Technology in Society 78 (2024) 102620

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Exploring macro-environmental catalysts and barriers of healthcare 4.0 transformation in Central-Eastern European countries: A comprehensive study in Hungary

Péter Halmosi [a,*], Márta Aranyossy [b]

[a] University of Szeged, Hungary
[b] Corvinus University of Budapest, Hungary

ARTICLE INFO

Keywords:
Healthcare
Industry 4.0
Healthcare 4.0
Macro-environment
PESTLE
PESTEL
Europe
Hungary

ABSTRACT

The pursuit of a secure, efficient healthcare system responsive to patient needs remains a crucial goal for developed countries. Governments, grappling with rising healthcare demands, are increasingly turning to technological innovation as a transformative solution. Healthcare 4.0, integrating cutting-edge industrial technologies, aims to enhance patient experience, promote health, control costs, and boost clinical satisfaction. The COVID-19 pandemic has catalysed investments in digitalisation, but the promises of Healthcare 4.0 are still seemingly unrealized. This is especially true in the Central-Eastern European (CEE) region, particularly in Hungary, where substantial Industry 4.0 innovation potential intersects with shrinking financial resources, a challenging political environment, a transitioning healthcare system hindering the widescale transition to Healthcare 4.0. Thus, this paper aims to explore the macro-environmental factors influencing Healthcare 4.0 adoption in Hungary. Leveraging qualitative content analysis of interviews with 21 Hungarian healthcare technology startup founders, we aim to map the catalysts and barriers of a Healthcare 4.0 transition using a PESTLE framework. This explorative study contributes to the literature with valuable insights from the innovators' perspective, serving as a foundation for future policy interventions in the quest for widespread Healthcare 4.0 implementation.

1. Introduction

A safe, effective healthcare system which is also responsive to patients is considered as one of the most important goals of governments in developed countries [1]. A possible path towards this goal and part of the solution for governments faced with increasing demand for healthcare services is the transformation of healthcare by integrating technological innovation [2]. Healthcare 4.0 strives to improve patient experience, promote health, control costs, and enhance clinical satisfaction through the integration of state-of-the-art industrial technologies [3]. This integration of Healthcare 4.0 technologies is expected to result in superior patient care [4] and the early identification and treatment of diverse diseases [5]. In the targeted future, medicine will not focus on curing the sick, but on preventing diseases. At the same time, technology advancement can support decreasing the already burdensomely high levels of healthcare costs [6].

Although the promised benefits of Healthcare 4.0 innovations are significant [7], and healthcare is one of the leading industries in terms of growth of spending and social utility, it is also one of the latest adaptors in terms of digital innovations [8]. Merely seven percent of healthcare and pharmaceutical enterprises have gone digital, while this rate reached 15 % in other in other industries [9]. During the COVID-19 pandemic the healthcare industry has witnessed a trend with notable emphasis on prioritizing convenience and access to care [10,11], thus catalysing investments in digitalisation as well, but the promises of Healthcare 4.0 is still seem to be unrealized. This motivates our research agenda on exploring the key macro-environmental catalysts and barriers of a wide-scale Healthcare 4.0 transformation in a comprehensive manner.

This proposition is especially relevant in Central-Eastern European (CEE) countries where – like in Hungary – the significant Industry 4.0 [12] and Healthtech [13] innovation potential is coupled with a controversial political environment, a transitioning health care system [14] and economic barriers and scarcity of financial resources [15] of

* Corresponding author.
E-mail address: halmosi@eco.u-szeged.hu (P. Halmosi).

https://doi.org/10.1016/j.techsoc.2024.102620
Received 7 December 2023; Received in revised form 14 April 2024; Accepted 30 May 2024
Available online 13 June 2024

wide-scale Healthcare 4.0 transition. Concerning the DESI index (Digital Economy and Society Index) Hungary ranked 22nd among 27 EU countries in 2022, with indicators significantly underperforming the average of the European peers [16]. One of the bottlenecks of progress seems to be the digital skills of the population, which also hinders the digitalisation of private and public sector [17]. At the same time concerning eHealth indicators, Hungary's performance is above-average, ranking 11th among the EU27 member states, providing widescale access to electronic health records to citizens [18]. This seems to be an environment where Healthcare 4.0 innovators count on a supporting infrastructure and at the same time deal with many macro-level barriers. Thus, this explorative study aims to map the catalysts and barriers of Healthcare 4.0 in the CEE region focusing on Hungary, based on qualitative content analysis of interviews with 21 Hungarian innovators, founders of healthcare technology startups. We believe that analysing the macro-economic environment from the innovators' perspective is especially useful to enrich the related literature and serve as a basis for future policy actions.

After the introduction of key concepts regarding the Healthcare 4.0 phenomenon our paper focuses on the chosen PESTLE framework and its past applications in healthcare and Healthcare 4.0 context, providing a summary of the literature on previously identified macro-environmental factors. Section 4 introduces the research questions and the methodological considerations, which is followed by the results of the analysis and a discussion. As part of the conclusions the novel elements of the research are highlighted as well as the policy implications and limitations.

2. Healthcare 4.0 in the literature

Industry 4.0 is an interconnected phenomenon characterized by digitalisation of networks, products and services, and new market models as well [19], a general phenomenon in the intersection of technology and society [20]. Healthcare 4.0 is a relatively new phenomenon which integrates Industry 4.0 technologies into healthcare. The generation of tremendous amount of data offers new perspectives when applied in healthcare delivery [21]. Inspired by the Industry 4.0 paradigm, Healthcare 4.0 "describes the digital frontiers and disruptive innovation in the health care sector that is driving new business models and value networks" [22], aiming for higher service level and efficiency gains for the health care sector. These innovations also lay the groundwork for a transition from traditional hospital centric care to decentralised care [23]. This includes the healthcare implementations of innovative digitalisation, artificial intelligence, Internet of Things, machine learning, big data mining technologies [5] as well as the combination of cloud-based solutions with industrial internet of things [29].

Healthcare 4.0 – similarly to Industry 4.0 – is described by technological paradigms. Aceto et al. [24] described the interrelation of healthcare technologies by a multi-level interaction of ICT pillars, ICT paradigms and ICT-based healthcare paradigms building on each-other: ICT pillars are the technological building blocks of new solutions and together with the novel ICT paradigms converge into emerging new ICT-based healthcare paradigms. See Table 1 for a quick overview of the main ICT-based healthcare paradigms and a sampling of the relevant Healthcare 4.0 literature.

There are many studies on the driving forces and barriers of Industry 4.0 [e.g. 3]. However, it is not clear how the transformation in a more complex sector like healthcare will take place. Most studies introduce a single utilization of a new technology in healthcare (see examples in Table 1) and only few papers (e.g. 5) shed light on a complex form and process of this transformation. The unfolding nature of Healthcare 4.0 is considered to be responsible for the scarcity of analysis of its possibilities and boundaries on healthcare delivery [41]. Most studies measure improvements in healthcare service delivery without analysing specific illnesses and their effect on health outcomes opening a gap of knowledge regarding to what extent these innovations meet patients' current needs and long-term expectations [42]. Studies on healthcare 4.0 suggest that a successful transformation requires a better understanding of stakeholders' attitudes.

Table 1
Related concepts and Healthcare 4.0 literature in the structure of Aceto et al. (2018).

ICT-based healthcare paradigms	E-health - combined use of electronic communication devices in the health sector [25]
	Mobile health - direct access to services by using latest telecommunication technology infrastructure [26]
	Personalized healthcare - patient-specific treatment [27]
	Smart health - smart device driven treatment [28]
	Pervasive health - domination of social impacts over technology in healthcare [29]
	Ubiquitous health - long term positive health effects without physical connection of people [30]
ICT paradigms	Internet of Things [31]
	Cloud computing [32]
	Fog computing [33]
	Edge computing [34]
	Mobile cloud [35]
	M2M [36]
	Blockchain [37]
ICT technology pillars	Robotics [30]
	Big data [38]
	3D printing [39]
	Augmented/Virtual reality [45]
	Artificial intelligence [44]
	Additive manufactoring [40]
	Smart production [29]
	RFID [5]
	Smart/Wearable devices, sensors and networks [44]

- ICT platform communication helps building permanent connections between doctors and patients [43]. The role of communication in health service level is twofold: raising awareness of new products and services and also establishing positive perceptions [44]. This is especially important in providing drug related information [45] and treatment effects [46,47].
- New technologies like artificial intelligence are considered new sources of increased efficiency in healthcare delivery. On the one hand, this will enable the reallocation of scarce professionals to urgent cases and increase competences, but on the other hand it will boost confidence by empathy and compassion [48]. Better judgement of the emotional state of patients – which is important for certain age or illness groups – will build both trust for further Healthcare 4.0 innovations and improve patient experience.
- The use of low-cost wearable IoT devices, and sensors in healthcare are stretching the framework of traditional healthcare. The ability of constant monitoring and detecting of normal and abnormal health state of patients will only improve healthcare delivery if it is automated [49].
- Implementation of Healthcare 4.0 offers competitive advantage to healthcare organisations, but it also stresses the need for training professionals, motivating patients and ensuring confidentiality. Classified use of electronic medical records builds trust in patients and the proper use of innovative technologies can prevent health related risks [50].
- Introduction of new diagnosis or therapy requires the consideration of ethical and cultural aspects as well [51]. Negative attitude in target groups may prevent the successful implementation of new technologies.
- There is still scarce information on how efficiently Healthcare 4.0 technologies can be successfully implemented in developed and developing countries [52].

Healthcare sector in CEE countries has different characteristics than Western European countries. Even though the per capita GDP growth

was higher in CEE region than in Western European countries, growth of public spending in the healthcare sector has lagged behind [52]. Life expectancy is 3–6 years lower and hospital-centric care has remained dominant. Laaksonen [2001] argues that health gap can be explained partly by social factors and health-related behavioural attitudes. Also, patients in Western European developed countries have more access to innovative therapies and face lower mortality rates than in CEE countries [53]. Recently, the COVID-19 pandemic forced CEE governments to increase public healthcare spending resulting in the intense use of innovative solutions. The pandemic increased digitalisation of services, but preventive care is still less emphasized in the region [54]. Public healthcare systems require further investment to meet aging population requirements and keep pace with therapeutic innovations.

In Hungary specifically, the spread of digital technologies in healthcare has not started to increase until the COVID-19 pandemic [55], digital healthcare literacy developed only in recent years. On the other hand, Hungary has been a pioneer in using health technology assessment in Central and Eastern Europe [56]. It is also famous for academic life science publications and a lively startup ecosystem [57]. This makes Hungary an ideal starting point for an explorative study of catalysts and barriers of Healthcare 4.0 innovations in the CEE region.

3. PESTLE analysis in healthcare

3.1. PESTLE analysis as a research tool

PESTLE analysis is used to get a clear understanding of external factors an organisation, a collaborative business partnership or an entire industry faces [58]. It is a general tool to assess political, economic, social, technological, legal and environmental factors of an organisation's macro-environment [59]. The political environment includes government policies, changes in institutions, while the economic environment refers to income, labour market and tax issues. Socio-cultural environments transmit norms, values, behaviour forms and attitudes. The technological environment relates to technical infrastructure and trends, the legal environment corresponds to laws and regulation, and finally, the environmental factors encompass everything that is influenced by the surrounding (natural) environment [60].

PESTLE analysis has been used in health care research before, first mostly in the context of strategic planning [61] or quality management [62,63] of health care organisations, later even focusing on risk management under COVID-19 [64] (See further examples in Table 2.). Lately, Walsh et al. [65] and Patel & Sinha [66] presented PESTLE analysis on the effects of technology on healthcare and changes in organisation management systems and inter-institutional collaborations. Based on the relatively wide scale research use of PESTLE in healthcare, and even on the field of healthcare technologies, we can conclude, that it is a suitable framework to explore influential factors of the macro-environment of Healthcare 4.0 innovations.

Table 2
Evolution of PESTLE in healthcare.

Author (s)	Context	Focus
[67]	Improving healthcare services	Improving patient outcomes suffering from atrial fibrillation
[68]	Access to health services	Improving productivity of healthcare services
[69]	Epidemic control	Context analysis for epidemic control
[70]	Healthcare public-private partnership	Assessing risks of healthcare investments
[56]	Strategic planning in healthcare	Allocation of resources, organisational values, budgeting
[60]	E-learning in healthcare	Using e-learning to gain new knowledge and skills in healthcare
[71]	Mental health strategy	Mental health strategy planning in rural and urban areas
[59]	Risk management under COVID-19	External factors determining the transmission of COVID-19
[61]	Digitalisation of healthcare system	Effect of new technologies on efficiency and efficacy
[72]	Cooperation among healthcare institutions	Development of policies, analysing bureaucracies relating to cooperatives
[58]	Managing medical services	Quality management of medical services

3.2. Existing research on the PESTLE factors of healthcare 4.0

In a recent comprehensive study Schlecht et al. [73], arguing that the effect of disruptive technologies on business value creation needs to be clarified, uses the PEST framework to identify the potentials of blockchain in the healthcare sector. The study sheds light on general environmental barriers, like scaling concerns due to the lack of standards, enormous transaction volumes, data protection concerns and related legal compliance costs. Implementation and scaling will require a long time in order to gain trust and acceptance from users while unfamiliar functions, methods will result in adoption obstacles.

Other studies focus more on one or two elements of the PESTEL environment only (see summary in Table 3). **Political** benefits of establishing a Healthcare 4.0 system will emerge from prevention of contagions and an increased citizen satisfaction with modern services [74,75]. Healthcare systems are suffering in most developed countries from challenges of an ageing society, increasing the need for new solutions. Inuwa et al. [76] calls for a new economic policy, legal and financial framework in order to host revolutionary technologies in the healthcare sector. They argue that awareness is required from both governments and the corporate sector to develop new skills of employees and change traditional attitudes to work flow.

Considering the **economic** aspects of Healthcare 4.0, digitalisation

Table 3
Summary of potentials and barriers in Healthcare 4.0 in literature.

Dimensions	Catalysts	Barriers
Political	- prevention of contagions, increasing service level, better allocation of resources [29,69] - building modern healthcare capacities [70]	- legislation does not accommodate new technologies [71]
Economic	- digitised value chain offering higher service level [74] - inclusion of new business models in healthcare [76]	- lack of standards and customised solutions [68]
Social	- societal benefits from new forms of collaborations [76] - COVID-19 increased the awareness of digital benefits [75]	- paradigm change requires social responsibility [75]
Technological	- improved healthcare processes and improved access to expert assistance [88] - training and education is required to boost acceptance [89]	- lack of comprehensive assessment of ICT's impact on health and healthcare is [73] - health sector is vulnerable to technological development by digitalisation and transformation in service provision [90] - some negative experiences with early-stage technologies [78]
Legal	- easing effect on product lifecycle regulatory compliance [81]	- costs of legal compliance and IT security [68,80] - lack of uniform standards for information exchange [91]
Environmental	- veterinary healthcare targets met [75] - decreased pollution by green home healthcare supply chains [82] - environmental health tracking activities and collaborations [92]	- environment related big data raises complexity of healthcare systems [93]

and the spread of innovative technology solutions in healthcare transforms the entire value chain in the sector [77], although there is a need for comprehensive evaluation of ICT's impact on the sector [78]. The transformation is fuelled by the need to adapt to the new global environment and increased complexity of regulation. This will affect businesses in the health care sector, resulting in a shift from traditional to digitalised value chains [79]. Digital value chains will offer services in higher volume at potentially lower prices by more intensive involvement of patients. Early and efficient targeting of emergency cases will also decrease costs. Economic benefits of the transition to Healthcare 4.0 are strongly related to scaling of new medical services.

Social factors also play a critical role in the transformation of healthcare. The COVID-19 pandemic heightened public awareness regarding the need for innovation and digitisation of healthcare [80]. Paradigm changes were initiated by social responsibility, while there are already promising signs of new social collaboration forms [81]. Scheduling problems in the healthcare sector may be dissolved by new schemes bridging information gaps.

As seen during the COVID-19 pandemic [75] digital **technologies** can be used to provide information on the health status of millions of people. Disruptive technologies relieved medical professionals and offered a new form of collaboration via monitoring of patients [82]. The more widescale use of these technologies is hindered by the fact that both the development and operation of these systems are expensive for providers and patients alike. Also, one of the key technological conditions of digitalisation in healthcare is the secure and legalised exchange of electronic health information – especially via the cloud, fog or on edge devices. In recent years cyber-attacks have been growing as fast highlighting the importance of this issue. Considering technological potentials and barriers of Healthcare 4.0, Lopes et al. [83] also analysed the adoption barriers of augmented reality application. They conclude that applications in the early technological stage create negative experience and attitudes in potential user groups. This calls for a need to raise social and professional acceptance of new technologies. For example, beside a reliable tracking of surgical operations, registration of new solutions and technologies is also critical for a widescale adoption of new solution by surgeons.

Legal environment is generally considered a key barrier of widescale Healthcare 4.0 implementations. As stakeholders of the industry share data and information in order to design and manufacture new products and services [84], companies must audit and secure their internal information management system and decide on contractual terms of data exchange with third parties. Negotiations on IP and data issues will affect the organisation's new role in the value chain as well [79]. Related compliance costs and standardisation of information exchange will substantially prolong transformation [68,85], although Industry 4.0 technologies might have an easing effect on product lifecycle regulatory compliance [86].

Finally, there are some promising studies on the **environmental** context of Healthcare 4.0. The elevation of human healthcare to a new level will pave the way for veterinary healthcare as well. Using green supply chains in the newly developed digital context can substantially contribute to environment pollution goals as well [87]. On the other hand, the addition of big data based environmental information in healthcare systems will increase complexity - and potentially cost - of the systems as well.

4. Methodology

Our overarching aim is to identify the macro-level factors promoting or hindering the implementation of industry 4.0 technologies in healthcare, looking at the PESTLE environmental factors from the innovators perspective. After systematically analysing the PESTLE factors identified by the international literature, the geographical focus of our empirical research has been chosen. Central Europe has been underrepresented in Healthcare 4.0 research, and Hungary's complex and unexplored environment, with a weak general DESI index but above-average eHealth indicators [16–18], and a century-long history of healthcare technology innovation, presented itself as an ideal research arena [94]. Thus, in pursuing our research aim we intended to answer the following research questions.

RQ1: How do innovators perceive the influence of PESTLE (political, economic, social, technological, environmental and legal) factors on the implementation of Healthcare 4.0 innovations in Hungary?
RQ2: Which of the PESTLE factors act as barriers (with a negative effect) or catalysts (with a positive effect) of the implementation of Healthcare 4.0 innovations in Hungary?

The inherently exploratory character of our investigation has led us to adopt a qualitative research methodology, aligning with Gummesson's assertion [95]. [170–171] that the evolving landscape of the digital domain has prompted a shift towards more intricate research methodologies, thereby underscoring the preference for qualitative modes of inquiry.

4.1. Sampling and data collection

As our investigative focus revolved around the landscape of digital healthcare innovations analysed from the perspective of innovators, consequently, our data collection strategy centred on entrepreneurs in the healthcare technology sector. The selection of startups that had successfully secured funding served as an objective criterion to sift out nonviable entrepreneurial ventures and mitigate data bias, as suggested by Ref. [96]. Given the absence of a comprehensive database cataloguing Hungary-based digital healthcare startups, our initial roster of companies was compiled through an exhaustive examination of publicly available venture capital portfolio information of the last five years (2019–2023). The analysed investment portfolios included Hungarian technology incubators, public and private venture capital funds and professional investors. Subsequently, we filtered our company list choosing suitable candidates who focus on Healthcare 4.0 technologies in their business models. This resulted in a shortlist of 26 innovative Healthcare 4.0 startups. Of the initial 26 companies approached, 21 consented to participate anonymously in our research. Key characteristics of our sample, including the products/services offered and the underlying technologies applied, are summarized in Table 4.

Data was collected via structured interviews conducted between November 2022 and March 2023. Ethical considerations were paramount: interviewees were apprised of the research objectives and privacy policy, and they gave their written consent. The interviews, conducted via the Microsoft Teams platform, were recorded with explicit consent. The interviews adhered to a standardised format, designed to encompass two core themes: (1) discussion of the company's unique business model and the embedded Healthcare 4.0 element and (2) eliciting the respondent's insights concerning broader industry developments and national macro-environment. All 21 interviewees held positions as founders and/or CEOs of the respective companies, with high-level comprehensive knowledge about industry-wide trends. Our interview protocol incorporated some questions necessitating respondents to select responses from predefined lists or assess statements on a 1–7 Likert scale (not intended for quantitative analysis but primarily to stimulate further discourse or validate other inquiries), but predominantly, the interviews were dedicated to explorative open-ended questions, with responses transcribed in their entirety.

4.2. Methodology for content analysis

To unravel the nuances embedded within the data, we applied the content analysis methodology, a systematic approach for exploring textual data to discern salient information [97]. Qualitative content analysis allows researchers to gain insights into participants'

Table 4
Sample composition, technological profile of the selected entrepreneurs' startups.

Innovator ID	Cyber-Physical System (CPS)	Internet of Things (IoT)	Cloud Computing	Artificial Intelligence (AI)	Blockchain Technology	Additive Manufacturing	Smart Manufacturing	Virtual and Augmented Reality	Cyber Security	Simulation and Modelling	Big data	RFID	Edge Computing
I1			X	X			X		X	X	X		X
I2			X	X									
I3	X	X	X	X	X	X	X		X	X	X		
I4		X	X	X		X			X		X		X
I5		X	X	X	X				X		X		X
I6			X	X					X	X	X		
I7			X								X		
I8		X	X										X
I9		X	X		X				X		X		
I10				X					X	X			
I11				X								X	
I12		X	X								X		
I13		X	X	X						X	X		X
I14		X	X	X	X					X	X		X
I15		X	X			X				X	X		
I16		X	X	X	X	X	X	X		X	X		
I17		X	X	X			X				X		
I18		X	X	X						X	X		
I19		X	X	X		X		X	X	X	X		X
I20	X	X	X	X		X	X	X		X	X		
I21		X	X	X	X			X	X	X	X		

experiences and perspectives and, consequently, identify and comprehend themes, patterns, and underlying connotations present in textual data. Stemler [98] delineates three principal approaches to content analysis of textual data: empirically driven automated content analysis, theoretically driven content analysis, and an intermediary approach referred to as emergent coding. We adopted a primarily inductive, emergent coding approach to identify the environmental catalysts and barriers of Healthcare 4.0 implementations perceived by the innovators. There was no initial code structure, only the high-level framework of PESTLE, the specific codes related to barriers and motivating factors were developed during the coding process, facilitating the discovery of every meaningful underlying pattern [99]. Subsequently, the resulting codes underwent rigorous scrutiny by the research team to achieve consensus and were meticulously defined in the coding protocol.

Our procedure started with the importation and organisation of all interview transcripts into an NVivo project [100]. A preliminary coding round was conducted to refine the coding protocol [101], followed by the concurrent coding of all materials by two researchers to ensure inter-rater reliability [102]. The short and intense coding period (two weeks) contributed to better intra-rater reliability. For the assessment of inter-rater reliability, we employed Cohen's kappa coefficient, weighted by the text-lengths (see Appendix 1), revealing a minimum of moderate agreement (>0.41) for all codes and, in most instances, good agreement (>0.61) [103].

5. Results

In order to build a bridge between the theoretical framework of Healthcare 4.0 PESTLE and the emergent coding content analysis of the interview responses from the healthcare innovators we summarized our results in Table 5. The table displays the various macro-environmental aspects that impact Healthcare 4.0 advancements, as identified by our exploratory research (refer to columns 3 and 5), in comparison to previous studies in the field. We distinguished between 'catalysts', which have a beneficial impact, and 'barriers', which impede the deployment of Healthcare 4.0.

Table 5 already shows where our analysis confirms earlier results, where it extends it and where our data leads to different conclusions than other studies. Table 6 illustrates this in a more condensed manner. We conducted a comparative analysis of the frequency with which a particular aspect of the Healthcare 4.0 environment has been characterized as either a catalyst or a barrier in both the literature and by our content analysis, or conversely, our how often our results do not confirm or outright contradict, challenge earlier results.

Table 6 shows that while our results are more in line with the existing literature in terms of macro-level barriers, Hungarian experts see catalysts very differently. It is evident that the macro-environment lacks significant political and environmental catalysts, while the social, technological, and legal aspects are perceived as more burdensome than stimulating. On the other hand, 30–50 % of the barriers identified by other researchers internationally are be present in Hungary as well, moreover it appears that social and legal barriers are even more pervasive and influential in this particular context. Our high-level results offer insights into the reasons behind the underutilization of the potentials of Healthcare 4.0 [see 51] in the region, but in the next section we provide a detailed qualitative analysis of each macro-environmental dimension.

6. Discussion

In order to reveal more in depth qualitative implications from interviews we analysed interviewee's responses in details, following the logic and dimensions of PESTLE and supporting the analysis with direct quotes from the data collection.

Table 5
Summary of results in the PESTEL framework: a comparison of macro-environmental factors influencing Healthcare 4.0 developments identified by this research and earlier studies Data in the Respondents columns refers to the respondent's Innovator ID (as shown in Table 4) who mentioned that particular factor.

Dimensions	Catalysts (+)		Barriers (−)	
	Earlier studies	Respondents of this study	Earlier studies	Respondents of this study
Political				
Political will to increase service levels	[29,69]	I1; I5; I14; I17; I20		
Political will to build modern healthcare capacities	[70]			
Political will to prevent epidemies, contagions	[29,69]			
Political interests working against innovations				I10; I12; I21
Allocation of resources will increase	[29,69]			I9
Political impact on legislation does not favour new technologies			[71]	I5
Efficiency of service delivery is lagging behind			[104]	I9
Economic				
Technology innovation is very expensive				I1; I7; I8; I10; I13; I18; I20;
Efficiency of service delivery is lagging behind other sectors			[107]	I9
Lack of financing		I9		I9; I2; I10; I20
Health care financing structures		I7; I9; I21		I18
Lack of competition as a motivator				I14
Entrepreneurial attitude		I11; I13		
New business models will be developed in healthcare	[76]	I17		
Increasing (and solvent) demand				I10; I11; I21
Cost cut and profit-increasing opportunities – for example:		I1; I5; I14; I18; I21	[73]	I12
- Working processes and access to expert assistance will be improved	[83]	I5; I7; I10; I12; I19; I20; I21		
- Training and education with new technologies will increase services level and awareness	[84, 101]	I1		
- Image and data visualisation improves efficiency of surgical intervention	[101]	I1; I17; I18		
- Evidence based treatment will be enabled by patients' genetical and social big data	[105]	I6; I17; I19		
- Complex symptoms will be considered in diagnosis by using independent data sources	[77]	I11		
- Wearable devices will increase efficiency and reduce healthcare costs	[106]	I17		
- Digitised value chain offers higher service level	[74]	I7		
Social				
Collaborations will be more intense throughout the ecosystem	[76]			I12
Lack of organisational flexibility of large institutions				I2; I3; I5; I8; I10; I13; I14; I20
The shortage of healthcare workers		I2		I3; I4; I12; I15
Lack of interdisciplinary (technology – data science – medicine) experts		I13; I20		I17
Conservative attitude of medical professionals		I15		I7; I11; I13; I16; I19; I20; I21
Perceived viability, effectiveness, user satisfaction will help housing new technologies	[102]	I1; I14; 15; I20		
Shared social value is created	[104]	I1; I2; I4; I5; I7; I19; I21		
Digital supply chain requires social responsibility			[75]	I1; I5; I19
Awareness is raised by pandemy like COVID-19	[75]	I14		
Physicians will develop new values by interpreting medical data to patients	[76]	I4; I13		
Healthcare practitioners are afraid of losing their jobs			[107, 108]	I13
Patients are concerned about confidentiality of personnel data sharing			[109]	I5; I6
Generations' attitudes to digital technologies show significant differences		I3	[110]	I3; I20
Aging society		I6; I10		
Automation and scheduling of patient care will increase efficiency of prevention and aftercare – thus encouraging adoption by professionals	[5,111]	I3; 15; I21		
Building trust in patients supports validating products	[103]	I3; I4; I10; I19; I21		I3; I13
Technological				

(continued on next page)

Table 5 (*continued*)

Dimensions	Catalysts (+)		Barriers (−)	
	Earlier studies	Respondents of this study	Earlier studies	Respondents of this study
Application of modern technologies is lagging behind			[112]	I14
Health sector is vulnerable to technological development in form of external and internal environment factors			[85]	
negative experience with early stage technologies		I9; I18	[78]	I1; I11
The ease of use, user friendliness of new technologies		I13; I17		I1; I16; I18
Uniform standards for information exchange is lacking			[86]	I5; I9; I19
Business scaling is lacking of standards and customised solutions			[68]	I4; I11
Medical data of a society is a valuable asset but it is stored in an unstructured form, and access to database is not defined yet, lack of system integration			[113]	I1; I2; I3; I5; I6; I8; I14; I18
Underdeveloped, outdated IT infrastructure at healthcare institutions				I4; I5; I14
Cybersecurity risks		I13		I3; I17
Wearable devices will increase efficiency and reduce healthcare costs			[110]	I17
Legal				
Digitalisation of regulatory data supports compliance throughout product lifecycle	[81]			I2; I17
Regulation of medical devices is very strict, expensive and delays market entry			[68,80, 106]	I3; I4; I7; I8; I10; I15; I17; I18; I19
Outdated regulations, slow legislative changes		I2		I2; I7; I10; I11; I14
Data security legislation, as a barrier to access and share healthcare data		I5		I1; I2; I5; I10; I12; I13; I16; I17; I19
Uniform standards for information exchange is lacking			[86]	I9
Efficiency in healthcare 4.0 is determined by the renewal of „old" public health service contracts			[114]	I18
Environmental				
Veterinary healthcare targets met	[75]			
Decreased pollution by green home healthcare supply chains	[82]			
Environmental health tracking activities and collaborations	[87]			
Environment related big data raises complexity of healthcare systems			[88]	

6.1. Political catalysts and barriers

The role of government is inevitably decisive in the transformation of the healthcare sector. **Political interest** on the one hand is in favour of introducing new technologies and services to gain appreciation from voters, however, fiscal possibilities and complications from technological transmission cause uncertainties and keep on eroding political will. Respondents formed concerns regarding the catalyst role of governments.

- **Resistance to embedding new technologies in healthcare**: New technologies increase public healthcare cost while positive effects are hardly measurable on a national level. Efficiency requires an optimal allocation of public and private resources and capacities which will establish a confused mixture of stakeholders' targets. "*In public health care institutions, spread of healthcare 4.0 technologies is slower because acceptance of new technologies is determined by political will to increase service level [I14]*". Governments must take the responsibility to regulate and allow the use of patients' health data to support the spread of new technologies. "*Patients are only motivated to share data if they can see a concrete benefit but this is not feasible without testing new models using personal data [I5; I6]*".
- **Concerns on returns on healthcare investments**: The rise of cost efficiency is considered an unquestionable positive effect of new technologies in healthcare. Currently, healthcare is full of performance variances. The rise of efficiency and so the return on transformation investments will vary in medical fields and healthcare institutions. *"Younger physicians will bring more efficiency rise to the system than older colleagues [I1; I5; I14; I17; I20]"*.

6.2. Economic catalysts and barriers

Considering the **economic effect** of healthcare 4.0, the ecosystem has huge potentials which can be the driving force of the transmission.

- **Market environment in healthcare 4.0**: transformation of "old" healthcare systems will change the relationship between private and public healthcare providers. Private sector companies are the driving force of innovation, however, the imbalance in innovation activity will set back sectoral efficiency level. New solutions will disclose new user values which will require the transformation of prevailing business models. Traditional public healthcare business models do not support innovation. Private health insurance companies suffer significant business profit losses because of information asymmetry. They are supposed to be the biggest global winners of new technologies once they can spare on unjustified disbursements after medical care. *"The role of private insurance companies is important to develop new business models since they have a business interest in it [I17]"*.
- **Increase of efficiency and effectiveness by technology**: The efficiency loss of private and public healthcare institutions is a driving force to perform cost cutting and profit increasing reforms. Public healthcare service is dominating over private healthcare service in most European countries. For this reason, the public healthcare

Table 6
Distribution of responses in PESTLE dimensions Frequencies of identified factors in each PESTEL dimension that either match earlier findings, extend or contradict earlier results.

Dimensions	Catalysts (+)				Barriers (−)			
	This study confirms earlier findings	This study does not confirm earlier findings	This study contradicts earlier findings	Total	This study confirms earlier findings	This study does not confirm earlier findings	This study contradicts earlier findings	Total
Political	25 %	50 %	25 %	100 %	50 %	25 %	25 %	100 %
Economic	67 %	8 %	25 %	100 %	29 %	29 %	43 %	100 %
Social	42 %	8 %	50 %	100 %	30 %	10 %	60 %	100 %
Technological	0 %	0 %	100 %	100 %	50 %	20 %	30 %	100 %
Legal	0 %	0 %	100 %	100 %	50 %	0 %	50 %	100 %
Environmental	0 %	100 %	0 %	100 %	0 %	100 %	0 %	100 %

sector shall be more integrated in the form of applied medical and information technologies. "*Information technology developments in healthcare are partial and sometimes comprehensive [I12]*". New technological solutions can only be applied on a wide scale once physicians and patients have a good understanding of them. "*Training (of doctors) with new technologies will increase service level and also help to understand patients their diagnosis and treatment [I1]*". Once patients will understand the potential of new technologies they will be interested in the diagnosis of complex symptoms as well. "*The reliability of diagnosis and treatments will rise once they have been validated by comparable but independent medical sources [I11]"*.

- **Establishing new financial mechanisms**: Public healthcare financing is usually characterised by efficiency gaps. Establishing professional correlation between cases by valid information will pave the way for performance-based financing. "*Technology adoption can be a motivating factor for healthcare institutions if they get a reward based on higher healthcare service performance [I21]*". It is however concerning that financial mechanism changes are not the cornerstone of healthcare governments. "*Healthcare reforms are motivated unfortunately by sad circumstances like Covid-19 [I9]*." If patients' genetic information are used safely in healthcare, evidence-based financing can be applied in order to prevent damage to health.
- **Complex integration of IT solutions**: Healthcare has been digitised in recent years due to epidemic pressures under Covid-19. This has already brought efficiency gains in patient visits and allocation of scarce human resources. Digitisation will offer new perspectives in healthcare. *"New technologies can perform only local positive effects. Digitalisation has an important role in value creation by extending and broadening the value chain [I7]"*. Sensors and wearable transmitters are important in healthcare 4.0 in order to build up a society level database. Patients are no longer monitored after they leave the hospital. New technologies can help in gathering and processing constant data on patients' health status. "*The decrease of healthcare cost depends on the acceptance and integration of wearable devices. This has already been recognized in China [I17]*".

6.3. Social catalysts and barriers

The implementation of Healthcare 4.0 technologies can face several **social** barriers while motivated by other social trends – the following factors were highlighted by our panel of Central-Eastern European (CEE) innovators.

- **Cultural norms and values around health**: if the value attributed to health by the society is relatively high, that boosts demand for higher quantity and quality healthcare services. [I4, I5 I21, I19, I2, I1] *"Human health is of great value." [I19] "Patients expect technological standards, which develops demand." [I21]*
- **Aging society**: health care demand is also increased by the shift towards older generation in demographic composition of the societies, that increases the need for capacity building technology innovations. [I6, I10] *"An ageing society is interested in improving health care" [I6] "The longer we live, the more such medical technology will be needed." [I10]*
- **Generational differences in technology acceptance**: as the more tech-savvy generations become the majority of patients, it will automatically increase technology adoption society-wide. [I3] *"And obviously, that [resistance to technology] will be completely eliminated a generation further away. They will no longer reprimand the use of such devices." [I3]* Younger generation might have higher acceptance rate among professionals as well. [I20]
- **Cultural norms and trust regarding technology**: the lack of general or healthcare-specific trust in technology is a barrier for society-wide technology adoption. [I3, I13, I14] *"The speed of technology adoption is primarily influenced by the attitude towards technology." [I14] "There is a kind of natural resistance on the part of people about the results provided by computers." [I3]* On the other hand, external shocks, like the COVID pandemic, can fast-track social acceptance. [I14] Also, information campaigns [I10, I21] and medical professionals as trusted advisors will be important in building patient trust [I4]. *"The value of these new tools will be defined by them [medical professional], they can communicate it to patients in the most reliable way. Acceptance and usage will depend on them." [I4]*
- **Labour shortage**: healthcare workers in general are already overworked and overwhelmed, which causes a shortage of human capacity needed for technology implementation projects. [I4, I3, I15] *"Obviously, no one in healthcare is famous for not working a lot beyond working hours, and this kind of [technology] projects take a lot of time to implement, which is usually not available to the people working there." [I15]* On the other hand, the labour shortage is also one of the key motivating factors of innovations aiming to supplement healthcare professionals or make their work more efficient thus creating new capacities. *"What are the main factors that motivate technological innovations to transform the health care system? Labor shortage." [I2]*
- **Need for an interdisciplinarily skilled workforce:** The implementation of Healthcare 4.0 technologies requires professionals skilled in technology, data analysis and medicine at the same time – of which there is a shortage in this region. [I17] This is also a problem for national or audit authorities [I17. Technology-infused training and/or retraining could be part of the solution [I13, I20] – although the second might also create frictions in the society. *"As we robotise solutions, we have to retrain people, and this can cause social*

problems in the short term. … It can be, of course, bad on the individual level, but inevitable from the global perspective." [I20]

- **Openness to innovations among medical professionals**: there is a general lack of openness towards technology innovation in the region among medical professionals [I7, I13, I15, I20] *"The conditions [for innovations] are not met in Hungary: there is a lack of openness (positive attitude)." [I20]* Some of the barriers are: profession-wide conservatism [I11, I16, I19, I21], habits [I13], lack of user friendliness or ease of use [I1, I13, I16, I17] or lack of perceived usefulness of the new technologies [I1, I14, I20]. *"They don't see how much added value there could be." [I20]* Doctors' distrust and resistance might be decreased by solutions that do not aim to substitute, but to complement their work, thus do not threaten job security [I13].
- **Institutional resistance to change:** medical organisations are famously rigid, inflexible [I5, I8, I13, I14, I16, I20], which is a serious barrier when new technology implementations need process level changes as well. *"There is no openness to restructure." [I20] "The problem is that they expect renewal from tools and software, but the renewal of organisational frameworks is a deeper thing. It should precede and not be triggered by the technology." [I5]* This inflexibility is partly caused by the strict legal regulations [I2, I10], as an external barrier to change.

It is noteworthy that our interviewees do not mention some other social factors to healthcare technology adoption, like the effect of the digital divide or health literacy on user adoption, or preferences regarding human touch in the doctor patient relationships – these currently do seem to be major concerns of health-tech innovators in the CEE region. While the interviewees identify data privacy concerns as the major barriers of healthcare 4.0 developments, but they see is mostly as a legal issue (see in the Legal sub-chapter), and not as a society-level normative or ethical issue.

6.4. Technological catalysts and barriers

Technological potentials of healthcare 4.0 are usually highlighted. Recent papers have also revealed concerns regarding the successful transition. Our respondents seemed to be familiar with them.

- **Negative experiences with modern technology**: Industry 4.0 has spread to all economic sectors but to a different extent. User's expectations are high but innovations need more time to be adopted. "*In healthcare, 5 years is a short period to achieve improvements in therapies [I3; I8; I18; I19]*". Users have negative feelings and attitudes towards immature technological solutions even if they are meant for validation purposes. Unlike other innovative products and services, healthcare products become mature after they have been tested publicly and user experience feedback has been fixed. "*Technologies developed 5 years ago have become mature enough by now to be spread on the market [I18]*". The time requirement of healthcare product development makes innovations vulnerable to changes in external and internal environments. Changes in healthcare policy priorities necessitates the urgent standardisation of information exchange, integration of medical systems and modernising outdated healthcare infrastructure.
- **Wide scale adaptation enabled by user friendly operation**: A new technology can modernise healthcare services if they provide users with an added value and a convenient operation. An innovation that can target efficiency gaps in the supply chain will change the operation of the whole system. *"In surgical care, the main problem is to get a "good-enough" solution which offers high quality visualisation at an affordable price. Companies that are able to develop these solutions will reign in the healthcare market in the upcoming years [I1]"*.
- **Increased healthcare costs by cybersecurity**: Personal health data is our most valuable asset. They can be used for cure and business as well. Guaranteeing data protection helps to build trust in patients who are otherwise not willing to share their healthrelated problems with third parties. Cybersecurity is a precondition to build a new system which will be based on intense data sharing, which needs IT investments from healthcare institutions. "*Cybersecurity will increase costs in healthcare which shall be compensated by efficiency gains [I17].*" Cyber protection of medical devices is essential in building trust in patients and doctors. This will generate increased product development cost in order to get regulatory approval. "*Cybersecurity generates additional costs for healthcare in order to keep our data safe. We will not get anything more [I10]"*.

6.5. Legal catalysts and barriers

Technological improvements are strongly related to **legal** issues in healthcare. Our experts agreed on the necessity of renewal of "old" regulations concerning the approval and application of medical products. Government bodies have also an important role in building new skills and expertise to host innovative healthcare solutions.

- **Acceleration of medical device regulation**: Notification bodies are responsible for assessing risks associated with new products. Part of their job is however connected to skills in information technology and medicine. The use of a new computer software or an embedded algorithm is hard to assess from a regulatory view. Complex evaluation of the effects of healthcare softwares not only delays market entry but may shorten product life cycle. Accelerating regulation approval by digitisation and product life cycle approval of medical products may help to realise potentials of technology innovations. "*New (medical) devices in most countries receive authorization for the concrete solution only not for lifecycle solutions [I17]*".
- **Reform of outdated legislation**: National healthcare regulation must be modified in order to regulate the access and share of public and private healthcare data. Prevention, diagnosis and therapy requires the comparison of personnel health data to anonymised aggregate health data. The sensitive nature of patient data is a barrier to reforming legislation. "*Interpretation of regulation is a problem. It is sometimes caused by the conservatism of medical professionals [I16]*". Regulation of financing for healthcare institutions shall also be changed.

6.6. Environmental catalysts and barriers

The last factor of PESTLE analysis covers **environmental** questions of healthcare. Medical devices and pharmaceuticals contain hazardous ingredients. Untaken and expired medicines are burdening our environment. Green economic targets shall also be formulated from the healthcare's perspective. Agricultural and veterinary sciences can also be beneficiaries of healthcare 4.0 innovations in the form of effective substances to plants and new therapies for animals. As soon as public health will reveal and analyse the environmental context of illnesses this factor will gain further importance in the future.

7. Conclusions

Some of the novelty of this paper is derived from its methodological approach: (1) The choice of the PESTLE framework allowed a comprehensive analysis of the environmental factors driving Healthcare 4.0 transition in the region. We argue that an explorative, qualitative, comprehensive analysis of the macro-environment is necessary to reveal the interdependence of these factors. PESTLE has been used in literature for describing evolution of Healthcare 4.0 in general. Building a bridge between theoretical framework and qualitative data can reveal new characteristics of Healthcare 4.0: conformities and deflections between earlier research findings and our innovators' responses can shed light on the evolving nature of Healthcare 4.0 and potential reasons behind the differences in the spread of innovative technologies. (2) At the same

time, the data collection's focus on innovators enables us to enrich the literature with the perceptions of one of the most important stakeholders: the innovative health-tech entrepreneurs'. Although there are many studies focusing on the patients' perspective and adoption of healthcare innovations [115,116] while the literature on the innovators' perspective is more sparse. Our conclusions also illustrate how understanding the health-tech innovators' perceptions might be useful for policy makers to efficiently create a supportive environment.

While we could confirm many earlier results concerning the key macro-environmental factors of the of Industry 4.0 revolution in healthcare, our research has identified some new and significant catalysts and barriers of healthcare 4.0 transition as well. We have found that governments are under pressure to increase service levels in healthcare which will act as a catalyst for the digital transformation of the sector [see also 29, 69]. More recently, political concern for epidemies shall boost public healthcare investment in the upcoming years. It is not clear though how governments can focus their scarce resources to build modern capacities and support the spread of innovative technologies at the same time. While governments have a national (political and economic) interest in leveraging national healthcare innovations in harvesting their benefits on the domestic market, relieving the national healthcare system, innovators currently perceive a lack of this policy-level supportive attitude in Hungary.

While economic incentives are important bottlenecks of developments internationally as well [7], economic factors seem to be especially influential in Hungary. The growth of public healthcare spending has risen during COVID-19 in CEE countries, but in Hungary the government healthcare spending as a percentage of GDP has fallen again in 2022 [50] as fiscal policy is under pressure by the international economic environment. At the same time, healthcare funding demand is rising, due to the inefficient operation of public healthcare institutions and adaptation of modern healthcare technologies required to meet aging population need. These economic conditions lead to a healthcare system, where implementations of technology innovations are more isolated instances than signs of a systemic change, healthcare financing mechanisms are scarcely promoting innovations, and the government remains in debt with a strategic plan that foreshadows a scalable and sustainable transformation of the health sector. Governments shall establish the framework for a national Healthcare 4.0 strategy, initiate comparative analysis on healthcare delivery progresses and share the financial risk with private entities. Hungarian innovators expressed their concern about the lack of investments in establishing viable healthcare innovations, even when the economic benefits of these potential innovation seems to be promising. Both academic and business professionals believe in the need and potential to achieve process level efficiencies in healthcare, and that information technology can be instrumental in that. Technological innovations promise to provide major benefits in diagnosis, therapy, prediction, prevention, justifying the high investment needs on the long run. New technologies will enable hospitals and other healthcare providers to reallocate scarce human resources to more complex tasks [58], while big data and artificial intelligence are expected to be responsible for new healthcare ventures in prediction and prevention. The real effect of Healthcare 4.0 is yet to be seen on a 5–10 year horizon in this region and to realise these benefits of the Healthcare 4.0 revolution entrepreneurial attitude and novel business models are necessary.

Regarding the social dimension of Healthcare 4.0 our experts considered conservatism of medical workers, misuse of personnel data and lack of organisational flexibility to be the most significant barriers to transformation. On the other hand, the COVID-19 pandemic has raised public awareness of the benefits of healthcare digitalisation, although our results have verified the need for raising awareness, developing communication between doctors and patients and creating positive consumer experience [see 53, 54, 55, 56]. As the goal is for these recent technological initiatives to spread and for daily use to turn into value creation for doctors and patients alike as highlighted by [117–119], developing trust and understanding intragenerational attitudes will be crucial for wide social acceptance [see also [120]]. Early-stage prototypes of new technologies in the validation phase offer insight into new perspectives of diagnoses and therapies, but some early negative user experience among doctors and patients make them less attractive for daily application [78]. We found evidence that patients' willingness and motivation to share (anonym) personal health information can be influenced by the existence of tangible benefit derived from the utilization of the information [as highlighted by 60]. The interaction of innovators, patients and doctors, their individual and societal attitude toward new Healthcare 4.0 technologies will determine the rise of technology-driven efficiency in medical care.

Disruptive technological innovations have already infiltrated the healthcare sector. As the COVID-19 pandemic expedited digitalisation in healthcare, Hungary joined the top 50 % of EU member states who connected electronic health records of public and private healthcare providers of the primary, secondary and tertiary care sector as well, making them accessible to citizens online [18]. However, the systhematic utilization of these interconnected healthcare databases for innovation and commercial use is still a future prospect. In general, Hungary lags behind EU states considering interorganisational electronic information exchange, and also in terms of Industry 4.0 technology (e.g. AI, cloud or big data) adoption [16]. One of the factors behind this developmental deficiency seems to be human capital: enhancing the significantly under-average digital skills of citizens' and the ratio of ICT specialists in the workforce [17] is going to be key for a blossoming digital economy and further Healthcare 4.0 developments. Our experts are also concerned about the outdated IT infrastructure in healthcare institutions and cybersecurity risks of data-driven technologies.

The legal environment – influenced also by political and social factors – is the other significant barrier of healthcare 4.0 innovations in the region. Complex regulations of medical devices increase the costs of innovations. A potential future standardisation of healthcare information exchange might not only decrease cost levels but increase efficiency in the form of potential new combinations of technologies [also in 68, 86, [121]]. It is important for policy makers to pave the way by breaking down legal barriers to market entry and regulating sensitive health data exchange in a way data provides privacy, data security and at the same time promotes the utilization of data and the interoperability of different health-tech solutions.

The influence of environmental concerns and opportunities of healthcare technologies the Hungarian innovators in our sample did not highlight any significant effect. This probably means that there are so many other – political, legal, economic and social – barriers of Healthcare 4.0 transition in Hungary, that stakeholders do not have the bandwidth to start considering potential environmental effects as well. Also, on the catalyst side, potential economic benefits seem to be more persuasive in the current macro-economic climate than environmental ones.

The findings of our paper are limited to the research sample, however, the sample size is also adequate concerning the explorative and qualitative nature of our research design and the 21 healthcare start-ups are highly representative the sector in Hungary. A recent study of EIT Health [13] – containing 29 responses from Hungary – has awarded "experimenter" title to Hungarian healthcare startups which is similar to the overall performance of healthcare startups in Romania, Poland, Czech Republic, Estonia and Italy. Although the study focuses on Hungary, it serves as an important starting point in exploring the characteristics of the CEE region. Further research might be needed in the region, and there is also a need for empirical pilot studies in order to better understand the spread of innovation in public healthcare system. Looking even one step further, the PESTLE analysis has revealed that the transformation of human healthcare may influence veterinary care establishing a modern veterinary medicine.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Péter Halmosi: Writing – original draft, Conceptualization. **Márta Aranyossy:** Writing – review & editing, Methodology, Conceptualization.

Declaration of Competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

Appendix A

Codes		Kappa	Kappa - weighted with text length
Barriers	Inflexibility of healthcare actors	0.668	0.618
	Funding	0.650	0.511
	Authority, official permission	0.912	0.867
	Human resources	0.707	0.615
	Information technology	0.796	0.684
	IP rights	0.997	0.996
	Lack of motivation	0.706	0.651
	Patient or user resistance	0.867	0.815
	Lack of standardization	0.853	0.785
	Regulation, legal environment	0.746	0.666
	Organizational	0.799	0.767
Motivating factors	Factors motivating innovation	0.912	0.849
	User needs	0.911	0.885
Phases of the health care process	Prediction	0.850	0.811
	Prevention	0.858	0.808
	Diagnosis	0.833	0.774
	Treatment	0.817	0.774
	Aftercare	0.807	0.713

References

[1] A. Behr, A.K. Theune, Health system efficiency: a fragmented picture based on OECD data, PharmacoEconomics Open 1 (2017) 203–221, https://doi.org/10.1007/s41669-017-0010-y.
[2] OECD, Improving health sector efficiency: the role of information and communication technologies. https://doi.org/10.1787/2074319x, 2010.
[3] A. Gupta, A. Singh, Healthcare 4.0: recent advancements and futuristic research directions, Wireless Pers. Commun. 129 (2) (2023) 933–952, https://doi.org/10.1007/s11277-022-10164-8.
[4] H. Alanazi, T. Daim, Health technology diffusion: case of remote patient monitoring (RPM) for the care of senior population, Technol. Soc. 66 (2021) 101662, https://doi.org/10.1016/j.techsoc.2021.101662.
[5] V.V. Popov, E.V. Kudryavtseva, K. Kumar, N. Katiyar, A. Shishkin, S.I. Stepanov, S. Goel, Industry 4.0 and digitalisation in healthcare, Materials 15 (2022) 2140, https://doi.org/10.3390/ma15062140.
[6] F. Kitsios, N. Kapetaneas N, Digital transformation in healthcare 4.0: critical factors for business intelligence systems, Information 13 (5) (2022) 247, https://doi.org/10.3390/info13050247.
[7] S. Allers, F. Eijkenaar, E.M. van Raaij, F.T. Schut, The long and winding road towards payment for healthcare innovation with high societal value but limited commercial value: a comparative case study of devices and health information technologies, Technol. Soc. 75 (2023), https://doi.org/10.1016/j.techsoc.2023.102405.
[8] H. Bell, D. Rees, L. Huxtable-Thomas, N. Rich, E. Miller, R. Thomas, Innovation adoption research in healthcare: understanding context and embracing complexity, European Conference on Innovation and Entrepreneurship 18 (1) (2023) 85–93, https://doi.org/10.34190/ecie.18.1.1865.
[9] A.I. Stoumpos, F. Kitsios, M.A. Talias, Digital transformation in healthcare: technology acceptance and its applications, 2023 Feb 15, Int. J. Environ. Res. Publ. Health 20 (4) (2023) 3407, https://doi.org/10.3390/ijerph20043407.
[10] R. Bhatia, Telehealth and COVID-19: using technology to accelerate the curve on access and quality healthcare for citizens in India, Technol. Soc. 64 (2021) 101465, https://doi.org/10.1016/j.techsoc.2020.101465.
[11] C. Appleby, J. Hendricks, J. Wurz, C. Shudes, Digital Transformation. From a Buzzword to an Imperative for Health Systems, Deloitte Insights, 2021. https://www2.deloitte.com/us/en/insights/industry/health-care/digital-transformation-in-healthcare.html.
[12] J. Nagy, J. Oláh, E. Erdei, D. Máté, J. Popp, The role and impact of industry 4.0 and the internet of things on the business strategy of the value chain—the case of Hungary, Sustainability 10 (2018) 3491, https://doi.org/10.3390/su10103491.
[13] EIT Health, InnoStars assessment of healthcare innovation ecosystem maturity in selected countries of the EIT regional innovation scheme. https://www.innostars assessment.eu/, 2022.
[14] C. Bálint, The capacities of primary health care in Hungary: a problem statement, European Journal of Investigation in Health, Psychology and Education 10 (1) (2020) 327–345, https://doi.org/10.3390/ejihpe10010025.
[15] International Trade Administration, Health technologies resource guide - Hungary. https://www.trade.gov/healthcare-resource-guide-hungary, 2018.
[16] European Commission, Digital Economy and Society Index (DESI) 2022 Hungary (2022) 1–13. https://ec.europa.eu/newsroom/dae/redirection/document/88704.
[17] European Commission, 2023 report on the state of the digital decade, Annex - All Member States, https://digital-strategy.ec.europa.eu/en/library/2023-report-state-digital-decade, 2023.
[18] L. Deimel, M. Hentges, V. Latronica, R. Thiel, F. Lupiáñez-Villanueva, Digital decade e-Health indicators development, Directorate-General for Communications Networks, Content and Technology (2023), https://doi.org/10.2759/530348.
[19] M. Mammadova, A.A. Ahmadova, A Conceptual Model of the Data Ecosystem Formation in the Health 4.0. Technology Transfer: Fundamental Principles and Innovative Technical Solutions, 2022, pp. 14–17, https://doi.org/10.21303/2585-6847.2022.002672.
[20] P.P. Jayaraman, A.R.M. Forkan, A. Morshed, P.D. Haghighi, Y.B. Kang, Healthcare 4.0: a review of frontiers in digital health, Wiley Interdisciplinary Reviews: Data Min. Knowl. Discov. 10 (2) (2020) e1350, https://doi.org/10.1002/widm.1350.
[21] K. Kotzias, F.A. Bukhsh, J.J. Arachchige, M. Daneva, A. Abhishta, Industry 4.0 and Healthcare: Context, Applications, Benefits and Challenges, Institute of Engineering and Technology, 2022, https://doi.org/10.1049/sfw2.12074.
[22] G. Aceto, V. Persico, A. Pscapé, The role of information and communication technologies in healthcare: taxonomies, perspectives, and challenges, J. Netw. Comput. Appl. 107 (1 April 2018) (2018) 125–154, https://doi.org/10.1016/j.jnca.2018.02.008.
[23] J.G. Mitchell, From Telehealth to E-Health: the Unstoppable Rise of E-Health, 1999, Commonwealth Department of Communications, Information Technology and the Arts, 1999.
[24] B.M. Silva, J.J. Rodrigues, de la Torre Dez, I.M. Lopez-Coronado, K. Saleem, Mobile-health: a review of current state in 2015, J. Biomed. Inf. 56 (2015) 265–272, https://doi.org/10.1016/j.jbi.2015.06.003. ISSN 1532-0464, http://www.sciencedirect.com/science/article/pii/S1532046415001136.
[25] S. Hiremath, G. Yang, K. Mankodiya, Wearable internet of things: concept, architectural components and promises for person-centered healthcare, in:

Wireless Mobile Communication and Healthcare (Mobihealth), 2014 EAI 4th International Conference on, IEEE, 2014, pp. 304–307, https://doi.org/10.4108/icst.mobihealth.2014.257440.
[26] J. Lee, Smart health: concepts and status of ubiquitous health with smartphone, in: ICTC 2011, 2011, pp. 388–389, https://doi.org/10.1109/ICTC.2011.6082623.
[27] A. Sobrinho, L.D. Da Silva, L.M. De Medeiros, A.C. De Brito Camara, Pervasive multiplatform health care support, in: Handbook of Research on ICTs and Management Systems for Improving Efficiency in Healthcare and Social Care, IGI Global, 2013, pp. 416–430, https://doi.org/10.4018/978-1-4666-3990-4.ch021.
[28] S.I. Moon, H.Y. Choi, Y.S. Kim, K.M. Song, Security issues and solutions in the u-health for the disabled, in: Proceedings, the 2nd International Conference on Information Science and Technology, 2013, 2013.
[29] H. El Zouka, M.M. Hosni, March 2021, 100036, Secure IoT Communications for Smart Healthcare Monitoring System Internet of Things, 13, 2021, https://doi.org/10.1016/j.iot.2019.01.003.
[30] P. Dutta, T. Choi, S. Somani, R. Butala, Blockchain technology in supply chain operations: applications, challenges and research opportunities, October 2020, Transport. Res. E Logist. Transport. Rev. 142 (2020) 102067, https://doi.org/10.1016/j.tre.2020.102067.
[31] A. Elhadad, F. Alanazi, A.I. Taloba, A. Abozeid, Fog computing service in the healthcare monitoring system forManaging the real-time notification, Hindawi Journal of Healthcare Engineering 2022 (2022) 11, https://doi.org/10.1155/2022/5337733. Article ID 5337733.
[32] PWC, Healthcare technology: from strategy to execution. https://www.pwc.in/assets/pdfs/industries/healthcare/healthcare-technology.pdf, 2022.
[33] O.F. Alsheiksalem, M. Al-Ani, Mobile cloud computing applied to healthcare approach international, Journal of Information Technology Convergence and Services 6 (5) (2016) 1–8, https://doi.org/10.5121/ijitcs.2016.6501.
[34] L.F. Samhan, A.H. Alfarra, S.S. Abu-Naser, I.A. Amassi, Classification of alzheimer's disease using convolutional international journal of academic information systems research (IJAISR), ISSN: 2643-9026, Neural Network. 6 (3) (2022) 18–23.
[35] A. Hasselgren, K. Kralevska, D. Gligoroski, S.A. Pederson, A. Faxvaag, Blockchain in healthcare and health sciences-A scoping review, Int. J. Med. Inf. 134 (2020) 104040, https://doi.org/10.1016/j.ijmedinf.2019.104040.
[36] S. Abbate, P. Centobelli, R. Cerchione, E. Oropallo, E. Riccio, Blockchain technology for embracing healthcare 4.0, IEEE Trans. Eng. Manag. 70 (8) (2022) 2998–3009, https://doi.org/10.1109/TEM.2022.3212007.
[37] S.R. Souza, L.S. de, R. de J. Macêdo, V.P. de Oliveira, W. de S. Santos, L.R. G. Alves, S.N. de B. Lordelo, I. Winkler, Augmented reality in education for industry 4.0: what are the barriers to adoption? Cuadernos De Educación Y Desarrollo 15 (1) (2023) 481–505, https://doi.org/10.55905/cuadv15n1-025.
[38] F. Facchini, S. Digiesi, G. Mossa, Industry 4.0 enabling technologies application in healthcare areas - a systematic review, in: IJCIEOM 2020 - International Joint Conference on Industrial Engineering and Operations Management, 2021, https://doi.org/10.14488/IJCIEOM2020_FULL_0012_37273.
[39] A. Gupta, A. Singh, Healthcare 4.0: recent advancements and futuristic research directions, Wireless Pers. Commun. 129 (2023) 933–952, https://doi.org/10.1007/s11277-022-10164-8.
[40] M. Sony, J. Antony, O. McDermott, The impact of healthcare 4.0 on the healthcare service quality: a systematic literature review, Hosp. Top. 101 (4) (2023) 288–304, https://doi.org/10.1080/00185868.2022.2048220.
[41] B. Wu, Patient continued use of online health care communities: web mining of patient-doctor communication, J. Med. Internet Res. 20 (4) (2018) e126, https://doi.org/10.2196/jmir.9127.
[42] T.S. Dagger, J.C. Sweeney, L.W. Johnson, A hierarchical model of health service quality: scale devel-opment and investigation of an integrated model, J. Serv. Res. 10 (2) (2007) 123–142, https://doi.org/10.1177/1094670507309594.
[43] L.R. Sabaté, L. Diego L, Are we offering patients the right medicines information? A retrospective evaluation of readability and quality in online patient drug information, Eur. J. Hosp. Pharm. 28 (2021) 144–148, https://doi.org/10.1136/ejhpharm-2019-002099.
[44] M. Bates, Health care chatbots are here to help, IEEE Pulse 10 (3) (2019) 12–14, https://doi.org/10.1109/MPULS.2019.2911816.
[45] S. Mierzwa, S. Souidi, T. Conroy, M. Abusyed, H. Watarai, T. Allen, On the potential, feasibility, and effectiveness of chat bots in public health research going forward, Online Journal of Public Health Informatics 11 (2) (2019) 4–16, https://doi.org/10.5210/ojphi.v11i2.9998.
[46] A. Kerasidou, Artificial intelligence and the ongoing need for empathy, compassion and trust in healthcare, Bull. World Health Organ. 98 (4) (2020) 245–250, https://doi.org/10.2471/BLT.19.237198.
[47] A. Rahman, T. Rahman, N.H. Ghani, S. Hossain, J. Uddin, IoT based patient monitoring system using ECG sensor, in: 2019 International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST), 2019, pp. 378–382.
[48] E.S. de Correa, W.C. Satyro, L.F. da Silva, M.L. Martens, J.C. Contador, J. C, Healthcare 4.0 implementation: opportunities and challenges in the healthcare sector, Peer Rev. 5 (15) (2023) 163–182, https://doi.org/10.53660/749.prw1933.
[49] J. Klich, Innovations in elderly care: key success factors, Zdrowie Publiczne i Zarządzanie 16 (3) (2018) 177–186, https://doi.org/10.4467/20842627OZ.18.020.10433. www.ejournals.eu/Zdrowie-Publiczne-i-Zarzadzanie.
[50] PWC, Healthcare outcomes and expenditure in central and eastern Europe - a review. https://www.efpia.eu/media/602945/pwc-strategy-report-increasing-healthcare-investment-in-cee-countries.pdf, 2021.
[51] A. Bíró, R. Branyiczki, Health gap in post-socialist Central and Eastern Europe: a life-course perspective, in: Health and Socio-Economic Status over the Life Course, De Gruyter Oldenbourg, 2019, https://doi.org/10.1515/9783110617245-017.
[52] E.U. AmCham, At a turning point: healthcare systems in central and Eastern Europe. https://www.efpia.eu/media/602945/pwc-strategy-report-increasing-healthcare-investment-in-cee-countries.pdf, 2022.
[53] OECD, Health spending. https://data.oecd.org/healthres/health-spending.htm, 2023.
[54] M. Csanádi, O. Löblová, P. Ozierański, A. Harsányi, Z. Kaló, M. McKee, L. King, When health technology assessment is confidential and experts have no power: the case of Hungary, Health Econ. Pol. Law 14 (2) (2019) 162–181, https://doi.org/10.1017/S1744133118000051.
[55] G. Bacsó, A. Havas, L. Jánoskuti, M. Matécsa, T. Vecsernyés, M. Mazza, Fueling the Hungarian Start-Up Ecosystem, McKinsey & Company, 2023. https://www.mckinsey.com/featured-insights/europe/fueling-the-hungarian-start-up-ecosystem.
[56] G. Johnson, K. Scholes, R. Whittington, Fundamentals of Strategy, Prentice Hall, FINANCIAL TIMES, Pearson Education, 2009.
[57] I. Yüksel, Developing a multi-criteria decision making model for PESTEL analysis, Int. J. Bus. Manag. 7 (24) (2012) 52–66, https://doi.org/10.5539/ijbm.v7n24p52.
[58] R. Perera, The PESTLE Analysis, ISBN 978 179 084 53 23, Nerdynaut Publishing, 2020.
[59] C. Clarke, Strategic planning in healthcare, in: E. Loh, P. Long, P. Spurgeon (Eds.), Textbook of Medical Administration and Leadership, Springer, Singapore, 2019, https://doi.org/10.1007/978-981-10-5454-9_3.
[60] A.A. Siddiqui, The use of pestel analysis tool of quality management in the health care business and its advantages, 2021, American Journal of Biomedical Science & Research 14 (6) (2021), https://doi.org/10.34297/AJBSR.2021.14.002046. AJBSR.MS.ID.002046.
[61] A. Stoyanova, V.P. Marinova, Impact of external and internal circumstances in managing medical services, in: Handbook of Research on Quality and Competitiveness in the Healthcare Services Sector, 2023, pp. 1–21, https://doi.org/10.4018/978-1-6684-8103-5.ch001.
[62] M.M. Saudi, A. Ahmad, M.N.M. Liki, M.A. Husainiamer, Risk management using PESTLE: external factors trigger COVID-19 transmission, in: 2021 International Conference on Intelligent Cybernetics Technology & Applications (ICICyTA), Bandung, Indonesia, 2021, pp. 34–39, https://doi.org/10.1109/ICICyTA53712.2021.9689153.
[63] K. Walsh, L. Bhagavatheeswaran, E. Roma, E-learning in healthcare professional education: an analysis of political, economic, social, technological, legal and environmental (PESTLE) factors [version 1], MedEdPublish 8 (2019) 97, https://doi.org/10.15694/mep.2019.000097.1.
[64] Ch Patel, K. Sinha, Digitalization of healthcare system in India-A perspective and PESTLE analysis, in: M.S. Kaiser, A. Bandyopadhyay, K. Ray, R. Singh, V. Nagar (Eds.), Proceedings of Trends in Electronics and Health Informatics. Lecture Notes in Networks and Systems, 376, Springer, Singapore, 2022, https://doi.org/10.1007/978-981-16-8826-3_17.
[65] C.A. Lichten, S. Castle-Clarke, C. Manville, V. Horvath, E. Robin, J. Krapels, S. Parks, M. Sim, O. van Zijverden J. Chataway, The future of anticoagulation management in atrial fibrillation in Europe: an assessment of today's challenges with recommendations for the future, 2015 Nov 30, Rand Health Q 5 (2) (2015) 2, https://doi.org/10.7249/RR1053. PMID: 28083378; PMCID: PMC5158282.
[66] S.Y. Cheng, D. Bamford, M. Papalexi, B. Dehe, Improving access to health services - challenges in Lean application, Int. J. Public Sect. Manag. 28 (2) (2015) 121–135, https://doi.org/10.1108/IJPSM-05-2014-0066.
[67] Y.L. Huizer, M.M. Kraaij-Dirkzwager, Aura Timen, T.J. Schuitmaker, J.E. van Steenbergen, Context analysis for epidemic control in The Netherlands, Health Pol. 119 (1) (2015) 66–73, https://doi.org/10.1016/j.healthpol.2014.10.004. ISSN 0168-8510.
[68] R.M. Visconti, Healthcare Public-Private Partnerships in Italy: Assessing Risk Sharing and Governance Issues with PESTLE and SWOT Analysis Corporate Ownership and Control, Vol. 13, Issue 4, Summer 2016, 2016, https://doi.org/10.22495/cocv13i4p12.
[69] D. Juengsiragulwit, A. Nikapota, Mental health strategy and policy, in: E. Taylor, F. Verhulst, J. Wong, K. Yoshida, A. Nikapota (Eds.), Mental Health and Illness of Children and Adolescents. Mental Health and Illness Worldwide, Springer, Singapore, 2020, https://doi.org/10.1007/978-981-10-0753-8_60-1.
[70] İ.B. Kanli, İ.T. Küpeli, A. Onat, A comparative analysis on the bureaucratic process in establishing health cooperatives: the cases of Turkey and the UK, in: M. H. Bilgin, H. Danis, E. Demir, V. Bodolica (Eds.), Eurasian Business and Economics Perspectives, Eurasian Studies in Business and Economics, 23, Springer, Cham, 2022, https://doi.org/10.1007/978-3-031-14395-3_17.
[71] L. Schlecht, S. Schneider, A. Buchwald, The prospective value creation potential of Blockchain in business models: a delphi study, Technol. Forecast. Soc. Change 166 (2021) 120601, https://doi.org/10.1016/j.techfore.2021.120601.
[72] C.I. Loeza-Mejía, E. Sánchez-DelaCruz, P. Pozos-Parra, et al., The potential and challenges of Health 4.0 to face COVID-19 pandemic: a rapid review, Health Technol. 11 (2021) 1321–1330, https://doi.org/10.1007/s12553-021-00598-8.
[73] M. Bresnen, D. Hodgson, S. Bailey, P. Hyde, J. Hassard, Managing Modern Healthcare. Knowledge, Networks and Practice, ISBN: 978-1-315-65850-6, Routledge Taylor & Francis Group, New York, 2017, https://doi.org/10.4324/9781315658506.

[74] H.N. Inuwa, A.R. Raja, A. Kumar, B. Singh, S. Singh, Status of industry 4.0 applications in healthcare 4.0 and pharma 4.0, Mater. Today: Proc. 62 (Part 6) (2022) 3593–3598, https://doi.org/10.1016/j.matpr.2022.04.409.
[75] J. Woodside, S. Amiri, Healthcare hyperchain: digital transformation in the healthcare value chain, 10, in: AMCIS 2018 Proceedings, 2018, https://aisel.aisnet.org/amcis2018/Health/Presentations/10.
[76] J.G. Anderson, C.E. Aydin, Evaluating the Organizational Impact of Healthcare Information Systems, Springer Verlag, 2005, https://doi.org/10.1007/0-387-30329-4.
[77] M. Beaulieu, O. Bentahar, Digitalization of the healthcare supply chain: a roadmap to generate benefits and effectively support healthcare delivery, Forecasting and Social Change 167 (2021) 120717, https://doi.org/10.1016/j.techfore.2021.120717. ISSN 0040-1625.
[78] M. Ahsan, Z. Siddique, Industry 4.0 in Healthcare: a systematic review, International Journal of Information Management Data Insights 2 (2022) 100079, https://doi.org/10.1016/j.jjimei.2022.100079.
[79] J. Al-Jaroodi, N. Mohamed, A.E. Abukhousa, Health 4.0: on the way to realizing the healthcare of the future, IEEE Access (8) (2020), https://doi.org/10.1109/ACCESS.2020.3038858.
[80] A. Haleem, M. Javaid, R.P. Singh, R. Suman, Medical 4.0 technologies for healthcare: features, capabilities, and applications, ISSN 2667-3452, Internet of Things and Cyber-Physical Systems 2 (2022) 12–30, https://doi.org/10.1016/j.iotcps.2022.04.001.
[81] L.M.D. Lopes, R.D.C. Moreira, L.A.D. Amaral, B.F. De Lucena, E.A. Martins, Educational innovations with the use of augmented reality: a systematic review, Educ. Rev. 35 (1) (2019) 1–20, https://doi.org/10.1590/0104-4060.60375.
[82] M.N. Soares, M. Kauffman, Industry 4.0: horizontal integration and intellectual property law strategies in England. July 2018, Revista Opinião Jurídica (Fortaleza) 16 (23) (2018) 268, https://doi.org/10.12662/2447-6641oj.v16i23.p268-289.2018.
[83] J.J. Hathaliya, S. Tanwar, An exhaustive survey on security and privacy issues in Healthcare 4.0, Comput. Commun. 153 (2020) 311–335, https://doi.org/10.1016/j.comcom.2020.02.018. ISSN 0140-3664.
[84] O. McDermott, I. Foley, J. Antony, M. Sony, M. Butler, The impact of industry 4.0 on the medical device regulatory product life cycle compliance, Sustainability 14 (2022) 14650, https://doi.org/10.3390/su142114650.
[85] A.M. Fathollahi-Fard, K. Govindan, M. Hajiaghaei-Keshteli, A. Ahmadi, A green home health care supply chain: new modified simulated annealing algorithms, J. Clean. Prod. 240 (2019), https://doi.org/10.1016/j.jclepro.2019.118200. Article 118200.
[86] C. Barton, R. Morris, J. Rothlind, K. Yaffe, Video-telemedicine in a memory disorders clinic: evaluation and management of rural elders with cognitive impairment, Telemed. J. e Health 17 (10) (2011) 789–793, https://doi.org/10.1089/tmj.2011.0083. Epub 2011 Oct 24. PMID: 22023458.
[87] M. Alloghani, D. Al-Jumeily, A. Hussain, A.J. Aljaaf, J. Mustafina, E. Petrov, Healthcare services innovations based on the state of the art technology trend industry 4.0, in: 2018 11th International Conference on Developments in eSystems Engineering (DeSE), Cambridge, UK, 2018, pp. 64–70, https://doi.org/10.1109/DeSE.2018.00016.
[88] I. Mustapha, N. Khan, M.I. Qureshi, A.A. Harasis, N.T. Van, Impact of industry 4.0 on healthcare: a systematic literature review (SLR) from the last decade, International Journal of Interactive Mobile Technologies (iJIM) 15 (18) (2021) 116–128, https://doi.org/10.3991/ijim.v15i18.25531.
[89] P. Ajmera, V. Jain, Modelling the barriers of Health 4.0–the fourth healthcare industrial revolution in India by TISM, Operations Management Research 12 (2019) 129–145.
[90] C. Hartwell, S. Lovell, J.J. Hess, et al., Barriers and facilitators to state public health agency climate and health action: a qualitative assessment, BMC Publ. Health 23 (2023) 145, https://doi.org/10.1186/s12889-023-14996-2.
[91] B. Buchelt, A. Frączkiewicz-Wronka, M. Dobrowolska, The organizational aspect of human resource management as a determinant of the potential of polish hospitals to manage medical professionals in healthcare 4.0, Sustainability 12 (2020) 5118, https://doi.org/10.3390/su12125118.
[92] B. Fabrègue, Medical Technology a well-established sector in Hungary, Blue Europe, https://www.blue-europe.eu/analysis-en/short-analysis/medical-technology-a-well-established-sector-in-hungary/, 2022.
[93] E. Gummesson, Qualitative research in management: addressing complexity, context, and persona, Manag. Decis. 44 (2006) 167–179.
[94] R. Spano, M. Massaro, S. Iacuzzi, Blockchain for value creation in the healthcare sector, Technovation (2021), https://doi.org/10.1016/j.technovation.2021.102440.
[95] K. Krippendorff, Content Analysis: an Introduction to its Methodology, Sage Publications, 2013.
[96] S. Stemler, Content analysis, in: R. Scott, S. Kosslyn (Eds.), Emerging Trends in the Social and Behavioral Sciences, John Wiley and Sons, 2015, pp. 1–14, https://doi.org/10.1002/9781118900772.etrds0053.
[97] H. Ramsdal, C. Bjørkquist, Value-based innovations in a Norwegian hospital: from conceptualization to implementation, Taylor & Francis Journals, Publ. Manag. Rev. 22 (11) (2020) 1717–1738, November.
[98] Lumivero, NVivo software. https://lumivero.com/products/nvivo/, 2023.
[99] S. Lacy, B. Watson, D. Riffle, J. Lovejoy, Issues and best practices in content analysis, Communication Studies Faculty Publications and Presentations 8 (2015) 1–36, https://doi.org/10.1177/1077699015607338. http://pilotscholars.up.edu/cst_facpubs/8.
[100] S. Stemler, An overview of content analysis, Practical Assess. Res. Eval. 7 (17) (2000) 1–6, https://doi.org/10.7275/z6fm-2e34.
[101] Q. Xie, Agree or disagree? A demonstration of an alternative statistic to Cohen's kappa for measuring the extent and reliability of agreement between observers, in: Conference Presentation at Federal Committee on Statistical Methodology Research Conference, Washington, DC, November 4-6, 2013. https://nces.ed.gov/FCSM/pdf/J4_Xie_2013FCSM.pdf.
[102] L. Garattini, A. Padula, Competition in health markets: is something rotten? Journal of the Royal Society Medicine 112 (1) (2018) https://doi.org/10.1177/0141076818816935.
[103] K.A. Phillips, P.A. Deverka, H.C. Sox, M.J. Khoury, L.G. Sandy, G.S. Ginsburg, S. R. Tunis, L.A. Orlando, M.P. Douglas, Making genomic medicine evidence-based and patient-centered: a structured review and landscape analysis of comparative effectiveness research, Genet. Med. 19 (10) (2017) 1081–1091, https://doi.org/10.1038/gim.2017.21. Epub 2017 Apr 13. PMID: 28406488; PMCID: PMC5629101.
[104] Y. Gao, H. Li, Y. Luo, An empirical study of wearable technology acceptance in healthcare, Ind. Manag. Data Syst. 115 (9) (2015) 1704–1723, https://doi.org/10.1108/IMDS-03-2015-0087.
[105] C. Chen, E.W. Loh, K.N. Kuo, et al., The times they are a-changin' - healthcare 4.0 is coming, J. Med. Syst. 44 (2020) 40, https://doi.org/10.1007/s10916-019-1513-0.
[106] S. Roy, T. Meena, S.J. Lim, Demystifying supervised learning in healthcare 4.0 (2022): a new reality of transforming diagnostic medicine, 2022 Oct 20, Diagnostics 12 (10) (2022) 2549, https://doi.org/10.3390/diagnostics12102549. PMID: 36292238; PMCID: PMC9601517.
[107] S. Kalkman, J. van Delden, A. Banerjee A, et al., Patients' and public views and attitudes towards the sharing of health data for research: a narrative review of the empirical evidence, J. Med. Ethics 48 (2022) 3–13, https://doi.org/10.1136/medethics-2019-105651.
[108] J. Offerman, S. Fristedt, S.M. Schmidt, et al., Attitudes related to technology for active and healthy aging in a national multigenerational survey, Nat Aging 3 (2023) 617–625, https://doi.org/10.1038/s43587-023-00392-3.
[109] J. Li, P. Carayon, Health Care 4.0: a vision for smart and connected health care, IISE Transactions on Healthcare Systems Engineering 11 (3) (2021) 171–180, https://doi.org/10.1080/24725579.2021.1884627.
[110] H. Gupta, A.K. Yadav, S. Kusi-Sarpong, S.A. Khan, S.C. Sharma, Strategies to overcome barriers to innovative digitalisation technologies for supply chain logistics resilience during pandemic, Technol. Soc. 69 (2022) 101970, https://doi.org/10.1016/j.techsoc.2022.101970.
[111] S. Dash, S.K. Shakyawar, M. Sharma, S. Kaushik, Big data in healthcare: management, analysis and future prospects, Journal of big data 6 (1) (2019) 1–25, https://doi.org/10.1186/s40537-019-0217-0.
[112] W.A. Odendaal, K. Ward, J. Uneke, H. Uro-Chukwu, D. Chitama, Y. Balakrishna, T. Kredo, Contracting out to improve the use of clinical health services and health outcomes in low- and middle-income countries, Cochrane Database Syst. Rev. 4 (4) (2018) CD008133, https://doi.org/10.1002/14651858.CD008133.pub2.
[113] D. Arora, S. Gupta, A. Anpalagan, Evolution and adoption of next generation IoT-driven health care 4.0 systems, Wireless Pers. Commun. 127 (4) (2022) 3533–3613.
[114] H.K. Park, J. Chung, J. Ha, Acceptance of technology related to healthcare among older Korean adults in rural areas: a mixed-method study, Technol. Soc. 72 (2023) 102182, https://doi.org/10.1016/j.techsoc.2022.102182.
[115] K. Askedal, L.S. Flak, E. Abildsnes, Reviewing Effects of ICT in Primary Healthcare Services Twenty-Third Americas Conference on Information Systems, Boston, 2017.
[116] M.A. Hillen, R.M. Postma, M.G.E. Verdam, et al., Development and validation of an abbreviated version of the trust in oncologist scale-the trust in oncologist scale-short form (TiOS-SF), Support. Care Cancer 25 (2017) 855–861, https://doi.org/10.1007/s00520-016-3473-y.
[117] M.L. Tan, D. Vlahov, E. Hagan, M.M. Glymour, L.M. Gottlieb, E.C. Matthay, N. E. Adler, Building the evidence on making health a shared value: insights and considerations for research, SSM Popul Health 9 (2019) 100474, https://doi.org/10.1016/j.ssmph.2019.100474. PMID: 31485479; PMCID: PMC6715953.
[118] H.K. Park, J. Chung, J. Ha, Acceptance of technology related to healthcare among older Korean adults in rural areas: a mixed-method study, Technol. Soc. 72 (2023) 102182, https://doi.org/10.1016/j.techsoc.2022.102182.
[119] A. Nüssler, The new European Medical Device Regulation: friend or foe for hospitals and patients? Injury 2023 (2023) 110907 https://doi.org/10.1016/j.injury.2023.110907. ISSN 0020-1383.