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DIGITALIZATION IN THE CZECH HEALTHCARE

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Declaration of authorship

I, Veronika Klimková, hereby declare that the thesis “Digitalization in the Czech healthcare” was written by myself and that all presented results are my own, unless stated otherwise. The literature sources are listed in the List of literature section.

Prague, April 26th, 2019

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Signature Prague, April 2019

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Abstract

The Master's thesis deals with the advancement of the Czech healthcare's digitalization, firstly by providing a comprehensive sector overview and subsequently by analysing both its recent scientific results, as well as its future trends and tendencies, as seen by relevant stakeholders. In total, this gives the reader a clear understanding of which direction the Czech healthcare environment is going to assume in the period of the following 10 years. An important contribution of the thesis' analyses is the identification of potential business opportunities.

Keywords

Digitalization, Industry 4.0, healthcare, Czechia

Table of Contents

List of Abbreviations

AI	Artificial Intelligence
DESI	Digital Economy and Society Index
EHR	Electronic Health Records
ESIF	European Structural and Investment Funds
GDPR	General Data Protection Regulation
HR	Human Resources
IOM	Institute of Medicine
IoMT	Internet of Medical Things
IoT	Internet of Things
IP	Intellectual property
IPR	Intellectual property rights
POC diagnostics	Point-of-care diagnostics
DRG	Diagnostic Related Groups
SME	Small and medium enterprise
SÚKL	State Institute for Drug Control
UK	United Kingdom
U.S.	United States

Introduction

We are now living in an era where almost every field around us gets disrupted by new, unconventional ideas and business models driven by unprecedently fast technological advances. Innovations, which were not so common only a couple of years ago, nowadays, define standards of living for populations in most of the developed countries. Yet, judging by the level of satisfaction of healthcare workers, patients themselves, or just by looking at the sector's responsiveness to difficult challenges that modern lifestyle puts it through, healthcare still does not seem to have experienced the same pace of evolution as the other ones.

A number of studies point to several difficult challenges which global healthcare systems inevitably have to confront. Looking at the global population, demographic development points at a rising life expectancy in OECD countries. Solely between 1990 and 2015, an average increase of 5.5 years has been recorded.[1] Only in Europe, around one fifth of the whole population is going to be older than 65 years by 2022.[2] Also, a major pressure on streamlining the healthcare sector is caused by various diseases, which we either find difficult or impossible to cure, often due to patients lacking access to prescribed medicine. While cases of communicable diseases are estimated to decline, occurrence of non-communicable diseases, such as diabetes, obesity or cancer, are expected to increase by 5.5% between 2015 and 2030.[3] The expected development constitutes a huge challenge for healthcare systems across the globe, also translated into financial terms, if no changes occur. The projected increase in global healthcare spending is estimated to be around 4.2% annually.[4] Thus, global political leaders and other relevant decision-making bodies gradually find themselves in a need to adopt new policies in order to prevent a complete disintegration of national healthcare systems.

The Czech healthcare system, the primary subject to be discussed in this thesis, is no exception. Nevertheless, the onset of the Fourth Industrial Revolution and the accompanying state-of-the art technologies give us a good reason to expect to see possibilities to reverse the trends and speed up the necessary healthcare sector transformation. The question remains then, what the future will hold for the way the Czech healthcare sector advances. Similarly, what business opportunities are there still left intact in Czechia? Finally, how could businesses within the Czech healthcare sector embrace the opportunities brought about by Industry 4.0?

Since, there are many questions to be answered, and many difficult issues that need to be solved before the healthcare sector is modernised and enhanced up to its full potential, further research was conducted in this area and the key information summarized to give a proper

overview on the sector's actual state, competitiveness, current and future development as well as possible business opportunities.

The goal of the thesis is to describe the upcoming changes in the healthcare system and predict how they will affect the Czech healthcare environment. The findings are going to be supported by a thorough mapping-out of the Czech healthcare system, its functioning, problems and all that not merely in general terms but also with respect to concrete solutions applied in connection to its digitalization. Following the primary analysis of trends, the secondary goal is to identify business opportunities for companies in Czechia to pursue when willing to introduce new digital technology-based solutions within the healthcare sector.

The hypothesis of this thesis is that the level of quality of the Czech healthcare environment as well as the number of digital solutions implemented is growing, nevertheless, not the same trends in and intensity of R&D activities are going to be recorded across various medical technology areas (e.g. 3D technology, medical imaging, health analytics etc.). The aim is to find out which areas are the fastest growing ones in order to present more accurate suggestions on where opportunities for new business activities could be found.

The literature review is to be found primarily in the first chapter. The first chapter relates to a general understanding of the healthcare sector and the specifics that make it more complicated to flexibly adopt changes. Consequently, technological changes brought about by Industry 4.0 are going to be discussed, before moving to global trends and recent development in digital healthcare. The second chapter is going to orientate more towards Czechia, with discussion on its current state and identification of macroeconomic indicators relevant to the level of the country's level of digitalization. The chapter ends with a summary of some of the best practices of businesses, medical research institutes and other organizations as pioneers operating within the Czech digital healthcare.

The analytical part of the thesis is going to be divided into two main analyses. Firstly, a data analysis is going to be performed, whereas data on patents, research projects and other scientific results of the Czech entities is going to be obtained in collaboration with UNICO.AI[1], a Prague information and technology start-up company. In the second part, expert interviews with relevant respondents, identified as local digital healthcare innovators, are going to be conducted. The contribution of this part of the research lies in understanding the sector's possible future development.

The combination of both subjective and objective information on the healthcare system's past and future progression is going to produce an insight into what trends are present. Based

[1] UNICO.AI: Seznamte se s UNICO.AI. *UNICO.AI* [online]. [cit. 2019-03-23]. Retrieved from: https://www.unico.ai

on those findings, suggestions are going to be outlined on where researchers, established companies and brand-new entrepreneurs should focus their future endeavours to stay up-to-date and relevant, eventually leading to maximizing their bottom lines in the long run.

1. Healthcare in the digital era

The aim of the first chapter is to provide a general understanding of the healthcare sector. A separate section is going to be dedicated to Industry 4.0, since it is crucial for understanding how its evolution made digitalization across sectors possible.

To give readers a proper introduction to the topic, they are going to be acquainted with specifics of the healthcare sector in the first part of the chapter. The specifics discussed serve to demonstrate the complexities of the healthcare sector, making it different from the traditional free market, which the reader might be more familiar with.

The second sub-chapter summarizes the most significant technological changes and challenges businesses deal with in connection to the rise of Industry 4.0. The reader is going to learn about marked changes in production as well as see the link between the spread of the concept and revolutionary transitions in society.

The final part of the chapter deals with global trends and recent developments in the healthcare sector with regards to the impact of Industry 4.0 on its digitalization. Global statistics as well as predictions of the sector's development in the upcoming years are going to be included.

1.1 Specifics of the healthcare sector

No sector has been perceived as being as complex as healthcare. With the number of actors operating in this area, the combined model of private and public financing (at least in some rather socially oriented countries), and the regulatory role of governments, it is especially difficult to manage all its underlying processes and introduce innovations in response to changes on the market. Nevertheless, with new technological advancements and increasing pressure on higher efficiency and quality in all areas of our society, it is apparent that even the healthcare sector will need to undergo sweeping changes. Its complete reorganization could serve to better reflect the latest societal and technological development in order to ensure a continual match with changing customer needs.

In this part, the sector's specifics are going to be further inspected to better understand their role in shaping it as a whole. Based on that, conclusions and recommendations are going to be provided at the closing chapter of this thesis on the possibilities for businesses to deliver innovations, principally in relation to digitalization.

Asymmetry of information

In contrast to other sectors, healthcare is characterised by many distortions preventing the perfect allocation of resources. Firstly, there is a large asymmetry of information in the relationship between a patient and a doctor.[2] This bestows great power on doctors, whose professional advice and deep expertise are the only reliable sources of information a patient can adhere to. But the lack of knowledge on the part of a patient prevents them from making an informed decision on their own and usually impedes the possibility to shop-around for medical products and services.[3] The fear of possible negative consequences caused by a bad decision is therefore substantial. Thriving on this imbalance, the information asymmetry usually gives space to various charlatans assuming the role of a specialist. However, despite numerous well-intended public endeavours aimed at consumers' protection (e.g. licencing by state medical associations), every governmental act of intervention necessarily goes with creation of other unintended distortions such as difficult market entry, leading to less or no free competition and stifled innovation potential.

Another demonstration of asymmetric information could be found in the relationship between an insurer and insured, where the person purchasing insurance dispose of information that an insurer has by no means a chance to get access to.[4] In literature, this particular problem is often referred to as adverse selection which points to a dangerous situation based on varied characteristics of those willing to be insured. If we suppose that the population could be divided into two groups, the first containing healthy individuals and the second formed by those with a higher susceptibility to serious illnesses, it is probable that the latter would be more willing to pay for their insurance. Since the risks entailed are higher for insurance companies (had they known the medical condition, they would not have provided any insurance to this group), they raise prices in order to cover medical care for a "sicker-than-average" individual. This, in turn, discourages many "healthy individuals" from paying such a high price. However, if this situation of higher prices for the insurance leads to consumers refusing the coverage, the financial market fails at mitigating the financial risks stemming from getting ill.[5]

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[2] A. Wells, David, MSc, Joseph, S. Ross, Joseph, MD, MHS, S. Detsky, Allan, MD, PhD (2007): What Is Different About the Market for Health Care? *JAMA* [online]. (Vol 298, No. 23), p. 3 [cit. 2018-10-07]. Retrieved from: https://vbidcenter.org/wp-content/uploads/2014/11/What-Is-Differente-About-the-Market-for-Health-Care_AMA_2007.pdf

[3] Kaiser Health News (2017): Few Patients Shop Around for Healthcare. *Kaiser Health* News [online]. 2017 [cit. 2018-10-26]. Retrieved from: https://www.healthleadersmedia.com/finance/few-patients-shop-around-healthcare

[4] Shmanske, Stephen (1996): Information Asymmetries in Health Services: The Market Can Cope: *The Independent Review* [online]. (Vol.I, No.2), p. 9 [cit. 2018-10-08]. ISSN 1086-1653. Retrieved from: http://www.independent.org/pdf/tir/tir_01_2_shmanske.pdf

[5] Harvard University (2017): The Economics of Healthcare. *Harvard Library* [online]. 2017-08-30, p. 14 [cit. 2018-10-27]. Retrieved from: https://scholar.harvard.edu/files/mankiw/files/economics_of_healthcare.pdf

Strict regulation

Another easily identifiable characteristic of the healthcare sector is its strict regulation. No matter whether we look at the system in the U.S., Europe or elsewhere in the world, there is a broad set of laws and regulations applied. For the sake of the end-consumer, in this case a patient, all procedures, products and pharmaceuticals must comply with prescribed norms.

New medical solutions are required to undergo clinical trials, their harmless, therapeutic effects must be confirmed by well-funded research studies and it might eventually take up a decade to obtain the official approval. Therefore, it is especially difficult for new entrants to appear on the market and compete with established players.

In spite of this constant scrutiny, we have been able to witness a new trend of tech-based companies making a great effort to enter the market with new technological solutions, after having dealt with pressing customer issues on other markets successfully. Nevertheless, unlike other industries, such as the fast-moving consumer goods, the companies have to beware of the "move fast, break things" attitude, since it does not seem to translate into better, more profitable business results in the area of healthcare.[6] Recently, we have had a chance to observe the scandal covered by global media, when a tech company Theranos introduced its seemingly breakthrough invention of blood-testing with just a few droplets of blood. Trying to circumvent the established norms, the start-up decided to lie about the accuracy of their technology leading to its CEO and COO face civil fraud charges and a 500,000-dollar fine. And there seem to be more companies willing to take risks of bypassing regulations.[7]

Still, whether companies consider the marketplace ideal or not, the state finds itself responsible for setting the balance, where the invisible hand of the free market cannot reach.

Moral hazard

Another distinctive feature of the healthcare sector is market distortion caused by moral hazard. Moral hazard is the result of a partial coverage of the medical costs by a third party, usually government or an insurance company.[8] The basic rule of economic theory states that as long as value of services exceeds costs incurred to patients, they continue consuming them.

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[6] Fast Company (2016): Dear Silicon Valley: There Are No Shortcuts In Health Care. *Fast Company* [online]. 2016 [cit. 2018-10-07]. Retrieved from: https://www.fastcompany.com/3056658/dear-silicon-valley-there-are-no-shortcuts-in-health-care

[7] The Guardian (2018): Once-heralded blood-testing startup Theranos is closing – report. *The Guardian* [online]. 2018 [cit. 2018-10-07]. Retrieved from: https://www.theguardian.com/technology/2018/sep/05/theranos-closing-blood-testing-startup-report

[8] Shmanske, Stephen (1996): Information Asymmetries in Health Services: The Market Can Cope: The Independent Review [online]. (Vol.I, No.2), p. 9 [cit. 2018-10-08]. ISSN 1086-1653. Retrieved from: http://www.independent.org/pdf/tir/tir_01_2_shmanske.pdf

This means that sharing healthcare costs with other entities makes it considerably easier for patients to get access to more of those services. This value-cost imbalance generally leads to overconsumption. However, the real problem underlying the moral hazard is the change in consumer behaviour. Rather than avoiding unhealthy actions, aware of the security provided by the insurance company, consumers deliberately take higher risks than they would in case of not having any insurance at all. [9]

Two roles of a healthcare provider

The unique position of a healthcare provider comes down to the existence of two different roles in the relationship with a patient.[10] The basic premise states that it is a doctor's utmost duty to comply with ethical and social norms when rendering services. Here, a doctor acts as a patient agent. The other role puts doctors into the position of an independent business owner when gaining profit by provision and ordering of particular services.

The healthcare provider as an organization is also assigned with multiple roles. Its role division is based on healthcare providers bearing accountability both on various dimensions and to various parties. The former pertains responsibility for dimensions such as financial matters, standardized quality of care and the actual provision of services. Additionally, apart from a patient, providers are held responsible to a variety of actors – payers, communities, or their own executive boards, just to name some of them. Even the level of formality and matters for which they are accountable vary accordingly. The real problem with an organization's accountability arises when the related trade-offs are taken into account. A good example would be a purchase of a new technology. While a new equipment might be welcomed by the medical staff, payers are more likely to hinder the purchase, if the financial expenses entailed are too high. [11]

Monopoly power

It is also very common in the healthcare sector to monopolyze some professions resulting in limiting the market competition. In general terms, the source of monopoly power lies in a unique product. Due to difficulties associated with assessing each novelty feature of a

[9] Shmanske, Stephen (1996): Information Asymmetries in Health Services: The Market Can Cope: The Independent Review [online]. (Vol.I, No.2), p. 9 [cit. 2018-10-08]. ISSN 1086-1653. Retrieved from: http://www.independent.org/pdf/tir/tir_01_2_shmanske.pdf

[10] A. Wells, David, MSc, Joseph, S. Ross, Joseph, MD, MHS, S. Detsky, Allan, MD, PhD (2007): What Is Different About the Market for Health Care? JAMA [online]. (Vol 298, No. 23), p. 3 [cit. 2018-10-07]. Retrieved from: https://vbidcenter.org/wp-content/uploads/2014/11/What-Is-Differente-About-the-Market-for-Health-Care_AMA_2007.pdf

[11] Gray, Bradford H. (1991): The Profit Motive and Patient Care: the changing accountability of doctors and hospitals. Cambridge, Mass.: *Harvard University Press*, ISBN 06-747-1337-0

marketed medical product and a specific medical equipment, it usually takes only to signal their sophistication and uniqueness by the producer to persuade buyers to choose their products instead of those of a competitor. Consumers, unable to determine the additional value, are more willing to pay a higher price for products they are led to believe are of a higher quality and thus provide a more efficient solution. In reality, customers, and in many cases even physicians, are unable to objectively assess such a product's quality which leads them to rely only on indirect indicators (e.g. product presentation by personnel with a degree from a prestigious university).[12]

Externalities

Unlike perfect competition, the healthcare sector is associated with the existence of a variety of externalities. Those are situations when unintended side-effects on bystanders are produced, be it positive or negative, for which their originator has no financial compensation, nor any financial obligation. As an example, if a person gets vaccinated, they do not only preserve their own health, they also protect others when preventing the spread of a contagious disease. [13]

As a whole, it is clear that healthcare shows many deviations from the free market. Although several were discussed in this section, it is important to note that there still remain many more aspects where specifics could be found. The described market distortions, as well as many others, such as different availability of healthcare based on wealth of an individual[14], under-consumption caused by information bias[15] or the inability to exclude non-payers from the national healthcare system[16] have all contributed to the way the healthcare sector operates today. Understanding the causes of the sector's persisting rigidity and resistance to changes could provide the reader with a better explanation on why the whole sector is perceived as lagging with regards to digitalization and adoption of innovations.

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[12] Hilsenrath, Peter (1991): Monopolistic competition and the health care sector. Health services management research: an official journal of the Association of University Programs in Health Administration / HSMC, *AUPHA*. 4. 82-8. 10.1177/095148489100400201

[13] Harvard University (2017): The Economics of Healthcare. *Harvard Library* [online]. 2017-08-30, p. 14 [cit. 2018-10-27]. Retrieved from: https://scholar.harvard.edu/files/mankiw/files/economics_of_healthcare.pdf

[14] Powell, Alwin (2016): The costs of inequality: Money = quality health care = longer life. *The Harvard Gazette: Health and Medicine* [online]. [cit. 2018-10-26]. Retrieved from: https://news.harvard.edu/gazette/story/2016/02/money-quality-health-care-longer-life/

[15] Roberts, Jennifer (2017): The economics of healthcare. *Economic Review* [online]. [cit. 2018-10-19]. Retrieved from: https://www.hoddereducation.co.uk/media/Documents/Magazines/Sample%20Articles/November%202017/EcRev35_2_Nov2017_sample.pdf

[16] Harvard University (2017): The Economics of Healthcare. *Harvard Library* [online]. 2017-08-30, p. 14 [cit. 2018-10-27]. Retrieved from: https://scholar.harvard.edu/files/mankiw/files/economics_of_healthcare.pdf

1.2 The Impact of Industry 4.0

Over the course of history, our society has witnessed three industrial revolutions, whereas currently, the fourth one is largely discussed, not only in the media, but also among companies that gradually realize its great potential impact both on production, as well as business. Yet, calculations of its real consequences on society and business remain unclear, with predictions talking about an annual cost reduction of 3.6% and growth in revenues by 2.9% on average across various companies.[17] That being said, the reader is going to learn what events contributed to the emergence of the idea of Industry 4.0 in this sub-chapter. As a part of it, the concept's variations across countries, national spending and associated technological changes are going to be discussed.

The Fourth Industrial Revolution, also commonly referred to as Industry 4.0, is generally recognised as the strengthening of a company's long-term competitiveness via increased flexibility and effectiveness of the production, enabled by all production elements communicating via the Internet and the company accessing information and technology.[18] In other words, by going in line with the Industry 4.0 concept, companies are capable of achieving increased performance, cost reduction and produce higher-quality tailor-made products and services, which are based on proper understanding of consumer needs, desires and behaviour.[19]

The term Industry 4.0 (originally Industrie 4.0) was coined in Germany in 2006, when the German cabinet proposed a strategic plan on the implementation of new technologies in key research and innovation areas to create a wholly integrated industry. Four years later, Germans decided to continue with the initiative, when an updated version of the original strategy was introduced. The so-called High-Tech Strategy 2020 shifted the country's policy attention within the field of research and innovations towards selected projects to maximize the potential of scientific and technological progress.[20]

The principal thought of the German strategy lies in the close collaboration between industry and science and, thus, the creation of a powerful bond between knowledge and abilities

[17] PricewaterhouseCoopers (2016): 2016 Global Industry 4.0 Survey: Industry 4.0: Building the digital enterprise [online]. 2016, p. 36 [cit. 2018-05-17]. Retrieved from: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

[18] Gabriel, Magdalena, Pessl, Ernst (2016): Industry 4.0 and Sustainability Impacts: Critical Discussion of Sustainability Aspects with a Special Focus on Future of Work and Ecological Consequences. *Annals of the Faculty of Engineering Hunedoara*, 14 (2), 131-136. [cit. 2018-04-18] Retrieved from http://search.proquest.com/docview/1793945829?accountid=17203

[19] Gajewski, Jerzy, Paprocki Wojciech, Pieriegud, Jana (2016): Cyfryzacja gospodarki i społeczeństwa – wymiar globalny, europejski i krajowy, *Cyfryzacja gospodarki i społeczeństwa. Szanse i wyzwania dla sektorów infrastrukturalnych*, Publikacja Europejskiego Kongresu Finansowego, Gdańsk *Retrieved from:* https://www.efcongress.com/sites/default/files/publikacja_ekf_2016_cyfryzacja_gospodarki_i_spoeczestwa.pdf

[20] Lydon, Bill (2016): Industry 4.0: Intelligent and flexible production. *INTECH*, 63(3), 12-17. [cit. 2018-04-18] Retrieved from http://search.proquest.com/docview/1799786990?accountid=17203

of individuals. In its latest version, the strategy puts emphasis on the application of Internet of Things (IoT), whose contribution rests in connecting electrical appliances to the Internet and in the usage of communication and web services in production to create networks. As a result, networks consisting of the entire production process enable conversion of factories as we generally know into a "smart environment". This occurs with the help of intelligent machines, storage systems and production facilities. The adjective "intelligent" stands for "a higher level" or a "higher standard" where machines, or the environment itself are able to communicate with their immediate surroundings, while making, to a certain point, independent decisions with the help of set-up parameters, and thereby positively influencing the whole production process.[21]

The main accompanying features and characteristics of IoT revolve around the necessary disruption of central hierarchical management, when all processes, communication and coordination acquire a more decentralised role. The full integration of production and logistic processes across the whole company helps to create a more efficient and flexible ecosystem with real-time lean manufacturing (only that is produced what is required by the customer). As an advantage of such production, the streamlining of the value-creating supply-chain is usually stated, ranging from simplification of the original product idea-creation across product development, production and maintenance to recycling. This means that customer preferences and requirements for the optimization of individual stages of production could be continually processed at whichever stage of a supply chain. Incorporating companies into value-chains, thus, enables the optimization of either individual production stages or the entire supply chain.

Moreover, engaging in the Industry 4.0 initiative helps companies to maintain a closer collaboration between business partners (suppliers and customers) and among individual customers with the aim of achieving mutual benefits. [22]

Since the original German initiative was presented, many other countries have put forth their own strategies related to boosting specific industry sectors in line with the Fourth Industrial Revolution (e.g. Chinese "Made in China 2025" or "Advanced Manufacturing Partnership" initiated in the U.S.[23]). Despite all international efforts, it is important to mention that Germany is by now still considered as the leader in industrial automation worldwide.[24]

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[21] Lydon, Bill (2016): Industry 4.0: Intelligent and flexible production. *INTECH*, 63(3), 12-17. [cit. 2018-04-18] Retrieved from http://search.proquest.com/docview/1799786990?accountid=17203

[22] Lydon, Bill (2016): Industry 4.0: Intelligent and flexible production. *INTECH*, 63(3), 12-17. [cit. 2018-05-15] Retrieved from http://search.proquest.com/docview/1799786990?accountid=17203

[23] Liao, Yongxin, Loures, Eduardo Rocha, Deschamps, Fernando, Brezinski, Guilherme, Venâncio, André (2017): The impact of the Fourth Industrial Revolution: a cross-country/region comparison. Production, 28, e20180061. DOI: 10.1590/0103-6513.20180061 [cit. 2018-05-17]

[24] Gerbert, Philipp, Lorenz, Marcus, Rüßmann, Michael, Waldner, Manuela, Justus,Jan, Engel, Pascal a Harnisch, Michael (2015): Industry 4.0: The future of Productivity and Growth in Manufacturing Industries. *BCG* [online]. 2015 [cit. 2018-05-15]. Retrieved from: https://www.bcg.com/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries.aspx

The Fourth Industrial Revolution, thus, provides the opportunity to significantly transform traditional ways of production. In its report from 2015, Boston Consulting Group highlighted nine transformative technologies to accompany this major shift, which apart from the industrial IoT and the horizontal and vertical system integration, include simulation, cybersecurity, cloud computing, additive manufacturing, augmented reality, big data, analytics and autonomous robots. See table below for the complete list of the identified technologies.

Table 1: List of nine transformative technologies

List of Nine Transformative Technologies
Simulation
Horizontal and Vertical Integration
The Industrial Internet of Things
Cybersecurity
The Cloud
Additive Manufacturing
Augmented Reality
Big Data and Analytics
Autonomous Robots

Source: own representation based on Gerbert, Philipp, Lorenz, Marcus, Rüßmann, Michael, Waldner, Manuela, Justus,Jan, Engel, Pascal a Harnisch, Michael (2015): Industry 4.0: The future of Productivity and Growth in Manufacturing Industries. *BCG* [online]. 2015 [cit. 2018-05-15]. Retrieved from: https://www.bcg.com/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries.aspx

The changes brought about by IoT and vertical and horizontal integration have been outlined in the previous paragraphs. To provide a full picture, the remaining seven technologies are going to be briefly discussed in the following lines, to better understand their individual impact.

It is important to note that many of the abovementioned technologies have already been introduced into production previously (many falling under the Third Industrial Revolution), making the transition between the Third and the Fourth Industrial Revolution somewhat blurred. A new feature Industry 4.0 has introduced, however, is their interconnection and full integration within optimized production flow, substituting the prior, traditional approach with isolated departments or "silos".[25] The concept of silos represents a type of corporate mentality

[25] Gerbert, Philipp, Lorenz, Marcus, Rüßmann, Michael, Waldner, Manuela, Justus,Jan, Engel, Pascal a Harnisch, Michael (2015): Industry 4.0: The future of Productivity and Growth in Manufacturing Industries. *BCG* [online]. 2015 [cit. 2018-05-15]. Retrieved from:

where individual company departments are not willing to cooperate by sharing information among each other. This seemingly negligible problem, however, could easily lead to a considerable drop in efficiency and lower morale in the workplace, eventually ruining the overall productivity of a company.[26]

Simulation

The first transformative technology to mention is simulation, which allows customers to interfere with product design through virtual space in phases preceding production, providing valuable insight to producers when adapting processes and/or product features and qualities to customers' expectations. Taking customer needs into consideration, businesses might substantially increase their competitiveness on the market.[27] Another use of simulation is in plant operations, where displaying real-time data in a virtual model allows manufacturers to test and optimize machine settings for production before physically reorganizing the machine, resulting in time savings and quality enhancement.

Autonomous robots

Another separate field consists of autonomous robots which in the meantime, have been developed to be capable of interacting with human employees - either assisting with their work, or learning from them to perform the same tasks on their own. The major advantages of this technology include lower costs of robots and their potential to take over a large scope of various repetitive and tedious activities previously done by their human counterparts. [28]

https://www.bcg.com/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries.aspx

[26] Gleeson, Brent (2013): The Silo Mentality: How to Break Down The Barriers. *Forbes* [online]. [cit. 2018-05-27]. Retrieved from: https://www.forbes.com/sites/brentgleeson/2013/10/02/the-silo-mentality-how-to-break-down-the-barriers/#694c6e198c7e

[27] Mařík, Vladimír et al. (2016): Průmysl 4.0: Výzva pro Českou republiku. Praha: Management Press. [cit. 2018-05-15] ISBN 978-80-7261-440-0

[28] Gerbert, Philipp, Lorenz, Marcus, Rüßmann, Michael, Waldner, Manuela, Justus,Jan, Engel, Pascal a Harnisch, Michael (2015): Industry 4.0: The future of Productivity and Growth in Manufacturing Industries. *BCG* [online]. 2015 [cit. 2018-05-15]. Retrieved from: https://www.bcg.com/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries.aspx

Additive production

Additive production has become a trend or many times even a necessity in cases such as production of customised components or prototypes. The idea is to connect materials, layer by layer on the basis of 3D digital data and 3D print while employing augmented reality.[29]

Augmented reality

Augmented reality complements our real world with a virtual one consisting of objects generated by a computer, making both realities seem to coexist in the real space in the eyes of the observer. Augmented reality is mostly used for activities such as seeing building layouts[30], receiving repair instructions via mobile devices, or organizing a virtual training for personnel.[31]

Big data, cloud and cybersecurity

The newest technology also provides an opportunity for companies to analyse, process and deliver immensely large sets of data (big data) to people, machines and production sites. Furthermore, by using cloud computing, storing information with immediate use is also ensured. The work with data increases production quality, enhances equipment service and contributes to substantial energy savings. Cybersecurity is also a very important issue to tackle, as interconnected production systems need to be secured.[32]

In the end, it is the mutual relation between physical and digital technologies that affect the experience and interaction of customers, employees and parts of business with the organization.[33]

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[29] Mařík, Vladimír et al. (2016): Průmysl 4.0: Výzva pro Českou republiku. Praha: Management Press. [cit. 2018-05-15] ISBN 978-80-7261-440-0

[30] Van Krevelen, Rick (2007): Augmented Reality: Technologies, Applications, and Limitations [online]. 2007-04-18, 25 [cit. 2019-03-23]. Retrieved from: https://www.researchgate.net/profile/Rick_Van_Krevelen2/publication/292150312_Augmented_Reality_Technologies_Applications_and_Limitations/links/56ab2b4108aed5a01359c113/Augmented-Reality-Technologies-Applications-and-Limitations.pdf

[31] Gerbert, Philipp, Lorenz, Marcus, Rüßmann, Michael, Waldner, Manuela, Justus,Jan, Engel, Pascal a Harnisch, Michael (2015): Industry 4.0: The future of Productivity and Growth in Manufacturing Industries. *BCG* [online]. 2015 [cit. 2018-05-15]. Retrieved from: https://www.bcg.com/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries.aspx

[32] BBC: Re-booting industry for the digital age. *BBC* [online]. [cit. 2016-09-30]. Retrieved from: http://www.bbc.com/future/bespoke/specials/connected-world/industry-4-0.html

[33] Cotteleer, Mark, Sniderman, Brenna (2017): Forces of change: Industry 4.0, *Deloitte* [online]. 2017-12-18 [cit. 2018-05-17]. Retrieved from: https://www2.deloitte.com/insights/us/en/focus/industry-4-0/overview.html

Nonetheless, with all those trends and constant pressure on innovations and rapid changes in production, what managers must bear in mind is that it is not necessary to violently introduce any technologies. Initially, one of the possibilities is to gradually integrate sophisticated sensors into production facilities to record and evaluate data to help reveal concrete locations and specific elements of production processes for potential improvement more accurately, or simply to invent new business models. The change needs to happen gradually and in an organized manner. [34]

In addition, embracing Industry 4.0 varies and will vary across industries and countries depending on the way and speed of new technologies' launch. Flexible production will be the key advantage for industries characterised by a greater amount of product variants, e.g. the automotive industry, whereas pharmaceuticals might benefit from higher accuracy, preventing occurrence of errors, owing to more advanced data analytics. Furthermore, countries with higher costs of labour will embrace automation of many repetitive jobs in combination with tackling the increasing demand for highly-skilled employees. On the other hand, countries with young, technology-savvy populations may concentrate on creating new labour opportunities, which nowadays, might be especially relevant for many emerging markets. To give an example, the situation in the UK illustrates that a loss of certain jobs due to automation, precisely 800,000 in the period between 2001 and 2005 could be compensated by the creation of new ones. Only in the UK, the amount of new jobs generated amounted to 3.5 million during the same period.[35]

For the workforce to successfully overcome the new challenges, the shifts and changes on the labour market have to be necessarily accompanied by an up-to-date education system reacting to the constantly changing needs of industry and services as well as sufficient technological infrastructure (fixed- and mobile-broadband services). Close collaboration of governments, industry associations and the business sphere will be needed to prepare the ground for successful realization of Industry 4.0.

Looking into the current engagement of various countries and regions in connection to the Fourth Industrial Revolution, more precisely on the annual investments incurred by local governments, it is clear that U.S. is the leader with its annual investments amounted to 1.96 billion euros, followed by Italy and France with 0.87 and 0.63 billion euros respectively. As a part of its programme referred to as the "Advanced Manufacturing Partnership (AMP)", the

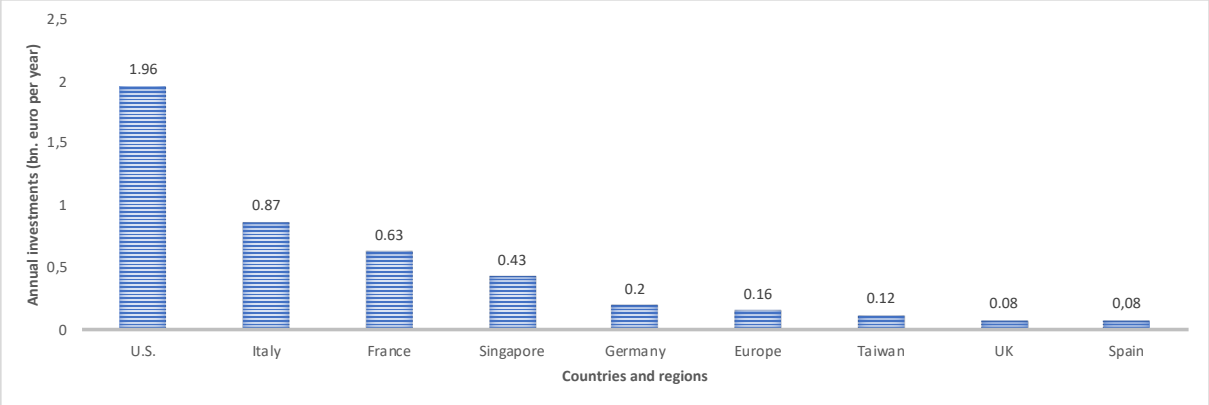
[34] Hannover Messe (2016): Hannover Messe to highlight the benefits of "Industrie 4.0". *Hannover Messe* [online]. [cit. 2018-05-15]. Retrieved from: http://www.hannovermesse.de/en/news/upcoming-hannover-messe-to-highlight-the-benefits-of-industrie-4.0.xhtml

[35] Deloitte (2016): Talent for survival: Essential skills for humans working in the machine age*, Deloitte LLP*, 2016, [cit. 2018-05-17] Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/Growth/deloitte-uk-talent-for-survival-report.pdf

U.S. supports bringing universities, industries and federal government together to fund new technologies and design methodologies, as well as to establish a fruitful innovation environment in general. Italy, U.S.'s immediate follower, has done early state investments under its "Piano Nazionale Industria 4.0" plan for the period of 2017 to 2020, while France has been supporting new industrial projects via subsidies or repayable advances since 2013. The numbers were obtained from those countries and regions whose topic-related documents were accessible to the researchers of the Pontifical Catholic University of Paraná in Brazil, who conducted research into countries' policies related to the Fourth Industrial Revolution. Available data is relevant to those years when information on each country's policy was available. More detailed information and comparison is provided in Graph 1.

The column Europe stands for finances allocated as a part of the European „Horizon 2020"strategy, when Europeans decided to support the so called "Factories of the Future".

Graph 1: Annual investments related to Industry 4.0 based on countries and regions in billion euros per year



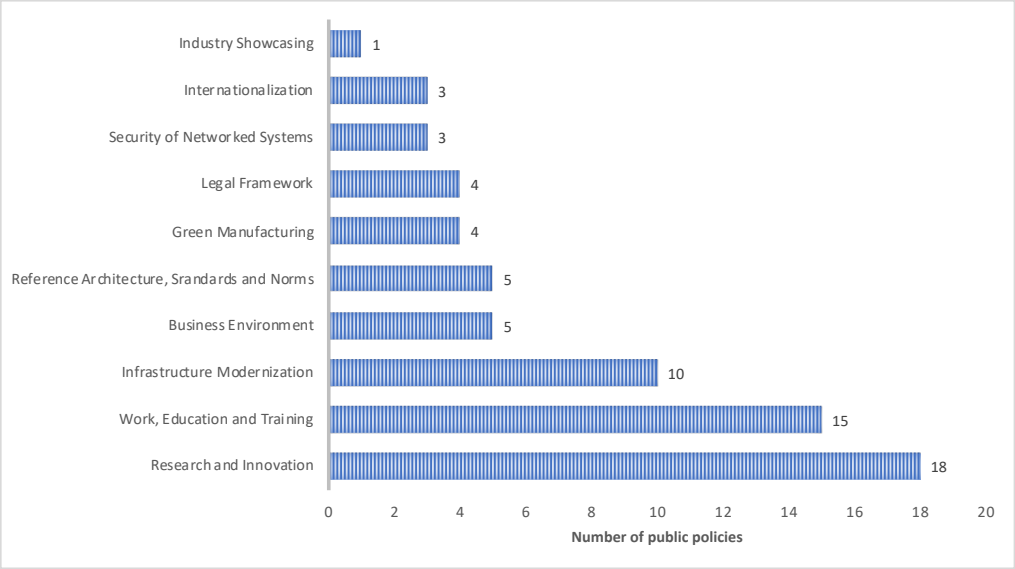
Source: own presentation based on Liao, Yongxin, Loures, Eduardo Rocha, Deschamps, Fernando, Brezinski, Guilherme, Venâncio, André (2017): The impact of the Fourth Industrial Revolution: a cross-country/region comparison. Production, 28, e20180061. DOI: 10.1590/0103-6513.20180061 [cit. 2018-05-17]

The second graph shows the main areas that 18 researched countries[36] and regions predominantly focus on within their public policies. As seen from the graph, all countries and regions allocated budget for research and innovation actions. In terms of work, education and training, 13 countries and 2 regions are active whereas 9 countries and 1 region prioritise modernization of infrastructure as well. In contrast, only one country is interested in industry

[36] Canada, China, Europe, France, Germany, India, Italy, Japan, Malaysia, Mexico, Netherlands, Singapore, South Korea, Spain, Sweden, Taiwan, UK and U.S.

showcasing. [37]

Graph 2: Areas tackled by public policies



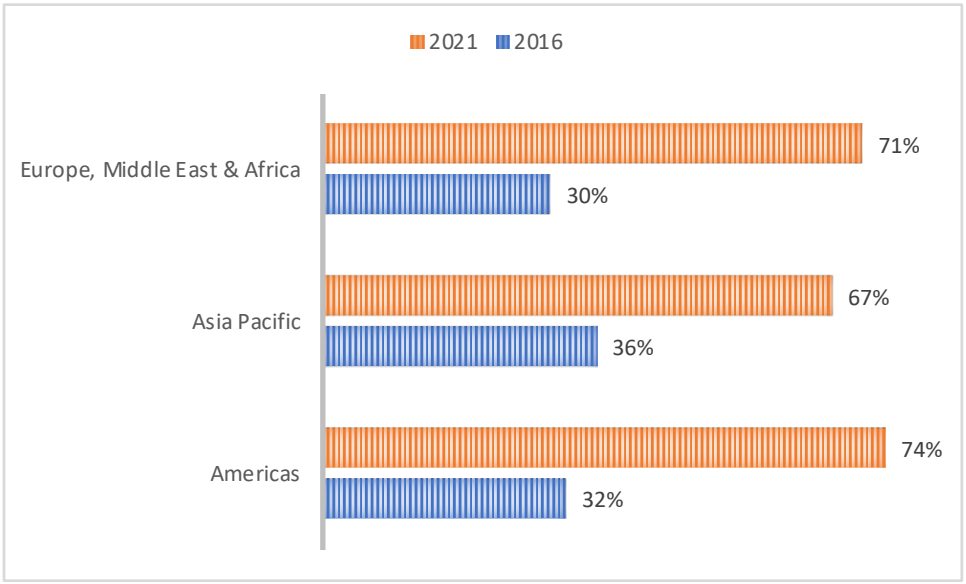
Source: own presentation based on Liao, Yongxin, Loures, Eduardo Rocha, Deschamps, Fernando, Brezinski, Guilherme, Venâncio, André (2017): The impact of the Fourth Industrial Revolution: a cross-country/region comparison. Production, 28, e20180061. DOI: 10.1590/0103-6513.20180061 [cit. 2018-05-17]

The evaluation of the expected level of digitalization across regions worldwide is also in place in this thesis. A study prepared by PricewaterhouseCoopers in 2016 indicates a shift in forecasted digitalization across regions between 2016 and 2021. By looking at Graph 3 it is clear that while the level of digitalization was highest in Asia Pacific in 2016 (36%), subsequent increase in digitalization is going to create changes leading to the Asian region ending up third behind Europe, Middle East & Africa and America, each of them achieving 67%, 71% and 74% respectively. When looking at digitalization more closely, businesses in Germany and Japan focus on internal operations digitalization and horizontal integration to maximise operational efficiency, production quality and to minimise costs. In contrast, the U.S.-based companies digitalize their offerings with the intention to disrupt the existent business models, which eventually enables them to achieve increased revenues. Excelling both in increasing revenues and lowering operation costs, Chinese industrial companies are doing their best to digitalize all labour-intensive production processes.[38]

[37] Liao, Yongxin, Loures, Eduardo Rocha, Deschamps, Fernando, Brezinski, Guilherme, Venâncio, André (2017): The impact of the Fourth Industrial Revolution: a cross-country/region comparison. Production, 28, e20180061. DOI: 10.1590/0103-6513.20180061 [cit. 2018-05-17]

[38] PricewaterhouseCoopers (2016): 2016 Global Industry 4.0 Survey: Industry 4.0: Building the digital enterprise [online]. 2016, p. 36 [cit. 2018-05-17]. Retrived from: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

Graph 3: Percentage of digitalization across regions in 2016 and 2021



Source: own representation based on PricewaterhouseCoopers (2016): 2016 Global Industry 4.0 Survey: Industry 4.0: Building the digital enterprise [online]. 2016, p. 36 [cit. 2018-05-17]. Retrieved from: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

1.3 Global trends and recent development in healthcare

The introduction of Industry 4.0 and the accompanying transformative technologies revolutionized the way plants produce and business is done in many fields. For the purpose of the analysis of the healthcare sector, which is the cornerstone of this thesis, global trends shaping this field are going to be further inspected. Furthermore, several important statistics are going to be included as a proof of the increasing significance of the analysed trends. Issues tackled by new digital solutions in healthcare are going to be discussed and predictions about future development of healthcare are going to be summarised.

With unprecedentedly fast advances driven by technology, stakeholders are on their way to find cost-effective solutions based on innovations for rendering "smart" healthcare services, both inside and outside hospital facilities, the latter being provided at home or ambulatory care facilities. With this in mind, along with the knowledge of the world population increasing in age and number, higher quality of medical care, growth of developing markets and rising labour costs (as many markets compete for better-skilled healthcare providers), global healthcare spending is estimated to soar at a rate of 4.1% annually between 2017 and 2021. However, before moving on in this chapter, it is crucial to put the definition of "smart" healthcare in stark terms.

According to the industry outlook elaborated by Deloitte in 2018, "smart" healthcare consists of several elements. At the centre of it stands the word "appropriate", as not only the treatment provided to a patient is supposed to be appropriate, but also the place and time need to be fitting in order for patients to receive the care they need. The appropriateness of selected medical procedures becomes better in time, since curing a patient is now more precise and goal-oriented. Now, clinicians have modern technology available that enable the more accurate diagnosis and treatment of diseases. At the same time, technology is not the only helpful medium. The human factor remains to be important, as clinicians are able to communicate and make use of information within the whole ecosystem in an effective way. Technology, then, ensures that information stems from data located in one place and that the right individuals devote their time to the right activities. For instance, correct workload distribution and roles assignment prevents medical specialists from being snowed under administrative tasks, tasks easily handled by other, less busy employees or even robots in some cases. This gives clinicians more space and time to use their expert capacity for treating patients, of which information provision and active involvement in the treatment are an essential part. Moreover, new, cost-effective models of healthcare delivery are on the rise, with the potential to make treatments approachable to a larger number of patients, accessible at new, even distant or scarcely resided regions. Overall, the major contribution of "smart" healthcare can be seen in the reduction of the total waste. As the sector increases in efficiency, however, achieving the maximum of those benefits might still prove to be difficult due to the sector's complexity, especially when logistical or technological hindrances arise.

According to Transparency, a U.S. Market Research company, the global market with smart healthcare products is projected to go up at a CAGR of 8.84% in the period of 2015 and 2023, leading to a lift in market's valuation from 31.71 billion dollars (2016) to 57.85 billion dollars (2023).[39]

But there are many pending issues to be tackled before global healthcare can eventually be defined as smart. For the sake of an easier orientation in the discussed areas, the reader might take a look at the following table. The table includes a list of challenges discussed in this sub-chapter that healthcare has to inevitably handle if wanting to drive change and innovation and reap benefits of the Fourth Industrial Revolution.

[39] Transparency Market Research (2016): Smart Healthcare Products Market (By Product Type - Smart Syringes, Smart Pills, Smart RFID Cabinets and Electronic Health Record; By Application - Health Data Storage and Exchange, Monitoring and Treatment, and Inventory Management - Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2015 - 2023: Global Smart Healthcare Products: Snapshot. *Transparency: Transparency Market Research* [online]. 2016-02 [cit. 2019-03-24]. Retrieved from: https://www.transparencymarketresearch.com/smart-healthcare-products-market.htmlhttps://www.transparencymarketresearch.com/smart-healthcare-products-market.html

Table 2: Challenges of the healthcare sector

Challenges
Financial performance
Shift from volume to value
Regulation of risks
Exponential technologies
Improving patients' experience
Staffing shortage
The emergence of new markets
New entrants

Source: Own representation based on Deloitte (2018): 2018 Global health care outlook: The evolution of smart health care [online]. p. 32 [cit. 2018-05-19] and Van Den Heuvel, Roger, Stirling, Christopher, Kapadia, Anuj, Zhou, Jia (2018): *Medical devices 2030: Making a power play to avoid the commodity trap. Thriving on disruption series* [online]. *KPMG*. 01/2018, p. 25 [cit. 2018-05-24]

Financial performance

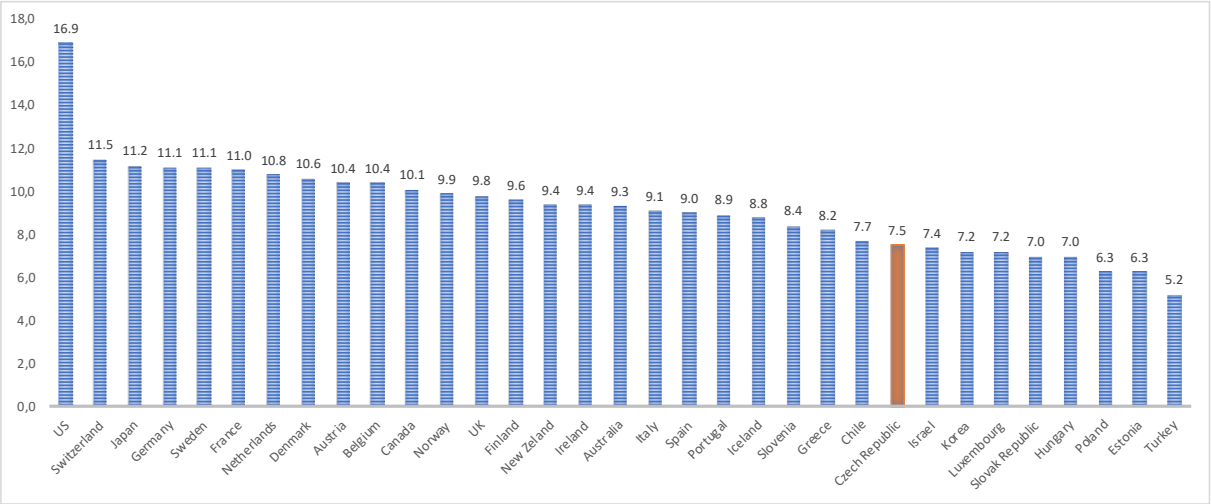
One of those challenges revolves around financial performance and operating margins within public and private healthcare systems. The sector has experienced a huge pressure on its revenues due to a simultaneous increase in costs and a decrease in profit margins. The outlook seems to be the same for upcoming years, since, as a result of increasing life standards, as well as life expectancy, a larger number of office visits and high-quality services are gradually more demanded. At the same time, the sector needs to be prepared for an urgent need to invest into infrastructure and advancements in medical treatment. A huge driver for increased healthcare expenditures is the aging population. To mention an alarming example, the share of those above 65 years is expected to reach 30% of the total population by 2021 in Japan. For the sake of comparison, in Western Europe, this share constitutes approximately 21%.

Another aspect that leads towards a rapid rise in costs is associated with the research on and the eventual treatment of chronic and communicable diseases, the result of our predominantly sedentary, modern lifestyle. To a major extent, this is typical for populations of developed economies.

The current sector spending is illustrated in Graph 4. In 2016, the U.S. was the leader with regards to the share of expenditure of their GDP, reaching 16.9%, with Switzerland coming as the second with its share of 11.5% of GDP. Apparently, the healthcare sector is also a priority for countries such as Japan, Germany, Sweden, France, the Netherlands, Denmark, Austria,

Belgium and Canada, where the healthcare spending accounts for more than 10% of the countries' respective GDP. Healthcare expenditures in Czechia were recorded at 7.5%.

Graph 4: Healthcare expenditures as a share of GDP in 2016



Source: own presentation based on OECD

Across the globe, however, many initiatives are under way, providing opportunities for collaboration in terms of access to innovations, delivery of services and financing models, so that players within the sector may cut costs and provide higher quality services at the same time. Some of those players pursue novel cost-cutting strategies to increase margins. One of the ways to do so includes letting their employees work with accessible intellectual property and thus, creating innovative medical devices, health information technology tools, training videos or simply sell or license IPR to other stakeholders within the industry. Other hospital facilities engage in joint ventures to make use of their foreign assets or they found philanthropic organisations.

Shift from volume to value

Another aspect the healthcare sector has to deal with is the necessary shift from providing volume to delivering value. Current business models work on the basis of a fee-for-service model, where providers are motivated to raise payment rates, their speciality and volume, all eventually leading to creation of separate silos. Thanks to the shift, however, it will be the role of smart hospitals to integrate all processes, so that its elements communicate between each other and information sharing is stimulated by use of information technology. This, in turn, will enable to maximize the value provided.

Supporting government reforming policies plays a key role here. Initiatives introduced in Singapore could serve as a good example, with their focus on automation of labour-intensive

procedures or upskilling workforce. It is, however, essential to pick the right areas for investments.[40] The Institute of Medicine (IOM) presented its calculations pointing to the fact that around 765 billion dollars of U.S. healthcare spending was in vain, when it flowed into services that were no longer necessary.[41]

Moreover, population healthcare management is a new prospective area, that, although being extremely complex and difficult to implement, could support creating greater value in the long run. The idea lies in leveraging data analyses in terms of trends of vulnerable populations in order to keep them safe and healthy, as well as improving the overall effectiveness of the healthcare services provided. Apart from adding value, the model helped focus on prevention rather than the actual treatment of illnesses. The self-interest and easier access to information (mainly regarding patients' genetic profile and effectiveness of various medical procedures) also empowered individuals enough to engage in a proactive behaviour. Consumers have started to download health applications and use wearables monitoring their overall health condition.[42] In the meantime, with 100,000 mobile health applications available, this so-called mHealth market has doubled in only four years.[43]

Regulation of risks

A separate group of challenges that transition towards smart healthcare is going to face is related to government policies and initiatives steered towards the regulation of risks caused by the sector's complexity. In general, each region or country has its own, unique issues to deal with and assume control of, however, the most pressing ones are usually present regardless of the location. Those issues encompass patients' safety, healthcare quality, cyber threats, as well as reduction of fraud occurrence.

Digital health is enabled today by advanced technologies relying on large amounts of data, which needs to be collected, stored and analysed for doctors to provide personalised care. There are many technological solutions facilitating work with patient records. One of them is cognitive computing, a method used for the management and processing of big data that changes rapidly over time. With cognitive computing, it is possible to generate predictive models based on previously collected data that help detect the onset of diseases, identify certain

[40] Deloitte (2018): 2018 Global health care outlook: The evolution of smart health care [online]. p. 32 [cit. 2018-05-19]

[41] National Academies (2012): "Transformation of Health System Needed to Improve Care and Reduce Costs," *news release*, [cit. 2018-05-19]. Retrieved from : http://www8. nationalacademies.org/onpinews/newsitem.aspx?RecordID=13444

[42] Deloitte (2018): 2018 Global health care outlook: The evolution of smart health care [online]. p. 32 [cit. 2018-05-19]

[43] Deloitte (2017): The future awakens: Life sciences and health care predictions 2022, [cit. 2018-05-19]. Retrieved from: https://www2.deloitte. com/uk/en/pages/life-sciences-and-healthcare/articles/healthcare-and-life- sciences-predictions.html, citing mHealth app developer economics 2016. Research2Guidance, 2016. See also: https://research2guidance.com/product/ mhealth-app-developer-economics-2016/

patterns among data or perform patients' segmentation.[44] A frequently used technique is machine learning that enables creation of a 360° patient overview.[45] Thanks to its great precision, it is particularly useful for gaining insight into a patient's medical history and for correctly determining changes in their lifestyle or the choice of optimal treatments.[46] In addition, hospitals are adopting interoperable health records, accessible anytime by cloud solutions. Possible information to be included in those health records encompass patients' financial, clinical, genetic, social and behavioural background. One way to ensure cost-reduction and increase in efficiency is offered by the Internet of Medical Things (adaptation of IoT in healthcare), which has proven especially valuable.[47]

The abovementioned technologies signal the future of healthcare, nevertheless, in order for the applied technology to work properly and for patient data to be duly protected, possible cyberattacks have to be mitigated against. In fact, the health sector is currently the second most prone sector to threatening cyberattacks (in annual terms) right after the financial industry.[48] This topic gains importance especially at times, when patients themselves actively gain control of their overall health condition. It is getting gradually easier to make use of various modern medical devices and applications, or to get information in a less traditional environment, e.g. comfortably at home. Looking at it as a whole, questions of responsibility, information ownership, extent of maximum possible control and protection and opportunities to monetize data, thus, urgently need to be settled.[49] Some of these issues are already being addressed by the European Commission's legislation aimed at mitigating security concerns and data access - General Data Protection Regulation (GDPR), issued in May 2018. Thanks to its enforcement, citizens are now more in control of their personal data and rules applied to digital economy are defined more clearly.[50]

Exponential technologies

Exponential technologies are in high demand, since they accelerate change via turning healthcare delivery into cheaper, more efficient and an accessible set of services worldwide. At

[44] Deloitte (2018): 2018 Global health care outlook: The evolution of smart health care [online]. p. 32 [cit. 2018-05-19]

[45] Deloitte (2017): Cognitive health care in 2027: Harnessing a data-driven approach in personalized health care, *Deloitte University Press*, 2017, [cit. 2018-05-19]. Retrieved from: https://dupress. deloitte.com/dup-us-en/focus/cognitive-technologies/cognitive-health-care- in-2027.html

[46] Virtual Health (2015): VH White Paper: In Pursuit of the 360 Degree Patient View [online]. p. 5 [cit. 2018-05-20]. Retrieved from: https://www.virtualhealth.com/pdf/VH-WHITE-PAPER-360-Degree-Patient-View.pdf

[47] Deloitte (2018): 2018 Global health care outlook: The evolution of smart health care [online]. p. 32 [cit. 2018-05-19]

48 "2017 Data Breach Investigations Report," Verizon Communications, 2017. [cit. 2018-05-20] Retrieved from: [http://www.verizonenterprise.com/verizon-insights-lab/dbir/2017/].

[49] Deloitte (2018): 2018 Global health care outlook: The evolution of smart health care [online]. p. 32 [cit. 2018-05-19]

[50] European Commission: Data Protection [cit. 2018-05-20] Retrieved from: http://ec.europa.eu/justice/data-protection/

the same time, there is a potential to capitalize on synergic effects achieved by the simultaneous use of multiple technologies. The most notable examples of these technologies are synthetic biology, 3D printing, nanotechnology, companion diagnostics, biosensors and trackers. [51]

Briefly, the purpose of synthetic biology, which combines biology and engineering, is to construct DNA, genomics and proteomics. After obtaining sufficient information about one's DNA sequencing, 3D printing may be used to print a new issue for a patient. [52] In other cases, when a clinician is in the role of selecting the appropriate treatment for their patient, companion diagnostic could facilitate their decision, as with the help of imaging tools or diagnostics in laboratories, crucial additional information may be provided. Therefore, the era of trial-and-error methods is about to end, considerably contributing to the cost and risk reduction.[53]

Improving patients' experience

Important actions need to be undertaken towards the improvement of patients' experience. As shown in a study conducted by Deloitte, ideas of an optimal patient experience vary across generations. While younger patients between 16 and 24 value communication, as well as sensitivity during doctors' exams, with people above 65 years, the physician has to put emphasis on clear communication both during the exam and the follow-up. [54] Identifying communication as a top priority, a patient now has an omni-channel access, that connects them with their healthcare provider almost immediately via software apps, portals, self-check-in kiosks or personalised digital information kits.[55]

Increasingly, more attention is directed towards social media, telehealth, virtual and augmented reality. Social media serve as an important source of patients' data, aiding to personalize healthcare based on certain health trends.

Furthermore, with its focus on prevention, telehealth is gaining popularity among consumers, as it manages the monitoring of patients' health condition and reduces the number of doctors' visits they would otherwise have to undertake. Prevention could be also enhanced by interactions with a patient inside an artificially generated environment, enabled by augmented or virtual reality and by exposing them to a simulated, almost real-like experience.

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[51] Deloitte (2018): 2018 Global health care outlook: The evolution of smart health care [online]. p. 32 [cit. 2018-05-19]

[52] Deloitte (2017): My Take: In an era of exponentials, health care is on the cusp of a potential major transformation," Health Care Current, [cit. 2018-05-20]. Retrieved from: https://www2.deloitte.com/us/en/pages/ life-sciences-and-health-care/articles/health-care-current-october3-2017. html?id=us:2em:3na:hcc:awa:chs:100317#1

[53] Deloitte (2016): 2016 Global health care outlook: Battling costs while improving care, [cit. 2018-05-20]

[54] Deloitte (2018): 2018 Global health care outlook: The evolution of smart health care [online]. p. 32 [cit. 2018-05-19]

[55] Deloitte (2017): The hospital of the future: How digital technologies will change hospitals globally, [cit. 2018-05-19] Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Life-Sciences-Health-Care/us-lshc-hospital-of-the-future.pdf

One of the possible use cases is to encourage a patient to break their unhealthy habits in a more effective way.[56]

Health facilities prioritizing the improvement of customer experience reap many benefits in the long run, usually those associated with strengthened customer loyalty, better reputation and positive word-of-mouth marketing.[57] For hospitals, this means operating in a more business-like way. Starting with market segmentation, catering to increasing patients' needs and effective communication could all eventually contribute to better customer retention.[5859]

Staffing shortage

The problem of staffing shortage is present globally. The situation gets even more serious when we look at the scarcity of skilled, strategically-thinking leaders willing and capable of bringing about all the changes discussed in this chapter. In many countries, the staff feels to be discouraged, underpaid, sometimes even on the brink of burnout due to the extreme workload and pressure to make the right choices at the right time.

Although appointing a capable leader could stimulate technological changes, the problems with gradually increasing demands on a rather low number of healthcare workers will have to be solved in a different fashion. Predictions point out that upskilling employees will play a crucial role, since they will soon have to work co-ordinately, side-by-side with robots in years to come. Those changes could dramatically alleviate the perceived burden, as, thanks to robots, healthcare specialists would have more capacity to devote their working hours to core activities, with more priority given to communication, care, treatment, correct diagnosis (point-of-care (POC) diagnostics) and a better use of analytical and interpersonal skills in the decision-making process. On the other hand, technology driven workforce will replace staff in repetitive, manual or administrative processes, while helping physicians arrive at better decisions based on a precise analysis, reducing errors and enhancing overall productivity.[60]

[56] Deloitte (2018): 2018 Global health care outlook: The evolution of smart health care [online]. p. 32 [cit. 2018-05-19]

[57] Deloitte (2017): 2017 Global Health Care Outlook: Making progress against persistent challenges, [cit. 2018-05-21] Retrieved from: ttps://www2.deloitte.com/us/en/pages/life-sciences- and-health-care/articles/global-health-care-sector-outlook.html

[58] Deloitte (2018): 2018 Global health care outlook: The evolution of smart health care [online]. s. 32 [cit. 2018-05-21]

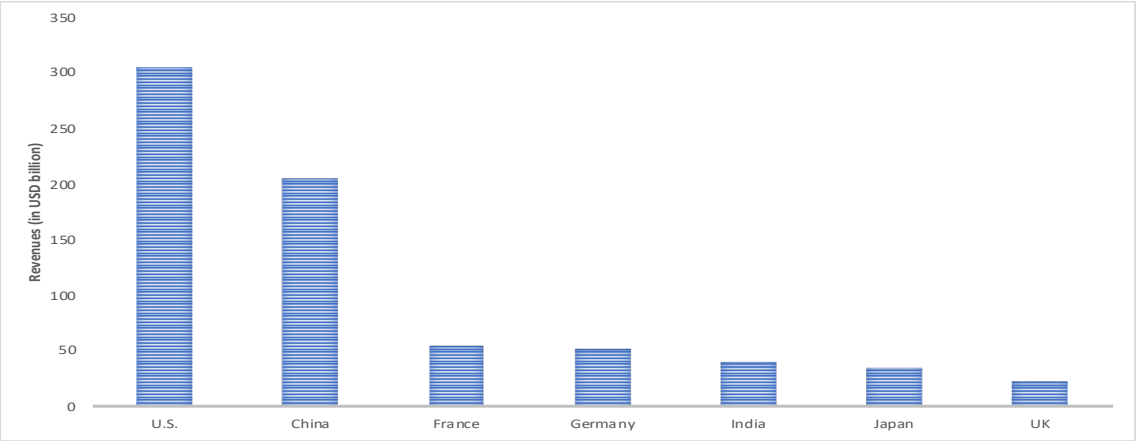
[59] National Academies (2012): "Transformation of Health System Needed to Improve Care and Reduce Costs," *news release*, [cit. 2018-05-20]. Retrieved from: http://www8. nationalacademies.org/onpinews/newsitem.aspx?RecordID=13444

[60] Deloitte (2018): 2018 Global health care outlook: The evolution of smart health care [online]. p. 32 [cit. 2018-05-19]

The emergence of new markets

A different perspective on the future of healthcare is brought by KMPG (2018), which adds emergence of new markets as one of the most marked changes in the global healthcare sector. The largest ones are captured in Graph 5.

Graph 5: The largest medical device markets based on revenues (USD billion) by 2030



Source: own presentation based on industry reports of each country[61][62][63][64][65][66][67]

When evaluated by forecasted revenues, there are going to be seven major markets with accelerated growth of opportunities for well-established incumbents and new entrants to the medical device industry by 2030.[68] Not changing its position, the U.S. will keep its dominance with its revenues exceeding 300 billion dollars.[69] China is going to be the second largest market,

[61] Emergo: USA - Overview of medical device industry and healthcare statistics, *Emergo website*, [cit. 2018-05-22] Retrieved from: https://www.emergogroup.com/resources/market-united-states

[62] Export.gov (2017): China - Medical Devices, China Country Commercial Guide, *US export.gov website*, [cit. 2018-05-22] Retrieved from: https://www.export.gov/article?id=China-Medical-Devices

[63] Export.gov: France - Medical Equipment, France Country Commercial Guide, *US export.gov website*, [cit. 2018-05-22] Retrieved from: https://www.export.gov/article?id=France-Medical-Equipment

[64] Export.gov: Germany - Medical Equipment, Germany Country Commercial Guide, *US export.gov website*, [cit. 2018-05-22] Retrieved from: 2017 https://www.export.gov/article?id=Germany-Medical-Technologies

[65] Khaleej Times: Medical Devices Manufacturing in India: A Sunrise Segment, *Khaleej Times*, [cit. 2018-05-22] Retrieved from: https://www.ibef.org/arab-heatlh-2017/download/EEPC-IBEF-Arab-Health-Supplement-30-Jan-201.pdf

[66] Pacific Bridge Medical: Japan Medical Market, *Pacific Bridge Medical*, [cit. 2018-05-22] Retrieved from: http://www.pacicbridgemedical.com/target-asian-markets/japan-medical-market/

[67] Export.gov: United Kingdom - Medical Equipment, United Kingdom Country Commercial Guide, *US export.gov website*, [cit. 2018-05-22] Retrieved from: https://www.export.gov/article?id=United-Kingdom-Medical-Equipment

[68] Van Den Heuvel, Roger, Stirling, Christopher, Kapadia, Anuj, Zhou, Jia (2018): Medical devices 2030: Making a power play to avoid the commodity trap. Thriving on disruption series [online]. *KPMG*. 01/2018, p. 25 [cit. 2018-05-24]

[69] Emergo: USA - Overview of medical device industry and healthcare statistics, *Emergo website*, [cit. 2018-05-24]. Retrieved from: https://www.emergogroup.com/resources/market-united-states

with its sales over 200 billion dollars. This number stands for one quarter of the global market.[70] The third largest non-European market by revenues, India, is going to account for 40 billion dollars. The pace of growth is for both China and India twice as high as achieved by the global medical device market, stimulated by major reforms in the field of healthcare as well as other government incentives, combined with an increasing demand for healthcare services in both countries.[71] In addition, they are both developing themselves into innovation hubs. In this manner, India is engaged in the so-called frugal engineering that helps local producers come with low-cost medical devices with significant potential to the market.[72] Frugal engineering gives the opportunity to produce more, while using considerably less resources. (The term was coined by CEO of Renault-Nissan, Carlos Ghoshn).[73]

If a business considers entering any of those markets, they would have to pay close attention to market differences. Not only a specific, well-thought-out strategy has to be applied, but also further investments often come in place. In order to succeed, a new entrant is often supposed to understand local sales and distribution channels, and/or join forces with local value chain stakeholders and most importantly, take into account different legislation.

As far as European medical device markets are concerned, France and Germany are definite leaders.

New entrants

Similarly to other industries, new, technology-driven business models are very likely to cause disruptions in the way healthcare services are provided by identifying opportunities to deliver higher value to patients at lower costs. As a result, value chains typical for this market will have to eliminate several redundant elements. For companies it is important to remember that a threat of new competitors might be very unpredictable and apart from technology companies that are most likely to pose a threat, even players from completely unexpected industries, e.g. gaming, might enter the market and "change the rules of the game". Probably

70 Export.gov (2017): China - Medical Devices, China Country Commercial Guide, *US export.gov website*, [cit. 2018-05-24]. Retrieved from: https://www.export.gov/article?id=China-Medical-Devices

71 Business Standard: India can be among world's top 5 medical devices markets, *Business Standard*, [cit. 2018-05-24]. Retrieved from: http://www.business-standard.com/content/b2b-pharma/india-can-be-among-world-s-top-5-medical-devices-markets-himanshu-baid 117021500535_1.html

72 Van Den Heuvel, Roger, Stirling, Christopher, Kapadia, Anuj, Zhou, Jia (2018): Medical devices 2030: Making a power play to avoid the commodity trap. Thriving on disruption series [online]. *KPMG*. 01/2018, p. 25 [cit. 2018-05-24]

73 Kumar, Nirmalya, Puranam, Phanish, Puranam, Phanish (2012): Frugal engineering: An emerging innovation paradigm. *Ivey Business Journal* [online].[cit. 2018-05-24]. Retrieved from: https://iveybusinessjournal.com/publication/frugal-engineering-an-emerging-innovation-paradigm/

the most dangerous competitors are those who are willing to temporarily give up their profits in order to gain a large market share as quickly as possible.[74]

Amazon might serve as a good example of a game changer at this point. Thanks to its robust logistic infrastructure and vast customer base, it was able to manoeuvre towards healthcare, selling items such as syringes, gloves and medical accessories for dentists, physicians and hospitals in general. The increased competition led to drop in prices and margins, putting other players on the market under pressure.

Another successful business strategy could be to establish contact with various stakeholders on the medical device market, where new possibilities for cooperation occur in terms of creating additional value for consumers. To illustrate, Google partners with Ethicon in their common initiative called Verb Surgical to devise smart surgical robots capable of image data reading and analyses enabled by AI.[75]

Finally, in order to understand how medical product offerings changed in the course of time, the following brief discourse is included. This is going to provide an explanation for how value creation evolved in time and what new entrants should nowadays especially focus on.

Approximately between 1920s and 1980s, the differentiation of healthcare product offering was realized through innovations executed on the products offered, without the provision of any additional services, and so, the value created was fairly low. Later, in the following period, just until 2010, healthcare providers expanded their product by a wide range of accompanying services rendered to payors, physicians and other providers. This caused a considerable shift towards the offerings' higher value.

Now, however, with digital transformation being strongly present, businesses are gradually more apt to gain competitive advantage against competitors through operations efficiency and the implementation of new customer channels and services, which lead to the historically best product value offered to their customers.[76]

[74] Van Den Heuvel, Roger, Stirling, Christopher, Kapadia, Anuj, Zhou, Jia (2018): Medical devices 2030: Making a power play to avoid the commodity trap. Thriving on disruption series [online]. *KPMG*. 01/2018, p. 25 [cit. 2018-05-24]

[75] Mass Device (2016): J&J and Google's Verb Surgical looks to define, lift robotic surgery, *Mass Device*, [cit. 2018-05-24]. Retrieved from: http://www.massdevice.com/jj-googles-verb-surgical-looks-de ne-lift-robotic-surgery

[76] Hosseini, Morris (2015): What will the future look like under Industry 4.0 and digital transformation in the healthcare space?. *In: Roland Berger Strategy Consultants* [online]. Stuttgart, 21/04/2015, p. 19 [cit. 2018-05-26]

2. The healthcare system and digitalization in Czechia

Drawing on the discussed trends and our understanding of the functioning of the global healthcare sector, the focus is going to be narrowed down to the national level.

The overall future outlook on the sector is going to be tackled in the first part of this chapter. This part is going to look into the digital infrastructure, as well as technology access and savvy of the Czech population constituting the indispensable macroenvironment for new technologies and innovation to thrive on.

Since the healthcare system differs across countries and regions, it is necessary to continue with a description of its current state in Czechia. An overview of the regulatory environment, politics, its future direction and a complex assessment on an international scale are going to be included.

The chapter is going to be concluded by the introduction of some of the most significant domestic market players engaged in healthcare innovations to better understand which market opportunities have already been discovered and taken advantage of.

2.1 The state of digitalization in Czechia

One of the goals of this chapter is to provide an understanding of the changes which Czechia is about to introduce within the healthcare sector. Yet, the successful adaptation of digital strategies depends on the readiness of the country as such to a large extent. What is the level of availability of digital technology to the general public? Does the country dispose of developed digital infrastructure upon which other services could be build? How did businesses and the government embrace digitalization in Czechia? Answers to those questions could be provided by analysing country data on digital economy, while comparing them either to those of similar economies or to digital leaders. The Digital Economy and Society Index (DESI), developed by the European commission, serves as a leading tool to track the country's progress in the field of digitalization. It is the role of the European Commission to prepare yearly country reports of all 28 EU-members to assess five main groups entailing indicators such as connectivity, human capital, use of internet services, integration of digital services and digital public services. At this point, each group is going to be discussed to better grasp the potential of Czechia to digitize healthcare and indicate the Czech digital environment's maturity level that businesses could further build on.

Czechia places significant importance on the society's digitalization and therefore positive results might be attributed to the effort the country puts on creating the so called

"Society 4.0". Society 4.0 marks the societal impact of processes accompanying the spread of Industry 4.0. The country's leaders understood that this new phenomenon changes the whole system of value-chains and the relations among customers, producers and suppliers. This prompted important debates among relevant actors at the national level, serving as indispensable milestones of the society's transformation. The present government established the function of a digital coordinator in 2016, whose tasks include the coordination of the Alliance Society 4.0 (Aliance Společnost 4.0), the national digital agenda, steering collaboration between economic and social partners and representatives of the academic and scientific community. His other important goal relates to engaging ministries, economic and social partners and IT businesses into a more profound communication. In April 2017, Ondřej Malý was appointed to this position thanks to his background in telecommunication and IT.[77] In the same year, the Czech government also approved of the national action plan for the Society 4.0 (Akční plán ke Společnosti 4.0) and the principles for creating digital-friendly legislation (Zásady pro tvorbu digitálně přívětivé legislativy)[78]. The action plan introduces priorities in five key areas – industry, business and competitiveness, education and labour market, connectivity and mobility, the computerization of public administration, and security.[79]

According to the 2018 DESI report, Czechia was ranked 17th in general terms which places it to the cluster of medium-performing countries, together with Austria, France, Germany, Latvia, Lithuania, Malta, Portugal, Slovenia and Spain. All groups of digital indicators showed improvement, except for the integration of digital technologies, where Czechia underperformed compared to 2017. Slightly less satisfactory results were observed from the share of mobile broadband users. On the other hand, the current score of 4G coverage was exceptionally high (99%).[80]

The following table illustrates comparison of Czechia with the EU and the abovementioned group of medium-performing countries ("Group")[81] across all five DESI categories – connectivity, human capital, the use of the Internet services, integration of digital technology and digital public services - between 2017 and 2018.

[77] Digiczech: Koordinace. *Digiczech* [online]. [cit. 2018-12-07]. Retrieved from: https://digiczech.eu/koordinace/

[78] Úřad vlády České republiky (2017): První krok k digitálně přívětivě legislativě. *Úřad vlády České republiky* [online]. [cit. 2018-12-07]. Retrieved from: https://ria.vlada.cz/prvni-krok-k-digitalne-privetive-legislative/

[79] European Commission: Index digitální ekonomiky a společnosti 2018: zpráva o České republice [online]. 11 [cit. 2018-12-07]. Retrieved from: https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic

[80] European Commission: Index digitální ekonomiky a společnosti 2018: zpráva o České republice [online]. , 11 [cit. 2018-12-07]. Retrieved from: https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic

Table 3: Comparison of Czechia with the EU and the Group across the DESI categories between 2017 and 2018

	DESI 2017			DESI 2018		
	Czechia	EU	Group	Czechia	EU	Group
CONNECTIVITY						
Ranking	16	x	x	**16**	x	x
Score	59.0	58.5	58.8	**63.9**	**62.6**	**62.4**
HUMAN CAPITAL						
Ranking	13	x	x	**13**	x	x
Score	53.1	54.6	56.5	**55.1**	**56.5**	**58.6**
USE OF THE INTERNET SERVICES						
Ranking	21	x	x	**20**	x	x
Score	43.0	47.5	45.0	**46.5**	**50.5**	**48.3**
INTEGRATION OF DIGITAL TECHNOLOGY						
Ranking	11	x	x	**13**	x	x
Score	40.8	36.7	38.5	**40.4**	**40.1**	**42.1**
DIGITAL PUBLIC SERVICES						
Ranking	23	x	x	**22**	x	x
Score	44.7	53.7	54.9	**50.2**	**57.5**	**58.5**

Source: Own representation based on European Commission: Index digitální ekonomiky a společnosti 2018: zpráva o České republice [online]. 11 [cit. 2018-12-07]. Retrieved from: https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic

Connectivity

The indicators on connectivity point out that although being in line with the EU-average, Czechia has not made any significant progress (16th place in 2018) compared to the previous year. Higher than the EU-average position was achieved in areas such as 4G coverage, next generation assess coverage, ultrafast broadband coverage, ultrafast broadband take-up and even fixed broadband coverage. The growth in the number of subscribers to fast broadband is more characteristic of well-developed urban areas and the uptake in ultrafast broadband could be solely attributed to new market entrants. In order to compensate on a weaker connectivity in rural areas, the government decided to rely on the EU funds of the Enterprise and Innovations for Competitiveness Operational Programme that is expected to supply broadband access to around 500,000 Czech households by 2023. [82]

[82] European Commission: Index digitální ekonomiky a společnosti 2018: zpráva o České republice [online]. 11 [cit. 2018-12-07]. Retrieved from: https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic

Human capital

Human capital is one of the two areas where Czechia tends to score the best (the other one is Integration of Digital Technology). In 2018 as well as in 2017, the country managed to finish on the 13th place. Detailed information relates to the population's improving digital skills, its higher online presence and regular use of the Internet.[83] Despite this positive news, the lack of ICT specialists constitutes an ongoing problem, reported by about two thirds of Czech businesses interested in recruiting an ICT personnel in 2017.[84]

Even in the area of human capital, the Czech government tries to stay active and satisfy the increasing demand for ICT education and qualifications of its citizens brought about by Industry 4.0. For now, two strategies have been formulated, the Digital Education Strategy and the Digital Literacy Strategy, important tools to support both open and lifelong education, computational thinking as well as digital literacy. [85] Moreover, the purpose of The National Coalition of Digital Jobs is to ensure an effective and up-to-date educational system, mainly via facilitating an effective dialogue among relevant actors, to be able to provide life-long learning opportunities for those interested in bettering their digital skills.[86]

Use of the Internet Services

When it comes to the frequency of Internet usage, it needs to be highlighted that the country succeeded in moving up in the ranking (from the place 21 in 2017 to 20 in 2018). As compared with other EU-citizens, significantly more Czechs read online newspapers (91% as compared with 72% EU-average) and process online banking transactions (67% as compared with 61%). On the other hand, their propensity to shop online is still slightly lower than that of the EU-average despite the difference gradually diminishing.[87] The most common online shoppers are identified as female university graduates between the age of 25 and 34.[88] Generally, Czechs do less video calls, use social networks to a smaller extent and even play less

[83] European Commission: Index digitální ekonomiky a společnosti 2018: zpráva o České republice [online]. 11 [cit. 2018-12-07]. Retrieved from: https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic

[84] European Commission, Digital Scoreboard

[85] European Commission: Index digitální ekonomiky a společnosti 2018: zpráva o České republice [online]. 11 [cit. 2018-12-07]. Retrieved from: https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic

[86] Národní ústav pro vzdělávání (2017): Czech National Digital Skills and Jobs Coalition. *Národní ústav pro vzdělávání* [online]. 2017 [cit. 2018-12-07]. Retrieved from: http://www.nuv.cz/bloky-titulka/zvyraznena-aktualita-en/a2?lang=2

[87] European Commission: Index digitální ekonomiky a společnosti 2018: zpráva o České republice [online]. , 11 [cit. 2018-12-07]. Retrieved from: https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic

[88] Median, s.r.o. (2017): Digitální gramotnost: Zpráva o stavu a výuce digitální gramotnosti a komparace se zahraničím [online]. *Median, s.r.o.,* 2017-08, , 35 [cit. 2019-03-31]. Retrieved from: https://www.mpsv.cz/files/clanky/31592/Digitalni_gramotnost_reserse.pdf

music, videos and games. The most striking difference may be observed from the percentage of individuals using videos on demand (4% to 21% across EU).[89]

Integration of Digital Technology

Despite the Integration of Digital Technology being one of the best performing digital-related areas for Czechia, the score reached in 2018 was lower than that of the previous year. Good news is, however, that Czechia advanced to a higher rank (from 20th place to 21th place). There was a decline in the percentage of businesses using electronic information sharing, the percentage of SMEs operating their sales online and also the percentage of e-commerce turnover of SMEs. Interestingly enough, with the e-commerce turnover of 16.3% and sales online of 22.9%, Czechia still positions itself above the EU-average (10.3% and 17.2% respectively).[90] Further advances in this field are envisaged to be co-financed from the Enterprise and Innovation Operational Programme. Many support programmes have a basis at the national level.

The digital activity of enterprises is stimulated by various initiatives, one of them being the possibility to apply for Innovation Vouchers[91], a valuable instrument for fostering collaboration and knowledge-sharing between SMEs and research organizations.[92]

Digital Public Services

The area of Digital Public Services is the most difficult area for Czechia to outperform some of its EU-peers in. Especially, the intensity of online interactions between Czech citizens and the government is one of the weakest ones. Still, some of the government's initiatives have proven effective and the amount of data prefilled in online forms as well as administrative steps concerning major life events conducted online (expressed in percentage) grew rapidly. The year 2017 was marked by facilitating secure access to e-government services, where two laws were passed by the government, both contributing to Czechia's advancement by one place in the ranking (from 23rd to 22nd place).

[89] European Commission: Index digitální ekonomiky a společnosti 2018: zpráva o České republice [online]. 11 [cit. 2018-12-07]. Retrieved from: https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic

[90] European Commission: Index digitální ekonomiky a společnosti 2018: zpráva o České republice [online]. 11 [cit. 2018-12-07]. Retrieved from: https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic

[91] European Commission: Index digitální ekonomiky a společnosti 2018: zpráva o České republice [online]. 11 [cit. 2018-12-07]. Retrieved from: https://ec.europa.eu/digital-single-market/en/scoreboard/czech-republic

[92] Agentura pro podnikání a inovace: Inovační vouchery. *Agentura pro podnikání a inovace* [online]. [cit. 2019-03-31]. Retrieved from: https://www.agentura-api.org/programy-podpory/inovacni-vouchery/

The law on electronic identification is historically the first one to set rules for Czech citizens taking part in the process of electronic identification. Its main contribution is enabling to prove the individual's identity via online means, remotely and comfortably in every life situation.[93]

The second one is the amendment to the law on citizen's identity cards, that came in force in June 2018, thanks to which e-ID cards were established and issued. With this regulation, the Czech government promises greater security and simplification of administrative procedures to its citizens. Such an ID card is issued with many new functionalities like opportunity to vote online, or its use for healthcare insurance and pension provision that could be potentially activated for full use in the near future.[94]

2.2 Current state of the Czech healthcare system

The Czech healthcare system is generally considered stable. Being based on public health insurance, it provides general coverage with a generous array of paid services. Since its origins in 1920s, little has been changed in terms of its institutional functioning. The main administrative and regulatory body is the Ministry of Health of the Czech Republic. The Ministry is the owner of some of the healthcare providers, in particular all university hospitals and some of the psychiatric facilities, nevertheless, since 2003, some of the hospitals are owned by regional authorities. The collection of contributions and provision of benefits are the responsibility of individual self-governing health insurance companies.[95] The General Health Insurance Company (Všeobecná zdravotní pojišťovňa) is the largest, being responsible for round 60% of the Czech population. Managed by a special act, the insurance company's payment obligation is strictly supervised by the state.[96]

Since 2008, the State Institute for Drug Control (Státní ústav pro kontrolu léčiv - SÚKL) operates as the official regulatory body for drug pricing and reimbursement. However, some

[93] Ministerstvo vnitra České republiky (2017): Senát schválil zákon o elektronické identifikaci. *Ministerstvo vnitra České republiky* [online]. 2017 [cit. 2018-12-08]. Retrieved from: https://www.mvcr.cz/clanek/senat-schvalil-zakon-o-elektronicke-identifikaci.aspx

[94] Ministerstvo vnitra České republiky Vláda schválila novelu zákona o občanských průkazech. *Ministerstvo vnitra České republiky* [online]. [cit. 2018-12-08]. Retrieved from: https://www.mvcr.cz/clanek/vlada-schvalila-novelu-zakona-o-obcanskych-prukazech-570989.aspx

[95] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, *OECD Publishing, Paris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]

[96] Health Insurance Bureau (2018): Health insurance system in CZ: A Brief Summary of the Czech Public Health Insurance System:. *Health Insurance Bureau* [online]. 2018-02-12 [cit. 2019-03-24]. Retrieved from: https://www.kancelarzp.cz/en/links-info-en/health-insurance-system-in-cz

find its decision-making processes rather bureaucratic, focusing extensively on formal and legal transparency.[97]

In view of the direction of the sector's advancement in recent years, particular attention is going to be paid to characteristics inherent in the Czech healthcare system. The goal is to summarize and briefly describe all areas that are either successful cases of the sector's advances or present a burden to the system's operations and quality enhancement.

Implementation of reforms

A strong need for healthcare reform has been identified over the past ten years, aiming at increasing efficiency and transparency of healthcare provision, improvement of data systems and scaling down the costs. Despite many efforts, however, the implementation itself turns out to be problematic and usually changes are delayed. The Diagnosis Related Groups qualification system (DRG) may be considered a successful implementation case, which has become the most widely used payment method in the area of acute hospital care in the course of ten years.[98] The system enables an effective distribution of financial sources to healthcare providers based on the average costs of treatment of patients belonging to one of 500 identified diagnostic groups.[99] In this way, long-term care, rehabilitation and outpatient services are financed based on a capped fee of services provided. Furthermore, a successfully operating redistribution system tackles the financial imbalance among insurance companies. In 2018, the redistribution system was planned on being extended by pharmaceutical cost groups. [100]

Healthcare expenditures

As compared with other EU-countries, healthcare expenditures have been one third lower than the EU-average (1, 841 euros and 2, 797 euros per capita respectively), while still being higher than in the majority of newer EU members in 2015. Even though healthcare expenditures only amounted to 7.3% of GDP (EU average is around 10% of HDP), Czechia

[97] Gulácsi, László, Rotar, Alexandru M., Niewada, Maciej, Loblová, Olga, Rencz, Fanni, Petrova, Guenka, Boncz, Imre, Klazinga, Niek S. (2014): Health technology assessment in Poland, the Czech Republic, Hungary, Romania and Bulgaria. *The European Journal of Health Economics* [online]. 15 (S1), 13-25 [cit. 2019-03-31]. DOI: 10.1007/s10198-014-0590-8. ISSN 1618-7598. Retrieved from: http://link.springer.com/10.1007/s10198-014-0590-8

[98] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, *OECD Publishing, Paris/European Observatory on Health Systems and Policies, Brussels*. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]

[99] Mladá fronta (2011): Lidé se musí naučit systém DRG používat. *Madá fronta* [online]. 2011-06-02 [cit. 2018-11-24]. Retrieved from: https://zdravi.euro.cz/denni-zpravy/z-domova/lide-se-musi-naucit-system-drg-pouzivat-460083

[100] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, OECD Publishing, *Paris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]

had the fourth highest share of public financing (82.4%), after Germany, Denmark and Sweden, according to data obtained in 2015.[101] A year later, healthcare expenditures were still at a similar level of 7.2 % of GDP.[102] On the other hand, private expenditures make up only 14.8% of all healthcare expenditures and predominantly comprise of direct expenditures on over-the-counter medications, medical products and other services not covered by the public health insurance.[103]

Number of acute beds

The number of acute beds in Czechia still remains to be slightly above EU-average, even despite efforts made to decrease their number. The number of all hospital beds for patients is strikingly above that of an average European country. The rate of hospitalization is another important indicator to look at in this regard, as it shows accessibility of hospital beds (especially access to long-term care). In contrast with 173 patients on the EU level, in Czechia there are 206 hospitalized patients per 1000 inhabitants. This not only provides the reader with a better understanding of the existence of excessive capacity, but also leads to question the overall system's efficiency.[104]

State of healthcare facilities

Another problem the Czech healthcare has already been facing for a long time is the quality of healthcare facilities. Many psychiatric, long-term care and nursing facilities, as well as smaller rural hospitals are in urgent need of modernization, but tackling the problem remains to be difficult due to the facilities' large number and low levels of healthcare spending.[105] In the face of recurring calls for modernization, Czechia decided to take advantage of European Structural and Investment Funds (ESIF) available in the programming period of 2014 – 2020 with the aim to modernize the healthcare infrastructure, build capacity in data collection and processing and develop human resources.

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[101] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, OECD Publishing, *Paris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]

[102] OECD (2018): Strukturální kapitola - Zlepšení systému zdravotní péče v České republice [online]. *OECD*, 2018-07 [cit. 2019-03-30]. Retrieved from: http://www.oecd.org/eco/surveys/economic-survey-czech-republic.htm

[103] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, OECD Publishing, *Paris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]

[104] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, OECD Publishing, *Paris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]

[105] OECD (2018): Strukturální kapitola - Zlepšení systému zdravotní péče v České republice [online]. *OECD*, 2018-07 [cit. 2019-03-30]. Retrieved from: http://www.oecd.org/eco/surveys/economic-survey-czech-republic.htm

Interestingly enough, even though the legislation clearly defines the minimum requirements on technical equipment and hospital staff, no immediate sanctions are applied in case of non-compliance. Moreover, only some aspects of healthcare quality have to be reported, which makes it impossible for both patients and health insurance companies to make informed decisions. Only by making the whole system transparent could quality and security projects work properly. It is the goal of the implementation of the national eHealth system to interconnect data systems, to enable systematic performance monitoring and to help them both go in line with strategic planning.[106] So far, however, the eHealth system has not been implemented.[107]

Labour force

A positive news is that the total number of employees is similar to that of an EU-average. Nevertheless, what might be alarming is their age, education and expectations structure. The average age of a doctor is rapidly getting higher, in 2016, 30% of general practitioners were older that or at least reached 60 years. Job preferences also matter, as doctors give priority to working in large city hospitals and many of them are convinced of having access to better working conditions abroad. This, in turn, leads to a gradually smaller representation of quality specialists in rural areas and a threat of brain drain when it comes to the choice of Czechia as a final working destination for medical graduates. To illustrate, the number of specialists in the capital city, Prague, is at least twice as high as in rural areas. In order to compensate for longer waiting times and quality provided, patients tend to move across regions, in most cases to Prague. On the other hand, a large number of patients from Liberecký region has been hospitalized in Germany, probably due to convenient distance between the region and Germany and the expected differences in healthcare quality perceived by individual patients.

Special attention will have to be paid to the number of doctors within concrete specialized areas, above all in primary care, where the number of healthcare professionals is relatively lower.[108] Other sources argue that a bigger problem lies in primary care organizational efficiency, since the number of doctors is comparable to other EU members. Nevertheless, many shortcomings can be identified in the Czech primary care, especially in terms of patients having to wait long for a doctor's visit and the general perception of primary care's quality

[106] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, OECD Publishing, *Paris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]
[107] OECD (2018): Strukturální kapitola - Zlepšení systému zdravotní péče v České republice [online]. *OECD*, 2018-07 [cit. 2019-03-30]. Retrieved from: http://www.oecd.org/eco/surveys/economic-survey-czech-republic.htm
[108] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, OECD Publishing, *Paris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]

getting worse. A possible solution to this problem could be provided by the new reform whose goal is to increase the competence of the primary care doctors, so that patients do not have to look for specialists with every health problem they have. The reform presupposes motivation through financial incentives for more active primary care healthcare professionals. [109]

Long-term and social care coverage

Ongoing imbalances between long-term healthcare and long-term social care coverage encourages those who are long-term ill and elderly patients to seek opportunities to remain in hospitals longer than it is needed from the medical standpoint, resulting in high inefficiencies. The problem stems from the division of long-term care between two sectors - healthcare and social services – as patients are encouraged to opt for healthcare services free of charge instead of choosing social services that similar in nature for a fee.[110] In the future, this could pose an especially dangerous issue, since the number of elderly[111] and those chronically ill is on the rise.[112]

Healthcare system performance

Despite many inefficiencies, the Czech healthcare system is achieving positive results with regards to reduction in preventable deaths, which have been showing a declining trend since 2005. Looking into the issue more in detail, considerably positive results have been recorded with some infectious and non-infectious diseases, such as tuberculosis, HIV or asthma. The majority of other illnesses, however, remains to be in line with the EU-average and the number of preventable deaths of the total number of deaths was by 4 percentage points higher than an EU-average (16% and 11% respectively). Statistics point out that predominantly cancer treatment and its early diagnosis could be improved and the first step to succeed might be motivating people to a higher participation in national screening programmes. Other problematic areas include liver diseases and road accidents.

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[109] Zdravotnický deník (2018): Reforma primární péče potrvá 10 až 12 let. Udržet lékaře v potřebných lokalitách i v ČR obecně mají pomoci stabilizační dohody. *Zdravotnický deník* [online]. 2018-11-20 [cit. 2019-03-30]. Retrieved from: http://www.zdravotnickydenik.cz/2018/11/reforma-primarni-pece-potrva-10-az-12-let-udrzet-lekare-potrebnych-lokalitach-i-cr-obecne-maji-pomoci-stabilizacni-dohody/

[110] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, OECD Publishing, *Paris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]

[111] Český statistický úřad: Stárnutí se nevyhneme: Věková struktura se změní. *Český statistický úřad* [online]. [cit. 2019-03-30]. Retrieved from: https://www.czso.cz/csu/czso/ea002b5947

[112] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, OECD Publishing, *Paris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]

The real challenge is the implementation of programmes for supporting health and diminishing risk behaviour in relation to non-infectious diseases. A good example is the slow adoption of the law on tobacco control that was not introduced earlier than 2017. At the moment, the document Health 2020 - The National strategy for health support and protection and disease prevention is viewed as the steering document for the whole sector, while stating crucial long-term goals and strategies.

Another separate topic relates to vaccination of children which is obligatory and achieves a high coverage rate of 97 – 99% for tetanus, diphtheria, measles, whooping cough and hepatitis B. The children's vaccination is targeted at a wide range of infectious diseases and its schedules are regularly updated. Czechia is, however, lagging in terms of the vaccination of elderly against influenza, that remains to be below the EU-average. [113]

Accessibility

Unlike in other countries (e.g. U.S.), Czech citizens have the right to access healthcare. This means that provided a person is not economically active, it is the role of the state to bear the costs. The Czech healthcare system, thus, covers the cost of healthcare for 60% of the total population in Czechia, comprised mostly of children, students, retired persons, parents on maternity leave, the unemployed, prisoners and asylum seekers and the sources of those contributions are general taxes. Moreover, there is an upper limit to private healthcare expenditures of low-income households.

The general perception of healthcare accessibility is beyond average, since only a low share of population claims to have received unsatisfactory care (for reasons such as proximity, waiting times and cost).

However, the access of patients to primary care specialists seems to be above standard of many other countries, as doctors do not perform the role of a gatekeeper to the system, meaning that any patient could get an easy access to any specialist they seek without the need of obtaining a formal recommendation. On the contrary, owing to more frequent ambulatory visits, the Czech government plans on taking measures to combat wasting resources and strengthen costs controls.

In terms of prices for healthcare, there are ongoing negotiations between healthcare insurance companies and healthcare providers taking place. Unfortunately, the process is often strikingly inefficient, without producing a mutual agreement between both parties. In such a

[113] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, OECD Publishing, *Paris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]

case, the Ministry of Health issues a decree setting prices and sometimes also reducing the range of services provided. [114]

With regard to access to the necessary medicine, the pharmacy network is unevenly distributed across the state, with higher concentration of pharmacy branches in larger cities. The lowest number of pharmacies, including detached departments of drug distribution, is in the Karlovarský, Liberecký and Vysočina regions.[115]

Long-term sustainability

The main risks to sustainability identified in Czechia are the aging population, labour force fluctuations and the current definition of the income base, the latter of which caused significant complications during the financial crisis in 2008 when a large share of economically active people became unemployed and stopped financially contributing to the system. It is apparent that a clearer vision will have to be put in place in the near future, preceded by government parties coming to terms on issues such as the increase in private spending. The use of more goal-oriented government strategies is also needed to address many other risks from those mentioned above.

Capital investments into the renovation of healthcare facilities could be considered as a separate area owing to the shared responsibility of the healthcare and social sectors presenting a difficult challenge when arriving at an actionable solution.

In addition, there is space for improving the sector's overall technical effectiveness. Return on expenditure on amenable mortality could be higher based on the data of those countries that record the same amount of such expenditures. In terms of hospital care, inefficiency is visible from the average length of stay (9.3 days in comparison with the EU average of 8 days), an excess of hospital beds and their lower occupancy rate, the large number of ambulatory visits. There is also a potential to increase efficiency of public contracts on pharmaceuticals.

Nevertheless, before tackling specific issues, a sector's higher transparency would have to be ensured, achieved by the creation and sharing of concrete quality-measuring indicators. It would not only considerably contribute to better performance, but also enable better decision making when choosing a healthcare provider or a healthcare insurance company. [116] It is

[114] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, OECD Publishing, *Paris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]
[115] Ústav Zdravotnických Informací a Statistiky ČR: Zdravotnická ročenka České republiky 2017 [online]. 2017, p. 203 [cit. 2018-12-03] Retrieved from: https://www.uzis.cz/katalog/rocenky/zdravotnicka-rocenka-ceske-republiky
[116] OECD (2017): Česká republika: zdravotní profil země 2017, State of Health in the EU, OECD Publishing, P*aris/European Observatory on Health Systems and Policies*, Brussels. http://dx.doi.org/10.1787/9789264285125-cs [cit. 2018-11-24]

especially important to restore confidence in the system of public procurement, which has been many times described as non-transparent, or even prone to corruptive behaviour of politicians engaged in its processes.[117]

The Institute of Health Information and Statistics of the Czech Republic (Ústav zdravotnických informací a statistiky ČR) is a national organization under the Ministry of Health of the Czech Republic that monitors the state and development of the Czech healthcare. Its yearly statistical publications focused on overall healthcare information include areas like demography, state of health, network and activity of healthcare facilities, employees and healthcare education, international comparison and regional overviews.[118]

Comparison with other European countries is done every year through the Euro Health Consumer Index that ranks 35 European countries based on the overall performance of their healthcare systems. Czechia has been showing decent results for a longer period of time already and ended up on the 16th place in the ranking in 2017 (the same as Slovenia). When it comes to its neighbour Slovakia (placed 13th in the raking), Czechia scored worse only due to a relatively lower access of patients to healthcare. With this score, however, Czechia reaches the level of some of the Western countries such as the United Kingdom or Spain, which is a remarkably good result in view of the country's healthcare spend expressed in Purchasing Power.[119]

In the end, the current progress in the innovation of the Czech healthcare is going to be outlined. Probably the most significant initiative has been the national eHealth project known as The National Strategy of eHealth (Národní strategie elektronického zdravotnictví) [120] coordinated by The National eHealth Centre.[121] Starting in 2016, the main actors responsible for the implementation set the goal of gradually digitalising the key parts of the Czech healthcare system by 2020, establishing important milestones for the whole period of 2016 – 2020.[122] The highly anticipated eHealth Act is currently in the preparatory process.[123]

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[117] Alexa Jan, Rečka Lukáš, Votápková Jana, van Ginneken Ewout, Spranger Anne, Wittenbecher Friedrich. (2015): Czech Republic: Health system review. *Health Systems in Transition*,17(1):1–165 [cit. 2018-12-03]. Retrieved from: http://www.euro.who.int/__data/assets/pdf_file/0005/280706/Czech-HiT.pdf

[118] Ústav zdravotnických informací a statistiky ČR: Základní informace o ÚZIS ČR. *Ústav zdravotnických informací a statistiky ČR* [online]. [cit. 2018-12-03]. Retrieved from: http://www.uzis.cz/nas

[119] Björnberg, Arne, Ph.D. (2018): Health Consumer Powerhouse: Euro Health Consumer Index 2017 [online]. In: *Health Consumer Powerhouse*, s. 100 [cit. 2018-12-03]. ISBN 978-91-980687-5-7. Retrieved from: https://healthpowerhouse.com/media/EHCI-2017/EHCI-2017-report.pdf

[120] iRozhlas (2018): Půl roku e-receptů. Lékaři jich vydali 29 milionů, brzy je Češi využijí i v zahraničí. *IRozhlas* [online]. 2018 [cit. 2018-12-04]. Retrieved from: https://www.irozhlas.cz/zpravy-domov/e-recepty-vydavani-leku-v-zahranici_1807080800_jak

[121] eZDRAV (2018): Národní centrum elektronického zdravotnictví. *eZDRAV.cz* [online]. 2018 [cit. 2018-12-08]. Retrieved from: http://www.ezdrav.cz/narodni-centrum-elektronickeho-zdravotnictvi/

[122] Mladá fronta (2016): ČISOK: Bez elektronizace zdravotnictví se Česko neobejde. *Mladá fronta* [online]. [cit. 2018-12-04] Retrieved from: https://zdravi.euro.cz/denni-zpravy/z-domova/bez-elektronizace-zdravotnictvi-se-cesko-neobejde-482964

[123] Based on information from semi-structured interviews

One example of the most important milestones of the National Strategy of eHealth are e-Prescriptions. Since the beginning of 2018, it is obligatory to give e-Prescriptions for medicine. An acceptable alternative is to send a receipt via an SMS or email. The Czech e-Prescriptions are also planned to be accepted in the whole EU-area by 2020.[124]

Provided its realisation runs smoothly and achieves all its goals, eHealth is supposed to increase quality of healthcare, considerably extend patients' possibilities and simplify their lives. This would be achieved by patients being able to look into medical records directly from their homes and easily send them to a chosen specialist in order to ask for a professional opinion. On the other hand, a doctor will always have all medical records fully available, which serves as a necessary prerequisite to precisely determine a patient's diagnosis. A patient will be granted the opportunity to plan their healthcare with the use of modern technology and compare quality of services thanks to databases of other patients' reviews. [125]

Another successful project is the implementation of the ePACS system for the electronic exchange of image documentation between the individual healthcare facilities. With 209 participating entities in 2019, the system enables to avoid a lengthy physical transport of CDs with patient data, as well as unsecured emailing.[126] In addition, the full digitalization of sick leave is planned in January 2020.[127]

2.3 Czech innovative firms in the healthcare sector

It has already been concluded in the previous sub-chapters that Czechia aims at modernizing its healthcare sector and that a lot of initiatives have being envisaged in the field of digital healthcare. What has not been discussed yet are cases of successful innovations either stemming from or being a part of the private or academic sector in Czechia.

Despite the sector still being at the beginning of embracing digitalization, there are multiple concrete, successful examples of Czech companies, institutions or emerging business ideas with high innovation potential to be found. To illustrate, several innovators have been identified whose innovative activities could be defined as game-changing or revolutionary and

[124] iRozhlas (2018): Půl roku e-receptů. Lékaři jich vydali 29 milionů, brzy je Češi využijí i v zahraničí. *IRozhlas* [online]. 2018 [cit. 2018-12-04]. Retrieved from: https://www.irozhlas.cz/zpravy-domov/e-recepty-vydavani-leku-v-zahranici_1807080800_jak

[125] Mladá fronta (2016): ČISOK: Bez elektronizace zdravotnictví se Česko neobejde. *Mladá fronta* [online]. [cit. 2018-12-04] Retrieved from: https://zdravi.euro.cz/denni-zpravy/z-domova/bez-elektronizace-zdravotnictvi-se-cesko-neobejde-482964

[126] eZDRAV (2019): V jaké fázi je elektronizace zdravotnictví nyní? *eZDRAV.cz* [online]. [cit. 2019-04-22]. Retrieved from: http://www.ezdrav.cz/ehealth-v-cr/

[127] Měšec.cz (2019): Elektronické neschopenky nás čekají až za rok. Změny ale pocítíte už letos. *Měšec.cz* [online]. 2019-04-01 [cit. 2019-04-22]. Retrieved from: https://www.mesec.cz/clanky/elektronicke-neschopenky-nas-cekaji-az-za-rok-zmeny-ale-pocitite-uz-letos/

that are well-fitting in this sub-chapter, as their activities are based on the transformative technologies outlined earlier in this thesis.

The following table includes a list of companies and institutions operating on the Czech market that introduced digital solutions in various areas within the Czech healthcare. There is always information on the company's or institution's year of establishment, location, main activity in healthcare as well as examples of digital solutions introduced.

At this point, it is important to note that the list does not include all companies and institutions active in the field of digital healthcare in Czechia. The list serves merely as an illustration of some of innovative entities with digital healthcare solutions to get a basic overview and to better grasp the level of digitalization of the Czech healthcare.

Table 4: Examples of digital solutions by companies

Institution/Company	Year	Location	Main activity in healthcare	Examples of digital solutions
Biotronik Praha, spol. s.r.o.	1991	Prague	Remote monitoring devices for heart and blood vessel diseases	▪ BIOTRONIC Home Monitoring system ▪ Closed Loop Simulation device for tracking and optimizing cardiac activity ▪ devices for atrial fibrillation detection, specially adjusted defibrillators and pacemakers
CleverTech s.r.o.	2005	Prague	Telemedicine	▪ home care patient monitoring ▪ remote patient monitoring
Czech National eHealth Center	2012	Olomouc	Telemedicine	▪ remote patient monitoring ▪ disease management ▪ a web interface for doctors
EUC a.s.	2002	Prage	Outpatient care, premium care, mamoscreening and medical care for employers	laboratories with fast delivery of results and their availability online
GE Medical Systems Česká republika, s.r.o.	2000	Prague	Medical imaging, software and IT, patient monitoring and diagnostics	▪ magnetic resonance imaging (MR) and computed tomography (CT) ▪ Centricity Cardiology Enterprise - a database of medical images and information
Institute for Clinical and Experimental Medicine (IKEM)	more than 45 years in operatio n	Prague	Organ transplants, cardiovascular diseases, metabolic disorders and diabetology	▪ devices for remote monitoring and control of patient's core heart functions ▪ transmission of patient data through web interface (e.g. data on changes like arrhythmia) ▪ alerts via email, fax or a short message ▪ an integrated clinical portal "Zlatokop" for data search in the digital patient card
Institute for the Application of Modern Technologies in Medicine, z.ú.	2018	Prague	Fostering collaboration among relevant actors in the digital healthcare environment	▪ electronic system for arranging medical check-ups for deaf persons
Invent Medical Group, s.r.o.	2015	Ostrava	Development and design of customized prosthetic and orthotic products	▪ product personalization ▪ colecting patients' anatomical data via 3D and 2D scanners ▪ 3D printing
Konica Minolta Business Solutions Czech, spol. s r.o.	1990	Brno	Diagnostic and imaging equipment	▪ precision medicine ▪ smart glasses
LINET spol. s.r.o.	1990	Želevčice u Slaného	Hospital and old people's beds production; mobile equipment	▪ resuscitation bed "Multicare" equipped with a lateral tilt function for preventing fall and health complications ▪ development phase of smart sensors for monitoring of vital functions
MDT-Medical Data Transfer, s.r.o.	2008	Brno	Telemedicine	EKG monitoring
Medical Monitor - Národní dohledové centrum	2014	Prague	Telemedicine	patient monitoring in elderly homes
Mindpax s.r.o.	2015	Prague	Telemedicine for mental health attacks prediction	▪ a wearable device, a wristband, to collect patients' data ▪ a mobile application for data visualizations ▪ a web-based application, the data is systematically analysed, displayed and made available to patients, doctors, health institutions and researchers
Proma Reha, s.r.o.	1990	Česká Skalice	Production of medical equipment, beds and furniture	Smart beds - advanced functions for a safer and easier manipulation with patients, tilting functions
ProSpon spol. s.r.o.	1992	Kladno	Development, production and distribution of orthopaedic and traumatological implants, instruments and other medical devices	3D printer for titanium alloys to customize the products
ProVisio, s.r.o.	2013	Brno	Medical documentation analysis	▪ HarveyExplorer application ▪ clinic data standardization (data search, sorting, correct interpretation and practical application) ▪ assistance in disease diagnoses and health condition trends
Telemedicine centre in Ostrava	2015	Ostrava	Application of telemedicine in medical practice	▪ a barometer, devices keeping a track of breathing, heart functions and blood sugar level etc.
uLékaře.cz	2016	Prague	Healthcare counselling and a platform for arranging medical check-ups	▪ a website, a mobile app for healthcare counselling ▪ arranging medical check-ups online
University centre for energy efficient buildings (UCEEB), Czech technical university in Prague	2014	Buštěhrad	Laboratory of personalized telemedicine - "Living lab"	▪ new medical assistive devices and devices for smart home ▪ a system for mobile monitoring of patients' physiological parameters
YAKNA	2000	Prague	Applied neuropsychology	▪ smart neurorehabilitation software Eddie for treating patients with head injuries and brain malfunction ▪ information portal Neuroportal
Zachranka, z.ú.	2016	Brno	Mobile application for calling an ambulance	▪ research, development and implementation of the application's software. ▪ patient data transmission to the healthcare headquarters ▪ identification of users' actual position via GPS ▪ interactive manual on the first aid
ZDRAVeL	2017	Prague	Electronic health records platform	▪ medical reports, complete overview of patients' health condition, examination results, overview of prescribed medicine ▪ scheduling medical check-ups, communication with specialists online in case of need for consultancy ▪ measuring, input and analysis of physical data with help of interactive graphs or simply making personal records (functionality for patients)

Source: Own representation based on companies' official websites

Both domestic and international businesses can be found in Czechia. International companies tend to operate via a foreign branch, since Czechia, as a country situated in the heart of Europe, offers possibilities for further expansion to other geographically, socially and culturally close neighbours. However, since the Czech market is a rather small one, with a higher level of distrust of the local population in the newest medical solutions, the most cutting-

edge technologies are seldom presented here. For this reason, Czechia is usually perceived as a complementary market, rather than the focus of an international company's core activities. Konica Minolta Business Solutions Czech, spol. s.r.o. serves as a good example here. Even though the company has its R&D area of Konica Minolta Laboratory Europe located in Brno, they cannot enjoy a strong position in the Czech healthcare sector and have to significantly adapt the range of services offered to the local demand. In contrast, they succeeded in becoming a local leader in the U.S.[128] As later found out during the semi-structured interviews, it is a frequent strategy even of some of the Czech companies to start their business abroad (e.g. Mindpax, a mental health innovator, in Germany) and after verifying success of their business concept, they return to slowly conquer their home market as well. For national entities it is a rather natural move to make the first step into healthcare in the familiar, home environment.

Looking at the age structure of the listed companies and institutions, they were established no earlier than in the 1990s with more than half of them being set up after 2010. In our list, Institute for the Application of Modern Technologies in Medicine z.ú. is the most recent healthcare innovation representative. Their novelty could also be attributed to the approach they come with in Czechia, when they aim at connecting relevant parties in healthcare to facilitate collaboration and eventually bringing digital solutions to end customers. They did so in the case of supporting the creation of a system whose role lies in arranging medical check-ups for deaf persons. It is also worth mentioning that the whole idea comes from a primary care specialist, offering his own professional standpoint and experience from medical practice to combat healthcare digitalization bottlenecks.[129] Another institution to engage in enabling an effective dialogue is the Czech National eHealth Centre. Apart from spreading its positive vision on digital healthcare, the Centre representatives engage in launching new telemedicine products on the Czech market. They see a huge growth potential in this field, as compared to other Western nations (mainly the U.S. or western European countries), Czechia is still falling behind.[130]

Clearly, the oldest representative in the table is the Institute for Clinical and Experimental Medicine (IKEM). The institute became famous for its unquestionably breakthrough achievement when the first patient with an implanted cardiac device received the system for the remote control of their core heart functions in 2010.[131] This could be viewed

[128] Based on information gained during a semi-structured interview

[129] Based on information gained during a semi-structured interview

[130] Národní dohledové centrum: Zdravotnické zařízení. *Národní dohledové centrum* [online]. [cit. 2019-02-13]. Retrieved from: https://ndcentrum.cz/personal

[131] Týden.cz (2010): Lékaři z IKEM mohou kontrolovat srdce na dálku. *Týden.cz* [online]. [cit. 2019-02-11]. Retrieved from: https://www.tyden.cz/rubriky/zdravi/lekari-z-ikemu-mohou-kontrolovat-srdce-na-dalku_173594.html

even more significant, given the increasing share of Czech population succumbing to cardiac disorders.[132]

It is also apparent that the most of the identified key Czech digital healthcare players are based in larger Czech cities such as the capital Prague or Brno.

Moving onto the area of activities, telemedicine or remote patient monitoring could be considered as popular activities to engage in in Czechia. Only in our overview, there are already seven important players recognized, namely Biotronik Praha, spol s.r.o., CleverTech s.r.o., Czech National eHealth Centre, MDT- Medical Data Transfer, s.r.o., Medical Monitor – Národní dohledové centrum, Telemedicine Centre in Ostrava and University Centre for Energy Efficient Buildings. The last player mentioned, University Centre for Energy Efficient Buildings, hosts the Laboratory of Personalized Telemedicine, the so-called "Living lab", a laboratory space simulating real-life environment, where experts from the area of hardware and software development, telemedicine and home care are able to test new technologies that are currently under development.[133]

Furthermore, there are distinguished producers of medical implants active in Czechia, such as Invent Medical Group, s.r.o. and ProSpon spol. s.r.o., the latter having a long tradition, with the start of their business activities going back to 1992. Both companies follow the trend of using 3D printing and AI in the manufacturing of their final products, giving them a unique opportunity to customize products to individual client needs. [134][135]

In the recent years, many companies and institutions steered their activities exclusively towards digital solutions, probably as a response to fast advancements on foreign healthcare markets. Thanks to the website uLékaře.cz, patients now have an easy, 24/7 access to a professional, online healthcare counselling. In addition, the platform integrates a valuable function for its users to directly set up a medical check-up.[136] For a fast ambulance call, patients are free to use the mobile application, introduced by a non-profit organization Zachranka, z.ú. The application also ensures a precise identification of a user's actual position via GPS. [137]

The activities of ZDRAVeL and HarveyExplorer of ProVisio, s.r.o. leverage big data collected from a patient's documentation, that is generally highly disarranged, unstructured,

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[132] EuroZprávy.coz (2018): V Česku umírají statisíce lidí na nemoci srdce. Jak jim předcházet? *EuroZprávy.cz* [online]. 2018-09-28 [cit. 2019-04-02]. Retrieved from: https://eurozpravy.cz/domaci/zdravotnictvi/235843-v-cesku-umiraji-statisice-lidi-na-nemoci-srdce-jak-jim-predchazet/

[133] Laboratoř personalizované telemedicíny: Vývoj telemedicínských technologií v reálném pontředí bytu. *Univerzitní centrum energeticky efektivních budov ČVUT v Praze* [online]. [cit. 2019-02-12]. Retrieved from: http://www.uceeb.cz/laborator-personalizovane-telemediciny

[134] ProSpon: 3D tisk. *ProSpon* [online]. [cit. 2019-02-11]. Retrieved from: http://www.prospon.cz/3d-tisk

[135] Invent Medical: How It Works. *Invent Medical* [online]. [cit. 2019-02-13]. Retrieved from: https://www.inventmedical.com/start/

[136] uLékaře.cz: Objednání k lékaři. *uLékaře.cz* [online]. [cit. 2019-02-04]. Retrieved from: https://www.ulekare.cz/objednat-se

[137] Zachranka app: Funkce. *Zachranka app* [online]. [cit. 2019-02-02]. Retrieved from: https://www.zachrankaapp.cz/cs/funkce

proving to be difficult for healthcare professionals to deal with and make an informed decision regarding a patient's health condition based on its content. In the long run, the solutions help recognizing trends of each patient's profile, which in turn, doctors can evaluate and subsequently recognize risk groups of patients more susceptible to certain diseases. [138] The digital initiatives are reaching to fulfil their objective of healthcare digitalization, ensuring an easier orientation and enhancement of general healthcare literacy by electronic means. [139]

Those were some of the examples of companies and institutions that we encountered during our research conducted for this thesis. With some of them, we were able to discuss their activities and innovative future plans in person or via an online scheduled meeting. However, this is just a brief demonstration of some of the initiatives currently present in Czechia. A more complex overview of the structure of the Czech digital healthcare players would require a more thorough analysis. Moreover, it is difficult to be fully comprehensive about all existent trends in a sector that is about to evolve rapidly in the near future. Companies are constantly evolving and expanding their scope of operations, especially those well-established in both domestic and international environment. As an example, a successful Czech producer of hospital and nursing beds, a Czech innovator LINET spol. s.r.o., managed to get to the forefront in hospital bed manufacturing thanks to its vast investments in innovations, further stimulated by strong partnerships with numerous healthcare experts and professionals. In one of the recent interviews, its founder Zbyněk Frolík outlined the company goals for the upcoming period. In view of the newest trends, they would like to venture into production and business opportunities related to smart beds enabling the data collection of patients' vital functions, sleep phases quality and monitoring of spontaneous movements in sleep and their behaviour in bed in general. Smart sensors could be used to enable those functionalities combined with artificial intelligence to secure intuitive control. [140]

It remains to be a great challenge, however, to overcome a rather conservative attitude of the market, not only for LINET spol. s.r.o., but also for other game-changers willing to revolutionize the Czech healthcare sector and bring sustainable solutions for the sector to gain more efficiency and modernity in the long term.

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[138] HarveyX: Řešení pro pokročilé zdravotnictví. *HarveyX* [online]. [cit. 2019-02-11]. Retrieved from: http://www.harveyx.cz

[139] ZDRAVeL: Institut pro podporu elektronizace zdravotnictví z.ú.: Základní informace. *ZDRAVeL* [online]. [cit. 2019-02-15]. Retrieved from: https://www.zdravel.cz/institut

[140] Muži v Česku (2018): Král nemocničních lůžek Frolík o prodeji Linetu: Musím přemýšlet, jak mé dítě posunout dál. *Muži v Česku* [online]. 2018-12-14 [cit. 2019-02-02]. Retrieved from: http://www.muzivcesku.cz/staneme-se-softwarovou-firmou-a-zamerime-se-na-domaci-peci-rika-sef-firmy-linet/

3. Trends and future prospects

The analytical part of the thesis is divided into two main analyses. Firstly, a data analysis was performed where data was obtained in collaboration with UNICO.AI[5], a Prague information and technology start-up company. It was decided to work with publicly available data on Czech R&D results, predominantly with data on the number of patents, scientific projects and other scientific results of Czech entities. The two key databases to work with were Orbit Intelligence[141] for patents and "Informační systém výzkumu, experimentálního vývoje a inovací[142]", a platform that integrates data on research, development and innovation supported through Czech public funds. The collected data was evaluated in terms of the number of scientific results across various healthcare-related digital technology types. The most crucial digital technology types were identified previously during the initial research and were expressed as keywords. The number of scientific results was then attributed to each of those keywords. The full list of keywords can be found in Appendix 1. This way it was possible to determine where the majority of R&D activities was directed in the course of the past 10 years. The sub-chapter "Data analysis of recent trends" is dedicated to this analytical part.

In the second part, the so-called semi-structured interviews were conducted in collaboration with local companies, universities and research institutes that were identified as digital healthcare innovators, and therefore, relevant for the goals of this thesis. The purpose of a semi-structured interview is to gain valuable insight into the topic of digitalization of the Czech healthcare from relevant respondents in an approximately one-hour personal or phone conversation (in this case, it was frequently relied on the modern alternative to phone interviews, the Skype application). An array of open-ended and closed questions is the main tool of the semi-conducted interview, where underlying motives for respondents' answers are also usually inquired.[143] The sub-chapter "Perceptions of healthcare professionals" deals with this analytical part.

The main instrument guiding the conversations with respondents was a pre-prepared questionnaire. It was structured into four parts and included questions on the basic identification of respondents, reasons for doing business or conducting research in Czechia, assessing the innovation potential of the subjects and most importantly, a set of questions aimed at outlining

[141] Orbit Intelligence: Orbit Intelligence Retrieved from: https://www.orbit.com

[142] Informační systém výzkumu, experimentálního vývoje a inovací: Retrieved from: https://www.rvvi.cz

[143] Wholey, Joseph S., Hatry, Harry P. Newcomer, Kathryn E. (2015): *Handbook of Practical Program Evaluation* [online]. Hoboken, NJ, USA, 2015 [cit. 2019-04-02]. ISBN 9781119171386. Retrieved from: http://doi.wiley.com/10.1002/9781119171386.ch19

their view on the future development of the digitalization of the Czech healthcare. The questionnaire can be found in Appendix 2. All four parts of the questionnaire were necessary for a thorough analysis of the situation. However, it was expected that via a natural flow of the conversation, spurred by the last questions directed towards respondents' personal standpoints, many more essential details were going to be revealed. The contribution of the whole second research method lies in understanding the sector's possible future development.

All in all, merging both objective (data) and subjective (interviews) information on the healthcare system's past and future development is going to provide an insight into what digital trends are present in the Czech healthcare system. On the basis of those findings, suggestions are going to be made on where researchers, established companies and brand-new entrepreneurs should focus their future scientific and business endeavours to stay up-to-date and relevant, eventually leading to maximizing their bottom lines in the long run.

3.1 Data analysis of recent trends

The first type of scientific results to begin with are scientific projects. As outlined earlier, the relevant data was extracted from the "Informační systém výzkumu, experimentálního vývoje a inovací" database. The database keeps an entire list of research projects financed by Czech public funds and the list is complete, since the registration of projects is mandatory by law. The role of the database operator is performed by the Research, Development and Innovation Council, a consultancy body of the Czech government.[144] The main public funding bodies are the Technology Agency of the Czech Republic, the Czech Science Foundation, departmental programmes of Czech ministries and the Czech Academy of Sciences.

Firstly, data on all research projects was obtained, based on keywords identified as those that best describe technological trends in digital healthcare. Those results had to be further processed as some of the keywords were rather general and could be present across various business sectors, not just healthcare (e.g. cloud). It was also decided to include only data of the past 10 years (2009 – 2019) to make sure the analysis is focused on the most recent digital development. Eventually, there were 649 research projects left for further analysis. In order to get the final outcome, which is presented in Table 5, all healthcare-related research projects had to be separated into distinctive healthcare-related digital technology groups (column "Topic"). The column "Number of projects" signifies the total number of projects where each of the

[144] Research Development and Innovation Council: About us. *Government of the Czech Republic* [online]. [cit. 2019-04-11]. Retrieved from: https://www.vyzkum.cz/Default.aspx?lang=en

digital technology identified as a keyword occurred. The hypothesis was that the higher the number of projects, the more significant the trend in the area of the associated topic.

Table 5: Top 5 technologies in Czech healthcare based on the focus of research projects (2009-19)

Ranking	Topic	Number of projects	Most common combinations
1	3D	136	ultrasound, machine learning, virtual reality
2	Bioinformatics/Bioinformatic	98	machine learning
3	Ultrasound	49	3D
4	Biosensor	24	3D, molecular diagnostics, aptasensor
5	Gene therapy	20	machine learning, bioinformatics
6	Molecular diagnostics	19	personalized medicine
7-8	Artificial Intelligence/AI	18	robotics, 3D
7-8	Personalized medicine/personalized healthcare	18	telemedicine
9	Machine learning	14	bioinformatics
10	Virtual reality/VR	12	3D
11-12	E-health	8	telemedicine, medical imaging
11-12	Telemedicine/Telecare/Telehealth	8	e-health, health informatics, medical imaging, personalized medicine
13-14	Optical imaging	7	3D
13-14	Wearable	7	e-health, IoT
15-16	Medical imaging	6	3D, e-health
15-16	Nanomedicine	6	ultrasound
17-20	Big Data	5	machine learning
17-20	Genetic engineering	5	
17-20	Internet of Things/IoT	5	wearable, e-health
17-20	Robotics	5	virtual reality, 3D
21-22	Cloud	3	
21-22	Disease management	3	
23-25	Brachytherapy	2	
23-25	Health Informatics	2	telemedicine, e-health
23-25	Synthetic biology	2	
26-29	Aptasensor	1	biosensor
26-29	Augmented reality	1	
26-29	In-vitro diagnostics	1	
26-29	Nanodiagnostics	1	

Source: Own representation based on publicly available data from www.rvvi.cz

Table 5 shows the top 5 technologies accompanying digitalization in Czech healthcare during the last 10 years as identified based on publicly available information on research projects. Accordingly, the majority of research projects has been elaborated in the area of 3D, bioinformatics, ultrasound, biosensor and gene therapy. Very frequently, those technologies were not standalone and rather came in various combinations with other digital technologies. As an example, whereas 3D was usually paired with ultrasound, machine learning or virtual reality, gene therapy relied heavily on machine learning and bioinformatics.

The obtained data also included valuable information on institutions, with their most active faculties, which have participated in the projects. Therefore, it is possible to provide a list of those that have been particularly active in research projects related to the top 5 technologies. The findings are illustrated in Table 6.

Table 6: The most engaged institutions by technology type in the Czech healthcare system based on scientific project focus (2009-19)

Ranking	Topic	The most engaged institutions
1	3D	**Charles University** (First Faculty of Medicine, Faculty of Science, Second Faculty of Medicine, Faculty of Humanities, Faculty of Physical Education and Sport, Faculty of Mathematics and Physics) **The Czech Technical University in Prague** (Institute of Experimental and Applied Physics, Faculty of Electrical Engineering, Faculty of Nuclear Sciences and Physical Engineering, Faculty of Mechanical Engineering, University Centre for Energy Efficient Buildings - UCEEB) **Masaryk University** (Faculty of Informatics, Faculty of Medicine, Faculty of Science, Central European Institute of Technology - CEITEC)
2	Bioinformatics/Bioinformatic	**Charles University** (Faculty of Science, First Faculty of Medicine) **Masaryk University** (CEITEC) **Institute of Biophysics of the Czech Academy of Sciences** **The Biology Centre of the Czech Academy of Sciences**
3	Ultrasound	**The General University Hospital in Prague** **Palacký University Olomouc** (Faculty of Health Sciences, Faculty of Medicine and Dentistry) **Institute for Clinical and Experimental Medicine (IKEM)**
4	Biosensor	**Masaryk University** (Faculty of Science) **University of Chemistry and Technology Prague** (Faculty of Food and Biochemical Technology) **Jan Evangelista Purkyně University** (Faculty of Science) **Institute of Molecular Genetics of the Czech Academy of Sciences** **Institute of Macromolecular Chemistry of the Czech Academy of Sciences**
5	Gene therapy	**Charles University** (Second Faculty of Medicine, First Faculty of Medicine, Third Faculty of Medicine) **Institute of Molecular Genetics of the Czech Academy of Sciences** **Institute of Hematology and Blood Transfusion**

Source: Own representation based on publicly available data from www.rvvi.cz

Looking at the table as a whole, it is evident that Charles University and Masaryk University have been engaged in a great deal of research projects performed in the top 5 technology areas. Moreover, the table bears a very important message that in order to make digitalization of healthcare possible, a healthy innovation ecosystem across diverse fields is needed, such as medicine, mathematics, physics, electrical engineering, informatics or even nuclear sciences.

Most of the digital technology trends were also confirmed by the subsequent analysis of other scientific results. This category is deliberately referred to as other scientific results due to the fact that there are many different outputs of scientific work, beyond projects, that were not analysed previously, e.g. publications, published books, contractual research, results with legal protection, conferences, workshops or various methodologies.[145]

After accessing the "Informační systém výzkumu, experimentálního vývoje a inovací" database, 225 scientific results were retrieved based on the identified keywords. Predominantly, data on publications and contractual research was extracted.

Table 7 provides an overview of the 6 digital technologies most frequently mentioned in the retrieved other scientific results in the area of Czech digital healthcare between 2009 and

[145] Informační systém výzkumu, experimentálního vývoje a inovací: Přehled číselníků: Druh výsledků. *Informační systém výzkumu, experimentálního vývoje a inovací* [online]. [cit. 2019-04-12]. Retrieved from: https://www.rvvi.cz/is?s=prehled-ciselniku

2019. As there were two technology types with the same number of results found, the table includes 6 important entries rather than a compilation of only the top 5.

Table 7: Top 6 technologies in the Czech healthcare system based on the focus of other scientific results (2009-19)

Ranking	Topic	Number of results
1	3D	93
2	Ultrasound	76
3	Biosensor	33
4	Artificial Intelligence/AI	6
5-6	Cloud	5
5-6	Internet of Things/IoT	5
7-8	E-health	3
7-8	Virtual Reality/VR	3
9	mHealth	2
10-11	Bioinformatics	1
10-11	Exoskeleton	1

Source: Own representation based on publicly available data from www.rvvi.cz

In line with research projects, 3D, ultrasound and biosensors enjoyed great popularity in this period. The difference lies in bioinformatics being a more common technology to work with in research projects rather than to be a part of other scientific results. Furthermore, many research institutes, universities and companies participated in the research on the potential use of genetic information as a part of gene therapies, a trend that is not recognizable in other scientific results.

The fourth and the fifth/sixth place in the table belong to AI, cloud and IoT respectively. Probably due to the planned transformation and digitalization of the Czech healthcare, many methodologies and publications had to be elaborated first on subjects such as AI, cloud and IoT before being transformed into viable solutions through research projects. This argument is supported by a large number of scientific publications published on those three topics in reputable scientific journals, as was seen in the data sample from the source database.

Similarly to research projects, the most engaged institutions in the digitalization of the Czech healthcare participating on the development of other scientific results were also analysed. The period under consideration remains the same, which is 2009 - 2019. The final overview can be found in Table 8.

Table 8: The most engaged institutions by technology type in the Czech healthcare based on the focus of other scientific results (2009-19)

Ranking	Topic	The most engaged institutions
1	3D	**The Czech Technical University in Prague** (CIIRC, Faculty of Biomedical Engineering, Faculty of Electrical Engineering, Faculty of Nuclear Sciences and Physical Engineering, Faculty of Civil Engineering, Faculty of Mechanical Engineering, UCEEB) **Brno University of Technology** (Faculty of Electrical Engineering and Communication, Faculty of Mechanical Engineering) **Palacký University Olomouc** (Faculty of Physical Culture, Faculty of Medicine and Dentistry, Faculty of Science) **Charles University** (Faculty of Medicine in Hradec Králové, Faculty of Mathematics and Physics, Faculty of Science)
2	Ultrasound	**The General University Hospital in Prague** **St. Anne´s University Hospital** **University Hospital Hradec Králové** **Palacký University Olomouc** (Faculty of Health Sciences, Faculty of Medicine and Dentistry) **Brno University of Technology** (Faculty of Electrical Engineering and Communication, Faculty of Chemistry)
3	Biosensor	**Masaryk University** (Faculty of Medicine, Faculty of Science, CEITEC) **Mendel University in Brno** (Faculty of AgriSciences)
4	Artificial Intelligence/AI	**Bulovka Hospital** **St. Anne´s University Hospital**
5-6	Cloud	**Czech Technical University in Prague** (Faculty of Electrical Engineering, Faculty of Biomedical Engineering, Faculty of Electrical Engineering)
5-6	Internet of Things/IoT	**Czech Technical University in Prague** (Faculty of Electrical Engineering) **Brno University of Technology** (Faculty of Electrical Engineering and Communication, Faculty of Information Technology)

Source: Own representation based on publicly available data from www.rvvi.cz

In contrast to research projects, it is apparent that healthcare facilities also have a place at the table of other scientific results. Apart from many university faculties and institutes, there are various Czech hospitals included, e.g. St. Anne's University Hospital in Brno, the General University Hospital in Prague and Bulovka Hospital. The interest of those hospitals is mainly placed on AI and the ultrasound technology. From academic institutions, the Czech Technical University in Prague and Brno University of Technology act as the main players, especially in 3D, IoT, ultrasound (Brno University of Technology), and cloud (Czech Technical University in Prague).

In order to make the analysis complete, the data on active patents (granted patents or published applications) filed abroad by Czech-based institutions and Czech residents was also evaluated.[146] The key data source was Orbit Intelligence.

The patent data processing was similar to that of research projects or other scientific results. Data was extracted and only patents with an application date (priority date) later than 2009 were taken into consideration. Nevertheless, when looking into healthcare-related digital-technology patents applied during the specified period, only 10 patents were found. This could be explained by a relatively new trend of digitalization of the Czech healthcare combined with the demanding nature of scientific work for which a patent can be granted. Also, only the active patents filed abroad were taken into consideration. The list of all 10 patents divided into individual digital technology groups is presented below, in Table 9.

Table 9: Top 5 technologies in the Czech healthcare based on patent focus (2009-19)

Ranking	Topic	Total number of patents for each topic	Patent applicants with respective application years
1	3D	4	▪ Contipro a.s. (2012) ▪ National Institute for Nuclear, Chemical and Biological Protection; Oritest spol. s r.o. (2012) ▪ Brno University of Technology; Student Science s.r.o.; Institute of Experimental Medicine CAS.; University of Veterinary and Pharmaceutical Sciences Brno, Faculty of Veterinary Medicine; The Czech Technical University in Prague, Faculty of Biomedical Engineering (2013) ▪ The Czech Technical University in Prague, Faculty of Biomedical Engineering (2014)
2	Ultrasound	3	▪ Charles University, Faculty of Medicine in Plzeň (2009) ▪ Illuminare Holdings Ltd. (2009) ▪ Palacký University Olomouc (2014)
3-5	Artificial Intelligence/AI	1	Zentiva, k.s. (2016)
3-5	Biosensor	1	Charles University, Faculty of Science (2015)
3-5	Cloud	1	Ing. Vladimír Kranz (2010)

Source: Own representation based on publicly available data from https://www.orbit.com

Once again, 3D and ultrasound were two of the most significant technologies, followed by AI, biosensors and cloud solutions, all taking the third place in the ranking. The right-hand column lists all patent applicants with respective application years according to the respective digital technology category.

Although the list is short, the diverse background of patent applicants suggests the existing interest in digital healthcare technology of several significant players in the Czech healthcare-orientated community, ranging from academia and Czech Academy of Sciences to individual entrepreneurs and private businesses.

[146] An assumption was made that the patents filed abroad would be of greater importance as well as have a higher potential for the application in practice.

With regard to the age of the patents, the newest ones are owned by the Faculty of Science of the Charles University (2015) for the recombinant protein biosensor (biosensor), the Faculty of Biomedical Engineering of the Czech Technical University in Prague (2014) for a biotelemetric system for the support of monitoring human psychophysiology (3D) and lastly, Palacký University Olomouc (2014) for inventing a method for the preparation of silver colloidal particle layers onto glass substrate (ultrasound).

3.2 Perceptions of the healthcare professionals

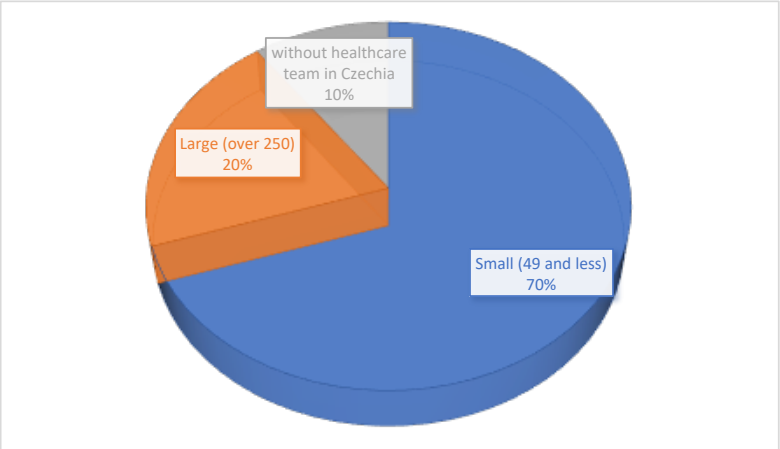
The semi-structured interviews for the purpose of this Master's thesis were conducted in the course of three months, between February and April 2019. In the beginning, the contact database of UNICO.AI was consulted, the company whose assistance was particularly helpful for the initial guidance through the Czech healthcare sector. It was also recommended to contact several businesses that were known to the employees of the Faculty of International Relations of the University of Economics in Prague. The rest of the interviewing process could be characterized by the "snowball effect", when respondents introduced other relevant entities operating in the Czech healthcare sector. One time a consecutive meeting was organized with a respondent due to their interest in sharing their professional efforts as well as talking about various background details on the organization of the healthcare sector. All respondents were offered the possibility to either stay anonymous in their responses or present the name of the company or the institute they represented in the opening part of this thesis.

A pre-prepared questionnaire served as a guidance tool during the conducted interviews. Its aim was to a large part to provide a direction for the semi-structured interviews and if a respondent seemed to be exceptionally knowledgeable in their field, or was especially interested in sharing their experience, the interview turned out to be looser. Therefore, the questions within the questionnaire were not strictly adhered to. Moreover, following on the deeper knowledge gained on the sector, some of the questions turned out to be less relevant to be asked in light of the nature of respondents' activities. Still, in order to obtain relevant and comparable information, the questions regarding the choice of location and digitalization trends were regarded as a priority.

In total, there were 10 respondents interviewed. The majority of them (70%) could be described as small organizations (less than 49 employees), the other 20% were represented by larger companies with over 250 employees. One internationally operating company declared

they only had a team of developers in Czechia, not a team of healthcare technology specialists, unlike in other countries.

Graph 6: Size of the organizations involved in semi-structured interviews (based on number of employees)



Source: Semi-structured interviews

Looking into the organization size based on financial strength, the organizations' turnover ranged from 2 millions of early start-ups with high R&D-related expenditures to 2-billion multinationals. This question was not relevant for some of the respondents, since two of them were a non-profit organization and other two are for the most part funded by public grants.

In terms of the year of establishment, except for two large respondents, there were predominantly young organizations interviewed, being established no earlier than 2002. The other two respondents commenced their activities in Czechia already in the 1990s.

Table 10: Year of establishment of the organizations involved in semi-structured interviews

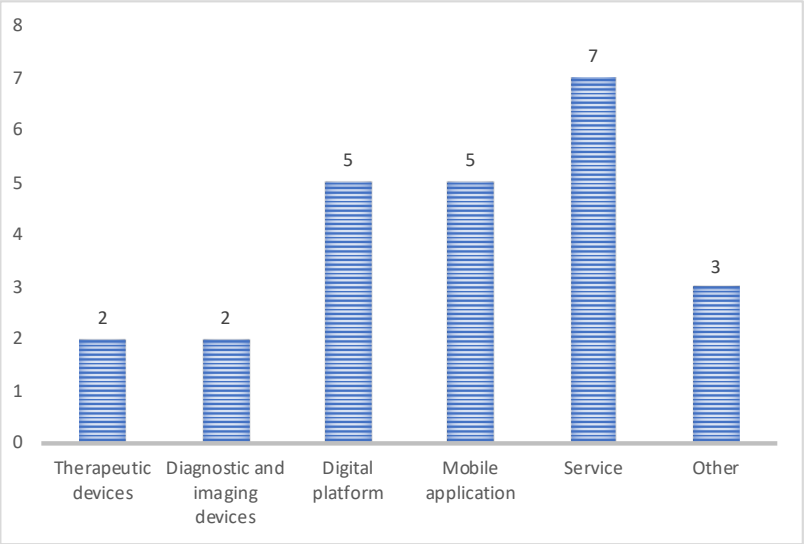
Respondent number	Year of establishment
1	1990
2	1993
3	2002
4	2005
5	2012
6	2014
7	2015
8	2016
9	2017
10	2018

Source: Semi-structured interviews

The goal of respondent selection was to obtain a sample of innovators operating in diverse healthcare areas. Among respondents, the share of those focused on telemedicine was dominant (5 respondents in total). There were two organizations that contribute to an increased awareness of digital healthcare through collaboration with various relevant stakeholders. The activities of the others were related to operations with regards to electronic health records, the production and distribution of active medical devices (mostly physiotherapeutic, aesthetic and cardiac), imaging and precision medicine and the provision of healthcare to the general public, as well as to company employees.

However, the Czech healthcare sector is not an easy place for performing business and scientific activities. The sector's digitalization is in its beginnings and many times a new entrant to the market or an organization introducing a new digital solution have to educate their target groups beforehand. Except for a wide portfolio of products, respondents very often have to include services such as consultancies, trainings, organizing workshops or simply awareness raising of awareness to attract the attention of those concerned with the digital novelties. As a result, it was deemed necessary to classify respondents into distinctive categories based on the type of their main product or service. An overview of the most common products and services captured in Graph 7.

Graph 7: Main product or service of the organizations involved in semi-structured interviews

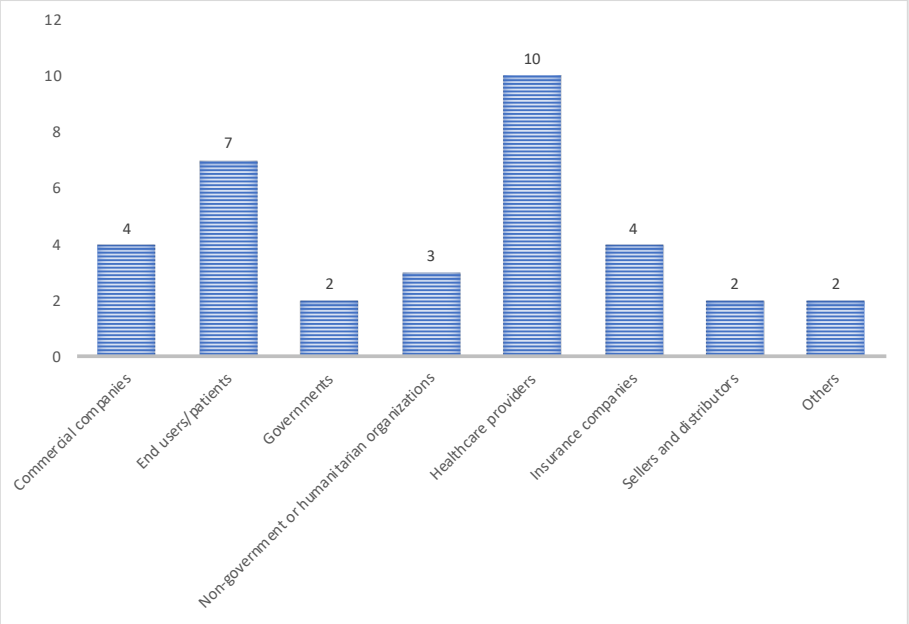


Source: Semi-structured interviews

The graph supports the argument that many respondents are devoted to the provision of services. As far as other types of products or services are concerned, it was expected to end up with a large share of those operating a digital platform or a mobile application, since they go hand in hand with telemedicine. Some of the interviewed organizations also offer other hardware, software or cloud solutions.

When analysing the sample by customer typology, the majority of respondents caters to healthcare providers (e.g. hospitals, psychiatric clinics or private doctors), followed by end users (patients), commercial and insurance companies. Only two respondents stated a collaboration with the Czech government and sellers or distributors. Furthermore, some of the respondents deal with domestic and international universities, a fitness centre or research institutions. The customer typology is illustrated in Graph 8.

Graph 8: Customer types of the organizations involved in the semi-structured interviews



Source: Semi-structured interviews

The last three identification questions concerned the sources of financial and organizational support of respondents. The aim was to understand whether the Czech digital healthcare innovators were capable of bringing new digital solutions to the market by their own means, or alternatively, whether engaging an external subject was necessary.

According to the statements of respondents, only one interviewee collaborates with business incubators and this is not done in Czechia. The last two semi-structured interviews revealed that one of the reasons is a lacking medically-orientated business incubator in Czechia.

To fund their scientific and business activities, respondents rely more on public grants than on private investments.

During the interviews, more background information on the motivation of respondents with regards to external funding emerged. One of them talked about their own experience with private investors. As a university spin-off, the company attended multiple meetings with investors in search for the "whole package" of financial resources and a business team, headed by a competent CEO. It is especially typical for university spin-offs to appoint an external business leader, so that their founders have more time capacity for research activities and new product development. Unfortunately, their wish was not met. Not only the addressed investors wanted to participate solely through owning a share in the company, also the amount offered was always lower than required.

With public funds, most of the respondents have been granted EU funds. H2020 (Horizon 2020), OPIK (Operational Programme Innovation and Competitiveness) and grants of the Technology Agency of the Czech Republic were repeatedly mentioned. It also became clear that Czech hospitals rely heavily on the IROP programme (Integrated Regional Operational Programme), through which they get a chance to modernize the information systems. One of the respondents mentioned that they had been in the process of applying for a grant before, however, they had not finished the application due to, in their view, overly demanding administrative procedures. Moreover, there was a respondent that considers public grants as a potential threat to their reputation due to a perceived lack of transparency in application procedures.

Location

The second section of the questionnaire was essential to grasp why companies and research institutions choose Czechia as a target market for their business and research activities. Findings of this part reflect on the potential of Czechia to attract foreign healthcare players as well as clarify why respondents base, or alternatively do not base their core activities in Czechia.

Firstly, respondents were asked to name advantages of operating in Czechia. A lot of times their reactions were sceptical and they remarked that there are more disadvantages than advantages entailed. In addition, they often named benefits that under certain circumstances could also be viewed as discouraging elements when considering entering the Czech healthcare sector. Nevertheless, respondents eventually managed to come up with a couple of factors that make the Czech healthcare a promising market for launching new activities.

The primary stimulus for choosing Czechia is the size of the market. Generally, it is easier to work with a small market (less competition, less diversified customer needs), even though its potential is considerably limited. Its stability, openness and proximity to other European markets is also widely appreciated among respondents. Situated in the hearth of Europe, among countries of varying economic development, Czechia provides a unique opportunity for foreign companies (mostly American-based) to test their business concepts and products before pursuing business interests across other European states. On the other hand, the small market (e.g. based on the size of Czech hospitals) might discourage foreign companies, giving more opportunities to the local players. Another influencing factor to favour the presence of Czech entities is the cultural proximity, which is especially relevant in terms of the language. Being able to communicate in their mother tongue helps companies ensure a smooth, authentic communication with a patient.

Very frequently, respondents praised the especially high quality of the Czech healthcare and the well-educated healthcare professionals. When it comes to the cost of labour, experts' opinions differ. Some perceive the cost of labour and R&D to be lower than abroad, others claim that both PhD students as well as healthcare professionals are generously rewarded.

Another justified reason for digital innovators to settle down in Czechia is paradoxically hidden behind the yet insufficient level of digitalization. A large potential lies especially in the area of telemedicine and electronic health records, as Czechia is still falling behind in these topics. This business opportunity is further supported by the National eHealth Strategy that sets a condition that the majority of digital services has to be rendered by private companies. In addition, the forthcoming eHealth Act assumes a system of paid digital services, meaning that insurance companies are going to be compensated for each patient.

As far as disadvantages are concerned, the basic challenge lies in the very nature of the healthcare sector. The healthcare sector in general is fragmented on national levels, requiring companies to adapt to local specifics. Above all, on the small Czech market, it cannot be reliably determined whether there is going to be great interest in a company's product. In the beginning, a new entrant has to invest heavily into R&D activities. Nevertheless, if the final production, or novel solution is supposed to be developed solely for a small market with lower demand, the development and subsequent adaptation to the market's specifics may not turn out to be cost-effective. Therefore, some of the internationally present respondents suggested that it would be better to start a business abroad and consider Czechia as a possibility for future business expansion.

One of the distinct features that makes it more difficult to perform well in the Czech healthcare sector is the separation of the areas of healthcare and social services. Also, in comparison to Northern European countries, the Czech healthcare sector is the recipient of a significantly lower funding. This often makes operating conditions more challenging.

What is more, Czechia still does not have a functioning EHR system for exchanging patients' health records, making orientation in patients' data extremely difficult. Nevertheless, it is indispensable to have a unified eHealth system administration. One of the respondents shared their view that two possible solutions are offered in this place. It would either be possible to designate one sovereign provider of the EHR system, or to allow more providers to operate their solutions while standardizing certain types of communication. It would be then upon the decision of the individual healthcare providers to choose an EHR provider, however, the interoperability of individual EHR systems would have to be ensured. According to the respondent, the latter seems to be a more viable option, since the system of deciding for a

sovereign EHR provider would not be transparent (too many private subjects are interested in assuming that attractive role).

A more detailed view on the standardization of the EHR system was provided by another respondent. According to them, adopting the HL7 standard, which is common across other, more digitally-savvy European states, would make it more attractive for investors to enter the sector. The current solution is in the form of the DASTA standard. It is a specific Czech solution and it incurs further costs to foreign entities, as they are expected to adapt to this local standard first to be able to share data.

A couple of digital solutions for data exchange are already present in several hospitals; however, their interoperability has not been ensured yet. At this point, it is interesting to mention that some of the respondents believe that doctors' negative attitude towards medical information-sharing is to blame. According to them, doctors are still unwilling to share such information, since they are afraid that their professional decisions regarding the choice of a therapy would be scrutinized. Overall, the interviewed experts are convinced that Czechia lags behind other European countries substantially in the efforts to digitize its healthcare.

More respondents agreed that the whole healthcare system is too complicated and non-transparent, as there are too many administrative procedures to follow. As a result, doctors usually lose orientation in the current legislation, causing them further administrative problems. One of the examples is the existent regulation of the digitalization of patients' health records. All electronic documentation has to bear an electronic signature, but its validity is limited to only one year. Also, it occurs frequently that although a company plans to introduce an innovative solution that is already present in the area of healthcare abroad, it is sometimes impossible to bring it to Czechia due to excessive national regulation. The respondent says this provides an explanation why the Czech healthcare is lagging behind in the European context.

Furthermore, there is no cross-border communication in place that would be operated nationwide. The only initiative to take place was the pilot project in the Vysočina region, known as the Patient Summary. The project's objective was to transfer patient data to ambulances through mobile devices such as tablets. The basic patient information was immediately translated into a foreign language for specialists to work with a patient more effectively.

Another topic to discuss is the communication with competent authorities. As stated by one respondent, the communication with SÚKL proves to be demanding in the long run. According to the respondent, the problem stems from SÚKL being insufficiently staffed. The employees are overloaded and do not manage to perform the assigned tasks on time. Another problem constitutes "incomprehensible requirements" placed on companies before being able to provide their brand-new medical devices on the market.

The last disadvantage to mention is that existing patient organizations are very weak and the lobby groups are uncoordinated, lacking a proper strategy. This often leads to the government implementing partial legal solutions orientated on a partial area of the healthcare without solving the problem of the sector as a whole.

All respondents are convinced that there are obstacles for new entrants to the healthcare sector. Usually, their responses differ as they are all better aware of the entry barriers typical to their respective discipline, rather than understanding the healthcare sector in general.

A major barrier is the lack of insurance categories. A company may come up with a new, innovative digital solution, but unless the insurance companies are willing to cover its costs to patients, patients are unlikely to purchase it. The current situation in the area of telemedicine is no exception. If a doctor wants to use telemedicine during a patient's treatment, they either apply for a grant or purchase the technology on their own. Respondents state that an effective collaboration with relevant stakeholders during earlier phases of product development gives a higher probability to stakeholders' interest in the solution (eventually leading to the interested subject paying for it). This sends an alarming message that without a doctor's or possibly a community's initiative, novel telemedical solutions would rarely be available to the Czech patients. Therefore, even insurance companies have to clearly understand the benefits of telemedicine in the healthcare. It would require digital innovators to prepare studies for insurance companies, calculating the financial benefits of cured patients. In the end, the basic premise is that the healthier patients, the lower the burden on the reimbursement system.

The readiness of Czechia for digitalization is also a key issue. Respondents are convinced that in many aspects, Czechia is not prepared to accept new digital solutions. The implementation of the electronic identity of citizens and ensuring high-speed Internet connection should be, thus, at the top of the list of the government's priorities. Also, the already mentioned interoperability of electronic data systems has to be tackled. A practical solution would give telemedical companies the opportunity to send collected patient data to hospitals via a standardized system.

A producer and distributor of active medical devices sees the excessive regulation as one of the greatest hindrances. It requires a lot of time and a large amount of financial resources to start a business in their field, not only for R&D, but also for the obligatory certification. At the same time, they are aware that the situation is similar across the whole Europe. A new regulation at the EU level is planned for March 2020 that is going to change the demands put on the production of medical devices. The respondent states that it is expected that most small companies are not going to be able to comply any longer. Great bureaucracy in the field enables

exclusively larger players to operate. Unless joining with a bigger company, it will not be natural for start-ups to enter this field.

In the opinion of another respondent, there are serious difficulties for new entrants in terms of trade barriers. The respondent witnessed a situation when a new, revolutionary solution was developed, however, it could not be commercialized as the current healthcare players already had the market divided. Adding a competitive solution would be too provocative considering the well-established positions of other players.

Some view public funding policies insufficient. Those who can compare Czech policies with those of foreign governments are convinced that Czechia places little interest in this type of innovation support. Moreover, awarded grants are said to be used ineffectively. As an example, Czech hospitals often direct received finances to just a minor, yet still insufficient modernization of their information systems.

When confronted with the topic of patients' concerns about new technology, respondents talked about the necessity to organize conferences for the general public.

Innovativeness

Before analysing where and how the interviewed organizations contribute to the digitalization of the Czech healthcare, it was important to understand the strength of their innovation background. A special section of the questionnaire was therefore dedicated to topics such as collaboration with other industry stakeholders, product innovation cycles, share of foreign employees and the number and structure of protection solutions owned.

The interviewing process revealed that 8 respondents out of 10 regularly talk to end consumers and incorporate their wishes and needs into the functionalities as well as the design of a new product (Graph 9). There was only one respondent without knowledge of any ongoing company-patient collaboration. In another case, a telemedical respondent indicated that a more intense communication is held during the treatment process when the treatment is personalized based on measured values and the overall health condition of a monitored patient. Also, rather than communicating with an individual patient, producers explore the common characteristics of the whole patient group (e.g. diabetics).

A useful insight was provided by a telemedical respondent that claims that although their organization likes to look for inspiration for new products and services abroad, a simple introduction of such solutions on the Czech market would never work. To illustrate, the distance between a patient and a doctor is greater in the U.S. than in Czechia, which leads to a greater demand of Americans for telemedicine.

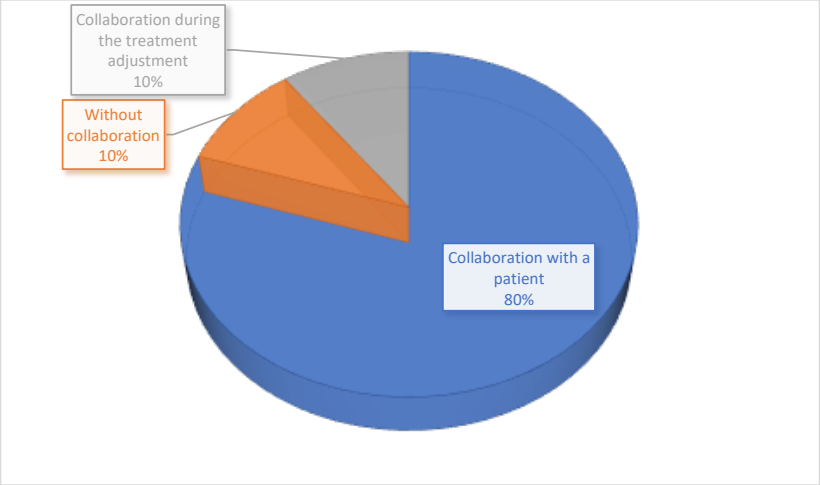
However, minimum three distinctive phases are distinguished in the process of human centred design in healthcare. It is the exclusive role of a healthcare professional (e.g. a doctor) to evaluate the therapeutic benefits and the applicability of a product in practice. Consequently, a product's technical parameters are evaluated by an authorized certifying body before presenting the proof-of-concept to customers. On the other hand, a patient is only capable of assessing a product's usability (Is the product comfortable? Do I know how to use it? Is the product design appealing?).

Frequently, communication with patients takes place when a specific group of patients needs to be educated on the causes of a disease in order for the treatment to achieve the desired effect (e.g. the importance of a regular exercise and a balanced diet to prevent diabetes).

All respondents consider collaboration with healthcare providers an indispensable step in product development and design (see Graph 10). Respondents either keep close relations with experts in the medical community (domestic, or international) or have doctors directly as part of their teams. It was also found out that unlike communication with patients, collaboration with healthcare providers takes place constantly.

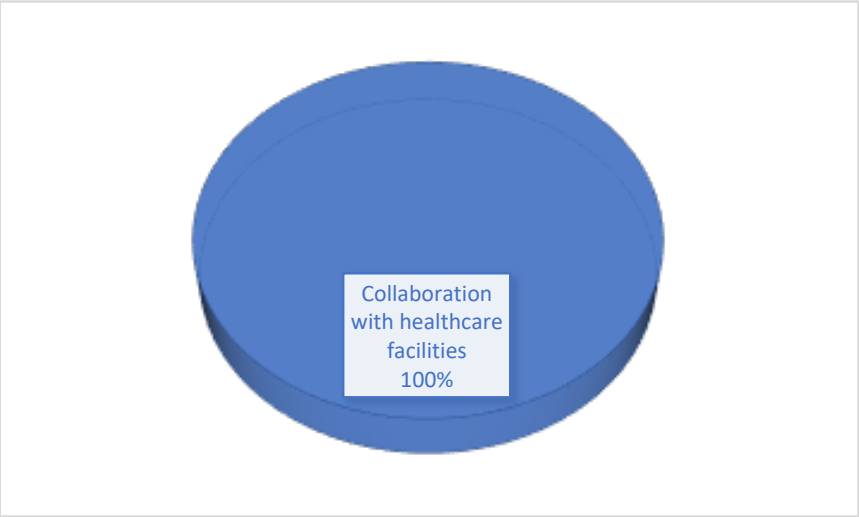
To make the analysis of possible ways of collaboration among interested stakeholders complete, respondents shared their experience with university/ research-business collaboration. As seen in Graph 11, half of the respondents relies on business-academia partnerships. The interviewed university laboratory acknowledged the interest of the commercial sector for the development of new, tailor-made products and services in their laboratory. There would also be room for cooperation in the education of medical students on digital technology. Another way for the commercial sphere to leverage the expertise of academics lies in informal consultations on upcoming digital solutions. Two respondents stated that close collaboration with researchers is enabled by their presence in the work team. There was only one respondent that does not have knowledge of any research-business collaboration within their organization.

Graph 9: Collaboration with the end customer (patient) on product development and design



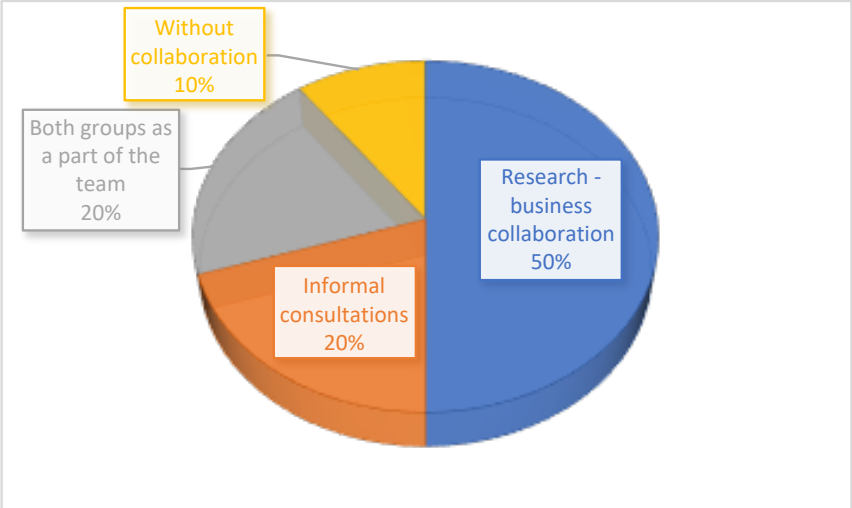
Source: Semi-structured interviews

Graph 10: Collaboration with healthcare providers on product development and design



Source: Semi-structured interviews

Graph 11: University/Research institute – business collaboration



Source: Semi-structured interviews

When asked about the number of new products introduced on the market annually, reactions varied a lot. Some of the respondents argued that it is difficult to say, since they are still a newly-established company, or they rather focus on product variations and adding of functionalities to their current digital platforms. For those reasons it was not possible to compare their innovation cycles on simple graphics. Larger companies from the sample of respondents claimed to introduce 1-3 products annually. The number is not remarkably high as it is a time- and knowledge demanding process to invent a new healthcare product.

It was expected that higher innovativeness in respondents (since they can be truly considered innovators in the area of digital healthcare) could have been spurred by knowledge-sharing within an international team. Not all respondents employ foreign employees, however. On the other hand, staying in touch with foreign experts and organizing business trip or business exchanges tends to be more common. One of their benefits is the opportunity to compare new technological solutions. The information exchange with foreign competitors could lead to lower costs of technology offered on the Czech market.

Although the majority of respondents looks for its workforce via established internal HR processes, they are open to collaboration with eager innovators, with whom they share one vision. One-time collaborations on concrete projects with external subjects are also taking place regularly, usually with doctors, developers, businesses, communities or regions. In order to recruit medical graduates, respondents maintain close contact with reputable universities. The

only problem with medical students is that after graduation, they need to obtain an attestation, which is only possible in hospitals.

The innovative potential of respondents was also analysed through the number of solutions with legal protection[147]. At this point, not all respondents were capable of offering an exact number, moreover, some stated they did not have any intellectual property rights (IPR). With regards to patents (here, all company patents were taken into consideration, not merely those associated with digital healthcare and applied abroad as was the case of the research conducted in the previous sub-chapter), respondents frequently owned several patents, usually for each novel product. While larger companies tend to own hundreds of patents, small start-ups dispose of 3 patented technologies on average. During its brief presence in the area of digital healthcare, the interviewed university laboratory was granted 2 patents in total. The number of patented solutions of respondents increases in time. In terms of other types of IPR, some mentioned utility models and marketing-related trademarks.

With two respondents, the question on IPR triggered a deeper conversation on the balance between openness, transparency and the protection of innovative ideas. There was one respondent that dismissed the possibility to patent their digital platform and rather built their business on sharing their idea openly, an approach, which eventually attracted a lot of investors. Contrary to that, another respondent views patents as a fair business provided it is associated with a fair (licensing) policy.

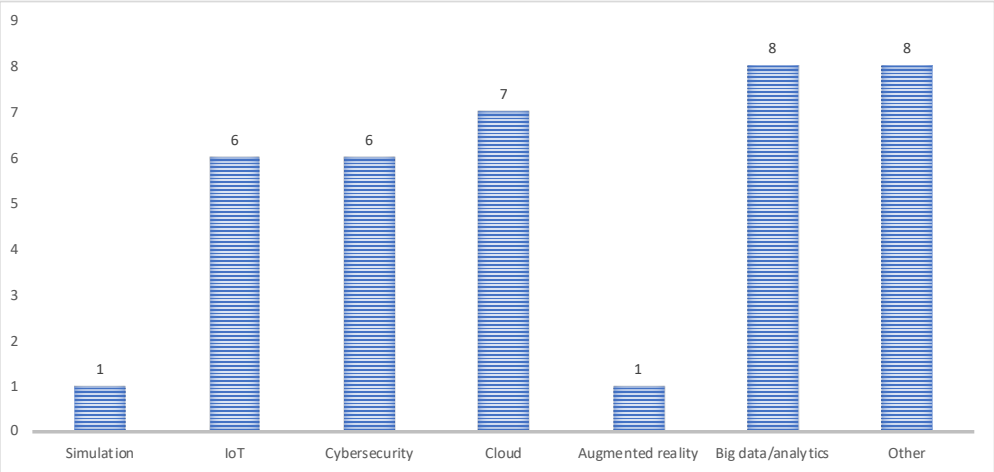
Digital healthcare

The principal focus of the semi-structured interviews was to understand trends in the Czech digital healthcare. While the preceding three parts were primarily aimed at characterizing the sample regarding basic indicators and innovation potential, and their view on the attractivity of Czechia as a target market, the fourth part deals with thorough analysis of digital technology trends in the Czech healthcare sector. The reader has a chance to get a proper overview of the technology already present in the Czech healthcare, future plans of respondents, their views on the current state of digitalization of the sector and its possible future development. In the end, respondents were also asked to suggest market opportunities for start-ups interested in bringing digital solutions to the local market.

The goal of the opening question was to assess which transformative technologies respondents base their products on (Graph 12).

[147] Unlike in the patent analysis in the previous sub-chapter, here, the respondents talked about IPRs in general. Thus, not only digital healthcare solutions are included but rather the companies‘ patented inventions in general.

Graph 12: The number of respondents with products based on various types of transformative technologies



Source: Semi-structured interviews

Although there are several dominant transformative technologies to be seen in Graph 12, respondents believe they take advantage of all technologies related to Industry 4.0. Thus, the answers rather reflect respondents' primary technological focus at the time of recording. A distinct trend of working with big data was revealed. Big data provides comprehensive insight into a patient's medical condition and its analysis is a cornerstone in personalized medicine. By having key patient data at hand, doctors do not only have a chance to diagnose patients earlier, they are often also able to apply an appropriate prevention care. The implementation of cybersecurity and cloud services serves to assure a more comfortable and secure work with the patient data. A large part of the interviewed organizations talked about other technologies that were more typical for the area of the healthcare they are interested in (e.g. sensors, artificial intelligence, 3D printing, natural language processing, machine learning and human computer interaction).

When confronted with the topic of their future plans on the use and implementation of digital technologies, some of the respondents explained that they are not in a position to dictate trends and will probably only continue focusing on flexibly reacting to market demand. Their reasoning is justified Czechia not being a trend-setter in the area of digital healthcare. Nevertheless, it was still possible to gain a basic understanding on which direction the interviewed organizations would like to assume.

For EHR pioneers, self-learning mechanisms build on AI, combined with natural language processing for reading unstructured texts are the top priority. Telemedical innovators will further capitalize on big data, disease management with the help of AI combined with

existing knowledge in the field of genetics. Machine learning will assist doctors to determine a diagnosis more appropriately. Many telemedical respondents identify great potential in the use of chatbots in the communication with a patient. According to them, though, a major obstacle to a faster advancement is low battery life in telemedical devices and, thus, new charging methods need to be developed. Genetics will also be crucial for producers of imaging devices. The producer and distributor of active medical devices plans on reducing the size of products offered for a more comfortable use and additional product functionalities. Expansion to new medical areas is also considered, mostly in the field of therapeutic and chirurgical lasers.

The second chapter of the thesis discussed current difficulties in the Czech healthcare sector. When asked whether they share this view, respondents were strongly critical of the current situation in healthcare digitalization, however, they perceived the Czech healthcare to be of exceptionally high quality. Furthermore, they praise new initiatives of individuals and local communities (e.g. the Patient summary).

In the process of digitalization, they unanimously stated that the Czech healthcare needs to work on developing its IT infrastructure. A functioning EHR system and the eHealth Act are seriously lacking. When talking about the EHR, respondents viewed the initial efforts in the introduction of the original IZIP system as very progressive. Czechia could have been one of the pioneers in Europe. Further development was, however, prevented by the following political decisions, leaving Czechia to become one of the last countries to digitize its healthcare sector. Also, the implementation of e-Prescriptions progressed slower than expected, according to some of the respondents. One of the respondents considers the low interoperability of healthcare information systems to be the principal barrier to the diffusion of digital solutions. Each hospital is free to choose their vendor, but vendors do not cooperate, which leads to each system being based on different principles, ruling out the possibility of smooth data exchange.

Disregarding digitalization, the underutilization of biological therapy, the weak emphasis on prevention, high rates of doctors' visits, overworking medical staff and the uncoordinated deployment of healthcare facilities preventing synergic effects of cooperation were identified as major shortcomings.

Naming all difficult challenges, respondents also presented suggestions for solutions to be implemented for the healthcare sector to advance. In general terms, several system solutions have been proposed.

The EHR pioneer puts trust in measuring the quality of healthcare. Telemedical innovators would welcome if hospitals were not forced to decide solely on price in public

tenders. More emphasis should be put on the quality of the purchased products and services. They also outlined that a better innovation ecosystem is required. Some see Germany as a role model here, where students are motivated to start a business already during their studies, supported by grants.

Another area to deal with revolves around more active public financing of healthcare and a better conceived education and training programmes for doctors to prepare them better for their future occupation (more practical, with an access to new technology, e.g. programming and applied physics).

More effective operations of healthcare insurance companies enabled by free competition could serve as a good motive for further discussions.

In terms of digitalization, all the above-mentioned digital healthcare challenges must be urgently solved. Virtually each respondent agrees that a functioning EHR, the implemented eHealth Act and the interoperability of healthcare systems have to be ensured. There were also suggestions on establishing an effective cross-border medical communication. Regarding telemedicine, the question of who is going to fund new, telemedicine-based therapeutical devices requires to be dealt with. As an example, new products are widely supported in the neighbouring Germany. The interest in new digital solutions of German decision-making stakeholders is visible from the large number of conferences organized on healthcare-related topics, as well.

Other ideas include knowledge-sharing among doctors based on remote communication, e.g. to consult a patient's diagnosis or symptoms and assigning more experts being involved in addressing key, strategic questions in healthcare to prevent one-time, short-sighted decisions.

One of the respondents, a doctor, thinks that the term digitalization is too broad. In his view, too many actors brandish with this concept, but only a fraction of them genuinely cares about the end recipient. He prefers to concentrate on the system and programme procedures whose primary goal is to help a patient. To him, the biggest difference lies in suggesting concrete steps in digitalization, not just a broad strategy, where economic, financial and ethical aspects serve as basic pillars. For a start, implementing a simple application for monitoring medicine prices and availability could considerably facilitate patients' orientation. At the same time, he is convinced that patients' initiative in naming their needs is crucial for companies to start acting on catering to them.

According to another respondent, participating in the currently developing international cooperation EURAMED 2 for information exchange on medical devices is also a way to enhance the Czech healthcare sector.

In the end, respondents believe that a change in mindset is required. In general, an effective way to support prevention is to introduce payed healthcare services to motivate a patient to take care of their health better. The problem is, however, that today the Czech patient already relies extensively on having the possibility to rely on unpaid services. Similarly, the mindset of doctors needs to be altered and their proactivity stimulated, particularly regarding the understanding of benefits provided by modern technology usage in practice. In addition to that, a certain rigidity in accepting digital technology and concerns for human health have a great influence on the speed of further digital development.

Afterwards, respondents were asked whether and how their activities contribute to dealing with the most serious issues of the Czech healthcare. A frequent response was engagement in strengthening prevention. Predominantly, big data (regression analysis of historical data) and telemedicine allow healthcare specialists to diagnose a patient in time and at lower costs (up to 40 % in costs incurred). In addition, popularizing telemedicine among patients increases the interest in monitoring their health condition via various wearables. Thus, doctors, mostly those in primary care, are put under pressure to increase the quality of the services by enabling their patients to use telemedicine as part of the therapy. But indeed, there are many benefits of telemedicine. Apart from disease prediction and prevention, a patient's quality of life is dramatically increased, the number of hospitalizations is reduced, leading to lower cost of treatment as well as lower workload of healthcare workers. One respondent talked about their effort to reduce the white coat syndrome among patients (increased blood tension caused among patients by the clinical setting[148]). AI and machine learning are predicted to have a similar effect on reducing the burden put on healthcare specialists when assisting in data analysis and decision-making.

Another telemedical respondent believes that doctors are insufficiently educated on the importance and use of modern, digital technologies. In their efforts to change this, they organize meetings with doctors where they present their solutions.

Sometimes, introducing advanced imaging devices is not enough, particularly at times when each digital device provides a doctor with thousands of important inputs. Therefore, the respondent active in this field works on the creation of a unified system, via which specialists could access information more easily.

[148] Ramli Anis, Halmey N, Teng CL (2008): White coat effect and white coat hypertension: one and the same? *Malays Fam Physician*. 2008;3(3):158–161. Retrieved from: https://www.researchgate.net/publication/26610036_White_Coat_Effect_and_White_Coat_Hypertension_One_and_the_Same

One of the respondents runs a digital platform where patients are connected with the most relevant and the most conveniently located healthcare specialist. Not only does the platform enable to solve health-related complications more quickly, its additional benefit lies in sharing patients' experience with a concrete specialist. Ranking in the platform allows patients to get access to skilled professionals, which in turn, motivates professionals to perform better.

Providing laboratory services, e.g. reporting the results of examinations can currently also take place via online means.

Subsequently, respondents expressed their expectations on the future development of the Czech healthcare sector in the following 10 years. In their opinion, any form of digitalization would facilitate the work of healthcare professionals and would constitute a major step forward. Principally, they are convinced that Czechia will succeed in achieving the complete digitalization, including the transfer of electronic patient data. Other advancements will go in line with healthcare trends of other western European countries and the U.S.

A more significant onset of telemedicine, with a greater market penetration of wearables (e.g. diabetics monitoring), various IoT-based and more precise connected devices and improved technological solutions are envisaged. Soon, Czech doctors are expected to regularly rely on digital ways of communication, both to contact their patients as well as when consulting their decisions with foreign experts. A doctor's decision-making process will be speeded up by the assistance of machine learning mechanisms.

One of the interviewed doctors sees the digital healthcare as a unique opportunity to treat polymorbid patients (patients suffering from multiple diseases at the same time[149]) thanks to personalised medication.

Digitalization could also modernize communication with the population regarding security notices (mobile phones will replace traditional media such as radio broadcasting).

Ultimately, considering the increasing number of mobile applications aimed at measuring user's vital body functions, international organizations have decided to establish their proper classification. In this way, mobile applications, now viewed as regular medical products, are going to adhere to certain safety rules to protect the patient.

[149] Velký lékařský slovník: Polymorbidita. *Velký lékařský slovník* [online]. [cit. 2019-04-14]. Retrieved from: http://lekarske.slovniky.cz/pojem/polymorbidita

The closing questions of the questionnaire investigated respondents' recommendations on promising healthcare areas for new start-ups to engage in, as well as the assessment of potential success of new business activities, in general.

As reported during the interviews, there is a vast potential in Czechia and future entrepreneurs are encouraged to look for inspiration among successful businesses abroad. But business opportunities are offered even to established companies and university spin-offs. On the other hand, two respondents believe it is hard to succeed in such a regulated environment as healthcare, particularly in Czechia. They added that moving business activities abroad and restricting operations in Czechia only to research is recommended.

A common business strategy for healthcare innovators is to come up with new solutions in the field of wellness mobile applications, as they present a less technologically demanding solution and therefore a start-up does not bear an unnecessarily large responsibility.

However, respondents warn that huge enthusiasm for start-ups has started to fall. Their success is often dependant on the gained trust of stakeholders, rather than a solution's functionality. In addition, a potential success rests on who an aspired entrepreneur is going to address with their novel solution. If it is a patient, it is going to be the task of a businessman to come up with funding solutions. On the contrary, in case of approaching an insurance company, a well-elaborated cost-benefit analysis would have to be presented for them to be willing to participate. In practice, though, it is very common that Czech companies do not obtain the resources necessary and are forced to direct their business efforts on foreign markets.

One of the interviewed companies warned against the attitude of millennials, characterized by excessive self-confidence and preparedness to defend their ideas even after a series of evident failures. Often, they lack humility and determination to get things done, which might cause distrust among potential investors.

Despite all obstacles, respondents believe that with the right mindset (particularly a great deal of patience), new start-ups have a chance to succeed in the Czech healthcare sector.

According to their statements, there are several prospective areas for commencing business activities:

- IoT for the construction of smart homes
- Big data for structuring a vast amount of unstructured data from health reports; real world data, predictivity, with emphasis put on genetic potential tracking to manage disease prevention accordingly
- AI for counselling a doctor, machine learning, disease management and a comprehensive approach to patients

- Genetics and biological treatment that is nowadays still largely restricted (patients are rarely granted permission to undergo such treatment, a usual exception is children)
- Shared medicine for medical information exchange (e.g. where to buy medicine at a lower price)
- Products such as smart glasses to access patient data during operation (e.g. from X-ray) enabled by the augmented reality
- Cognitive behavioural therapy. There are no limits for the start-up bringing this solution to be a Czech one.

Finally, the top three transformative technologies in the following decade are identified as big data and its analysis, AI and chatbots and augmented reality. Big data will help access essential information immediately when it is necessary. Its other benefit lies in enabling a doctor's decision to be based on data, rather than on their gut feeling. Secondly, AI will serve as an indispensable tool for assisting in determining a patient's diagnosis as well as the likelihood of occurrence of certain diseases. It is expected that with increasing awareness, more health-conscious patients will search for doctors themselves due to their interest in preventive examinations. With an increasing number of examinations and data provided, there will be a growing pressure on a more precise interpretation of individual markers in medical examination results. Lastly, augmented reality will find its use in education, also in the area of practicing operations for medical students.

Conslusion

The healthcare sector is very complex, characterized by multiple market distortions, making it a difficult environment to introduce innovations and disruptive changes to. Despite the sector's rather slow digital transition, as compared to other industries, more significant progress is expected thanks to the technological advancement brought about by Industry 4.0. The accompanying, transformative technologies are not brand-new; however, novelty could be found in the new approach to their interconnectedness, making it possible even for the healthcare sector to overcome its inherent characteristic: separate "silos". By successfully adopting new digital solutions and better coordinating its resources to embrace all the challenges, the sector stands a great chance of rapid advancement.

In this thesis, the Czech healthcare was of principal focus. The Czech healthcare system is generally considered stable. Being based on public health insurance, it provides general coverage with a generous array of paid services. The Euro Health Consumer Index ranked the overall healthcare performance of Czechia 16th out of 35 countries in 2017.

In terms of the sector's digitalization, the most significant initiative has been The National Strategy of eHealth, whose goal is to gradually digitalize the key parts of the Czech healthcare system by 2020. The highly anticipated eHealth Act is currently in the preparatory process. In the European context, the country's progress in digitalization is best reflected by the Digital Economy and Society Index, which ranked Czechia 17th in 2018, placing it to the cluster of medium-performing countries.

When searching for concrete, innovative digital solutions, several examples were identified. Areas where local companies are involved range from telemedicine through the manufacturing of medical implants, the operation of medical platforms and mobile applications to raising general awareness of digitalization's benefits.

In the analytical part of the thesis, trends in the digitalization of the Czech healthcare were identified. Public data from two key databases was extracted - "Informační systém výzkumu, experimentálního vývoje a inovací" for information about scientific projects and other scientific results and Orbit Intelligence for data on patents of Czech institutions, as well as Czech residents. By analysing all data obtained for the period of the last 10 years, it was concluded that the most frequent topics for research projects have been 3D technology, bioinformatics, ultrasound, biosensor and gene therapy, with Charles University and Masaryk University as the main actors. Other scientific results of the competent stakeholders, such as the Czech Technical University in Prague, Brno University of Technology and several public hospitals confirmed the interest in 3D technology and ultrasound. Apart from that, biosensor,

AI, cloud solutions and the IoT are other areas where healthcare stakeholders have been particularly active. As far as patents are concerned, 3D, ultrasound and biosensors are the leading technologies, followed by AI, cloud and IoT. There are various patent owners both from academia, as well as from the business sphere. However, the total number of digital healthcare-related patents is relatively small, merely 10 in total.

Subsequently, semi-structured interviews were conducted with a sample of 10 respondents, identified as local, innovative leaders, to understand their subjective views on the current and future development of the Czech digital healthcare. A typical respondent was a small (less than 49 employees), rather young organization, operating in telemedicine, mostly catering to the healthcare providers and end user (patients). In terms of organizational and funding support, the typical respondent does not use the services of business incubators, operates without investors' involvement and relies on the funding from public sources.

Assessing the innovation background of respondents, great importance is put on human centred design, with respondents regularly discussing new product design and development with both patients, as well as healthcare providers. In addition, the majority of them capitalizes on business-academia collaboration and maintains close contact with foreign healthcare experts. The interviewed respondents dispose of several patented solutions whose number tends to increase in time. Their innovation potential is further stimulated by hiring eager professionals with a positive mindset towards innovations.

Although respondents generally base their activities on all transformative technologies associated with Industry 4.0, big data, analytics and cloud solutions are currently considered as the most essential ones. As for the Czech-based players, they plan to follow and actively respond to the trends set by more digitally developed healthcare markets abroad.

Based on the interviews, the Czech healthcare needs to improve its IT infrastructure. Smooth patient data exchange could be enabled by ensuring interoperability of the currently diverse healthcare information systems. Other possible areas for improvement include cross-border medical communication, increase in the number of categories covered by healthcare insurance companies and a change in the mindset of many healthcare stakeholders. Disregarding digitalization, underutilization of biological therapy, weak emphasis on prevention, high rate of doctors' visits, overworking medical staff and uncoordinated deployment of healthcare facilities were identified as the sector's major shortcomings. Respondents, however, believe that their innovative endeavours contribute to dealing with the most pressing issues of Czech healthcare.

According to respondents, the Czech healthcare will succeed in achieving a complete digitalization, including the enabled transfer of electronic patient data in the following decade.

Other advancements will go in line with healthcare trends set by western European countries and the U.S. Secondly, a more significant onset of telemedicine, with a greater market penetration with wearables, various IoT-based and more precise connected devices and improved technological solutions is envisaged. In addition, Czech doctors are expected to regularly rely on digital ways of communication, both to contact their patients as well as when consulting their decisions with foreign experts. Their decision-making processes will be speeded up by the assistance of machine learning mechanisms.

The analysis of business opportunities in the Czech healthcare sector revealed vast potential for local start-ups, despite respondents being aware of many location-related disadvantages. Large potential stems from a small, easier to penetrate and operate market, as well as the possibility to rely on high quality healthcare and healthcare professionals. Paradoxically, the yet insufficient level of digitalization provides another important stimulus for healthcare players to engage. Although less common, Czech healthcare could also serve as a testing ground for international companies.

On the other hand, to ensure a successful implementation of novel, digital solutions, one must gain the trust of competent stakeholders. Possible threats to success on the market also result from the market's limited potential and a prevalent general distrust towards digital technology. Other possible obstacles to consider include the separation of the areas of healthcare and social services, lower public funding and transparency, insufficient digital infrastructure, strict local regulation, weak patient organizations and uncoordinated lobbying.

One of the proposed possible business strategies for prospective healthcare innovators could be to come up with new solutions in the field of wellness mobile applications, as they present a less demanding technological solution without unnecessarily large responsibility borne by the provider. Another approach, a more conservative one, suggests limiting business activities to solely research in Czechia, while doing business abroad (e.g. Germany). Later, after succeeding abroad, Czechia could be penetrated as a complementary market.

In the end, several prospective areas for commencing business activities were identified. Some of them involve big data for structuring unstructured data from health records, AI for counselling a doctor, genetics and biological treatment, shared medicine, cognitive behavioural therapy as well as smart homes and products. Based on the interviews, the top three transformative technologies that will define the future of the Czech healthcare in the following decade are big data and their analysis, AI and chatbots and augmented reality.

To conclude both analyses of this thesis, during the past 10 years, up until now, 3D technology, ultrasound and biosensors are the technologies in which Czech healthcare organizations have been engaging the most, as a part of their scientific activities. On the other

hand, according to expert opinions of the selected sample respondents, big data and their analysis, AI and chatbots and augmented reality will become the principal technology trends for the upcoming decade.

List of Graphs

List of Tables

Appendix 1
List of keywords

List of keywords			
Number	Keywords	Number	Keywords
1	3_d	55	IoMT
2	3D	56	IoT
3	3D printing and nanotechnology	57	m-Health
4	3D prosthetic	58	Machine learning
5	3D prosthetic	59	Medical imaging
6	3d_printer	60	Medical imaging tool
7	3d_printing	61	Medical platform
8	4-D ultrasound imaging	62	Medical_microbiology
9	AI	63	mHealth
10	Aptasensor	64	Molecular diagnostics
11	Artificial intelligence	65	Multifunctional MRI
12	Artificial organ	66	Multifunctional radiology
13	Augmented reality	67	Nanodiagnostics
14	Big Data	68	Nanoformulation
15	Bioinformatic	69	Nanohealth
16	Bioinformatical	70	Nanomedicine
17	Bioinformatics	71	Nanotherapy
18	Bionic human	72	Nanovaccinology
19	Biosensor	73	Neuroprosthetics
20	Blockchain	74	Open healthcare
21	Blockchain genomics transformation	75	Optical imaging
22	Brachytherapy	76	Personal healthcare
23	Cloud	77	Personalized medicine
24	Companion diagnostics	78	Phagosensor
25	Digital health assistant	79	Precision medicine
26	Digital pathology	80	Predictive analytics
27	Digital patient experience	81	Radiation therapy
28	Digital twin	82	Real-time diagnostics
29	Disease management	83	Remote patient monitoring
30	E_health	84	Robo-doc health advisor
31	E-health	85	Robotics
32	EHR	86	Smart medical device
33	EHR microchip	87	Smart pill
34	Electronic health record	88	Surgical laser
35	Exoskeleton	89	Surgical robot
36	Fitness monitor	90	Synthetic biology
37	Fitness tracker	91	Telecare
38	Four-dimensional ultrasound imaging	92	Teledentistry
39	Gene therapy	93	Telegenetic
40	Genetic engineering	94	Telegenetics
41	Genomics data	95	Telehealth
42	Health analytics	96	Telehealth
43	Health app	97	Telemedicine
44	Health application	98	Telemetry device
45	Health informatics	99	Teletherapy
46	Health information exchange	100	Three_d
47	Health information technology	101	Translational_bioinformatics
48	Health tracker	102	Ultrasound
49	Home healthcare	103	Virtual caregiver
50	Immunoinformatics	104	Virtual check-up
51	In-vitro diagnostics	105	Virtual reality
52	Integrated vital signs monitoring	106	VR
53	Internet of Medical Things	107	Wearable
54	Internet of things		

Appendix 2

Master thesis questionnaire

Topic: Digitalization in the Czech healthcare

General information

1. **When was the organization founded?**

   _____

2. **What is the organization's main product portfolio/ service?**

   _____

3. **What category do your products/services belong to?**
   - Disposable products
   - Medical and chirurgical devices
   - Therapeutic devices
   - Diagnostic and imaging devices
   - Digital platform
   - Mobile application
   - Service (specify)
   - Other: _____

4. **What is the organization's turnover?**

   _____

5. **What is the size of your organization? (in number of employees)**
   - Small (49 and less)
   - Medium (50-249)
   - Large (250 and more)

6. **Who are your customers based on the following categories?**
   - MedTech companies
   - End users/patients
   - Procurement consortia
   - Governments
   - Non-government or humanitarian organizations
   - Healthcare providers (e.g. hospitals)
   - Insurance companies
   - Sellers and distributors
   - Others: _____

(For small companies and start-ups also questions regarding financial resources)

7. **Did the company used services of a business incubator?**

   _____

8. **Did the company collaborate with VCs or, business angels or other external investors to obtain finances for its operations?**

   _____

9. **Did your company use EU funds for some of its projects?**

   _____

Location:

10. **What are the main advantages of operating in the Czech Republic?**
    - Specific know-how *(state which one in particular)*
    - Collaboration with local research institutes and/or universities
    - Local infrastructure (roads, harbours, intermodal equipment, IT, freight transport etc.)
    - Labour costs
    - Export administration
    - Custom and import procedures
    - Government programmes/initiatives
    - Industry consortia or other cluster activities
    - Proximity to the Czech market (spatial, psychological, cultural)
    - Proximity to other European markets
    - Other: _____

11. **If there are any, what are the main disadvantages of operating in the Czech Republic?**

    _____

12. **How difficult is it to introduce new, technology-backed products/services to succeed with your customers, or potentially end-user?**
    - We do not see any problems
    - There are obstacles on the market

13. **If there are some obstacles, what are the most crucial ones?**
    - Distrust towards new technology
    - Data security concerns
    - Technological illiteracy
    - Lack of information
    - Government and other regulations
    - Lacking complementary infrastructure in hospitals and/or other healthcare facilities
    - Lacking finances for huge investments from the part of hospitals and/or other healthcare providers
    - Lacking finances from the part of end-users
    - Lacking government incentives and funding
    - Lacking insurance contracts for new, costly products/services
    - Other_____

Innovativeness

14. **Does the organization communicate with end customers regarding their need for new products and services and/or collaborate on product design?**
    - o Yes *(How?)* _____
    - o No

15. **Does the organization communicate with doctors, hospitals and/or other healthcare facilities and providers regarding their need for new products and services and/or collaborate on product design?**
    - o Yes *(How?)* _____
    - o No

16. **Does the organization have a university/research institute – business collaboration when developing new solutions?**
    - o Yes *(How does it work?)* _____
    - o No

17. **How many new products/services/solutions does the organization introduce on the market annually?**

    _____

18. **What is the share of employees with foreign nationality?**

    _____

19. **Where does your organization frequently look for its engineers, managers and other employees?**

    _____

20. **How many patents does your organization own?**

    _____

21. **If applicable, is the number of patents increasing or decreasing?**
    - o Increasing
    - o Decreasing

22. **Does your organization own any other "protective solutions" such as trademarks, industry patterns etc.?**
    - o Yes *(What field? How many?)*
    - o No

23. **What share of your profit goes to R&D?**

    _____

24. **What share of your profit goes to the employees' training?**

    _____

Digital healthcare

25. **Which of the following technologies is your service/product based on?**
    - o Simulation
    - o Horizontal and/or vertical integration

- Internet of things
- Cybersecurity
- Cloud
- Additive manufacturing
- Augmented reality
- Big Data and/or analytics
- Autonomous Robots
- Other

26. Where do you plan to orientate yourself in the area of new technologies and innovations in the next 10 years?

_____

27. The Czech healthcare sector faces many challenges at the moment (e.g. quality of healthcare facilities, age, education and expectations of available workforce), do you strive to tackle some of them with your products/ services (emphasis put on digital solutions)?

_____

28. What should be done to tackle those challenges?

_____

29. How could digitalization help here?

_____

30. How do you perceive the area of the Czech healthcare sector? How do you view its current development with the focus on digitalization?

_____

31. Where do you see the Czech healthcare sector in the future (emphasis put on digitalization)?

_____

32. Do you identify any market opportunities for the use of technology in healthcare?

_____

33. Do you think that there is a space for new digital healthcare start-ups on the Czech market? How successful could they be?

_____

34. What are, in your opinion, the top 3 technologies that are going to transform and define the Czech healthcare sector in the next 10 years?

_____

Other comments:

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