccines, and vital COVID-19 tests and samples
UAVs	Rwanda, Haiti, The Dominican Republic, Papua New Guinea, Switzerland, Germany	Blood product transportation
	Italy	Delivery of automatic external defibrillators (AEDs) and personal protective equipment (PPE)
Helicopters	Haiti	Delivering hygiene products and medical Resources after a disaster
	USA	Transportation of extracorporeal membrane oxygenation (ECMO) for COVID-19 treatment

Source Scott and Scott (2017), Zaliani (2020), Xavier et al. (2021), Salas de Armas et al. (2021), Yakushiji et al. (2020), and Poljak and Šterbenc (2020)

transportation, and transportation of medical products such as blood samples and vaccines by crewless aerial vehicles are discussed. The study explains the health products carried by the drones produced by Matternet, DHL Parcel, Zipline, Flirtey, and Delft University. The payload weights of medical products are between 2 and 4 kg. In addition, two distribution models were developed by the researchers, and as a result of the analysis, it was determined that the models contributed to the cost-effective and timely distribution. The characteristics of the crewless aerial vehicles and drones used in this context are given in Table 11.3.

Table 11.3 Characteristics of some drones used in Health medical transportation

Drone company	Delivery method	Launching pad	Healthcare items	Range	Payload	Speed
DHL Parcel	Automated Skyport	Automated Skyport	Blood, medications	12 km (7.5 miles)	4.4 lb	>40 mph
Delft University	Ground landing	Hospital, clinic	Defibrillators	12 km (7.5 miles)	4 kg (8.8 lb)	60 mph
Matternet	Automated ground station	Automated ground station	Blood, medications	10 km (6.25 miles)	2 kg (4.4 lb)	40 kmph 25 mph
Flirtey	Dropped by rope	Airport	Medications	20 miles	2 kg (4.4 lb)	–
Zipline	Paper parachute	Nest	Vaccines, blood	45 miles	3 lb	90 mph

Source Adapted from Scott and Scott (2017)

11.3.3 Oversea Transportation

Medicines and medical materials developed in the treatment of many diseases all over the world need to be delivered to all parts of the world. The medical transportation system ensures that all these drugs are transported under the required conditions. This way, it is possible to transport drugs, which are very important for human health, from one place to another. The sea route is preferred in this type of transportation because more products can be delivered to the required places in a single shipment. Because the transport ships are pretty comprehensive, the number of products that other transport modes cannot transport can be transported by one ship. In addition, these features of the ships are accepted as a way of transporting drugs without causing casualties.

Moreover, transportation costs are much lower than air and land transportation. With the protection systems used in maritime transport, serums, cancer drugs, and injection drugs, which are very easy to spoil, are transported. Medical maritime transport is not a system used only for drugs; thanks to this transportation method, all kinds of products, devices, and machines used in the medical sense can be easily transported (Umt Express 2022).

Maritime transport can be used extensively to transfer non-emergency medical supplies due to its cost-effectiveness and environmental friendliness. For example, Sanofi company carries out 85% of its medical products by sea transportation. In addition, it is stated by the company in question that boats are used in river and open sea transportation (Sanofi 2021). However, seaway is not a preferred mode for transferring health materials that must be transported urgently.

11.3.4 Rail Transportation

Rail transport, like maritime transport, makes it possible to transport more cargo cost-effectively but over a long time. For example, during the COVID-19 pandemic, medical products were transferred from Croissy DC, France, to Hangzhou, China (Sanofi 2021). Like in the seaway, the railway is not a preferred mode for transferring health materials that must be transported in emergent situations.

11.4 Literature Survey

In this part of the study, studies involving prominent new approaches in the transportation of medical products were examined. In this context, studies on the use of modern vehicles and transportation modes in the transportation of medical products in the literature are discussed (Table 11.4).

As a result of the examinations, it has been observed that uncrewed aerial vehicles offer new solutions in the distribution of medical products, especially in last kilometer deliveries, in disaster areas, and in situations where access is difficult. In summary, the new dimensions of helicopters, drones, and crewless aerial vehicles are stated below.

i. Providing flexibility and speed in the last kilometer delivery,
ii. Reducing contact in order to prevent the spread of infectious diseases,
iii. Reaching hard-to-reach disaster areas,
iv. Providing advantages in terms of cost and time.

11.5 Conclusion

The transport of medical products has required increasingly complex and special solutions in recent years. In this context, it has been observed that researchers, pharmaceutical and logistics companies are trying to reveal new approaches in the transportation of these products. It is seen that specific criteria such as storage and transportation conditions of medical products, time constraints, and difficulty of access make new solutions necessary. Although it is seen that large amounts of transfers are made by traditional land, sea, and rail transport, it is seen that new approaches are carried out, especially by air. In particular, it has been understood that technological developments have shown their effectiveness in every field, as well as new solutions in the transportation of medical products. In this context, it has been seen that crewless aerial vehicles offer new solutions.

Air transport is prominent in the rapid transport of medical products, especially in processes such as pandemics and epidemics. It has been understood that air transport provides advantages, especially in the rapid delivery of products without losing their

Table 11.4 Literature survey over new dimensions in Health medical product transportation

Authors	Year	Abstract
Scott and Scott	2017	The authors published a study on drones' transport of medical health products. This study discusses the transportation of medical products by unmanned aerial vehicles. The study explains the health products carried by the drones produced by Matternet, DHL Parcel, Zipline, Flirtey, and Delft University. The load weights of medical products are between 2 and 4 kg. In addition, two distribution models were developed by the researchers, and as a result of the analysis, it was determined that the models contributed to the cost-effective and timely distribution
Fakhrulddin et al.	2019	Researchers have developed a model for transporting first aid kits by crewless aerial vehicles. It has been determined that the model, which provides the transfer of necessary first aid kits employing drones by determining the points where first aid is required, provides significant time savings compared to the ambulance
Zaliani et al.	2020	The authors conducted a meta-analysis to examine the scientific evidence of the positive impact of drone transportation on maternal health. They searched ScienceDirect, PubMed, and EMBASE databases with the search terms related to UAVs and drones. They investigated 236 publications. They found that in only two studies, drones were used for delivering blood products and in one study drones are used for transporting blood samples
Ning et al.	2021	The authors proposed a two-stage combined transportation method based on clustering via helicopters for medical supplies. They proposed an algorithm and simulated it to optimize transportation by helicopter. Their results showed that the algorithm achieved the optimization goal and effectively decreased the number of vehicles
Salas de Armas et al.	2021	The authors investigated the transportation of extracorporeal membrane oxygenation (ECMO) via helicopters during the Coronavirus Disease 2019 (COVID-19) pandemic. According to research14, patients have been placed on ECMO support at an outside facility. ECMO support was successfully transported via helicopter
Zaliani et al.	2021	Researchers comparatively analyzed the distribution of blood products by ambulance and drone. Transport time with a drone was shorter than with an ambulance, but the cost was higher compared to an ambulance. For this reason, it was stated that the speed provided by drone distribution is essential
Apotele and Ayamga	2021	Researchers analyzed academic studies on the transport of medical products by drones. As a result of 17 studies examined in this context, it was determined that drones transported most drugs, vaccines, blood products, and laboratory test samples. Drones have been determined to shorten response times and provide environmentally friendly service
Johnson et al.	2021	Researchers have examined the integration of drone delivery into the emergency medical system. Researchers have argued that drones are especially applicable in emergency medicine in terms of cost-effectiveness, speed, and convenience compared to ground transportation

(continued)

Table 11.4 (continued)

Authors	Year	Abstract
Banik et al.	2022	Researchers conducted a simulation study for the distribution of medical products during the COVID-19 pandemic. In this context, scenarios for distribution in urban and rural areas have been developed to determine the optimal number of drones. As a result of the study, it was observed that the payload capacity and the flexibility to carry packages provide a significant advantage in urban regions. In rural areas, it has been determined that the time to stay in the air is decisive

qualities. The role played by the airline industry in the urgent delivery of vaccines to different geographies during the COVID-19 pandemic process is significant and has made significant contributions to the timely delivery of vaccines to many COVID-19 patients.

It is foreseen that the distribution of medical products by crewless aerial vehicles will be a viable mode of transportation. It can be stated that these vehicles can be used effectively, especially in transportation to end users. In this context, it is seen that these small and practical vehicles provided significant advantages in last kilometer deliveries. It is considered that these vehicles will provide an advantage in speed and efficiency, especially in disasters and in reaching places that are difficult to reach. Therefore, it seems that UAVs will be a suitable model for transferring medicinal products at critical times.

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Chapter 12
Health Tourism Components and Intermediary Institutions as Supplier Businesses in the Context of Health 4.0

Gülüm Burcu Dalkıran

Abstract The desire to be healthy, which is among the reasons that lead people to tourism, has turned into a large sector in which many people and institutions operate. In this sector called health tourism, intermediary organizations that can act on behalf of service recipients by directing them and providing service logistics play an important role. The destinations that can be determined in the alternatives offered by intermediary organizations while conducting research on behalf of the patient can be in the form of getting a better quality health service at a cheaper price, as well as depending on the technology in health services. The concept of Health 4.0, which is the use of next-generation technologies in healthcare services, is used in a wide range of areas from artificial intelligence to big data analytics; from Internet of Things technology to augmented reality. In countries that adapt to technological innovations, health infrastructure attracts a large number of tourists to the destination and creates a great source of income. Unlike other types of travel, health travel between countries may involve some special conditions. Although these conditions vary according to the components in the health tourism market, they can be effective in all decision processes since human health is in question. Intermediary organizations, which can operate in every market of health tourism, provide sectoral logistics as the first gateway to patients, especially in medical tourism.

Keywords Health 4.0 · Technology 4.0 · Health tourism · Medical tourism · Service providers in health tourism · Intermediary institutions in health tourism · Supplier businesses in health tourism

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12.1 Introduction

In the health sector, technology structure is an important factor that can affect the quality of the service provided. The level of technology utilization is an important factor not only in the diagnosis and treatment stages of a disease, but also in activities that provide support services to maintain a healthy state.

The concept of Health 4.0 has emerged with the use of Technology 4.0 tools in the health sector, symbolizing the point where today's technologies have reached. The use of new technologies in the industry is expressed by the term Industry 4.0. Private or state investments in technology in the health sector increase the capacity to serve both citizens of the country and foreign tourists. Traveling for individual health services has created a health tourism sector with a very large market value and institutional structures in the sector have gained importance.

Today, differences between health systems and service costs drive health tourism travel. One of the differences in the system is the healthcare technology in the country and the presence of healthcare personnel who can use this technology well. This important difference initiates the process of patients coming to that country even from very distant countries.

Compared to other types of tourism, the elasticity of demand in health tourism is low. This can be explained by the low rate at which prices in the health sector affect the amount of demand. Examples of such reasons include the absence or scarcity of treatment alternatives for certain diseases, the ability to travel to certain countries due to the limitations of the disease, or the need for treatment with the support of technology. In addition, while touristic travel can be considered as luxury consumption, health expenditures are more of a necessity.

Health tourism, which includes the travels of people to receive health services, integrates the tourism and health sectors, which are two sectors with very different characteristics. Intermediary Institutions, as businesses that provide this integration and provide consultancy services by planning the travel and treatment processes of patients between countries, are also the structures that provide sectoral logistics. The activities of the intermediary institutions, which complete the preliminary preparation process with the communication of the party that will receive and provide health services, planning the treatment process, and obtaining the first expert opinions, continue until the health service recipient (patient) returns to the country where he/she lives (comes from). This may even include providing post-treatment services and managing the follow-up process.

In this section, the health tourism market as a sector affected by health technologies is discussed in general terms in terms of medical tourism and the activities of health tourism intermediary organizations are explained. In the study, the major changes in technology with the terms Technology 4.0 or Industry 4.0 are briefly discussed and their use in the health sector is emphasized. The activities of health tourism intermediary organizations as service providers in the health tourism market are also examined.

12.2 Use of Technology in Health Services: Reflections of Industrial Revolutions on the Health Sector

Since the First Industrial Revolution, which started with the use of steam power in production in the 1950s in England, changes in technology have led to radical changes. In this process, the acquisition of mechanical power, the shift of manufacturing from human labor to machinery and from home production to factory production, and changes in transportation and communication channels are the main technical developments that emerged with the Industrial Revolution (Outman and Outman 2003): The Second Industrial Revolution was the period when electrical energy started to be used in mass production and instruments such as the light bulb, telegraph, and radio were invented. In this period, the use of electrical energy developed the transportation sector, and the emergence of means of communication also contributed to this result. All these developments enabled people to travel more easily for various reasons and increased the number of world tourists (Topsakal et al. 2018). The Third Industrial Revolution can be considered as a period in which internet technology emerged and many subsequent revolutions were based on this revolution. In this period, changes in the transportation and communication sectors affected touristic activities as they affected every activity. The increase in travel has become one of the factors driving international relations and cooperation. In each period of technological developments, developed countries have been at the forefront and have directly or indirectly influenced other countries over time (Janicke and Jacob 2009).

With the transfer of the technology called Industry 4.0 to production, not only the fields based on numerical foundations such as industrial production or engineering services, but also the sectors within the field of social sciences have been significantly affected. Industry 4.0, which is called the fourth-generation technology, in the most general definition: "The period in which all kinds of living and non-living beings, human and machine, are in communication and interaction with the internet and other technologies, and high technologies realize smart and mass production" (Aksoy 2017; Mil and Dirican 2018). Industry 4.0, an industrial concept that provides personalization and virtualization in different fields, is based on advances and developments in areas such as smart robots, the Internet of Things, augmented reality, cyber security, cloud computing, horizontal/vertical software integration, and big data (Gökbulut et al. 2016).

Industry 4.0 (Ramanathan 2014), which refers to the transition from centralized production control systems to rational and flexible structures by combining the real and virtual worlds without disabling human beings, increases quality in engineering, planning, operations, production and logistics activities; It reveals businesses that optimize cost and resource consumption (Acatech 2013). The term Industry 4.0 was first used at the Hannover fair in 2011 (Rojko 2017) and emerged with the introduction of new generation technologies such as robotics, analytics, artificial intelligence and cognitive technologies, nanotechnology, quantum computing, wearable technologies, and the internet of things into the lives of people and businesses (Cotteler and Sniderman 2017). The use of fourth-generation technology tools in many public and private spheres has not only changed production and consumption patterns but also affected international trade and mobility. This mobility manifests itself in a wide range of areas, from the transfer of capital to different areas depending on the use of technology to touristic travel.

Although at an early stage, Industry 4.0 tools were thought to focus only on "smart factories" or "smart manufacturing" (Diez-Olivan et al. 2019), over time, with maturing applications and the development of information communication technologies, it has become a global phenomenon affecting all industrial processes (Rodič 2017). The health sector is among the sectors affected by this process.

Health 4.0, also called digital transformation in health, is the use of all applications under the umbrella of Industry 4.0 in health services. It involves the use of new technologies at many different stages, from the production of medical devices to the storage of patient data in a way that increases efficiency in the service process, to the drug tracking system.

The level of technology utilization in healthcare services may vary according to countries' development levels, health policies, and entrepreneurial activities. The primary purpose of investments in this field may not always be to serve the citizens of the country. Countries and regions that are suitable for the arrival of foreign patients can be given as examples. Economic factors such as exchange rate differences or labor costs are an attraction factor for foreign capital. In addition, a system that encourages foreign capital in the health sector also increases investments in this field.

The use of digital technologies such as artificial intelligence, Internet of Things (IoT), big data analytics, and machine-to-machine communication in the field of health care is changing the stages in the service process. With the tracking system provided by portable and wearable technologies in personal use, data flow can be provided at all stages from diagnosis to treatment. The digitalization of patient registration systems, the transformation of patient data into information that can be used in treatment, the use of robots in surgery, and the ability of artificial intelligence applications to shorten the diagnosis time can also increase the demand for health tourism.

The use of new technologies in healthcare services can be used as an attraction factor in destination promotion and pricing strategies can change accordingly. The main examples of Health 4.0 applications that can also affect health tourism can be listed as follows:

- ***Major Data Analytics***: The healthcare sector generates big data in different formats such as text and images every year. Compared to other sectors, data generated in the healthcare industry is at the forefront with a growth rate of 36%. This rapid data generation is due to the increase in the resolution of Magnetic Resonance Imaging (MRI) and other techniques used in imaging in recent years (Reinsel et al. 2018). In the sector, big data analysis is needed when transforming information obtained from personal data into meaningful information. Analysts who will make sense of these data and patterns and make inferences that will benefit both individual and social health will be able to guide today's and future health policies.

- ***Dimensional Printers***: Another technology that can be used in orthopedics, plastic/reconstructive and aesthetic surgery, and even dermatology branches is 3D printers. Countries that use this technology well can also stand out in health tourism. Orthopedic implants, the use of new tissue-producing prints in skin transplantation, living miniature organs (organoids) that can be used in drug tests (Önder et al. 2019) may become important revolutions of health technologies in the future.
- ***Artificial Intelligence***: Artificial Intelligence refers to robots that make decisions like humans by transferring human-specific abilities such as thinking, decision-making, and interpretation to computer programs or systems on the basis of functions specific to the human brain (Elmas 2018). Artificial intelligence applications, which are widely used in health services, can be used both in macro data in public health and in micro treatments in individual treatments in many countries. In Turkey, the Ministry of Health Centralized Physician Appointment System (MHRS) usage rates, Family Medicine performance reports, E-Nabız reports, and reports such as hospitalization, diagnosis, and operation reports constitute the data infrastructure for artificial intelligence applications (Akalın 2020). By revealing the algorithms in the data sets used with artificial intelligence applications in health services, it can be easier to achieve goals such as early diagnosis, correct treatment, or prevention of diseases. In addition, artificial intelligence-supported operations (robotic surgery), post-operative clinical decision support and home care services also use artificial intelligence-supported applications (Akalın and Veranyurt 2021).
- ***Virtual Reality (VR) and Augmented Reality (AR)***: Virtual reality, which is defined as a virtual environment consisting of different sensory stimuli by combining computer software and hardware (Zhang 2012), is used for different purposes in health and medicine, which quickly adapt to technological innovations. Virtual reality in health services is defined as applications with three-dimensional feedback that allow interactive and entertaining applications in the treatment process (Aran et al. 2011). Virtual Reality has also taken its place as a tool that increases efficiency in the field of health education. Virtual Reality can be used in the training of all health personnel in different fields and in patient/disease trainings. Virtual Reality applications, which have a high investment rate in the gaming and entertainment sector, are also prominent in cross-country healthcare activities. Virtual Reality applications can serve health tourism, especially in ensuring the coordination and service homogeneity of foreign chain hospitals in each country. Examples such as preoperative practice with surgical simulations or increasing training or treatment efficiency in different target groups with physical therapy simulations are important examples of Virtual Reality applications in health care. In addition, in the literature, Virtual Reality applications can be used in the treatment of phobias, anxiety disorder, and mental disorders, and in

the treatment of diseases of our age such as obesity and eating disorders (Demirci 2018). In addition, Virtual Reality technology, which can be part of the palliative treatment of bedridden patients with glasses, can also be included in the planning of psychological support for the patient's relatives.

- Augmented Reality technology is a technology that allows objects to be viewed in real time in a virtual environment. While the main medium in Virtual Reality is the digital environment, in Augmented Reality, there is a virtual-real mix. Investments in these technologies, which are widely used in the health sector, are increasing day by day. Examples of the applications of these two technologies in the healthcare sector can be given from different fields. A neurosurgeon's preparation process for a very critical surgery by performing virtual surgery many times using virtual reality in a digital environment can increase the success of the operation. An example of augmented reality is when the same surgeon utilizes virtual media by taking digital records over patient measurements while determining where to make an incision during brain surgery. Such applications can increase success, especially in large operations with high mortality rates, and promote the country's health system all over the world.
- ***The Internet of Things (IoT)***: Smart hospitals that enable patients to undergo treatment processes with mobile software and Internet of Things technology to ensure minimum human contact, especially under pandemic conditions, are among the features that can increase the demand for health travel. The basis of IoT applications in health care is the collection and processing of data without any restrictions and remote communication through smart devices (Bhatt and Bhatt 2017). It is used to achieve positive results such as establishing self-regulation in the field of personal health services, saving time and cost of health institutions, and increasing the success rate in public health policies. Global investments in this field are increasing day by day. As a result of research, it is estimated that more than 40% of the market share of IoT applications will consist of healthcare services by 2025 (Al-Fuqaha et al. 2015; Manyika et al. 2013).

IoT Technology owes much of its development to the technology in sensing devices. There is a need for large storage areas that can store the data (Big Data) produced by a large number of small sensor devices using wireless technology, and software that converts the stored data into important information that can be interpreted (Big Data Analytics). Websites that will reach this software with interfaces that will provide convenience to the user play an important role (Ercan and Kutay 2016). With IoT technology, patient data can be measured and presented to healthcare professionals in many diseases with wireless communication devices attached to the body. It is also possible for the recorded data to be monitored by individuals themselves, whose health literacy has increased. This way of tracking health data, especially for older individuals or chronic patients, can also be used in health tourism activities. IoT technology is needed to evaluate the patient before coming to the treatment and to follow up in the country after treatment.

12.3 The Concept and Scope of Health Tourism

Travel for health tourism dates back to ancient civilizations. It is known that many civilizations built structures to benefit from healing waters. The Temples of Asclepius built by the ancient Greeks in honor of Asclepius, the god of medicine, became the world's first health center and people from many countries went to these temples to heal their diseases. Similarly, India practiced alternative medicine methods even 5,000 years ago and attracted many patients to the country (Gülen and Demirci 2011).

With the process of globalization, economic and commercial borders have started to disappear, and with the developments in information and communication technologies, it has become possible for people to expand their mobility borders. Today, the number of people traveling outside their permanent residence for various reasons is increasing. Factors such as the increase in disposable incomes, practices that facilitate travel between countries, people's rapid access to information about travel, and the development of the transportation sector have been effective in achieving this result. As a multidimensional concept, tourism can be defined as people leaving the places where they live permanently and living there for a certain period of time and bringing about social, economic, and cultural changes (Aytuğ 1990). Countries or regions provide a continuous flow of income, generate foreign exchange income, and create employment by hosting tourists with all the values they have.

In addition to the main purpose of the trip, tourism types are named according to the main activity planned with the trip or the characteristics of the destination. The predominant type of tourism worldwide is the so-called mass tourism, which is mostly based on recreation and entertainment, focused on sea–sun–sand. These activities, which are concentrated in certain seasons, result in a decrease in the number of tourists and tourism income in other months of the year. For this reason, investments in tourism types that can be carried out in all four seasons of the year, that can generate demand without being concentrated in certain periods, and that can generate more income are increasing. Some of these investments are health sector investments that will meet both national and international demand and serve the health tourism market.

According to the definition of the World Health Organization (WHO, 1986), health is not only the absence of disease and disability, but also the "state of complete physical, mental and social well-being" (1986; Aydın and Aydın 2015). People's domestic and international travels to find this "state of complete well-being" are generally referred to as health tourism. However, health tourism, which is an umbrella concept, includes many different activities from thermal waters to herbal treatments, from surgical operations to massage therapies and even spiritual activities. In the most general definition, health tourism is when people travel to places other than their permanent residence for health-related purposes (Ross 2011). In terms of demand, although general tourist behavior emerges with effects such as staying in the destination for a certain period of time and spending behavior, it requires a slightly different supply structure than other types of tourism. These are more specific indicators such as the existence and staffing of basic and supporting institutions providing health services, technological infrastructure in treatment, and success rates in health services. The subcomponents of health tourism in the broadest classification generally accepted in the literature are medical tourism, thermal tourism, SPA-wellness tourism, and advanced age-disability tourism. These can be expressed as follows:

12.3.1 Medical Tourism

Medical tourism, which comes to mind first when it comes to health tourism and has the largest market share, can be defined as the medical treatment of a health-related problem outside the country of residence. Medical tourism, also referred to as medical tourism, is closely related to national health systems and is a type of tourism that depends on hospitals and health personnel, especially doctors. The fact that medical tourism is seen as an activity focused on foreign patients leads to international agreements and laws in this field. Since people living in the same country benefit from the same social security system, domestic travel for treatment is not reflected in medical tourism statistics. The reasons that push patients to seek treatment in another country can be very diverse. These reasons can be summarized as follows:

- ***Differences among countries' health systems***: The number and qualifications of hospitals and doctors affect the decision-making process in medical tourism. The difficulties that patients experience in accessing healthcare services in their home countries are differences such as long waiting times or insufficient staff, lack of qualified personnel, high service costs, or low government contribution to treatment services.
- ***Level of technology utilization in health services***: The effective use of today's health technologies in diagnosis and treatment makes it possible to reach a fast and successful treatment. Treatment planning with advanced technology tools can direct travel as a reassuring factor for patients. Patients from countries that do not have this technology receive treatment services abroad through their individual means or insurance companies.
- ***Legal restrictions***: There are restrictions imposed by law on the resolution of certain health problems or conditions that require medical support. For example, there are patients who go from countries where egg donation or surrogate motherhood is prohibited in IVF treatments to countries where these are allowed. Similarly, the prohibition of the right to euthanasia in some countries is another example.
- ***Request to keep treatment confidential***: The reason why people do not want to solve their health problems in their own country may be that they do not want this process to be recorded in their personal health information.
- ***The cost of accessing health services***: Differences in exchange rates are among the important factors that direct foreign tourism. The most important reason why countries with high exchange rates, i.e., countries with high purchasing power of

foreign currency, attract foreign tourists is the low cost of tourist expenditures. In other words, it is the opportunity to receive quality services at a lower cost.

- ***Tourism potential of countries***: As in health services, the characteristics of the tourism sector also affect the country to be traveled to. The rich natural resources of the destination, the attractiveness of its cultural structure and the quality of tourism enterprises, the availability of safe travel and accommodation, and good hospitality for foreign tourists are among the touristic attractions.
- ***Diaspora tourism effect***: Diaspora tourism, which refers to people's travels to countries that they see as their homeland, can also be effective when deciding on the country to receive health services. The fact that touristic expenditures are made to this country and that people who want to visit this country, even for health purposes, feel safer in this country can affect the success of their treatment.

12.3.2 Thermal Tourism

It is a type of tourism based on activities such as the application of natural waters that rise above ground at a certain temperature, healing waters containing different minerals directly or in the form of mud and steam. The use of waters thought to be healing dates back to ancient times. Finds from Germanic and Celtic people who lived in India, Egypt, Greece, Israel, Iran, and Italy in the past show that thermal springs have been used since ancient times (Nalbant 1988). The first scientific study on the therapeutic use of these hot waters in history was conducted by the Greeks. The Greek scholar Herodotus, known as the father of history, and the Greek physician Hippocrates are known to have mentioned natural spring treatments and spas in their works (Redman and Johnson 2008). Since the use of thermal waters includes medical applications, it also constitutes different fields such as Thermal Tourism Medicine or Spa Medicine. Thermal waters, which can be used in the treatment of many diseases, especially rheumatic diseases, skin, nerve, and muscle, respiratory diseases, can be recommended by experts as part of the treatment or used according to personal demand.

12.3.3 SPA and Wellness Tourism

The concept of SPA, formed by the abbreviation of the initials of the Latin term "Sanitas Per Aquam", which means health and well-being from water, refers to activities such as massage, therapy, and bathing with healing waters. In addition to the use of healing waters, SPA tourism, which includes beauty and care treatments and mud therapies, is seen as a part of thermal tourism. Today, SPAs, which include non-medical applications, are used to refer to beauty salons, wet areas of hotels, and cosmetic areas. Thermal or mineral waters are not always used in these areas, sometimes mains water and sometimes mineral salts and essences mixed with mains water are used (Karagülle 2007). This situation causes SPA centers to expand and increase in area.

Wellness tourism is one of the components of health tourism, which is carried out with the aim of improving health or feeling healthy rather than being treated. According to the wellness philosophy, which is formed from the English words "well being" and "fitness", the individual is at the center of his/her own life and is personally responsible for his/her health (Yirik et al. 2015). From this point of view, wellness tourism is defined as the participation of individuals without any disease in non-therapeutic healthy activities (Weiermair and Steinhauser 2003). These activities include physical activities such as yoga and massage, experiential activities such as art and entertainment festivals, psychological activities such as religious events, and social relaxation such as charity work (Mueller and Kaufmann 2001). Multidimensional wellness tourism is a type of tourism that focuses on physical, mental, and psychological well-being. In this respect, wellness tourism consists of personalized products. For this reason, it is broader than thermal tourism and SPA, which can consist of a wide range of activities (Temizkan 2015).

12.3.4 Elderly and Handicapped Tourism

Tourism activities that focus on the travel of people in the older age group are called advanced age tourism or third age tourism. The limit shown in the literature as advanced age may vary as 50, 55, or 60 years of age. However, with the prolongation of human life span due to various factors and the fact that it is possible for older individuals to be healthy, the age limit for old age can be updated over time. If it is necessary to make a definition without setting a numerical limit, it can be expressed as "the whole of the activities of individuals who do not have time problems because they have generally finished their working life, who have limited health and vacation budget opportunities and who may need different activities than other age groups during travel".

The *Geriatrics* field of medical science stands out in advanced age tourism. Geriatrics, which is briefly defined as old age medicine, deals with health problems in old age and the treatment of these problems. In addition to receiving healthcare services in the destination country (medical tourism), older tourists' travels abroad within the scope of health tourism can also be in the form of spa cure or rehabilitation services.

As is the case for older individuals participating in tourism activities, disabled individuals also need some special conditions to be able to travel. This type of tourism, which is also referred to as barrier-free tourism, is defined as activities in which individuals with limitations in functions such as vision, hearing, movement, or diseases related to mental disabilities can use the products in universally designed tourist attractions on an equal basis with other individuals and independently (Darcy and Dickson 2009). The comfort of individuals with advanced age or disabilities in service procurement processes in both tourism and health sectors shapes sectoral decisions and public policies within the framework of rights and freedoms.

12.4 Intermediary Institutions as Service Providers in Health Tourism

It is possible to say that the service procurement process in medical tourism, one of the components of health tourism, has four stages. These stages can be named as the decision stage, travel stage, treatment stage, post-treatment travel and control stage, respectively. Depending on the characteristics of the health problem or the service to be received, sometimes the tourism aspect of the event comes to the fore, but in general, quality health service may be important. The fact that international travel is involved in medical tourism can make service recipients uneasy at each stage of the process. In parallel with the development of the sector, the need for service provider institutions that can manage the health service to be received in this process with travel and tourism dimensions is increasing. Although it may be possible to initiate the service process individually with the efficient use of communication channels by health institutions, making all travel decisions may increase the risks and negatively affect consumers (health tourists). For this reason, Health Tourism Intermediary Organizations (HTAs) have emerged as professional service providers that can establish the connection between the patient and the health institution and direct all transactions on behalf of the patient.

In a study conducted by the World Tourism Organization, it was revealed that 53% of tourism movements are for entertainment and holiday purposes, 27% for health, faith, and other types of tourism, and 13% for business and professional purposes (WTO 2016). Countries where health-related travels are made are the countries where quality health services are provided. The main factors that determine quality are the equipment of health institutions, the skills of health personnel, and the low cost of service procurement. It is known that India, Singapore, and Malaysia are the leading markets in Asia; Brazil, Cuba, Mexico, and Costa Rica in the Americas; and Poland, Germany, and Slovenia in Europe. Similarly, Qatar, Jordan, and Bahrain are also destinations with high potential in the Middle East. When other components of health tourism are considered, India, Turkey, and Malaysia rank first in the thermal tourism and SPA/Wellness markets. Hungary, the Czech Republic, Austria, Bali, and Maldives stand out in advanced age and disability tourism (SHGM 2022).

As the first gateway to health tourism, intermediary organizations establish the first link between the tourist as a service recipient and the private insurance company that will partially or fully finance the service fee. Intermediary institution activities are governed by special regulations in each country and are basically carried out by businesses with similar functions. These businesses, which can operate in all areas of health tourism, are mostly involved in the medical tourism market. The main intermediary activities in this market can be listed as follows:

- Identifying and presenting country and/or hospital alternatives in an unbiased manner in line with the patient's request (health problem),
- Conducting preliminary interviews for the selected alternatives and making cost and service/quality comparisons,

- To ensure that medical data is prepared and sent to the other party as requested in line with the patient's decision,
- To plan the treatment process and carry out travel preparation procedures (such as visa procedures, travel planning, accommodation procedures, and organizing tourist trips),
- Providing support to the patient from the start of the journey, either in person with an attendant or through other forms of communication,
- It may consist of activities such as carrying out procedures related to the return during and after the treatment phase, providing feedback to the health institution after return, and following up during the recovery period.

In the medical tourism market, where intermediary institutions play an important role, there are four types of institutional structures (Binler 2015; Keckley and Underwood 2008; Temizkan and Konak 2018). One of these is ***Hotel Groups***. Hotels working in connection with hospitals not only provide accommodation services during the treatment process, but also organize by connecting with healthcare providers. In India, Malaysia, and Thailand, which are among the leading countries in the Asian medical tourism market, this connection between hotel groups and hospitals encourages patients to stay longer in the destination. For example, after the Tsunami disaster in 2004, hospitals in Phuket aimed to increase tourism revenues by preparing packages that could direct patients to hotels after treatment.

Another intermediary institution is the **Health Service Providers** that provide reciprocal hospital connections. These healthcare institutions provide the link between the sending and receiving country with their own internal units and operate in a way that addresses the logistical problems in this process. Bumrungrand Hospital in Thailand and a group of hospitals in India receive support from health service providers for patients coming from abroad. The organizations from which they procure services are only from providers that provide overseas patient connectivity (Deloitte 2008; Binler 2015).

Intermediary organizations that research and plan patients' treatment opportunities abroad as their representatives are called **Medical Travel Planners**. Examples of these intermediary organizations are MedRetreat, Planet Hospital, and Bridge Health International. These institutions, which provide healthcare consultancy to patients, can make the first contact with the patient and make decisions that guide the process. Some intermediary companies only refer to the hospital group they work with or make referrals by evaluating the country and center to be visited within the framework of their own quality criteria.

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It is possible to classify medical travel agencies as referral agencies, which generally provide limited services such as appointment booking, flight and accommodation reservations, and full-service agencies that provide assistance services at every stage of the medical travel process. The fields of activity of medical travel agencies cover a wide range of services that meet all the needs of consumers. However, while referral agencies offer limited services, full-service agencies offer a variety of services to consumers.

Among the prominent tasks of medical travel agencies is to guide consumers in the selection of destinations, hospitals, and doctors. However, these agencies do not have the authority to provide precise guidance to travelers for healthcare services in terms of hospital and doctor selection. Although they do not have the opportunity to choose for the consumer, they are obliged to provide a list of first-class hospitals and doctors to meet all their needs (Temizkan and Konak 2018).

There are differences between Tour Operators and Medical Travel Agencies. The functions of tour operators are in the same direction as medical tourism businesses, but both have two basic starting points: medical tour operators are medical groups that offer medical procedures and are therefore geographically bound; tour operators are the initial service providers. In other words, they are medical groups that offer medical services in addition to the leisure part of the package offered (Khafizova 2011).

One of the intermediary institutions is ***travel agencies***, which have an important place in the tourism sector. These institutions, which carry out activities such as holiday planning for touristic consumers, transportation ticketing, reservations, and visa procedures for travel abroad, are also prominent in health tourism. In some countries, there may be travel agencies that provide services only for the health tourism market, while in general, it can be said that there are agencies that operate in all types of tourism but have also entered the health tourism market.

12.5 Conclusion

Millions of people have traveled throughout history to receive better health care and today this has become an international industry. The health tourism market, with an economic size of 200 billion dollars, is a remarkable market in every aspect. Differences in healthcare systems between countries are the main factor driving travel in this market. The competence of health personnel, the capacity of health institutions, and the health technologies used are the main factors driving travel in this market. With the use of new generation technologies, decision-making and implementation times in diagnosis and treatment stages can be shortened and the success rate increases. In the new generation health services called Health 4.0, many tools from robots to virtual reality applications are used in health services.

It is easier to receive health services within the country and to travel for this purpose than outside the country. People traveling to a different country to receive a health-related service need support services that can guide the whole process by relieving their uneasiness. The institutions that provide this service and ensure sectoral logistics are intermediary institutions. These institutions, which can be called by different names according to their fields of activity, are obliged to provide information to the patient from the first meeting, to conduct research on his/her behalf, to be with him/her while receiving services in the country of destination, and to provide the services he/she needs until he/she returns to his/her country. While meeting these obligations, they plan the trip in the best way possible by acting together with their stakeholders in both the tourism sector and the health sector.

As a new business area in the growing health tourism market, intermediary activities provide a service that is needed in every country. Increasing the number and effective supervision of these institutions, especially the internationally accredited ones, which are established and operate in the legal infrastructure of each country, will contribute positively to the image of countries in health tourism.

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Chapter 13
Healthcare Logistics and Digital Transformation

Sema Kayapınar Kaya

Abstract Due to the complex and diverse structure of the healthcare industry, the healthcare industry's logistics practices have lagged far behind sectors such as retail and manufacturing. Therefore, in today's increasingly competitive and risky environment, it is critical for hospitals to improve their logistics management performance, increase the efficiency of health services, and reduce costs. This chapter synthesizes the contributions of healthcare logistics, the impact of medical logistics on healthcare providers, types of healthcare logistics. Addition, this chapter enables us to capture the research challenges associated with the healthcare logistics process, pharma logistics and show how digitalization initiatives can address them.

Keywords Health care · Logistics · Digitalization · Internet of Things · Pharma

13.1 Introduction: An Importance of Logistics in Health

Each sector has certain supply and logistics activities. While some materials are easily supplied, others should be maintained in a more sensitive and affordable way. One of the important branches of the logistics chain is undoubtedly health logistics. In order for logistics activities in the field of health to operate comfortably, logistics management must be harmonious, reliable, punctual, and sustainable. The slightest disruption or overlooked detail in this area can result in major and irreversible problems that threaten human health. In addition, when compared to other sectors, it is seen that the health sector supply chain has a more complex structure. The reason for this is that health services cover many complementary services such as catering, cleaning, laundry, patient transportation, and accommodation. In addition, these services are sometimes provided by using hospital resources, and sometimes by supplying them from suppliers due to lack of resources. The diversity of services

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offered requires establishing cooperation networks to provide these different services, and the strength of cooperation also affects the quality of the service provided.

For this reason, it is necessary to process health logistics within the logistics chain in a systematic way and to comply with the rules and regulations completely. Health logistics is more important than all other logistics branches in order to protect the quality and integrity of the transported product, to ensure the hygiene of the product during transportation and during the process until delivery, and especially to guarantee the lives of patients (Schneller and Smeltzer 2006; Acar and Bozaykut 2017).

Logistics management in the health sector is known as a field that requires expertise. It greatly contributes to the success or failure of many healthcare businesses. Health logistics is the control of personnel planning and product and information flow related to support/care/treatment activities to meet the needs of customers/patients. According to another definition, health logistics is a planning process that provides the purchase of products necessary to provide services to patients, inventory management, and replenishment of depleted resources. In short, health logistics includes all the activities necessary for the effective and timely delivery of health services.

13.2 What Is Health Logistics?

Health logistics is one of the most important building blocks of the health sector. Health logistics which is also known by different names such as hospital logistics, pharma logistics, is the process of raw material production, pharma production, medical device production and import, and the production and guarantee of all materials necessary for the health sector, storage, protection, and safe transportation and delivery of all these to the designated locations. The four main points that need to be taken into consideration while creating and developing this process are as follows; (i) the right time, (ii) the right quality, (iii) the required quantity and careful protection of the transported material against deterioration, breakage, and damage (Şentürk et al. 2020).

1. *Right time*: Materials received before their due time will be processed into the idle stocks of the health facility. Delayed purchases will result in the loss of healthcare recipients or the existing market. Economic Order Quantity, etc., methods are preferred in optimizing the timing (Şentürk et al. 2020).
2. *Right Quality*: The materials and services used in health facilities must have certain standards. It is obligatory to prove that they have these features with various certifications.
3. *The Right Amount and Being Safe*: Hospital operations require specific materials in sufficient quantity in line with the needs of patients and hospitals. Stock levels that minimize the annual supply cost should be preferred by health managers (Şentürk et al. 2020). The supply and storage of pharma should be carried out in a sheltered manner. Especially in healthcare, cold supply chain is a frequently

used method. At this stage, taking into account the hygiene rules, the vehicle used in the supply should be cleaned regularly, the temperature setting should be checked, and necessary precautions should be taken to transport the products that are likely to break (Benzidia et al. 2019).

As seen in Fig. 13.1, logistics processes from the health sector start with the manufacturers of pharma, medical devices, equipment, and consumables in health. Then, health products are sent to the central warehouses by carrier companies. Purchasing works are carried out through warehouses and medical barcoding/packaging operations are carried out. After these processes are completed, the medical products are transferred to the main warehouses of the hospitals and from there to the regional warehouses through the carrier companies, and then the products are delivered to the final consumers. Logistics activities do not end after the patients reach the health products. Patient relations management and the recycling process of medical products are also reverse logistics activities included in the health logistics business process.

When we look at the process of health institutions in the logistics chain, the first link of the chain is suppliers and manufacturers. Health logistics manufacturers can be defined as pharma and pharmaceutical manufacturers, medical and surgical equipment manufacturers, device manufacturers. Carrier companies and transporters constitute the second link of health logistics, they undertake the task of operating and transporting warehouses of medical and surgical materials. Warehouses must first be suitable for the sensitive pharma and equipment storage environment. The heat setting should be determined, and hygiene rules should be observed. Healthcare services with great demand requirements are provided by distributors. Medical distributors send health products to hospitals, clinics, physiotherapy centers, health centers, home care services, and rehabilitation centers. At the end of the supply network, there are patients and payers (government agencies, insurance companies, employers, etc.) (Kritchanchai 2014).

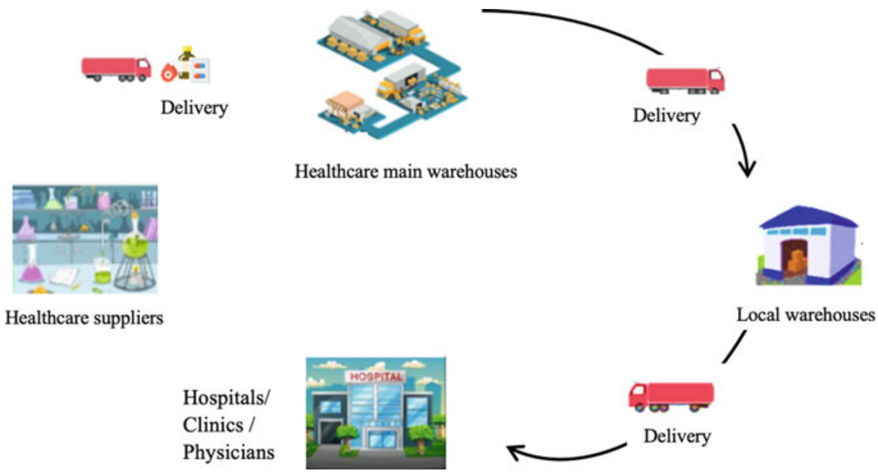

Fig. 13.1 Healthcare logistics networks *Source* (Umoren et al. 2021)

13.3 Features of Health Logistics and Differences of Health Logistics from Other Logistics Sectors

In the health sector, logistics is an element that provides support services for the provision of health services. The quality of this support service provided by the logistics unit also directly affects the service provided by the health institution. Logistics services provided in health enterprises should be carefully evaluated and presented without any mistakes (Atasever 2020).

Unlike the other logistic sectors, health logistics is one of the sectors where a mistake cannot be tolerated once again. Some products within the scope of health logistics are of critical importance. Failure to use these products throughout the supply chain can lead to life-threatening dangers. This feature is known as the most important feature that distinguishes the health sector from other logistics sectors (Ledlow et al. 2016). In the health sector, logistics has some differences that distinguish it from other sectors (Min 2014).

- The availability of the products that will be needed should be at a high level.
- If medical products are not available, they can endanger human health.
- Inventory management is multi-level.
- Used products and drugs need a special storage area.
- Healthcare organizations want to supply a wide range of products and services.
- There are materials used according to preference.
- Billing for wrong products and drugs means wrong inventory.

13.4 Types of Health Logistics

13.4.1 Pharma Logistics

Better quality of health services is closely related to the strength of the pharmaceutical industry. In addition, the pharmaceutical industry, which provides extremely important contributions in terms of economic development, should have a pharmaceutical industry that can produce to meet the pharmaceutical needs of the country in the face of factors such as war, epidemic diseases, and a possible embargo. The supply chain structure applied in the pharmaceutical industry today differs from the other supply chain structure. The aim of pharma logistics is to provide the right drugs at the optimum cost, in the right quantity and conditions, to the right healthcare providers (Chikumba 2009). In this case, logistics strategies that will provide competitive advantage and reduce costs are needed so that pharmaceutical manufacturers can reduce their costs and wholesalers and retailers can tolerate lower profit levels (Kopczak 1997).

The general logistics network structure consists of raw material supply, producers who convert these raw materials into intermediate goods and final products, and distributors who distribute them to customers. However, when the product in question is pharma, this logistics network structure will undergo some changes. The functioning of the logistics process in the pharmaceutical industry starts with the supply of raw materials and continues with the production process. Produced pharma is distributed to retailers such as pharmacies and hospitals through pharmaceutical warehouses, pharmaceutical cooperatives, which are in the position of wholesalers. Pharmaceuticals at retail points are distributed to consumers. In the pharmaceutical industry, products are subject to special temperature controls throughout the logistics network, as they are very sensitive to deterioration. In cold chain logistics, each medical product needs its own heat preservation. Temperature control is not only during the transportation of sensitive pharma; storage, loading and unloading of vehicles, inter-vehicle transfers, or placing in the area where it will be displayed at the retail point (Shih and Wang 2016). Cold chain activities in pharma supply:

- **Transportation**: In this transportation process, in addition to being durable and sturdy transportation of medical products, the products are transported by refrigerated and insulated vehicles. Since these types of products can spoil very quickly, they must be delivered in a very short time. When cold products are to be transported by air, the products are usually transported in standard containers with linings that hide insulation or dry ice. Transportation by the sea with cold air containers is used. In long-distance transports by land, the vehicle has a self-cooling system, while in short-distance transports, pharma is stored thanks to the ice batteries placed in the styrofoam.
- **Storage**: These are the places where perishable medical products are kept for a short time, where the temperature settings of cold storage can be controlled.
- **Packaging**: Insulated packages are used in cold chain logistics. Thanks to these packages, pharma, etc., health products prevent deterioration by maintaining the temperature level in a certain range.

Since pharma are also considered as perishable products, the ambient temperature must be at certain levels not only during transportation but also while they are kept in pharmacies or pharma stores. The pharmaceutical supply chain structure is shown in Fig. 13.2. In addition, the movements of pharma in the research phase, which are still under construction, among laboratories are carried out with the cold chain, while the transportation processes are followed more precisely. The importance of pharmaceutical cold chain logistics in the protection and transportation of vaccines during the COVID-19 pandemic that emerged in 2019 was also emphasized.

In recent years, thanks to new technologies, pharma transportation and storage have become easier to control temperature and humidity. With the help of Internet of Things technology and RFID, pharma can be tracked in real time and online information flow can be provided. In pharmaceutical logistics using the cold chain, physical facilities can be remotely adjusted to the appropriate temperature, humidity, and temperature controls, so that the products are supplied to the end customer without losing their properties (Pachayappan et al. 2016).

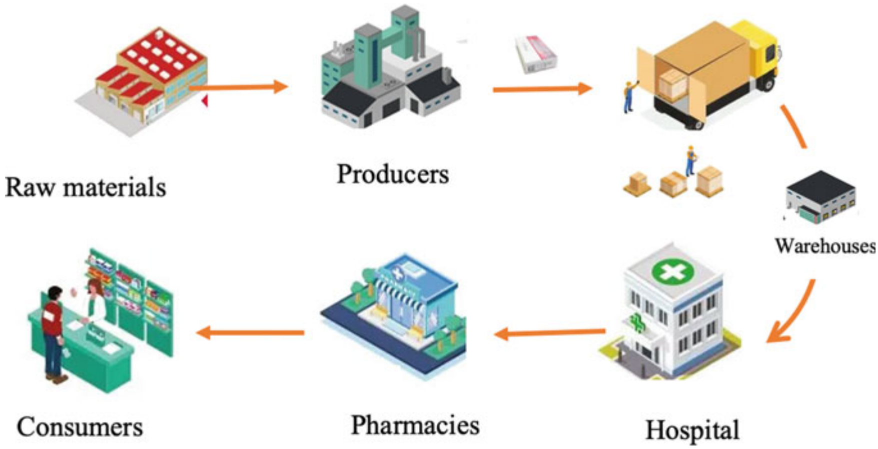

Fig. 13.2 The pharmaceutical supply chain structure

13.4.2 Medical Device Logistics

Medical devices, which play an important role in the diagnosis and treatment of diseases, are the biggest helpers of health personnel in this regard, and constantly renew themselves, are known as the most important element of the health sector. Health institutions have to keep up with the developing technology in order to increase the quality of service and improve themselves. With the constantly renewed medical devices and the old ones staying in the hospital, big problems arise. Medical device requests submitted by the authorities of health institutions for this situation are examined by the units they have established, and the demand is created by checking whether this device is really needed and whether there are authorized personnel who can use this device in the requested institution.

13.4.3 Medical Waste Logistics

Medical Wastes consist of infectious wastes, pathological wastes, and penetrating wastes. Infectious Wastes are wastes that require special handling and disposal. The main sources are; microbiological laboratory wastes, blood products and objects contaminated with them, used surgical clothes, dialysis wastes, quarantine wastes and infected experimental animal scavenger wastes, medical organ parts, all objects that come into contact with them. Pathological Wastes consist of anatomical waste tissues, organs and body parts and surgery, autopsy, etc., bodily fluids released during medical intervention; body parts, organic parts, placenta, amputated limbs, etc., originating

Fig. 13.3 Collection of medical waste in hospitals *Source* (Sterilization of Medical Wastes 2016; Medical Waste Hospital Garbage Bag 2022)

from places such as operating rooms, morgues, autopsies, forensic medicine, and guinea pig carcasses used in biological experiments. Penetrating Wastes consist of wastes like needle-containing cutters such as injector needle, scalpels, lam-lamellae, etc., which can cause injuries such as stinging and scraping (Bayhan and Görücü 2020). Medical waste points in hospitals is given in Fig. 13.3.

Since medical wastes are hazardous and environmentally harmful wastes, they require special precautions regarding their production, transportation, storage**,** and disposal. In medical waste logistics, medical waste is disposed of according to the Regulation on Control of Medical Wastes.

13.4.4 Humanitarian Aid Logistics

Without logistics activities, interventions in emergency situations cannot be carried out effectively. Therefore, since logistics is a very important factor in the management of disasters, it should always be done with different and modern perspectives. Humanitarian aid logistics is known as the delivery of necessary products to those in need affected by natural disasters and extraordinary events (Adiguzel 2019).

Humanitarian aid logistics are of great importance in order for the needy to return to their normal lives after disasters and to overcome the difficult situation they are in. Here, too, the supply chain needs to be managed very well. The functions of supplying, storing, distributing, and delivering the products to the needy on time must be fulfilled (Min 2014).

13.5 Digitalization of the Healthcare Supply Chain

The digitization of the supply chain plays an important role in the transformation of supply chain organizations (Wang and Wang 2020). Digital supply chain is being studied more and more in academia and different industries; (Kaya 2020; Stank et al. 2019; Hennelly et al. 2020). The digitization of the Supply Chain can be defined as the use of the capacities of traditional information systems and new advanced technologies such as the Internet of Things (IoT), big data, augmented reality, drones, and blockchain. With the help of digital supply chain, supply chain activities become more flexible and efficient. Digital healthcare supply chain network with IoT is shown in Fig. 13.4.

It is predicted that the supply chain management of the health sector is 20 years behind other sectors such as food and retail (Acar et al. 2017). Supply chain initiatives in the healthcare sector have often focused on managing supplies and reducing purchasing costs (Parker and DeLay 2008). At this point, digitalization in the health sector will gain importance in reducing costs and increasing quality. Digitization initiatives in hospitals mainly focus on the implementation of classical technologies such as enterprise resource programs (ERP) and electronic data interchange (EDI) used for supply chain integration (Benzidia et al. 2019). However, it has recently been integrated in tools such as radio frequency identification (RFID), automated guided vehicles (AGV), and IoT in the transport and storage of healthcare products (Morenza-Cinos et al. 2019). With its implementation in many public and private hospitals, AGV improves hospital flow management, including pharma and medical supplies, laundry, food, and waste. Implementing AGVs requires significant investment, but also provides long-term benefits to healthcare businesses in terms of optimization, flexibility, and quality of customer service (Ventura et al. 2015; Fazlollahtabar and Saidi-Mehrabad 2015).

RFID is one of the key technologies that make up the Internet of Things, a pervasive network environment where goods are tracked throughout the supply chain and applications are allowed to run simultaneously (Kortuem et al. 2009). RFID helps hospitals and clinics improve stock management, identify patients, and maintain patient records and treatments (Fazlollahtabar et al. 2015). Tracking the expiration

Fig. 13.4 Digital healthcare supply chain structure *Source* Končar et al. (2020)

date of the products in the pharma warehouses, updating the stock levels, and making the inventory records are done by RFID.

Since the emerge of IoT by the Massachusetts Institute of Technology in 1999, the field in "Internet of Thing" has got significant attention from practices and researchers. IoT is the configuration of physical devices, mechanical and electronic machines, and the other items embedded with RFID, sensor, chip, network connectivity that provide these objects to identify, collect, and transfer data over this network. IoT technology is the new communication platform including the number of mobile devices and network connected equipment that can communicate with each other simultaneously. With the IoT, significant contributions have been made to the field of health. Health data from the point of view of collecting the patient in the hospital or hospital, thanks to IoT. Continuous follow-up by doctors regardless of being out of the hospital can be achieved. Again, thanks to telemedicine applications, safe voice and remote monitoring of the patient via video connections, providing training is provided. Apart from these, location tracking with mobile health applications, home care of the elderly, and follow-up of chronic patients can also be done. According to the report published by Grand View Research (GVR), it is estimated that the healthcare sector's need for Internet of Things (IoT) technology will increase exponentially and will reach approximately $410 billion by 2022 (IntelliGuard 2020).

13.6 Conclusion and Future Study

One of the most crucial foundational elements of the health sector is health logistics. Health logistics, also referred to as hospital logistics or pharmaceutical logistics, is the process of manufacturing pharmaceuticals, manufacturing medical devices, manufacturing raw materials, importing those devices, manufacturing and ensuring the production of all materials required for the health sector, storing, protecting, and transporting those materials safely, and delivering those materials to the designated locations.

Logistics has become one of the largest cost factors for many healthcare organizations, especially for hospitals. At the same time, financial and human resources have decreased in many countries. This has meant an increasing demand for more efficient productivity and material flows, the reallocation of existing human resources, changes to former working methods, and the development of innovative working practices both in primary health care and especially in specialized medical care services.

Nowadays, healthcare logistics has the chance to construct off of those foundational changes to not only assist answer the cost-quality equation but also to power the industry's outlook efficiency. Furthermore, the transformation of a traditional logistics to a digital logistics creates sustainable value for healthcare logistics organizations. It gives everyone access to faster, safer, seamless, and more affordable healthcare logistics. In addition, digitization of the medical logistics helps medical systems bring down logistics operational costs and find growth opportunities. Digital transformation enables providers to deliver care, improve processes, and reduce medical logistics costs.

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