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Article

Applying the Theory of Constraints to National Healthcare Digitalization: A Cross-Country Comparison

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Abstract

The digitalization of national healthcare systems is a complex and context-sensitive process that requires systematic analysis to identify both current progress and areas needing further development. Traditional assessments often rely on secondary data, which can overlook operational-level implementation challenges that constrain effectiveness and remain invisible to policymakers. To address this gap, we collected primary qualitative data from healthcare professionals in Austria, Bulgaria, and Hungary. Using the Theory of Constraints (TOC) thinking processes, we analyzed the implementation of national digital health initiatives and their perceived impact on service quality. Our findings reveal distinct systemic bottlenecks in each country and support the development of targeted policy recommendations based on TOC frameworks from operations research. By applying TOC in a cross-national qualitative study, we contribute to the literature on healthcare digitalization and demonstrate that national cultural factors shape both the nature of the constraints and the pathways to effective digital transformation.

Keywords: healthcare digitalization; cross-country comparison; theory of constraints
JEL: I11, I18, M11

1. Introduction

A core policy objective of the European Commission (EC) is to ensure equitable access to adequate and affordable healthcare across member states (European Commission, 2019). Nevertheless, recent research highlights persistent disparities in healthcare accessibility within the European Union (EU) (Majcherek et al., 2023). The study underscores the potential of digital health solutions to add substantial value, particularly in contexts where conventional healthcare services are either ineffective or inaccessible. Digital health encompasses a broad spectrum of technologies, including telemedicine, wearable devices, electronic medical records, mobile health applications (mHealth), and advanced healthcare software systems (WHO, 2017). The integration of these technologies can play a pivotal role in enhancing the efficiency, accessibility, and quality of healthcare delivery, while also contributing to cost reduction and improved health outcomes (Agarwal et al., 2010; Chaudhry et al., 2006; Davidson et al., 2018). However, the digital transformation of healthcare systems faces numerous challenges, both within the EU and globally.

The complexity of digitalization in healthcare stems from the wide range of clinical applications, stringent regulatory environments, high risks, and culturally specific factors that vary across countries (Lee, 2017; Sermontyte-Baniule et al., 2022). Successful implementation depends on the coordinated efforts of multiple stakeholders, including healthcare providers, regulators, insurers, medical professionals, and patients, as well as governmental support for innovation. Because digitalization necessitates integration across primary, secondary, and tertiary care, as well as between healthcare and social services, national institutional frameworks introduce further complexity (Klecun et al., 2019). Additionally, national governments differ in their innovation strategies and investment priorities, as reflected in the European Innovation Scoreboard (EIS) (European Commission, 2022). The EIS reveals a pronounced divide within the EU: Innovation Leaders and Strong Innovators are predominantly located in Northern and Western Europe, while Southern and Eastern European countries tend to be Moderate or Emerging Innovators. While the performance gap between Innovation Leaders and Strong Innovators is minimal, Emerging Innovators lag significantly behind (European Commission, 2023).

Prior research on healthcare digitalization has predominantly focused on single-country case studies, often descriptive in nature and relying heavily on secondary data sources. These studies provide valuable accounts of implementation practices, benefits, and outcomes. For instance, Bogumil-Uçan and Klenk (2021) compare Austria and Germany and reveal that even among Innovation Leaders, differing institutional and political dynamics shape digital health implementation. However, the existing body of literature remains fragmented and under-theorized. Notably absent are comparative studies that analyze digital health adoption across countries with divergent innovation

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capacities and institutional settings. In addition, very few studies apply established theoretical frameworks to diagnose system-level barriers and propose targeted interventions. Most scholarship lacks explanatory depth, particularly when it comes to understanding how cultural, regulatory, and operational factors interact with national digital health strategies. These limitations have important implications for healthcare policy and practice. Without theoretically grounded and comparative insights, policymakers lack robust evidence to guide the implementation of digital health initiatives (Currie and Seddon, 2014). As a result, digital health strategies may fail to account for contextual constraints, leading to inefficient investments, uneven adoption, and limited improvements in healthcare delivery (Kierkegaard, 2015). Furthermore, the absence of cross-country analyses makes it difficult to identify transferable lessons across health systems, potentially exacerbating regional disparities in digital health adoption.

To address these gaps, this study examines the healthcare digitalization trajectories of three EU countries with contrasting innovation performance: Austria (a Strong Innovator), and Hungary and Bulgaria (both categorized as Emerging Innovators). We employ a qualitative research design based on 15 semi-structured interviews with healthcare professionals from these three countries. This primary data collection enables rich, context-sensitive insights into how digitalization is experienced by medical practitioners across diverse national settings, capturing both perceived benefits and operational constraints. The interviewees represent a range of clinical specializations, ensuring a comprehensive understanding of healthcare digital transformation dynamics. Theoretically, we apply the Theory of Constraints (TOC), a systems-thinking methodology from operations management that focuses on identifying and alleviating bottlenecks that hinder performance. In healthcare, such constraints may include policy inefficiencies, limited resources, or fragmented digital systems.

Our investigation is guided by the following research questions:

What is the current state of healthcare digitalization in Austria, Hungary, and Bulgaria?

To what extent does digitalization improve the quality and efficiency of healthcare services?

What are the key barriers hindering optimal digital healthcare transformation in these countries?

Addressing these questions is critical for both academic and policy communities. By bridging the gap between theory and practice, we offer a nuanced understanding of how institutional and cultural factors shape digitalization outcomes in healthcare. This is especially relevant for Emerging Innovator countries, where misalignment between top-down digital strategies and operational realities may exacerbate inequality in healthcare access and performance.

Our contribution is threefold: First, we provide a cross-national comparison of healthcare digitalization, an underdeveloped area in literature. Second, we apply TOC to a new empirical domain, digital health systems, extending its relevance beyond manufacturing and traditional healthcare operations. Third, by relying on first-hand professional insights, we surface barriers and solutions that remain invisible in secondary-data-based studies. These insights have theoretical implications for digital transformation frameworks and practical relevance for national policy design within the EU health innovation agenda.

For policymakers within the EU, especially those working in health ministries and innovation agencies, our findings provide comparative evidence on how national contexts and innovation capabilities shape the trajectory of digital health transformation. For healthcare administrators and practitioners, particularly in emerging innovator countries, the study offers valuable insights into overcoming systemic constraints and leveraging digital tools to improve service delivery. For scholars and theorists in operations management and health digitalization, this study provides a rare empirical application of TOC across diverse cultural and institutional settings, supporting both theory-building and refinement. Ultimately, this research supports the EU's broader strategic goals of reducing health inequalities, fostering innovation-driven growth, and improving the quality and accessibility of healthcare throughout the Union.

2. Theory

The TOC originated from the work of Goldratt, who initially introduced it through a scheduling software solution known as Optimized Production Technology. However, it gained broader recognition following the publication of the influential business novel "The Goal", which prompted growing scholarly interest in the late 1990s (Goldratt, 1990; Goldratt and Cox, 2016). TOC offers a structured yet intuitive approach to process improvement, emphasizing that many organizational systems are limited by a small number of critical constraints or bottlenecks that restrict their ability to meet goals effectively. At its core, TOC suggests that systems are typically governed by one primary limiting factor at a given time. Addressing this constraint has the greatest potential to improve system performance. To evaluate progress toward organizational objectives, Goldratt proposed three key operational metrics:

(1) Throughput—the rate at which the system generates financial value through sales;

(2) Inventory—the total capital tied up in items or resources intended for sale or use;

(3) Operating expense—the ongoing costs incurred to transform inventory into throughput (Goldratt, 1990; Goldratt and Cox, 2016).

Constraints can be physical, such as limited staff, equipment, or space, or policy-related, stemming from outdated procedures, rigid rules, or ineffective management

practices. While physical constraints are generally more visible and easier to address, policy constraints often have a deeper, systemic impact. Removing policy-related limitations tends to yield more significant and sustainable improvements than merely adding resources (Dettmer, 1997; Goldratt and Cox, 2016). To guide continuous improvement, TOC introduces the Process of Ongoing Improvement (POOGI), a five-step cyclical method:

(1) Identify the constraint: Determine the key limitation that restricts system performance. This may be a tangible resource or an embedded policy or rule that limits throughput.

(2) Exploit the constraint: Maximize the performance of the constraint using current resources without major investments or structural changes. In the case of policy constraints, adjustments may involve rethinking and replacing ineffective procedures.

(3) Subordinate other processes: Align all other system operations to support the constraint. This means adjusting activities of non-constraint areas, so they do not outpace or interfere with the performance of the limiting factor.

(4) Elevate the constraint: If prior steps don't sufficiently resolve the bottleneck, take more substantial actions, such as investing in new equipment, redesigning workflows, or reorganizing staffing, to increase the capacity or efficiency of the constraint.

(5) Repeat the process: Once a constraint is resolved, another will inevitably emerge.

TOC emphasizes the importance of continuously scanning for new limitations and restarting the improvement cycle. Additionally, previously helpful policies may themselves become constraints over time and must be re-evaluated in light of evolving circumstances (Goldratt, 1990; Goldratt and Cox, 2016).

This methodology has been widely adopted across various domains as a means of fostering systemic improvement and ensuring strategic focus on the most impactful barriers to success. The overarching objective of any TOC intervention is to increase throughput (i.e., the rate at which the system generates value) and/or reduce inventory, with a secondary focus on lowering operating expenses. This shift in measurement reframes how efficiency and success are understood in operational contexts.

TOC was later extended to address policy constraints, limitations embedded not in physical resources, but in decision rules, mental models, or systemic assumptions. This development introduced the Thinking Processes, a suite of cause-effect logic tools designed to diagnose, envision, and implement organizational change. The Thinking Processes are built around three fundamental questions: What to change? What to change to? How to cause the change?

These questions are addressed through tools such as:

(1) The Current Reality Tree (CRT), which maps systemic cause-effect relationships to identify core problems;

(2) The Evaporating Cloud (EC), which explores conflicts and proposes innovative solutions ("injections");

(3) The Future Reality Tree (FRT), which models the anticipated outcomes of proposed changes.

Together, these tools facilitate the systematic analysis and resolution of both operational and strategic constraints.

In summary, TOC has matured into a robust theoretical and practical framework that enhances the internal efficiency and adaptability of a wide range of systems (Rahman, 1998; Watson et al., 2007). Its integrated approach, linking performance measurement, process optimization, and strategic thinking, makes it uniquely suited to address the complex challenges faced by contemporary organizations.

Application of TOC in Healthcare Research

The TOC has gained traction in the healthcare sector as a process improvement strategy for managing operational bottlenecks and enhancing service delivery. A recent systematic literature review by Datt et al. (2024) provides a comprehensive overview of TOC's applications across various healthcare settings, summarizing 36 studies conducted between 1999 and mid-2021. TOC tools such as the Five Focusing Steps (FFS), Thinking Process (TP) logic trees, Drum-Buffer-Rope (DBR), and Throughput Accounting (TA) have been effectively applied to improve patient flow, reduce waiting times, increase resource utilization, and improve scheduling efficiency in traditional healthcare environments (e.g., emergency departments, operating rooms, and outpatient clinics). Reported outcomes include reductions in appointment delays (up to 70%), length of stay, and staff overtime, alongside improvements in service capacity and financial performance.

Healthcare studies tend to report physical constraints more frequently, although TOC traditionally emphasizes policy constraints, defined as rules or institutional assumptions that hinder system performance. Commonly cited limitations include shortages in hospital beds, staffing, clinical space, and medical equipment. This trend reflects the pervasive issue of underfunding and resource scarcity across many national healthcare systems (World Health Organization, 2021). Nonetheless, policy constraints remain highly relevant, particularly inefficiencies in authorization protocols, billing systems, interdepartmental patient handovers, and scheduling mechanisms. According to TOC principles, policy constraints often represent the most accessible levers for systemic improvements.

Much of the literature focuses on ambulatory care (e.g., emergency room services) and specialty outpatient care (e.g., non-overnight treatments by medical specialists). A small subset of the literature addresses ancillary, non-clinical services, such as insurance claims processing and appointment scheduling systems (see Appendix Table 14 for a summary of the literature review). Despite these contributions, none of the reviewed studies applied TOC

to digital systems or technologies such as electronic health records (EHR), telehealth platforms, digital diagnostics, or Artificial Intelligence (AI)-based clinical workflows. Although Mabin et al. (2018) briefly referenced the optimization of an electronic health record system, digital infrastructure itself is not treated as a system constraint or area of process redesign. This disconnect between TOC literature and digital health innovation suggests a significant opportunity for further exploration. While TOC has demonstrated value in optimizing traditional healthcare operations, its potential role in digital healthcare transformation remains largely unexplored. The current study seeks to address this gap by applying TOC frameworks to analyze digitalization efforts across three European healthcare systems, Austria, Bulgaria, and Hungary, with the goal of identifying system-level constraints, proposing context-specific solutions, and demonstrating how TOC can be adapted to complex, digitally mediated healthcare environments.

In addition to applying TOC, this study incorporates Hofstede's cultural dimensions as an exploratory analytical lens to better understand how national culture may shape both the emergence of constraints and the perceived feasibility of solutions (Hofstede, 2011). Integrating Hofstede's framework is theoretically meaningful for two reasons. First, it complements TOC by offering a context-sensitive explanation for why similar digitalization challenges may manifest differently across countries not just in technical terms, but in terms of stakeholder perception, organizational behavior, and resolution. Second, it allows us to explore the validity of TOC tools in diverse institutional and cultural environments, where values and norms influence how constraints are interpreted and addressed. This approach extends TOC's applicability by showing how its implementation must be attuned to the socio-cultural realities of national healthcare systems, where both authority structures and motivational orientations shape the dynamics of change.

3. Methods

In contrast to prior research on healthcare digitalization, we utilized primary data for our analysis. We gathered qualitative data from 15 practicing medical doctors in Austria, Bulgaria, and Hungary (5 from each country) through semi-structured interviews. We used theoretical sampling of front-line clinicians and interviewed until country-level thematic saturation, as commonly suggested in qualitative research to increase reliability (Ligita et al., 2020). Each interview lasted approximately 30 minutes and was conducted in the local language of the respective country. To gain a comprehensive understanding of the industry, we conducted interviews with doctors from various specialties, including dentistry, internal medicine, pain medicine, radiology, and others.

After collecting the data, we transcribed all interviews using voice-to-text software Cockatoo (2025; Cockatoo Inc., Scottsdale, AZ, USA) and manually reviewed them for transcription errors. We then manually translated all interviews conducted in German, Bulgarian, and Hungarian into English. Cross-language validity (i.e., equivalence of the original and the English language interview translations) was ensured by the choice of interviewers: Interviewer 1, who conducted the German and Bulgarian interviews speaks both languages at native proficiency and knows both countries' cultural and medical context due to her nationality. Similarly, Interviewer 2, who conducted the Hungarian interviews, speaks Hungarian at native proficiency, was born and raised in Hungary and has work experience in the Hungarian healthcare environment. Therefore, both emic (culture-specific) and etic (universal) concepts for achieving translation equivalence suggested in the seminal article of Triandis (1976) have been addressed by the choice of interviewers. Our further analysis was conducted in English.

Two researchers with backgrounds in qualitative academic research in international business and healthcare acted as coders in this study. Before the coding exercise, the two raters aligned on the coding processes and discussed to clarify any ambiguities. English transcripts were then read and organized into open codes by two researchers, which is a common first step when starting qualitative data analysis (Yin, 2015). Then, both researchers compared their open codes, discussed differences and agreed on a common list of 582 open codes. Following this, six emerging coding categories were created inductively based on a joint discussion of the two researchers:

(1) Financial Context: financial costs or savings;

(2) Human Resources: changes in employment or tasks of human workers (including doctors and paramedics);

(3) Infrastructure: physical or software infrastructure, hardware, medical equipment, including digital infrastructure provided by the government;

(4) Internal Processes: processes of providing medical care, including appointment scheduling, status, anamnesis, diagnosis, treatment, and follow-up;

(5) Patient Satisfaction: medical professionals' opinion about patients' satisfaction with digital health solutions;

(6) Service Quality: opinion about efficiency, accuracy, timeliness, and general quality of medical services provided by the healthcare system in general.

Afterwards, each researcher independently assigned the common list of open codes to category codes. Krippendorff's Alpha was employed to assess the inter-rater reliability of the rating scheme (Krippendorff, 2018). This statistical measure is particularly suited for studies with multiple raters and different levels of measurement. It is a measure that accommodates different numbers of raters, sample sizes, and missing data, making it appropriate for numerous study designs (Krippendorff, 2018).

In the present case, each rater independently provided ratings. The rated data were then input into the web-based statistical package K-Alpha Calculator (Marzi et al., 2024). The analysis provided a reliability coefficient for the coding scheme, indicating the extent of agreement among raters beyond chance. The resulting Krippendorff's Alpha coefficient is 0.938 (95% CI: [0.915, 0.959]; CI, confidence interval), recalling that the threshold for a satisfactory level of this coefficient is 0.80, as suggested by Krippendorff (2018).

Next, both researchers individually assigned a sentiment tag of 'positive', 'neutral', or 'negative' to all open codes in each of the six categories mentioned above. Krippendorff's Alpha was calculated again with the same procedure as described above. The resulting Krippendorff's Alpha coefficient for the sentiment coding is 0.878 (95% CI: [0.841, 0.911]). Afterwards, the researchers agreed on differences in the coding. Tables 1,2,3 present the number and relative frequency of these tagged codes for each country:

Table 1. Relative frequency and the number of open codes assigned to topics, by sentiment, based on Austrian interviews.

Austria	Positive	Neutral	Negative
Financial context	30% (7)	35% (8)	35% (8)
Human resources	45% (9)	35% (7)	20% (4)
Infrastructure	74% (29)	18% (7)	8% (3)
Internal processes	74% (28)	24% (9)	3% (1)
Patient satisfaction	40% (10)	40% (10)	20% (5)
Service quality	69% (36)	8% (4)	23% (12)
Sum	60% (119)	23% (45)	17% (33)

Table 2. Relative frequency and the number of open codes assigned to topics, by sentiment, based on Bulgarian interviews.

Bulgaria	Positive	Neutral	Negative
Financial context	4% (1)	31% (8)	65% (17)
Human resources	0% (0)	57% (4)	43% (3)
Infrastructure	21% (16)	55% (41)	24% (18)
Internal processes	16% (3)	47% (9)	37% (7)
Patient satisfaction	13% (3)	22% (5)	65% (15)
Service quality	79% (22)	14% (4)	7% (2)
Sum	25% (45)	40% (71)	35% (62)

Reliability of the coding procedures was established by two coders independently and fully coding the data. Additionally, each interview was coded by both the interviewer (who is most familiar with the context and possible non-verbal elements of the interview) and the other researcher (who is proficient in qualitative coding and healthcare terminologies but does not have an interviewer bias).

Table 3. Relative frequency and the number of open codes assigned to topics, by sentiment, based on Hungarian interviews.

Hungarian	Positive	Neutral	Negative
Financial context	56% (14)	20% (5)	24% (6)
Human resources	85% (17)	10% (2)	5% (1)
Infrastructure	73% (46)	19% (12)	8% (5)
Internal processes	43% (16)	30% (11)	27% (10)
Patient satisfaction	71% (10)	14% (2)	14% (2)
Service quality	69% (33)	19% (9)	13% (6)
Sum	66% (136)	20% (41)	14% (30)

To identify national-level constraints, we used the sentiment tables to select, for each country, the thematic area with the highest proportion of negative sentiment. These country-level constraints were then further analyzed using TOC thinking processes. For each country, we constructed a CRT beginning with a core problem statement and identifying related Undesirable Effects (UDEs) based on recurring negative-sentiment open codes in the interview data. The UDEs were connected to the core problem using explicit "if-then" logic to ensure internal causal consistency in line with standard TOC practice (Kendall, 2005).

To strengthen the robustness of this step, we triangulated the qualitative identification of UDEs and core constraints with a quantitative mapping of all negative-sentiment open codes to the formulated UDEs. This allowed us to assess whether the qualitatively identified core constraint was also supported by a high number of participant-reported negative experiences relative to alternative UDEs. An overview of the UDE selection process is presented in Appendix Table 15.

After identifying the core UDE in each country, we used the EC to formulate the central conflict underlying the constraint and to derive actionable policy "injections". We then used the FRT to map, again through "if-then" logic, how the proposed policy interventions could resolve the core problem while also alleviating other non-core UDEs. In this way, the Five Focusing Steps and TOC Thinking Processes were used sequentially to identify the main national constraint, select the highest-leverage UDE, formulate a solution, and assess the broader expected effects of the proposed interventions.

4. Results

In Austria, the core problem was framed as "Financing digitalization is a burden of progress". Six UDEs were identified:

UDE 1: Digitalization raises privacy concerns that hinder adoption.

UDE 2: Over-reliance on digital creates "risk of system downtime".

UDE 3: Cost and complexity of digitalization might create regional disparities in healthcare quality.

Table 4. Tabular representation of the current reality tree of Austrian healthcare system digitalization.

Logical steps leading to core problem	Related UDE	Connection rationale
1. Digital gap is arising in quality of service	UDE 3: Cost and complexity of digitalization might create regional disparities in healthcare quality (Core Constraint) UDE 5: Digitalization marginalizes non-digital populations' access to healthcare	
2. Digitalization increasingly seen as negative, slowing down progress	UDE 1: Digitalization raises privacy concerns that hinder adoption UDE 2: Over-reliance on digital creates "risk of system downtime" UDE 4: Constant digital change increases operational costs UDE 6: Digitalization requires funds that might take resources from other needed areas	Perception of "digital danger" Complexity increase might hinder efficiency increase
3. Financing digitalization is burden of progress (core problem)		

UDE, Undesirable Effect.

Table 5. Tabular representation of the evaporating cloud of Austrian healthcare system digitalization.

Core problem	UDE 3: Cost and complexity of digitalization might create regional disparities in healthcare quality	
Solution to core problem	Equalize regional disparities	
Requirements of the solution	1. Decrease the creation of regional disparities 2. Increase regional autonomy to create regionally relevant solutions	1. Increase focus on underperforming regions 2. National plan to identify and tackle underperforming areas
Injection	INJ1: Include regional compensation budget to tackle differences	INJ2: Inject more regional planning into national digitalization plan

INJ, Injection.

UDE 4: Constant digital change increases operational costs.

UDE 5: Digitalization marginalizes non-digital populations' access to healthcare.

UDE 6: Digitalization requires funds that might take resources from other needed areas.

The Austrian CRT with the UDEs is presented in Table 4.

In Austria, UDE 3 ("cost and complexity of digitalization might create regional disparities in healthcare quality") emerged as the core UDE. This choice was supported by both the CRT logic and the quantitative mapping of negative-sentiment codes to UDEs. Using the EC, we framed the Austrian solution as reducing regional disparities in digital healthcare. The central conflict lay between greater regional autonomy and the need for national coordination. We therefore proposed two policy injections: a regional compensation budget at county or city level and stronger regional planning within the National Digitalization Plan (Bundeskanzleramt Österreich, 2023). The Austrian EC is presented in tabular form in Table 5.

The Austrian FRT showed how these two policy proposals could reduce the financial burden of digitalization and mitigate several non-core UDEs. The full FRT is presented in Table 6.

In Bulgaria, the core constraint was identified as decreased patient satisfaction. Although "Financial Context" and "Patient Satisfaction" appeared with the same proportion of negative sentiment in the Bulgarian interviews (both 65% negative codes, see Table 2), we selected decreased patient satisfaction as the core constraint because it is the most actionable, high-leverage bottleneck at the level of care delivery. This choice is also consistent with the core TOC principle of identifying the factor that most directly limits the system's goal and throughput. In the healthcare context examined here, throughput can be understood as patient load, that is, the system's ability to effectively serve patients without avoidable delays, dissatisfaction, repeated contacts, or inefficient use of clinical capacity. Decreased patient satisfaction signals breakdowns in communication, coordination, and discharge processes that can disrupt patient flow, increase complaints and rework, and reduce the system's effective capacity to manage patient load. By contrast, although financial context is clearly important, it operates more as a structural background condition rather than as the immediate operational bottleneck most directly constraining throughput. In a state-funded system, increasing resources is typically a macro-level policy decision and often constrained by fiscal possibilities. By contrast, patient experience can be improved through process redesign and communication- and coordination-focused quality im-

Table 6. Tabular representation of the future reality tree of Austrian healthcare system digitalization.

Injection	INJ1: Include regional compensation budget to tackle differences	INJ2: Inject more regional planning into national digitalization plan
Logical steps to solution	1. Financial incentives to providers based on need and importance to catch up 2. Localized plan increases perception of "digital safety" 3. Investment in digitalization seen as desired	1. Non-digital population less neglected with more local action 2. Localized plan increases perception of "digital safety" 3. Investment in digitalization seen as desired
Solution	Financial burden on digital progress lifted	

provement that is frequently cost-neutral or cost-saving (e.g., discharge communication interventions and broader patient-experience improvement programs) (Becker et al., 2021). Moreover, patient satisfaction is not merely an "outcome"; it is closely linked to clinical effectiveness, safety, and utilization, meaning that improving experience can reduce avoidable complications and readmissions, pressures that themselves intensify the costs of healthcare (Doyle et al., 2013). Finally, the direction of dependence is asymmetric: while additional funding does not automatically translate into better patient experience without changes in delivery, better patient experience has been empirically associated with stronger financial performance (e.g., lower costs and higher revenue), making it a viable choice as a core constraint through which "financial context" can improve (Giese et al., 2024).

We identified the following UDEs that contribute to this core problem:

UDE 1: Telemedicine is not supported legally.

UDE 2: Lack of nationwide digitalization creates regional differences in quality of care.

UDE 3: Cost of digitalization is taken by doctors.

UDE 4: Inconsistent data access hinders collaboration between doctors.

UDE 5: Dual documentation reduces efficiency.

In Hungary, the core constraint was internal processes, defined as "digitalization does not increase process performance". UDEs resulting in this constraint are:

UDE 1: Incompatibility of statewide and private digital systems slows down adoption.

UDE 2: Technical challenges increase risk of downtime due to information technology (IT) problems.

UDE 3: Limited digital personalization challenges digital success in different medical areas.

UDE 4: User-unfriendliness of digital systems hinders efficient care.

UDE 5: Resistance to change slows down implementation at a different pace.

These CRTs for Bulgaria and Hungary are presented in Tables 7,8.

Based on these CRTs, the core UDE for Bulgaria was "dual documentation reduces efficiency", while in Hungary it was "user-unfriendliness of digital systems hinders efficient care".

In Bulgaria, we proposed replacing dual documentation with a fully digital standard documentation system. This led to two policy recommendations: a digital authentication system for doctors and patients, and nationwide standardization of documentation systems. The Bulgarian EC and FRT can be found in Tables 9,10.

In Hungary, the proposed solution was to improve the usability of digital systems. The central conflict was between keeping interfaces simple for clinicians and introducing new functionalities to improve care. We proposed two policy responses: first, automated and user-hidden functions for non-value-added administrative tasks (e.g., personal data synchronization, data retrieval, and duplicate data entry); second, government-led integration of a single best technological solution to reduce the experimentation burden on physicians. The Hungarian EC is shown in Table 11.

The Hungarian FRT showed that these policies could address the usability constraint and also mitigate the remaining UDEs. The resulting FRT from Hungary is shown in Table 12.

To enhance the applicability of our policy recommendation, we have additionally conducted a feasibility analysis of the suggested policies. All policies were deemed feasible, although with different implementation costs, time frames, risks and potential to risk mitigation. A detailed feasibility-analysis is presented in Appendix C.

Using the TOC methods presented above, we successfully analyzed the current state of healthcare digitalization in Austria, Bulgaria, and Hungary. Although the digital healthcare systems of these EU countries are somewhat harmonized, we discovered that the necessary interventions for further progress are very different based on the current healthcare situation in each country. Our findings show that the specific barriers to digitalization, and the necessary interventions, are deeply shaped by local institutional, financial, and operational contexts.

5. Discussion

This study examined the digitalization of healthcare systems in Austria, Hungary, and Bulgaria, three EU member states with comparable healthcare funding levels but differing degrees of digital maturity. Guided by three research questions, we explored: (1) how digitalization levels

Table 7. Tabular representation of the current reality tree of Bulgarian healthcare system digitalization.

Logical steps leading to core problem	Related UDE	Connection rationale
1. Patient visit creates less value added	UDE 5: Dual documentation reduces efficiency (Core Constraint)	Government system is not digitalized
2. More visits are needed per patient	UDE 4: Inconsistent data access hinders collaboration between doctors	
	UDE 1: Telemedicine is not supported legally	
3. Digital treatment not viable	UDE 3: Cost of digitalization is taken by doctors	
4. Decreased throughput of the system	UDE 2: Lack of nationwide digitalization creates regional differences in quality of care	Government does not support equalizing digitalization
5. Decreased patient satisfaction (core problem)		

Table 8. Tabular representation of the current reality tree of Hungarian healthcare system digitalization.

Logical steps leading to core problem	Related UDE	Connection rationale
1. Valuable face-to-face time is spent with non-value-adding digital problems	UDE 2: Technical challenges increase risk of downtime due to IT problems	
	UDE 4: User-unfriendliness of digital systems hinders efficient care (Core Constraint)	
	UDE 5: Resistance to change slows down implementation at a different pace	
2. Non-digital resource management is not changing with digitalization	UDE 1: Incompatibility of statewide and private digital systems slows down adoption	
3. Resources are not allocated based on need, but quickest gains	UDE 3: Limited digital personalization challenges digital success in different medical areas	System throughput is not changing at an even speed Different medical areas digitalize at an uneven speed
4. Digitalization does not increase process efficiency (core problem)		

IT, information technology.

Table 9. Tabular representation of the evaporating cloud of Bulgarian healthcare system digitalization.

Core problem	UDE 5: Dual documentation reduces efficiency	
Solution to core problem	Standard digital documentation	
Requirements of the solution	1. Digital administration system 2. Ministry of Health creates digital reimbursement system	1. Standardization of documentation 2. Nationwide standard digital system
Injection	INJ1: Digital authentication of patients and doctors	INJ2: Standardize documentation system based on other countries' example

Table 10. Tabular representation of the future reality tree of Bulgarian healthcare system digitalization.

Injection	INJ1: Digital authentication of patients and doctors	INJ2: Standardize documentation system based on other countries' example
Logical steps to solution	1. Enables telemedicine 2. More value added per visit with less administration 3. Cost of digitalization is compensated by savings on administration 4. Enables multi-doctor consultations 5. Reduces time spent per visit 6. Decreases regional access inequalities 7. Increased throughput of the system	1. More value added per visit with less administration 2. Increased throughput of the system
Solution	Increased patient satisfaction	

Table 11. Tabular representation of the evaporating cloud of Hungarian healthcare system digitalization.

Core problem	UDE 4: User-unfriendliness of digital systems hinders efficient care	
Solution to core problem	User-friendly digital systems	
Requirements of the solution	1. Doctor can use it effectively without much training 2. Simple interface with only necessary functions	1. Increases efficiency and quality of care 2. Integration of new technology with keeping working standards of care
Injection	INJ1: Automated and hidden functionalities not directly related to value added care	INJ2: Integrate only one (best) solution for necessary new technology

Table 12. Tabular representation of the future reality tree of Hungarian healthcare system digitalization.

Injection	INJ1: Automated and hidden functionalities not directly related to value added care	INJ2: Integrate only one (best) solution for necessary new technology
Logical steps to solution	1. Face-to-face time spent only with value adding 2. Time for personalization 3. Time for non-digital resource management	1. Technical challenges managed before deployment 2. Compatibility issues managed in backend 3. Less resistance in need-to-digitalize medical areas 4. System throughput change is agile
Solution	Process efficiency increasing with digitalization	

vary across countries, (2) whether digitalization enhances healthcare service quality, and (3) what systemic barriers hinder optimal digital transformation.

Our first contribution lies in adopting a comparative, cross-national lens that integrates cultural and institutional dimensions. While EU membership ensures shared policy frameworks, our findings show that national culture and administrative structures shape both the pace and nature of digital transformation. Applying the TOC allowed us to move beyond surface-level explanations, diagnosing context-specific bottlenecks and aligning policy strategies with national realities. This constraint-driven approach stands in contrast to generic reform prescriptions and emphasizes the importance of strategic focus.

Second, we demonstrate the value of TOC not only as a conceptual framework but as a practical tool for identifying and addressing core system inefficiencies. TOC posits that any complex system is limited by a few critical constraints, and removing these allows for disproportionate gains in system performance. Our analysis revealed distinct national bottlenecks: centralized documentation inefficiencies in Bulgaria, regional disparities in Austria, and usability limitations in Hungary. Rather than assuming underperformance stems from broad resource shortages, TOC helped us localize the problem and solutions within each system's structure (see Table 13).

Our TOC-based diagnoses also intersect meaningfully with Hofstede's cultural dimensions (Hofstede, 2011). While all three countries operate under a shared EU regulatory umbrella, Hofstede's cultural dimensions reveal key national differences that influence both the nature of system constraints and the level at which change can be most effective. The power distance dimension explains how authority is perceived and where decision-making power resides. In high power distance countries like Bulgaria (score 70), constraints often emerge from centralized governance, and top-down national reforms are needed to remove them. In Austria (score 11), a low power distance context, bottlenecks appear more locally, requiring bottom-up or regionally adaptive solutions. Hungary (score 46), with a moderate power distance, benefits from mid-level, collaborative interventions, such as co-development between government actors and IT professionals. Integrating TOC with this cultural dimension allows for a more accurate understanding of where constraints originate and how they should be addressed.

A second and equally important cultural factor is motivation for achievement and success, captured by Hofstede's masculinity vs. femininity dimension. This dimension reflects whether societies are driven by competition and performance (masculinity) or by quality of life and cooperation (femininity). Hungary scores very high on this scale (88), indicating a competitive, achievement-driven culture. Such environments may foster faster digitalization, as institutions seek to outperform peers through early adoption of innovation. Austria, with a similar but slightly lower score (79), also shows relatively high digital maturity. In contrast, Bulgaria's much lower score (40) may signal a cultural environment less motivated by competitive implementation, potentially slowing innovation diffusion.

While causality cannot be established, the link between power distance and achievement motivation and digitalization levels in our sample is notable. These cultural indicators, when combined with TOC's constraint logic, help explain not only what the core problems are, but also why they persist and what measures are best suited to resolve them.

To assess the perceived effects of digitalization on service quality, we analyzed coded sentiments from physicians across the three countries. In Austria and Hungary where digitalization is more advanced, physicians expressed significantly more positive views (60% and 66% of open

Table 13. List of digital health challenges and respective proposed policy recommendations with projected outcomes in Austria, Bulgaria and Hungary.

Country	Constraint	Core problem	Proposed actions	Projected outcome
Austria	Financing digitalization is a burden of progress	Cost and complexity of digitalization might create regional disparities in healthcare quality	INJ1: Include regional compensation budget to tackle differences INJ2: Inject more regional planning into national digitalization plan	Financial burden on digital progress lifted
Bulgaria	Decreased patient satisfaction	Dual documentation reduces efficiency	INJ1: Digital authentication of patients and doctors INJ2: Standardize documentation system based on other countries' example	Increased patient satisfaction
Hungary	Process efficiency is not increasing because of digitalization	User-unfriendliness of digital systems hinders efficient care	INJ1: Automated and hidden functionalities not directly related to value added care INJ2: Integrate only one (best) solution for necessary new technology	Process efficiency increasing with digitalization

codes, respectively) compared to Bulgaria (25%). However, when isolating "service quality" as a theme, satisfaction levels were relatively stable across countries. This suggests that while digitalization enhances overall perceptions of healthcare, it does not necessarily resolve more ingrained concerns about care quality. Physicians generally agreed that digitalization facilitates improved service delivery, even if its implementation is incomplete or uneven.

A particularly salient finding was the consistent negativity surrounding the financial context in all three countries. This aligns with EU-wide concerns about healthcare financing (European Observatory on Health Systems and Policies, 2023). Yet interestingly, physicians in Hungary and Austria were less critical of financial constraints than their Bulgarian counterparts despite comparable levels of national healthcare funding. This suggests that strategic allocation of resources, particularly toward resolving key constraints, may be more important than increasing overall spending.

To strengthen the practical relevance of our findings, we conducted a country-specific feasibility analysis. This assessed implementation costs, timelines, and potential risks for each recommended action. For example, Bulgaria's core issue, the dual documentation mandate, can be addressed relatively cheaply and quickly with political will. In contrast, Austria's regional disparities require more complex financial mechanisms, and Hungary's usability challenges demand co-design with clinical stakeholders. Appendix C summarizes these insights using TOC's logic of constraint effecting the solution and then respectively resulting in expected outcome.

Ultimately, our findings highlight that digitalization is not simply about deploying new technologies. It is about redesigning systems to relieve their most pressing constraints. TOC provides a structured way to identify those constraints, prioritize interventions, and match solutions to a country's cultural and institutional capacity for change. This analytical synergy between constraint-based thinking and cultural sensitivity offers a novel contribution to digital health literature.

One limitation of this study is its reliance on a relatively small set of qualitative interviews, which may limit the generalizability of findings. While this limits the statistical generalizability of the findings, the research design prioritizes analytical depth and contextual richness, which is characteristic of a qualitative inquiry. In this sense, the findings should be interpreted as exploratory, offering a foundation for future research that should incorporate quantitative, large-scale data to provide a more comprehensive analysis of persistent digital healthcare challenges. Additionally, further cross-country investigations into the cultural and institutional factors influencing adoption could offer further insight into observed disparities.

6. Conclusion

In conclusion, this study shows that advancing digital healthcare requires more than technical fixes. It demands a strategic understanding of systemic constraints, institutional complexity, and cultural fit. TOC, when integrated with cultural and institutional analysis, offers a powerful framework to guide more effective and context-sensitive reforms. We hope this approach can inform both policy and future research in international healthcare innovation.

Availability of Data and Materials

The interview data are not publicly available because sharing the underlying transcripts and recordings could compromise participant confidentiality. However, access may be granted to editors or reviewers upon legitimate request where this can be done without breaching these obligations.

Table 14. List of scientific articles applying the theory of constraints in healthcare.

Authors	Year	Paper type	Research method	Country context	Healthcare context category	Summary of findings
Ahmad et al.	2010	Theoretical	Conceptual	Malaysia	Ambulatory care	The paper proposes a novel approach combining System Dynamics and the Theory of Constraints for capacity planning in the emergency department of a government hospital, aimed at improving service delivery and reducing patient waiting times in a Malaysian context.
Rawson et al.	2016	Theoretical	Literature review	USA	Diagnostic care	The paper concludes that process improvement techniques, originally developed for manufacturing, can significantly enhance the efficiency and effectiveness of healthcare services, particularly in radiology. It emphasizes the importance of these techniques for radiologists in adapting to changing healthcare dynamics and improving patient care.
Young	2005	Theoretical	Conceptual analysis	UK	Healthcare system as a whole	The article explores the strategic role of simulation modeling in healthcare, proposing the use of industrial process philosophies like Lean Thinking and the Theory of Constraints to improve healthcare delivery systems, and suggests potential synergies between these philosophies and established simulation methods.
Sadat et al.	2013	Theoretical	Conceptual (system dynamics model)	not applicable	Healthcare system as a whole	The paper provides a theoretical framework for applying the Theory of Constraints to publicly funded health systems, proposing a system dynamics model to guide improvements in resource allocation and system performance.
Motwani et al.	1996	Theoretical	Conceptual paper	not applicable	Healthcare system as a whole	The paper suggests that management philosophies traditionally used in manufacturing, such as the Theory of Constraints (TOC) and Business Process Reengineering (BPR), can be effectively applied to improve performance in service organizations, including those in the healthcare sector.
Boaden	2009	Theoretical	Conceptual	UK	Healthcare system as a whole	The paper summarizes that in the field of healthcare, various quality improvement methods and tools, such as PDSA, SPC, Six Sigma, Lean thinking, TOC, and Mass Customization, have been evaluated and applied with varying degrees of success, emphasis, and integration. The effectiveness of these methods depends significantly on their implementation and alignment with the specific goals and contexts of healthcare organizations.
Kemper and de Mast	2013	Theoretical	Conceptual	not applicable	not applicable	The paper provides a conceptual framework and practical guidance for implementing measurement plans and methods for process flow improvement in services and healthcare, focusing on operational performance metrics and improvement techniques.
Womack and Flowers	1999	Empirical	Case study	diverse	not applicable	The study found that the application of the Theory of Constraints in healthcare settings resulted in overall positive outcomes. Implementations of TOC led to significant improvements in productivity and timeliness of care without necessarily requiring high investments. This suggests that TOC can be an effective approach to addressing the chronic problems faced by healthcare systems globally.

Table 14. Continued.

Authors	Year	Paper type	Research method	Country context	Healthcare context category	Summary of findings
Pergher et al.	2016	Empirical	Single case study	Brazil	Specialty outpatient care	The study successfully integrated the Current Reality Tree (CRT) from the Theory of Constraints and Process Failure Mode and Effects Analysis (PFMEA) to diagnose and improve the efficiency of the radiotherapy service authorization process in a large Brazilian hospital, enhancing service speed and quality.
Garza-Reyes et al.	2019	Empirical	Single case study	Mexico	Ambulatory care	The article demonstrates that the simultaneous application of lean thinking and Theory of Constraint methods can effectively improve the transport and logistics performance of Emergency Medical Services, as evidenced by a detailed case study in the EMS system of the Red Cross in Monterrey, Mexico.
Leskelä et al.	2016	Empirical	Single case study	Finland	Specialty outpatient care	The article concludes that the adoption of new healthcare technologies, such as a non-invasive treatment for Dupuytren's disease in the Finnish healthcare system, is influenced by a complex interplay of stakeholder incentives and systemic constraints, highlighting the need for a comprehensive analysis of these factors to facilitate effective technology adoption.
Gupta et al.	2015	Empirical	Single case study	USA	Inpatient care	The paper applied marketing orientation and theory of constraints in a public healthcare setting. Increasing throughput from the TOC logic corresponds to the customer and competitor orientation construct of MO. Suggests that TOC mediates the relationship between MO and business performance
Ahmed	2019	Theoretical	Conceptual	UK, USA	not applicable	The paper presents a theoretical integration of the DMAIC approach of Lean Six Sigma and the Theory of Constraints to improve healthcare performance, focusing on reducing costs, errors, and inefficiencies while enhancing patient satisfaction and loyalty.
Kosieradzka et al.	2022	Empirical	Single case study	Poland	Specialty outpatient care	The study found that the application of a TOC/Lean-based systematic hybrid approach significantly improved patient access to hyperbaric oxygen therapy services, reduced patient waiting times by about 90%, and enhanced financial performance of the healthcare provider, while also demonstrating resilience during the COVID-19 pandemic.
Taylor and Nayak	2012	Empirical	Single case study	USA	Ambulatory care	The paper provides an empirical analysis of a regional West Texas hospital's emergency department, using the Theory of Constraints and Goldratt's Thinking Process to identify and propose solutions to core problems affecting efficiency and revenue, with a focus on improving patient triage and service utilization.
Taylor and Sheffield	2002	Empirical	Single case study	USA	Ancillary non-medical service	The study found that applying Goldratt's Theory of Constraints to the claims processing system in a healthcare setting can significantly improve the efficiency of claim processing, reduce the backlog of unpaid claims, and enhance overall operational effectiveness, resulting in higher revenues and more effective resource allocation.

Table 14. Continued.

Authors	Year	Paper type	Research method	Country context	Healthcare context category	Summary of findings
Grida and Zeid	2019	Empirical	Simulation modelling	Egypt	Inpatient care	The findings of the article can be summarized as follows: Applying the Theory of Constraints and system dynamics modeling in a medium-sized hospital in Egypt led to a 6% improvement in patient throughput and a 30% decrease in the waiting list without increasing resources, and with a 40% increase in doctor availability, the system throughput improved by 13% with an 88% decrease in the waiting list.
Breen et al.	2002	Theoretical	Conceptual analysis	USA, UK	Specialty outpatient care	The paper provides a theoretical exploration of applying the Theory of Constraints in healthcare settings, demonstrating how identifying and managing constraints can lead to improved efficiency and service quality in healthcare systems.
Schaefers et al.	2007	Theoretical	Theoretical framework	not applicable	not applicable	The article proposes a new measurement system for healthcare organizations, integrating the Theory of Constraints (TOC) to shift focus from traditional financial and quality metrics to a more comprehensive, goal-oriented approach emphasizing improved health outcomes.
Hertz and Lahrichi	2009	Empirical	Simulation, modelling	Canada	Specialty outpatient care	The article presented a mixed integer programming model and a Tabu Search algorithm to optimize nurse-patient assignments in home care, effectively balancing nurse workloads and reducing travel times, as evidenced by tests on historical data.
Cox	2021	Empirical	Literature review	USA	Ancillary non-medical service	The study concludes that implementing the Theory of Constraints in primary care clinics, specifically through improved appointment scheduling and execution, can significantly reduce costs and enhance the quality and timeliness of healthcare. The paper suggests that a well-designed and executed Provider Appointment Scheduling System can lead to more efficient and effective healthcare delivery in primary care settings.
Bauer et al.	2019	Empirical	Single case study	Brazil	Ambulatory care	The paper presents a case study in a Brazilian hospital's emergency department, demonstrating how the Theory of Constraints (TP–TOC) can be applied to diagnose problems, optimize healthcare operations, and improve service quality.
Cattaneo and Bassani	2016	Empirical	Case study	Italy	Hospital as a whole	The study found that applying the Theory of Constraints, specifically the Thinking Process-Three-Cloud Approach, effectively identified and addressed various logistical, cultural, and informational conflicts in hospital management. This approach facilitated strategic and organizational changes in the hospital's new surgical block and material flow logistics.
Umble and Umble	2006	Empirical	Multiple case studies	UK	Ambulatory care	The study found that implementing buffer management in the Accident and Emergency departments of three NHS hospitals led to significant improvements in patient processing times and reduced waiting times, without requiring additional resources. This resulted in increased capacity in the A&E departments, improved patient satisfaction, and boosted staff morale.

Table 14. Continued.

Authors	Year	Paper type	Research method	Country context	Healthcare context category	Summary of findings
Groop et al.	2017	Empirical	Single case study	Finland	Home care	The paper demonstrates the application of the Theory of Constraints in improving Espoo's home care system in Finland, focusing on better caregiver resource allocation and efficiency, with the broader goal of enhancing system performance while considering various stakeholder needs and constraints.
Bacelar-Silva et al.	2021	Empirical	Monte Carlo simulation, game	Portugal	Ambulatory care	The paper demonstrates how applying the Theory of Constraints in an Emergency Department through a simulation game can significantly improve operational efficiency and patient flow, using existing resources more effectively.
Bacelar-Silva et al.	2024	Empirical	Case study	Brazil	Diagnostic care	The study found that applying the Theory of Constraints in an ophthalmology imaging practice significantly improved patient throughput by 64% in a few weeks, using existing resources and with little to no additional expense.
Boonmee et al.	2020	Empirical	Simulation and case study	Thailand	Specialty outpatient care	The study found that adding one technician to Room 3 and replacing the radiation machine in Room 2 with a model used in Room 3 could increase the number of patients served by 12.32%. This improvement plan also showed a benefit-cost ratio of 1.89 and a payback period of 2.80 years, indicating its economic viability.
Patwardhan et al.	2006	Empirical	Single case study	USA	Specialty outpatient care	The paper demonstrates the application of the Theory of Constraints to improve the Evidence-based Practice Center (EPC) process by identifying and addressing the core constraint of partners' inability to effectively articulate their needs, leading to the creation of more useful EPC reports.
Wu et al.	2009	Empirical	Simulation	China	Specialty outpatient care	The paper presents a methodology for optimizing resource allocation in the outpatient department of a Chinese hospital by combining process analytic methods and bottleneck theory, using a GERT model and Flexsim simulation. The study aimed to improve patient service levels by efficiently allocating resources to bottleneck areas.
Bisogno et al.	2017	Empirical	Discrete event simulation	Italy	Specialty outpatient care	The study demonstrated that the theory of constraints (TOC), particularly through its 'drum-buffer-rope' (DBR) techniques adapted for goods (DBRG) and services (DBRS), can effectively improve patient flows in healthcare settings by optimizing patient throughput and minimizing time in the system.
Groop et al.	2010	Empirical	Case study	Finland	Home care	The study finds that assessing health technologies based on their impact on organizational constraints, as per the theory of constraints, can lead to improved throughput and, consequently, cost reduction in healthcare settings. This approach is presented as more pragmatic and suitable for ICT evaluation in the healthcare sector.

PDSA, Plan–Do–Study–Act; SPC, Statistical Process Control; TOC, Theory of Constraints; EMS, Emergency Medical Services; MO, Market Orientation; DMAIC, Define–Measure–Analyze–Improve–Control; COVID-19, Coronavirus Disease 2019; TP, Thinking Process; NHS, National Health Service; GERT, Graphical Evaluation and Review Technique; ICT, Information and Communication Technology.

Table 15. Qualitative and quantitative choice rationale of UDEs.

Country	# of negative open codes	UDE (core problem italics)	Supporting interview quote	Choice rationale
BG	5	UDE 1: Telemedicine is not supported legally	"Telemedicine as part of a medical examination, it is not legal, it is not regulated." (Gynecologist)	Legal barriers limit digital care and force extra in-person visits, reducing patient satisfaction
BG	18	UDE 2: Lack of nationwide digitalization creates regional differences in quality of care	"The discharge summary in Bulgaria is still in paper form, not available electronically, so the patient can't see what tests were done in the hospital" (General practitioner)	Uneven rollout of national systems creates "digital deserts" and systematically lower satisfaction in lagging areas.
BG	15	UDE 3: Cost of digitalization is taken by doctors	"...we pay for the software we use in healthcare. For me, it's 500 leva (Bulgarian currency) and it has become an annual subscription fee for me to maintain and update the software." (General practitioner)	Providers' budget constraints and shifting digitalization costs onto them slows adoption and satisfaction gains.
BG	7	UDE 4: Inconsistent data access hinders collaboration between doctors	"But beyond [my own examination], if the patient continues their journey, we have no way of knowing what happens. Without the patient coming and telling us, "I went somewhere, did something."" (General practitioner 2)	Poor data sharing between doctors adds admin time and repeat visits, lowering efficiency and satisfaction.
BG	17	UDE 5: Dual documentation reduces efficiency	"Even though everything is done electronically now, the paper still needs to be signed. It remains, the paper is not going away" (General practitioner 2)	Dual documentation (paper + digital) lengthens visits without added value, frustrating patients and staff.
AT	5	UDE 1: Digitalization raises privacy concerns that hinder adoption	"People don't like to give their data away. I don't think he will have much success with it [digitalization], because people have become very cautious about giving out data" (Internal medicine)	Privacy concerns reduce adoption; privacy-robust systems are more expensive to deploy.
AT	3	UDE 2: Over-reliance on digital creates "risk of system downtime"	"Of course, every now and then there is a system failure where we have to do everything with pen and paper again. And that takes forever. So that's really terribly inefficient." (Traumatologist)	No outage backups risks care unavailability during failures; backups are costly and rarely needed.
AT	9	UDE 3: Cost and complexity of digitalization might create regional disparities in healthcare quality	"Vienna, for example, has almost no patient curves that are digital" (Internal medicine)	Federal fragmentation amplifies regional inequalities in care quality, especially in less affluent areas.
AT	2	UDE 4: Constant digital change increases operational costs	"I think that the state generally provides extremely little support in the ancillary area [digital upgrades]. I think it's also because the cliché is that the Doctor can afford to introduce digitalization into his office himself." (Internal medicine)	Frequent IT changes raise maintenance costs and disrupt workflows, reducing throughput.

Table 15. Continued.

Country	# of negative open codes	UDE (core problem italics)	Supporting interview quote	Choice rationale
AT	7	UDE 5: Digitalization marginalizes non-digital populations' access to healthcare	"[when a patient did not opt in for digital records] that is very difficult, because if something is abnormal, you have to send them a letter, and it is always a question of whether it will arrive or not. And some letters simply don't arrive." (Gynecologist)	Funding gaps leave underdigitalized regions unsupported, even where digital solutions are most needed.
AT	7	UDE 6: Digitalization requires funds that might take resources from other needed areas	"There is none [funding] at all. So there were digitalization pots like that a few years ago, but that's actually not at all now. I don't think the state has any money." (Dentist 2)	Upfront digital costs arrive before savings, temporarily diverting funds and creating tensions.
HU	6	UDE 1: Incompatibility of statewide and private digital systems slows down adoption	"For example, we can send a [medical] image to [a partner hospital] for neurosurgery so that they can assess whether the patient is neurosurgically suitable for the procedure. And so we are connected. But it is an individual judgement and not a nationwide system." (Radiologist)	No nationwide healthcare file-sharing system increases redundant administration and costs, undermining efficiency.
HU	3	UDE 2: Technical challenges increase risk of downtime due to IT problems	"[Integration to the national digital system] is a lot of authentication, a lot of steps, a lot of passwords that we don't know how to do, and so unfortunately we have to keep a double register for that. I have to keep the data in another software, but that's also extra time to upload to [the national digital healthcare system]... and sometimes the system does not work and we can not work either." (Dentist)	Outage vulnerability severely disrupts care delivery and efficiency when IT fails.
HU	7	UDE 3: Limited digital personalization challenges digital success in different medical areas	"There are certain specific situations, for example, [dental] impressions that are not completely digital, for example removable replacements. So there are situations where there is no suitable personalized solution yet, or there is rather lower quality of digital treatment than analogue." (Dentist)	Standardization vs. personalization limits digital efficiency gains in some clinical areas.
HU	10	UDE 4: User-unfriendliness of digital systems hinders efficient care	"I can only see, from the [national digital healthcare system], somebody I have ever treated, so if there is, say, a general practitioner and I want to ask something and he is not our patient or he has been to our institution, I cannot see his various records. If his findings were not done there, I don't see them, there is no big global system." (Pulmonologist)	Poor usability prevents digital tools from delivering efficiency improvements.
HU	4	UDE 5: Resistance to change slows down implementation at a different pace	"Obviously, part of these [digital] solutions is that it would reduce the turnover for major healthcare providers and diagnostic providers. What we talked about with respect to drugs would reduce the sales volume of the drug distributors, so there are countervailing interests from that point of view." (Pain medicine)	Uneven adaptability across regions/professions creates resistance where digitalization is most needed.

BG, Bulgaria; AT, Austria; HU, Hungary.

Author Contributions

DD, AB and VG designed the research study. AB and VG planned and carried out the data collection. AB and DD analyzed the data. DD and AB wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

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The authors declare no conflicts of interest.

Declaration of AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGpt-5 in order to check spelling and grammar. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Appendix

Appendix A

See Table 14.

Appendix B

See Table 15.

Appendix C

C1. Feasibility analysis of policy recommendations for Bulgaria

INJ1: Digital authentication of patients and doctors

Actors: National Healthcare System Provider

Costs: Low (leverage existing IT infrastructure; low maintenance)

Timeframe: Short-term

Risks: Digital exclusion (elderly/low-digital); Privacy/security concerns

Mitigation: Assisted onboarding; Informed consent; IT security via government servers

INJ2: Standardize documentation system based on other countries' example

Actors: National Healthcare System Provider

Costs: Medium (requires minor system redesign and change management; using proven standards reduces costs)

Timeframe: Mid-term

Main risks: Clinician resistance; Interoperability/migration failures; Vendor lock-in

Mitigation: Co-design with clinical users; Phased rollout; Open standards/Application Programming Interfaces (APIs)

C2. Feasibility analysis of policy recommendations for Austria

INJ1: Include regional compensation budget to tackle differences

Actors: Regional governments

Costs: High (direct need of fiscal transfer in already strained budgets)

Timeframe: Mid-term

Risks: Misallocation/inefficient spending; Weak accountability of efficient use of funds

Mitigation: Need-based allocation formula; Tie funding to milestones

INJ2: Inject more regional planning into national digitalization plan

Actors: Federal government

Costs: High (high transaction and administrative costs)

Timeframe: Mid-term

Main risks: Fragmentation (regions diverge); Slower decision-making; Conflicts over responsibilities

Mitigation: Regional flexibility within national standards; Clear governance + decision rights; Interoperability requirements

C3. Feasibility analysis of policy recommendations for Hungary

INJ1: Automated and hidden functionalities not directly related to value added care

Actors: National Healthcare System Provider

Costs: Low (simple software features in existing systems)

Timeframe: Short-term

Risks: Automation hides errors; Usability changes don't match clinical workflows

Mitigation: Human override + logs; Usability testing with clinicians

INJ2: Integrate only one (best) solution for necessary new technology

Actors: National Healthcare System Provider

Costs: Medium (procurement and integration costs can be higher; economies of scale apply)

Timeframe: Short-term

Main risks: Vendor/political resistance; lock-in; "One-size-fits-all" mismatch; Transition disruption

Mitigation: Transparent evaluation criteria; Require open APIs + data portability; Modular architecture; Transition support + parallel run during migration

References

Agarwal R, Gao G, DesRoches C, Jha AK. Research Commentary—The Digital Transformation of Healthcare: Current Status and the Road Ahead. Information Systems Re-

search. 2010; 21: 796–809. https://doi.org/10.1287/isre.1100.0327

Ahmad N, Ghani NA, Kamil AA, Tahar RB. A framework for emergency department capacity planning using system dynamics approach and the Theory of Constraints philosophies. In Proceedings of the 24th European Conference on Modelling and Simulation. 2010. https://doi.org/10.7148/2010-0143-0148

Ahmed S. Integrating DMAIC approach of Lean Six Sigma and theory of constraints toward quality improvement in healthcare. Reviews on Environmental Health. 2019; 34: 427–434. https://doi.org/10.1515/reveh-2019-0003

Bacelar-Silva GM, Cox JF III, Rodrigues P. Achieving rapid and significant results in healthcare services by using the theory of constraints. Health Systems. 2024; 13: 48–61. https://doi.org/10.1080/20476965.2022.2115408

Bacelar-Silva GM, Cox JF, Baptista HR, Rodrigues PP. Identifying and addressing the underlying core problems in healthcare environments: An illustration using an emergency department game. International Journal of Environmental Research and Public Health. 2021; 18: 10083. https://doi.org/10.3390/ijerph181910083

Bauer JM, Vargas A, Sellitto MA, Souza MC, Vaccaro GL. The thinking process of the theory of constraints applied to public healthcare. Business Process Management Journal. 2019; 25: 1543–1563. https://doi.org/10.1108/BPMJ-06-2016-0118

Becker C, Zumbrunn S, Beck K, Vincent A, Loretz N, Müller J, et al. Interventions to improve communication at hospital discharge and rates of readmission: a systematic review and meta-analysis. JAMA Network Open. 2021; 4: e2119346. https://doi.org/10.1001/jamanetworkopen.2021.19346

Bisogno S, Calabrese A, Ghiron NL, Pacifici A. Theory of constraints applied to scheduled and unscheduled patient flows: does it improve process performance?. International Journal of Services and Operations Management. 2017; 26: 365–385. https://doi.org/10.1504/IJSOM.2017.081943

Boaden R. Quality improvement: theory and practice. British Journal of Healthcare Management. 2009; 15: 12–16. https://doi.org/10.12968/bjhc.2009.15.1.37892

Bogumil-Uçan S, Klenk T. Varieties of health care digitalization: Comparing advocacy coalitions in Austria and Germany. Review of Policy Research. 2021; 38: 478–503. https://doi.org/10.1111/ropr.12435

Boonmee C, Kosayanon A, Chitapanarux I, Kasemset C. Radiotherapy Service Improvement: Simulation Study. Industrial Engineering & Management Systems. 2020; 19: 758–773. https://doi.org/10.7232/iems.2020.19.4.758

Breen AM, Burton-Houle T, Aron DC. Applying the theory of constraints in health care: Part 1—the philosophy. Quality management in health care. 2002; 10: 40–46. https://doi.org/10.1097/00019514-200210030-00010

Bundeskanzleramt Österreich. Digital Austria Act für mehr Wohlstand, Sicherheit und neue Chancen durch Innovation (61/10). 2023.

Cattaneo C, Bassani G. The TOC thinking process: The viability of change. Human Systems Management. 2016; 35: 301–323. https://doi.org/10.3233/HSM-161616

Chaudhry B, Wang J, Wu S, Maglione M, Mojica W, Roth E, et al. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. Annals of Internal Medicine. 2006; 144: 742–752. https://doi.org/10.7326/0003-4819-144-10-200605160-00125

Cockatoo. Cockatoo Inc. 2025. Available at: https://www.cockatoo.com/ (Accessed: 15 March 2026)

Cox III JF. Using the theory of constraints' processes of ongoing improvement to address the provider appointment scheduling system execution problem. Health Systems. 2021; 10: 41–72. https://doi.org/10.1080/20476965.2019.1646105

Currie WL, Seddon JJ. A cross-national analysis of eHealth in the European Union: Some policy and research directions. Information & Management. 2014; 51: 783–797. https://doi.org/10.1016/j.im.2014.04.004

Datt M, Gupta A, Misra SK, Gupta M. Theory of constraints in healthcare: a systematic literature review. International Journal of Quality & Reliability Management. 2024; 41: 1417–1456. https://doi.org/10.1108/ijqrm-02-2022-0056

Davidson E, Baird A, Prince K. Opening the envelope of health care information systems research. Information and Organization. 2018; 28: 140–151. https://doi.org/10.1016/j.infoandorg.2018.07.001

Dettmer HW. Goldratt's theory of constraints: A Systems Approach to Continuous Improvement. ASQ Quality Press: Milwaukee, WI. 1997.

Doyle C, Lennox L, Bell D. A systematic review of evidence on the links between patient experience and clinical safety and effectiveness. BMJ Open. 2013; 3: e001570. https://doi.org/10.1136/bmjopen-2012-001570

European Commission. European Innovation Scoreboard. 2023. Available at: https://research-and-innovation.ec.europa.eu/statistics/performance-indicators/european-innovation-scoreboard_en (Accessed: 15 March 2026)

European Commission. European Innovation Scoreboard 2022. Publications Office of the European Union. 2022. https://doi.org/10.2777/309907

European Commission. State of health in the EU: companion report 2019. Publications Office of the European Union. 2019. https://data.europa.eu/doi/10.2875/85326

European Observatory on Health Systems and Policies. Health systems in crisis: Countering shockwaves and fatigue (Eurohealth). 2023. Available at: https://eurohealthobservatory.who.int/publications/i/health-systems-in-crisis-countering-shockwaves-and-fatigue-(eurohealth) (Accessed: 15 March 2026)

Garza-Reyes JA, Villarreal B, Kumar V, Diaz-Ramirez J. A lean-TOC approach for improving Emergency Medical Services (EMS) transport and logistics operations. International Journal of Logistics Research and Applications. 2019; 22: 253–272. https://doi.org/10.1080/13675567.2018.1513997

Giese A, Khanam R, Nghiem S, Rosemann T, Havranek MM.

Patient-reported experience is associated with higher future revenue and lower costs of hospitals. The European Journal of Health Economics. 2024; 25: 1031–1039. https://doi.org/10.1007/s10198-023-01646-y

Goldratt EM, Cox J. The goal: a process of ongoing improvement. Routledge: London. 2016.

Goldratt EM. Theory of constraints. North River: Croton-on-Hudson. 1990.

Grida M, Zeid M. A system dynamics-based model to implement the Theory of Constraints in a healthcare system. Simulation. 2019; 95: 593–605. https://doi.org/10.1177/0037549718788953

Groop J, Ketokivi M, Gupta M, Holmström J. Improving home care: Knowledge creation through engagement and design. Journal of Operations Management. 2017; 53: 9–22. https://doi.org/10.1016/j.jom.2017.11.001

Groop J, Reijonsaari K, Lillrank P. A theory of constraints approach to health technology assessment. In 2010 Second International Conference on eHealth, Telemedicine, and Social Medicine. 2010. https://doi.org/10.1109/eTELEMED.2010.28

Gupta MC, Bridgman S, Kaur Sahi G. Application of TOC-based framework to improve market orientation in a non-profit organization. Journal of Strategic Marketing. 2015; 23: 579–599. https://doi.org/10.1080/0965254X.2014.1001865

Hertz A, Lahrichi N. A patient assignment algorithm for home care services. Journal of the Operational Research Society. 2009; 60: 481–495. https://doi.org/10.1057/palgrave.jors.2602574

Hofstede G. Dimensionalizing Cultures: The Hofstede Model in Context. Online Readings in Psychology and Culture. 2011; 2: 8. https://doi.org/10.9707/2307-0919.1014

Kemper B, de Mast J. Measurement plans for process flow improvement in services and health care. Quality Engineering. 2013; 25: 437–450. https://doi.org/10.1080/08982112.2013.805779

Kendall GI. Viable vision: Transforming total sales into net profits. J. Ross Publishing: Boca Raton, Florida. 2005.

Kierkegaard, P. Governance structures impact on eHealth. Health Policy and Technology. 2015; 4: 39–46. https://doi.org/10.1016/j.hlpt.2014.10.016

Klecun E, Zhou Y, Kankanhalli A, Wee YH, Hibberd R. The dynamics of institutional pressures and stakeholder behavior in national electronic health record implementations: A tale of two countries. Journal of Information Technology. 2019; 34: 292–332. https://doi.org/10.1177/0268396218822478

Kosieradzka A, Węgrzyk J, Smętek W, Strzelec P. Maximising performance of a hospital's HBOT laboratory using the theory of constraints. Scientific Papers of Silesian University of Technology, Organization and Management Series. 2022: 187–208. https://doi.org/10.29119/1641-3466.2022.155.13

Krippendorff K. Content analysis: An introduction to its methodology. Sage publications: Thousand Oaks. 2018.

Lee D. A model for designing healthcare service based on the patient experience. International Journal of Healthcare Management. 2017; 12: 180–188. https://doi.org/10.1080/20479700.2017.1359956

Leskelä RL, Herse F, Torkki P, Laine J, Vilkuna T, Raatikainen T. Analysis of the adoption of new health technology: the case of Dupuytren's disease. International Journal of Healthcare Technology and Management. 2016; 15: 210–227. https://doi.org/10.1504/IJHTM.2016.078360

Ligita T, Harvey N, Wicking K, Nurjannah I, Francis K. A practical example of using theoretical sampling throughout a grounded theory study. Qualitative Research Journal. 2020; 20: 116–126. https://doi.org/10.1108/qrj-07-2019-0059

Mabin V, Yee J, Babington S, Caldwell V, Moore R. Using the Theory of Constraints to resolve long-standing resource and service issues in a large public hospital. Health Systems (Basingstoke, England). 2018; 7: 230–249. https://doi.org/10.1080/20476965.2017.1403674

Majcherek D, Hegerty SW, Kowalski AM, Lewandowska MS, Dikova D. Opportunities for healthcare digitalization in Europe: Comparative analysis of inequalities in access to medical services. Health Policy (Amsterdam, Netherlands). 2023; 139: 104950. https://doi.org/10.1016/j.healthpol.2023.104950

Marzi G, Balzano M, Marchiori D. K-Alpha Calculator-Krippendorff's Alpha Calculator: A user-friendly tool for computing Krippendorff's Alpha inter-rater reliability coefficient. MethodsX. 2024; 12: 102545. https://doi.org/10.1016/j.mex.2023.102545

Motwani J, Klein D, Harowitz R. The theory of constraints in services: part 2-examples from health care. Managing Service Quality: An International Journal. 1996; 6: 30–34. https://doi.org/10.1108/09604529610109738

Patwardhan MB, Sarría-Santamera A, Matchar DB. Improving the process of developing technical reports for health care decision-makers: Using the theory of constraints in the evidence-based practice centers. International Journal of Technology Assessment in Health Care. 2006; 22: 26–32. https://doi.org/10.1017/S026646230605080X

Pergher I, Brandolf VP, Pacheco DA, Vaccaro GL. A patient-centric approach to improve health care services. Cogent Business & Management. 2016; 3: 1227232. https://doi.org/10.1080/23311975.2016.1227232

Rahman S. Theory of constraints. International Journal of Operations & Production Management. 1998; 18: 336–355. https://doi.org/10.1108/01443579810199720

Rawson JV, Kannan A, Furman M. Use of process improvement tools in radiology. Current problems in diagnostic radiology. 2016; 45: 94–100. https://doi.org/10.1067/j.cpradiol.2015.09.004

Sadat S, Carter MW, Golden B. Theory of constraints for publicly funded health systems. Health Care Management Science. 2013; 16: 62–74. https://doi.org/10.1007/s10729-012-9208-9

Schaefers J, Colin J, Aggoune R, Kucina M. A contribution to performance measurement in the healthcare industry: the in-

dustrial point of view. International Journal of Business Performance Management. 2007; 9: 226–239. https://doi.org/10.1504/IJBPM.2007.011864

Sermontyte-Baniule R, Pundziene A, Giménez V, Narbón-Perpiñá I. Role of Cultural Dimensions and Dynamic Capabilities in the Value-based Performance of Digital Healthcare Services. Technological Forecasting and Social Change. 2022; 176: 121490. https://doi.org/10.1016/j.techfore.2022.121490

Taylor III LJ, Nayak S. Goldratt's theory applied to the problems associated with an emergency department at a hospital. Administrative Sciences. 2012; 2: 235–249. https://doi.org/10.3390/admsci2040235

Taylor III LJ, Sheffield D. Goldratt's thinking process applied to medical claims processing. Hospital topics. 2002; 80: 13–21. https://doi.org/10.1080/00185860209598005

Triandis HC. Approaches toward minimizing translation. Translation: Applications and research. 1976: 229-243.

Umble M, Umble EJ. Utilizing buffer management to improve performance in a healthcare environment. European Journal of Operational Research. 2006; 174: 1060–1075. https://doi.org/10.1016/j.ejor.2005.02.059

Watson KJ, Blackstone JH, Gardiner SC. The evolution of a management philosophy: The theory of constraints. Journal of Operations Management. 2007; 25: 387–402. https://doi.org/10.1016/j.jom.2006.04.004

WHO. mHealth: Use of appropriate digital technologies for public health: report by the Director-General. 2017. Available at: https://apps.who.int/iris/handle/10665/274134 (Accessed: 15 March 2026)

Womack DE, Flowers S. Improving system performance: a case study in the application of the theory of constraints. Journal of Healthcare Management. 1999; 44: 397–405. https://doi.org/10.1097/00115514-199909000-00013

World Health Organization. Financing health for all: Increase, transform and redirect (Council Brief No. 2). 2021.

Wu F, Jia T, Liu SL, Qi JY. The analysis of service station allocation in the hospital based on bottleneck model. International Journal of Services Technology and Management. 2009; 12: 231-251. https://doi.org/10.1504/IJSTM.2009.025236

Yin RK. Qualitative research from start to finish. Guilford publications: New York. 2015.

Young T. An agenda for healthcare and information simulation. Health Care Management Science. 2005; 8: 189–196. https://doi.org/10.1007/s10729-005-2008-8