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AMMATTIKORKEAKOULU
University of Applied Sciences

ASSESSING THE DIGITAL MATURITY OF THE TELEMEDICINE AND E-HEALTH IN CROATIAN HEALTHCARE SYSTEM

A National-Level Assessment of Digital Health Maturity and
EHDS Readiness

Marta Alić

Supervisor/s:

Panagiotis Bamidis, PhD, Aristotle University of Thessaloniki

Date: 20.06.2026.



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Abstract

Advancing more rapidly during the COVID-19 pandemic, the digital transformation of healthcare systems has become a strategic imperative of the European Union. As the accelerated implementation of telemedicine services and e-health infrastructures have shaped health reforms in all Member States, including Croatia, new levels of digital maturity have been reached.

This thesis is set to examine the digital maturity of the Croatian healthcare system in the context of telemedicine and e-health development, with special focus on compliance with the European Health Data Space (EHDS) framework. The research applies the HIMSS Digital Health Indicator (DHI) as an analytical framework to evaluate national readiness across four core dimensions: Governance and Workforce, Interoperability, Person-Enabled Health and Predictive Analytics.

By using desk-based methodology on secondary data, the study operationalises DHI indicators into an analytical matrix to systematically analyse strategic documents, implementation reports and publicly available materials to evaluate digital maturity of Croatian healthcare.

Croatia demonstrates moderate digital maturity across set dimensions as system is characterised by operational national services, but incomplete systemic integration. Subsequently, results suggest partial readiness for large-scale telemedicine deployment and EHDS implementation, with key gaps related to workforce capacity, patient engagement and analytics utilisation.

By adapting an DHI framework for national policy analysis, the thesis makes methodology contributions and provide evidence-based recommendations for strengthening digital health governance and interoperability. The study also contributes to theoretical digital maturity research with applicative implications for healthcare practitioners, policymakers and organisations managing digital transformation in Croatia, identifying gaps in conformity between requirements and operational implementation.

Keywords: digital health, telemedicine, digital maturity, interoperability, European Health Data Space (EHDS), health data governance

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Glossary

AMAM — Analytics Maturity Model

CBOMM — Clinical and Business Operations Maturity Model

CEF Digital — Connecting Europe Facility Digital Programme

CEZIH — Central Healthcare Information System of the Republic of Croatia

CGM — Continuous Glucose Monitoring

C-COMM — Community Care Outcomes Maturity Model

CT — Computed Tomography

DESI — Digital Economy and Society Index

DHI — Digital Health Indicator

DIAM — Digital Imaging Adoption Model

žDIAL — Digital Impact Alliance

DPCMA — Digital Primary Care Maturity Assessment

DSA — Digital Subtraction Angiography

eHDSI — eHealth Digital Service Infrastructure

EHDS — European Health Data Space

EHIC — European Health Insurance Card

EEHRxF — European Electronic Health Record Exchange Format

EIF — European Interoperability Framework

EHR — Electronic Health Record

eID — Electronic Identity

EMH — Ericsson Mobile Health

EMRAM — Electronic Medical Record Adoption Model

EU — European Union

FAIR — Findable, Accessible, Interoperable, Reusable principles

GDHI — Global Digital Health Index

HEMS — Helicopter Emergency Medical Services

HIMSS — Healthcare Information and Management Systems Society

HZJZ — Croatian Institute of Public Health

HZZO — Croatian Health Insurance Fund

ICD — International Classification of Diseases

ICT — Information and Communication Technology

INFRAM — Infrastructure Adoption Model

MCPs — Multi-Country Projects

MRI — Magnetic Resonance Imaging

NAJS — National Public Health Information System

NCPeH — National Contact Points for eHealth

NIS2 — Network and Information Systems Directive

WHO — World Health Organization

Introduction

In today's data economy surroundings digital transformation represents a global imperative and key driver for social and economic change in the 21st century. It's acceleration since it has begun at 1950s has additionally spurred in last decade, progressing more rapidly by the COVID-19 pandemic, placing digital technologies in the core of development strategies worldwide. To guide this process, the European Union (EU) launched the Digital Decade 2030 (European Union, 2022) program, a comprehensive political and strategic framework that sets very ambitious goals across four cardinal areas: digital transformation of businesses, digital skills, secure and sustainable digital infrastructures and, of particular importance for this thesis, the digitalization of public services, particularly in area of healthcare.

To achieve these goals, the Digital Decade program established a yearly reporting cycle between the European Commission and Member States that includes a structured, transparent and common system for monitoring goals' progress based on the Digital Economy and Society Index (DESI). As the European Commission publish a report annually, assessing progress and providing recommendations for action, Member States are due to develop and periodically update their national strategic guidelines with planned policies and measures.

But looking at the broader context, the program also presents a geopolitical strategy aimed at strengthening the EU's digital sovereignty, reducing dependency on external actors and fostering innovation and competitiveness of "old continent's" industries in times of modern technological race and reorganization of the global order. Targets such as doubling the EU's share in global semiconductor production and wide gigabit connectivity through 5G mobile networks directly address the need to reduce dependence on other global actors, such as the United States and China, in strategically important technological areas. Given the recorded decline in the EU's share in global information and communication technology (ICT) market revenues (Parlementaire Monitor, 2025) and significant dependence on Asia in the semiconductor segment (Baraniuk, 2022), the Digital Decade's infrastructure and business goals are aimed at strengthening the Union's technological autonomy and global competitiveness.

Initiatives like the Digital Europe Programme, the Connecting Europe Facility (CEF Digital) and Multi-Country Projects (MCPs) have the goal of mobilizing resources to build a resilient, interoperable and inclusive digital ecosystem in EU (European Commission, 2024).

Study Rationale

Among the four pillars of the Digital Decade, the digitalization of public services is of upmost significance. It's goals have been set to reach absoluteness by the year of 2030, as all key public services should be fully available online, including that all citizens should have access to their electronic health records (EHRs) and that digital identity (eID) solutions should be universally accessible (European Union, 2022).

The conveyance of healthcare by information and communication technologies, or e-Health, is foundational for enabling cross-border healthcare services and real-time data sharing as an important element of the digital single market strategy (European Commission, 2018). But it's preconditions require robust digital infrastructure, harmonized legal frameworks and high levels of interoperability across national health systems.

So, in response, the European Commission in 2022 has introduced the European Health Data Space (EHDS) initiative to create a universal framework for the secure exchange of health data across all member states and their secondary use to support research and innovation and ensure that health data is used ethically and efficiently to improve healthcare outcomes (European Commission, n.d). The initiative was adopted on 11 February 2025 and published in the Official Journal of the EU on 5 March 2025 under Regulation (EU) 2025/327, introducing new mechanisms for data access, interoperability and governance, shifting their management from fragmented national systems to a unified European approach.

It is a pivotal step towards more inclusive and quality telemedicine as a broader dimension. Although it has achieved measurable progress over the past few decades, development of telemedicine has been limited within fragmented national frameworks and institution-centric models of care, constrained by limited interoperability, inconsistent legal regimes and restricted patient access to health data.

By operationalising e-health through a common European framework for health data access, EHDS addresses many of the structural limitations that have historically constrained telemedicine. Its focus on cross-border data exchange, standardisation and patient access to electronic health records enables telemedicine services to function as data-driven, continuous and coordinated care processes. The availability of interoperable electronic health records, secure authentication mechanisms and standardized data exchange frameworks, core elements of e-health policies at the EU level, are preconditions for the safe, effective and scalable deployment of telemedicine services.

And the acceleration of digitalization enforcement and adoption during the COVID-19 pandemic further illustrates this interdependence. Emergency regulatory adjustments and rapid digital uptake to enable remote care delivery exposed structural weaknesses related to interoperability, legal

uncertainty, data protection and unequal access to services. These challenges reinforced the need for governance-oriented e-health ecosystem capable of supporting sustainable telemedicine services across national borders.

Importantly, this ecosystem also marks a transformation in the role of patients. Whereas earlier telemedicine models primarily positioned patients as passive recipients of (digitally) mediated care, the e-health framework, introduced through EHDS, explicitly incorporates patients as active stakeholders within the health ecosystem. By granting individuals entry to their own health data and enabling its controlled use, new and improved infrastructure support new forms of patient engagement, shared decision-making and participation in care pathways. This evolution aligns with wider changes in healthcare business and service models, where value creation increasingly depends on data interoperability, platform-based coordination and patient involvement—topics addressed in theoretical segment of this thesis.

Accordingly, this thesis approaches telemedicine as a key analytical lens through which the broader effectiveness of e-health and digital public service strategies can be examined. By focusing on telemedicine, the study connects high-level policy objectives—such as digital sovereignty, interoperability, and patient empowerment—with concrete practices of healthcare delivery, allowing for an assessment of how European digital health frameworks are translated into real-world clinical and organizational outcomes.

Research problem and aim

As an EU member state from 2013. Croatia is expected to align national healthcare systems with EHDS requirements, while challenges such as fragmented IT systems, inconsistent adoption of interoperability standards and limited stakeholder coordination may delay effective implementation of this framework and its sustainability.

Despite existent infrastructure in strategic alignment with EU digital health policies, there is currently no comprehensive, system-level assessment of Croatia's digital maturity that would indicate whether the healthcare system is institutionally, technologically and organisationally prepared to support large-scale telemedicine and e-Health services as an aim of digital transformation.

So, the aim of this thesis is to appraise the digital maturity of the Croatian healthcare system using the HIMSS Digital Health Indicator (DHI) in order to evaluate the system's readiness to support telemedicine and e-Health services in the context of EHDS compliance.

Specific research objectives are defined as following.

- To analyse national digital health strategies and policy documents in Croatia in relation to EU digital health priorities.
- To operationalise the HIMSS DHI into an analytical matrix applicable at national level.
- To evaluate Croatia's digital maturity within four dimensions:
 - Governance and Workforce,
 - Interoperability,
 - Person-Enabled Health and
 - Predictive Analytics.
- To identify gaps between strategic ambitions and operational readiness.
- To assess Croatia's alignment with EHDS requirements from a digital maturity perspective.

To achieve aim and the general objectives of the research the main research question as well as specific ones are being set.

Main Research Question

To what extent digital maturity of the Croatian healthcare system is in alignment with the European Health Data Space to support sustainable telemedicine and e-Health services?

Specific Research Questions

- To what extent do Croatian governance structures, regulatory frameworks and workforce capacities support the scalable implementation of telemedicine and e-health services in line with EHDS principles?
- How mature is Croatia's technical, semantic and organizational interoperability infrastructure in enabling integrated telemedicine services and cross-border data exchange under EHDS requirements?
- To what extent are patients in Croatia digitally enabled to access, control and actively participate in their healthcare?
- How developed are Croatia's data analytics and performance monitoring capacities in supporting evidence-based decision-making and outcome evaluation?
- What gaps exist between strategic digital health ambitions and operational digital maturity in the implementation of telemedicine and e-health services?

This thesis has been written primarily in Croatian and translated via Artificial intelligence (AI) tools (Perplexity and ChatGPT). They were also used as supportive instruments, in accordance with institutional guidelines and academic integrity principles, for:

- brainstorming thesis structure,
- research design and analytical matrix and
- formatting assistance.

AI tools were not used as sources of information and all academic content, analysis, interpretation and conclusions were developed by the author. All references and AI suggestions were critically reviewed and verified against credible academic sources.

Chapter 1 - Literature Review

Systematic research on the digital transformation in the Croatian healthcare and the implementation of the European Health Data Space (EHDS) infrastructure in Context of EU remains limited and has been conducted sporadically, often within the context of comparative analyses involving other countries. However, literature review conducted with the help of an Scispace tool (October 2025: “Search research papers on the Croatian health system in the last 5 years” and “Find papers related to regulatory framework of Croatian healthcare in last 5 years”)¹ as well as author search within Scopus, Google Scholar and Hrčak (Portal of Croatian scientific and professional journals) databases with broad set of keywords: Croatian, healthcare, e-health, information systems, EHDS found studies across diverse scientific fields within recent 5 years that offer insights to the current state and challenges of the Croatian healthcare system.

These studies, originating from different fields, such as health informatics, public administration, health economics as well as information systems, reveal that, while Croatia has developed technically advanced digital health infrastructure, its long-term sustainability is constrained by governance, organisational and workforce limitations—dimensions directly reflected in the HIMSS Digital Health Indicator (DHI) framework.

The most recent study (Belani et al., 2024) related to Croatia’s implementation of cross-border e-health services with the members of EU, shows high technical interoperability maturity with multiple EU countries, enabling two-way exchange of patient summaries and ePrescriptions. Since 2019, Croatia has been fully connected to the eHealth Digital Service Infrastructure (eHDSI) as good foundation for upgrading national systems in relation to EHDS and actively participates in EU preparatory projects.

A paper by Bradašević (2023), focusing on the challenges and obstacles of EHDS regulatory provisions implementation, identifies human and financial resource constraints as key barriers to progress. In addition, it identifies major challenges in building the technical infrastructure, achieving interoperability with other EU Member States and linking data currently siloed in hospitals as Croatia has yet to develop a metadata catalogue, a critical requirement for cross-border interoperability.

¹ <https://scispace.com/chat/d8a5f726-bec0-42a6-9f67-34015e58d0a8>

A case study about the development and implementation of health information systems by Osvaldić (2021), focusing on digital transformation and e-health infrastructure of national healthcare, identifies numerous systemic challenges. Based on a systematic review of relevant international literature on informatization of healthcare, its legislation and the application of ICT, the study highlights persistent issues such as fragmentation and lack of interoperability, underfunded IT departments, outdated equipment as well as procurement delays in healthcare institutions. Notably, differences exist between public and private healthcare institutions. Nevertheless, research by Gvozdanović (2024) also points to barriers related to insufficient support staff and outdated equipment.

In the broader context of EU digital health initiatives, although Croatia is technically connected to the system MyHealth@EU, its transaction volumes are very low (Bruthans & Jiráková, 2023), suggesting that practical benefits for patients remain limited so far.

Regarding the telemedicine, Croatia belongs among the earliest adopters of telemedicine in Central and Eastern Europe. As early as 1998, a national teleradiology network was established, connecting 34 Magnetic Resonance Imaging (MRI), Computed Tomography (CT) and Digital Subtraction Angiography (DSA) scanners in 29 hospitals to a referral neurosurgery centre in Zagreb (Mrak et al., 2009) (Vuletić, 2001). More recent advancements include pilot project of remote patient monitoring program using the Ericsson Mobile Health (EMH) system for older and chronically ill patients in a rural, underdeveloped area of Sisak-Moslavina County (Keranović et al., n.d.) and study of the use of remote holter electrocardiogram analysis from 9 telemedicine centers of 130 patients in rural areas (Tuzla, 2022).

Focusing on the telemedicine use during the Covid-19 pandemic, several research show that telemedicine has become an operationally embedded component of care delivery. A single-center retrospective study (Koruga et al., 2022) at the University Hospital Center Osijek shows a substantial increase, compared with the period before Covid-19, in telemedicine utilization for neurosurgical consultations during the first pandemic year. The total number of telemedicine consults increased from 336 to 504, while trauma-related consults more than doubled, suggesting that telemedicine functioned primarily as an effective triage and decision-support mechanism. A national cross-sectional study in Croatian family medicine (Vučak et al., 2023), analysing changes in consultation modes during different pandemic phases provide complementary evidence. The study reports a marked organisational shift from face-to-face consultations toward virtual consultations, with face-to-face visits decreasing from 58.1% in 2019 to 41.2% in 2020, while virtual consultations increased from 41.9% to 58.8% in same period. Also, an increase in e-mail consultations was recorded as well as overall workload by the year of 2021.

The aforementioned examples show that the application of e-Health and m-Health (Blažić et al., 2022) is positioned as a priority for the Croatian healthcare system, but with underused potential, as portrayed within paper (Atanasov Georgiev & Shtereva-Tzouni, 2020) that provides a descriptive, policy-oriented overview of how e-health has developed in Austria, Bulgaria, Croatia, Estonia and Slovakia, highlighting large disparities in maturity, trust and potential cost savings. With an integrated healthcare information systems and digitalisation that enables that all providers (public and private) feed data into national registries and central systems possibilities for big data analytics and secondary use remain unutilized.

In another comparative study (Ćwiklicki et al., 2020) that analyzes institutional factors driving e-health adoption across 10 Central and Eastern European countries using qualitative comparative analysis on 2015 Global Observatory for eHealth data from World Health Organization (WHO). Croatia ranks second by e-health use (33% prescriptions, 26% consultations), with strong hospital EHR adoption (82%) and data exchange. But Croatia is still lagging from EU averages overall and in need of formalised frameworks any policies, combined with systematic training, to enable further telehealth and m-health expansion.

It's success is supported by strong infrastructure. The Central Healthcare Information System of the Republic of Croatia (CEZIH) connects over 2,300 general practitioner offices, pharmacies, laboratories, and hospitals to enable data sharing and services like e-prescriptions and e-referrals (Petrovčić et al., 2025). Also, the main e-Citizens portal integrates digital services for doctor selection, European Health Insurance Card (EHIC) applications and the Health Portal for high-security views of personal medical data and documents.

A most recent paper (Michalska et al., 2025) that offers a comparative, policy-oriented overview of how IT solutions are being used to mitigate health-worker shortages in Poland, Netherlands, Spain, Finland and Croatia, with a focus on administrative efficiency and availability of care, show obstacles across all five countries such as limited funding for infrastructure and training, interoperability problems, data-protection and cybersecurity compliance burdens as well as digital skill gaps among both staff and patients. In Croatia, Spain and parts of Finland there is significant resistance to change from staff (fear of workload disruption, job security concerns), regional inequalities in broadband and infrastructure and uneven accessibility to IT training. As Croatia and Finland rely on mixed, often employer-funded training in information technologies, in most organizations training is encouraged but not universally mandatory.

Furthermore, research by Šolić et al. (2024) reveals that, although Croatian healthcare professionals show high awareness of data security, formal education on digital security and interoperability is rare. Moreover, there is a gap between self-assessed knowledge and actual practices, underscoring the need for structured education and standardization in these areas.

On the patient side, Karačić et al. (2021) analyze patient complaints submitted to official bodies and the key non-government organization CAPR in Croatia, mapping them against the 14 rights outlined in the European Charter of Patients' Rights (ECPR). The analysis reveals persistent deficiencies in the patient rights protection - particularly with regard to access to information and privacy. These are crucial elements emphasized by the EHDS, which places a strong focus on patients' control over their own data.

Together, these findings form a robust foundation for further research and the operationalization of proposed research as telemedicine and e-health in Croatia should not be examined as isolated technologies but as a functional output of broader system. Their scalability and sustainability is irresistible from governance structures, interoperable infrastructure, workforce competencies and patient trust – dimensions that form analytical foundation of the HIMSS Digital Health Indicator.

Chapter 2 - Theoretical framework

2.1. Digital Transformation in Healthcare

Advancements in technology have disrupted traditional value chains in healthcare, challenging conventional roles and structures. The traditional horizontal value chain, which moves from material suppliers to consumers, has been disrupted, particularly in public healthcare systems (Walters & Jones, 2001) that relied on rigid structural levels of primary, secondary and tertiary care. Technology has empowered individuals to take more active roles in their health, catalysing the evolution of platform-based and patient-centred ecosystems (Abernethy et al., 2022).

The development of e-Health and m-Health has taken advantage in technologies to support home-based care, continuous self-management and even autonomous care, reducing transaction costs for providers while instilling new business models (Schiavone et al., 2021) as well as relationships between them and patients (Singhal et al., 2020). This shift towards a co-creation of value (Poblete et al., 2023) involves users as an active stakeholder, reorganizing resources such as knowledge, time, expertise and infrastructure to better meet the needs. For example, fitness trackers and health apps now grant users to monitor their health metrics, fostering a more interactive and personalized approach to healthcare. And by adopting such patient-centric perspective (Mickelsson et al., 2022), healthcare providers can leverage on deeper insights into patient needs and identify gaps or redundancies in care delivery, assuming that performance indicators are set up to reflect new metrics.

Digitalization trends have also led to the increasing influence of business, or private sector stakeholders in the healthcare market (Baru & Mohan, 2018). Public health systems, often slower to adopt technological innovations, face challenges from tech giants and other start-up players who

introduce disruptive innovations through platform-based business models. In these models, platforms thrive on network effects, where the platform with the most users attract even more, solidifying its dominance in the market (Charitsis, 2019). Leading platforms on market often offer comprehensive solutions that leave little space for competitors to differentiate themselves as they are predominant by advantages such as brand recognition, economies of scale and control over critical resources or data.

However, traditional healthcare systems need to adapt as try to remain competitive and address these challenges. So, healthcare providers, as well as policymakers, must align their strategies with emerging challenges and opportunities of new and emerging digital health ecosystems.

2.2. Challenges and opportunities of digital healthcare

Although digital transformation is reshaping healthcare by enabling innovation, research as well as the other opportunities, it nevertheless presents myriad challenges: ethical, legal and technical.

2.2.1. Ethical Challenges and Health Information as an Ethically Sensitive Category

Ethical concerns in digital healthcare stem from the intersection of medical ethics and digital ethics. While the first field is established on four principles (or pillars) of beneficence, non-maleficence, autonomy and justice, these principles can be challenged in digital environments by issues of data privacy and security, information asymmetry and transparency as well as discrimination and disparities. In addition, e-health and telemedicine environments intensify these challenges by scaling data collection, enabling secondary data uses and redistributing control over health information across complex socio-technical systems.

Healthcare is crucial in people's lives, and individuals have limited choices regarding it - they can either use it or avoid it at their own peril and responsibility. Similarly, they have little influence over what is entered into their medical records, as healthcare professionals are the ones documenting it. Yet, these records can significantly impact their lives—whether in securing certain jobs, obtaining professional licenses, negotiating insurance policies or exercising other rights. So, health information has several characteristics that make privacy particularly important and sensitive issue.

In this context, health information can be viewed as any data related to an individual's physical or mental condition. However, medical records may also include addresses, phone numbers, personal identification numbers, health insurance details, employment status and other relevant data. And since people generally do not want others to know about their health or fear the consequences if their illnesses or disabilities become known, health information is considered sensitive (Rainie & Duggin, 2016). Furthermore, health status can be a key element of personal identity and/or a foundation for

intimacy between individuals (Oyserman et al., 2007), making the protection of such data important for instrumental reasons as well. Despite regulatory and ethical prohibitions on disability discrimination, employers are less likely to hire or promote individuals with known "impaired" health conditions (Nagtegaal et al., 2023). They may also worry about health insurance costs, disability insurance and worker compensation expenses (Goodman et al., 2024).

On the positive side, employers could use available health information to improve workers' well-being through wellness programs, aiming to boost productivity. However, such programs carry risks for employees. Even with aggregated, anonymized data, employers can analyse and predict outcomes - such as how many employees are prone to become pregnant in the near future (Zarya, 2016) or require back surgery in the coming year (Silverman, 2016).

Moreover, access to health information can affect an individual's ability to secure loans or insurance premiums. Data-mining companies increasingly use predictive modelling to build algorithms that assess individuals' health risks for their clients. While algorithmic analytics are mostly proprietary, they may include data directly or indirectly linked to health. For example, sudden changes in credit card spending patterns or discontinuation of fitness app usage might suggest significant health shifts, which analytics firms could flag as lending risks. Even with de-identified data, re-identification risks are not entirely eliminated (Simon et al., 2019).

Ethical debates in digital health are often framed as a tension between privacy and data solidarity.

Nevertheless, population health data can be valuable for national security and public health, improving healthcare quality, identifying adverse drug or device effects, advancing precision medicine and medical research overall. Bioterrorism is a major national security concern. Periodic threats involving toxic agents like ricin or anthrax have led to mandatory reporting of suspected bioterrorism incidents in the United States, while the European Union has a coordinated emergency health reporting system for such events (Bengtsson et al., 2019). In these cases, medical information may be critical for identifying bioterrorism in emergencies, and patient identifiers are justified for accuracy verification, preventing duplicate counts and enabling interventions to contain outbreaks. Also, such "public" datasets were highly valuable within communities, as seen during the implementation of epidemiological measures to curb COVID-19 transmission and they also can a key role in preventive programs for diseases like cancer (e.g., National Cancer Screening Programs in Croatia).

Given the benefits of medical data for drug and treatment development and scientific research, the value of data on the health status of individuals within a population is unquestionable. But so are the risks to privacy rights.

E-mail and electronic medical records also present new confidentiality challenges for physicians. Communicating with patients via e-mail and other applications facilitates access to healthcare, but also poses risks if the communication is not secure, while some electronic medical record systems in use

do not include mechanisms to separate types of information that may require special ethical or legal protections (Končar & Luić, 2007) such as mental health information, information about abortion or other reproductive issues, and information about sexually transmitted diseases and genetic information. When these records are shared, access is provided to the entire record, rather than to parts that may be relevant to the care in question.

As the right-based approach is strong foundation in digital health systems, drawing upon international human rights mechanisms such as the Universal Declaration of Human Rights and relevant health-specific treaties, transparency plays a central ethical role in addressing information asymmetry, a situation in which one party has access to (better) information that the other does not have².

As digital technologies enable seamless data collection and exchange, individuals often lack meaningful insight into what data are held about them, how these data are processed and what consequences may follow. Ethical decision-making in such contexts is shaped by perceived costs and benefits (Laufer, Robert and Wolfe, 1977), social norms and cognitive heuristics, rather than by fully informed choice. So, transparency, as the availability and intelligibility of relevant information to stakeholders, is an ethical precondition for autonomy, accountability and trust.

The European Ethical Principles for Digital Health (Council of Europe, n.d.), an initiative of the French Presidency of the council of the European union, emphasize that individuals must be clearly informed about the benefits and limitations of digital health services, the mechanisms of their tools and the implications of data processing, including algorithmic decision-making.

Digital communication tools and electronic medical records, while improving access to healthcare and continuity of care, introduce also new vulnerabilities related to cybersecurity, unauthorized access and excessive data sharing. In some health information systems, technical architectures do not adequately support granular data segmentation, meaning that entire medical records may be shared even when only specific information is clinically necessary. This is particularly sensitive in relation to mental health records, reproductive health information, genetic data and sexually transmitted disease records, which often require heightened ethical and legal protection.

Moreover, as e-health and telemedicine have the potential to improve delivery of care, particularly to remote, often rural, or underserved populations, without deliberate ethical safeguards, they may intensify existing inequalities due to various barriers that can limit effective use of such services, such as digital literacy, accessibility, affordability, disability, age and regional infrastructure.

² A canonical example of this refers to the used car market, where sellers know whether their cars are in good condition or if they are so-called. "lemons", i.e. in bad condition, but customers do not have the opportunity to know this completely (Akerlof, 1970). Consequently, buyers should take into account the risk of buying a car in poor condition or give up on the purchase.

So, “digital health for all” is a core principle of WHO Global Strategy on Digital Health (World Health Organization, 2021a), adopted in 2020 by the World Health Assembly, as well as a cornerstone of forementioned European Ethical Principles for Digital Health. And to utilize it’s adoption trust must be central prerequisite; individuals must trust that their data are processed securely, fairly and for legitimate purposes as concerns around opaque data practices, proprietary algorithms and commercial reuse of health data can undermine confidence in digital systems.

2.2.2. Legal and Regulatory Framework for Digital Health in the European Union

While ethical principles define normative expectations, the legal framework establishes binding obligations that structure digital healthcare systems across the EU. Digital health and telemedicine operate within a multilayered regulatory environment that combines data protection law, patients’ rights, digital market regulation and sector-specific health legislation.

2.2.2.1. Legal and Regulatory Framework for Digital Health in the European Union

The General Data Protection Regulation (GDPR), adopted in 2016 and became directly applicable in all EU member states on 25 May 2018, without the need for additional transposition into national legislation, has set a legislative framework with high ethical principles for the protection of the rights of individuals as data subjects. In addition to informing them about data processing and its purposes, as a basis for making informed decisions, the principle of transparency also "extends" to the obligation to inform about unlawful sharing of data with other parties and all information breaches that may cause damage to the privacy of the data subject, i.e. the data subject, whose data has been compromised in this way.

It also establishes core legal principles including lawfulness, purpose limitation, data minimization, security and accountability, as well as enforceable rights for data subjects such as access, rectification, restriction and objection.

Under Regulation health data are classified as personal data of special category and subject to stronger protection requirements.

As an addition, in order to respond to the demands of new digital technologies and to facilitate the development of electronic communications services, the European Union adopted Directive 2002/58/EC on the processing of personal data and the protection of privacy in the electronic communications sector, also known as e-Privacy, on 12 July 2002. The subject matter of the Directive is the right to privacy in the electronic communications sector and the free movement of data,

communications equipment and services. The general obligation in the Directive is to ensure the security of electronic communications services by their providers towards the data subjects. The provisions of the Directive, thus, include the duty to inform subscribers of services whenever there is a specific risk related to information security, such as a virus or other malicious attack, as well as maintaining the confidentiality of information. Furthermore, the Directive obligate service providers to erase or anonymize processed traffic data when they are no longer needed, unless the conditions for exceptions have been met.

These provisions are particularly relevant in the context of telemedicine and e-health services, where communication between patients and healthcare providers increasingly occurs through digital platforms, mobile applications, remote monitoring systems and/or messaging services. It also establishes consent-based regimes for the processing of location data and for the use of cookies or similar tracking technologies, reinforcing transparency obligations and user control over data.

From a digital health governance perspective Directive plays an important role in protecting the confidentiality of communications as a cornerstone of patient-doctor privileged relationship, strengthening trust in remote healthcare delivery.

2.2.2.2. European Health Data Space (EHDS)

First proposed by the European Commission in March 2022, the European Health Data Space (EHDS) regulation, entered into force in 2025, has a goal to establish a common framework for the use and exchange of electronic health data across the European Union.

It establishes a coordinated legal and technical structure for electronic health record (EHR) systems that fosters interoperability toward a unified and interoperable data infrastructure rooted in democratic values, transparency and person-centricity (Hämäläinen et al., 2020) based on:

- enabling secure primary use of health data for care continuity and cross-border treatment;
- fostering the secondary use of health and well-being data for research, innovation, public health and policy-making;
- ensuring interoperability through harmonized data standards (e.g., HL7 FHIR, SNOMED CT) and
- embedding transparency and trust mechanisms as prerequisites for ethical data governance.

Regulation is structured to benefit a wide range of stakeholders that include individuals, healthcare professionals, researchers, regulators as well as innovators and industry.

With regards to their rights under the GDPR, patients received more control over their own (electronic) health data as they are able to add personal health information, view who accessed their data and restrict access to specific parts of their record or to specific persons, ask for corrections, if errors are found, and view health data in a standard European Electronic Health Record Exchange

Format (EEHRxF). Regulation also provides them with easy sharing of health data with health professionals, within and across borders, with security and privacy protections that are set by default. Moreover, individuals have the right to opt out of the secondary use of their data, subject to limited exceptions for high public interest (European Commission, n.d.).

On the other hand, healthcare professionals benefit from faster cross-border and cross-system access to patient records with reduced administrative burdens and minimized redundancies in diagnostics and treatments, leveraging it enhanced clinical decision-making (Hämäläinen et al., 2020).

Recognizing that data, especially from public sector organizations, is a valuable resource of competitive advantage, EU is pursuing policies of open data as a major priority within two-tier strategy of:

- Open Government Data (OGD), making datasets produced by public bodies available for reuse, including commercial usage and
- Open Science, encouraging full access to publicly funded scientific outputs while balancing intellectual property rights.

The Open Science strategy strive to make a system in which data, methods, publications and code are shared openly across institutional, national and disciplinary boundaries based on several core principles (European Commission: Directorate-General for Research and Innovation, 2018):

- open access to research outputs, including publications and datasets;
- FAIR principles (Findable, Accessible, Interoperable, Reusable) in research data management;
- citizen science and participatory research;
- open peer review and transparent research evaluation;
- responsible metrics and reward systems that value openness and collaboration;
- open notebooks and data management plans that ensure research reproducibility and integrity.

The EHDS is designed to strengthen Open Science by enabling framework for secondary use of data by providing researchers and academia with access to large-scale and high-quality datasets throughout structured data discovery tools indicating availability, provenance and quality to accelerate biomedical research, population health analytics and innovation in diagnostics and therapeutics (European Commission, n.d.)

Its architecture supports FAIR data sharing within secure processing environments, where data is accessed but not transferred or downloaded, and pseudonymisation and anonymisation protocols are strictly enforced and governed by Health Data Access Bodies at the Member State level.

Standardized access to anonymized and pseudonymized datasets for product development and clinical validation offers significant value to the private sector as well, while fostering collaboration

with research and healthcare institutions. According to the (European Commission, 2022), this is expected to drive 20–30% growth in the EU digital health sector over the next decade, accelerating value-based healthcare innovations.

Finally, EHDS improves the capacity of health policymakers and regulators to be proactive and data-driven in their public health strategies harnessing on health system performance evaluation and pandemic assessments.

In addition to the GDPR, which governs data subject rights concerning personal health data, the EHDS extends upon other existing EU frameworks for data processing and governance: the Data Governance Act, which facilitates trustworthy data sharing across sectors and borders; the Data Act, aimed at improving access to and use of non-personal and industrial data and the Network and Information Systems (NIS2) Directive, which strengthens cybersecurity requirements for essential digital infrastructure.

The Regulation also sets out robust security and interoperability requirements for electronic health record systems. These requirements are aligned with the European Interoperability Framework (EIF) and further reinforced by the recently adopted Interoperable Europe Act. EHR system manufacturers must obtain certification to demonstrate compliance with EHDS standards before entering the EU market.

2.2.3. Technical Foundations, Interoperability and Digital Maturity

While ethical and legal frameworks define what should be done, the implementation and operationalization of digital healthcare largely depend on technical capacity and system maturity. Digital health, as an ecosystem based on information and communications technologies to manage illnesses and health risks and to promote wellness (Ronquillo et al., 2013), present many challenges.

Despite substantial global investment health IT systems (Bowser et al., 2014) (Warren et al., 2013), large volumes of health data continue to be siloed, difficult to aggregate and inconsistently structured, which limits their clinical and analytical value. As a result, technical interoperability has emerged as one of the most critical prerequisites for effective digital transformation.

Besides legal, interoperability is founded also in technical, syntactic and semantic dimensions. While technical interoperability enables systems to exchange data, syntactic ensures that exchanged data follow standardized formats to ensure semantic interoperability that guarantees that the meaning of the data is preserved across systems. Internationally recognized standards such as HL7 FHIR, SNOMED CT, LOINC and other have significantly advanced foundational interoperability, yet extensive seamless exchange across heterogeneous platforms remains incomplete in many healthcare systems by most countries (Gopal et al., 2019).

Interoperable infrastructures are essential for telemedicine because remote consultations, image sharing, clinical decision support and remote patient monitoring rely on timely access to accurate and comprehensive patient information. Without interoperable connections between primary care doctors, hospitals, laboratories, pharmacies and (public) insurance systems, telemedicine services risk functioning as isolated digital channels rather than integrated components of healthcare.

And for realizing this and reap benefits a coordinated investments across macro- (policy and regulation), meso- (organizational structures and processes) and micro- (workforce skills and user adoption) levels are required (Dal Mas et al., 2023) as technical maturity is inseparable from organizational maturity: advanced systems alone do not guarantee improved outcomes if governance structures, workflows and human capacities are misaligned.

From this perspective, digital transformation is best understood as a socio-technical process. Technologies such as EHRs, telemedicine platforms, and health information exchange networks act as enablers, but their value depends on alignment with clinical workflows, leadership commitment, data governance frameworks and workforce competencies assessed within maturity models such as HIMSS DHI.

2.2.3.1. Digital maturity

Systems' or organizations' ability to respond to changes and trends in technology as a 'state of readiness' to be able to adapt to and integrate with new technologies is referred as digital maturity (NHS England, 2025).

Recent scholars further conceptualize digital maturity as a multidimensional construct encompassing governance capacity, interoperability, workforce preparedness, data analytics capabilities and the embedding of digital tools into clinical and organizational processes, rather than merely the presence of technological infrastructure (Snowdon et al., 2026).

To assess it various tools have been developed to help organizations and/or national health systems self-assess their own digital capabilities across various determinants, including technological infrastructure, governance, interoperability, workforce readiness, patient engagement and analytics capability.

Developed models evaluate the extent to which digital technologies are embedded into delivery and processes of care and can serve as indicators of gaps and improvement needs in metrics such as healthcare quality, efficiency and accessibility. Consequently, they can be used by policymakers, international organizations and healthcare institutions to benchmark progress as well as to guide strategic investment decisions.

A variety of maturity assessment frameworks have been developed to evaluate digital transformation readiness in healthcare systems, reflecting different analytical scopes, objectives and parts of healthcare systems. At national level World Health Organizations' Digital Health Maturity Assessment Framework (World Health Organization, 2021b) assess national digital health ecosystem readiness; the Global Digital Health Index (GDHI), developed by the Digital Impact Alliance (DIAL) in collaboration with international development partners, assesses policy, infrastructure, standards and workforce readiness, enabling international benchmarking (McNabb et al., 2016), while Digital Primary Care Maturity Assessment (DPCMA) tool is used to support and assess the effectiveness of the primary care services in United Kingdom (NHS England, n.d.). At the institutional level, hospital maturity models such as DigitalRadar (Geissler et al., 2024) evaluate infrastructure, clinical information systems and interoperability readiness.

Among the most widely recognized and internationally applied frameworks are the maturity models developed by the Healthcare Information and Management Systems Society (HIMSS), independent organization of researchers and professionals in the field that operates across North America, Europe, the United Kingdom, the Middle East, Asia-Pacific and Latin America since year 1961 (Healthcare Information and Management Systems Society, n.d.).

The society has produced various digital maturity assessment models: Electronic Medical Record Adoption Model (EMRAM), Analytics Maturity Model (AMAM), Infrastructure Adoption Model (INFRAM), Clinical and Business Operations Maturity Model (CBOMM), Community Care Outcomes Maturity Model (C-COMM), Digital Imaging (DIAM) and Continuity of Care (CCMM).

The Electronic Medical Record Adoption Model (EMRAM) assess the adoption and utilisation of electronic medical record (EMR) systems within hospitals and clinical settings. It defines an eight-stage maturity scale (0–7), each stage corresponding to progressively advanced capabilities such as clinical documentation, computerized physician order entry, clinical decision support, interoperability and health analytics. It is widely used to benchmark hospital digitalisation and to guide strategic planning for clinical information system investment. By providing a standardized assessment methodology, it supports strategic planning, investment prioritization and comparison of hospital digital maturity levels.

The Analytics Maturity Model (AMAM) assesses the maturity of an organisation's analytics capabilities, focusing on data governance and integration of descriptive and predictive analytics into clinical and operational decision-making using also 8 stages of progression. AMAM helps organisations determine how well they leverage data assets and advance from basic reporting to advanced analytics and artificial intelligence enabled insights.

The Infrastructure Adoption Model (INFRAM) evaluates the maturity of foundational IT infrastructure, including networking, cybersecurity, identity and access management, as well as use of

cloud services and other underlying technologies that support digital health systems to help organisations identify gaps in core infrastructure that may limit the deployment, integration or scaling of advanced digital solutions.

The Community Care Outcomes Maturity Model (C-COMM) is designed to assess how mature a community or health system is in managing and improving outcomes in integrated and community-based care settings. It is particularly useful in evaluating transformation toward value-based and community-centered healthcare models.

The Digital Innovation Adoption Model (DIAM) evaluates how organizations adopt, implement and scale digital innovations in healthcare and public service ecosystems. It is valuable in digital transformation initiatives analysis, particularly where adoption barriers, organizational culture and governance capacity influence outcomes.

The Care Coordination Maturity Model (CCMM) measures how effectively healthcare organizations coordinate care across providers, sectors and levels of service which can be relevant for chronic disease management in aging populations and telehealth-enabled integrated care systems.

2.2.3.2. HIMSS Digital Health Indicator (DHI)

Another solution or „product“ from HIMSS is the Digital Health Indicator (DHI), a comprehensive digital maturity assessment framework designed to evaluate healthcare systems across organizational, technological and strategic dimensions. It measures digital maturity across multiple interrelated dimensions, including governance and workforce enablement, interoperability and health information exchange, person-enabled health services, predictive analytics capability and digital infrastructure on broader level than institution-focused maturity models. As these dimensions collectively reflect the extent to which digital technologies are embedded in healthcare delivery processes, the DHI model captures both, technological readiness and organizational capability, reflecting the socio-technical nature of digital transformation in healthcare (Snowdon, 2020).

In the context of emerging European digital health policies, particularly the implementation of the EHDS requirements, the DHI model offers a relevant analytical structure for assessing national readiness. The framework provides scoring mechanisms that allow benchmarking across institutions, regions and countries, enabling identification of maturity gaps as EHDS mandates Member States to establish interoperable electronic health record infrastructures, standardized data exchange mechanisms and secure access frameworks.

Based on the conceptual foundations of digital maturity assessment and the HIMSS DHI framework, this study applies a structured analytical matrix derived from selected DHI dimensions, to

evaluate the digital maturity of telemedicine and e-health development in the Croatian healthcare system.

Chapter 3 - Methodology

In order to align the HIMSS Digital Health Indicator (DHI) framework with the national-level scope of this research and the requirements of the European Health Data Space (EHDS), selected DHI dimensions were operationalised into measurable analytical categories (Figure 3.1):

- Governance and Workforce,
- Interoperability,
- Person-Enabled Health and
- Predictive Analytics.

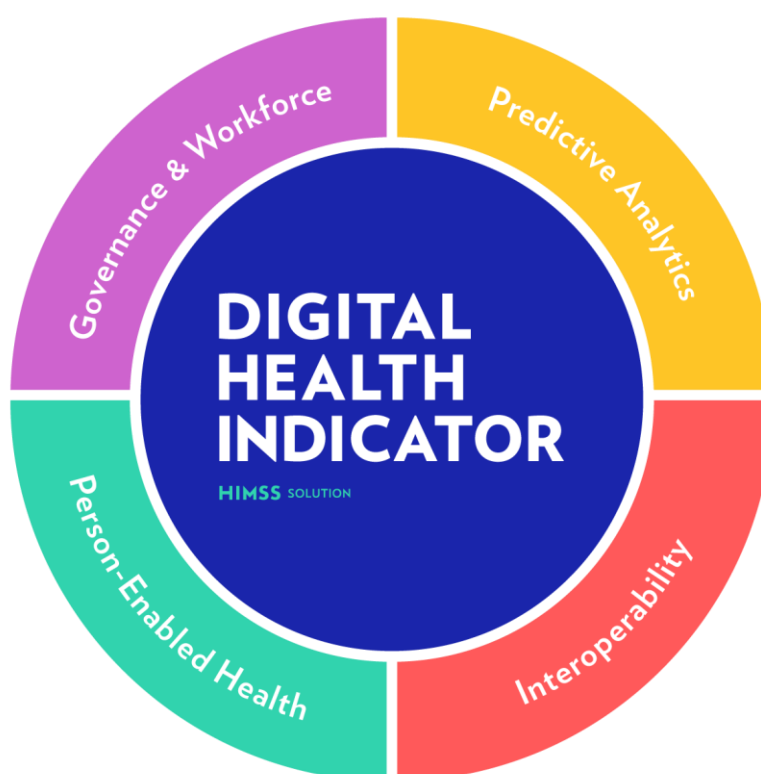


Figure 3.1 Dimensions of the HIMSS Digital Health Indicator Framework

Adapted from Digital Health Indicator Rapid Assessment by HIMSS, 2026.

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The Governance and Workforce dimension focuses on the institutional stewardship, policies and human capital capacity and competency requirements to sustain digital transformation. It assesses leadership strategies and decision making throughout processes and policies that incentivize

performance and derive accountability to assure the long-term sustainability of the digital health infrastructure.

Technical and semantic interoperability across healthcare institutions, at a base of Interoperability dimension, examines seamless data exchange and use of analytics and reporting tools across clinical settings, as well as the security and cybersecurity protocols necessary to maintain data integrity and patient privacy.

The Person-Enabled Health dimension shifts the focus toward personalized and patient-empowered health settings. It measures the degree to which patients utilize digital tools to self-manage wellness and connect to the healthcare providers when needed and is focused on predictive analytics dimension of DHI to enable mobilization of people to track population health towards set goals.

Dimension of Predictive Analytics represents the intelligence layer of the DHI and serves as a connected between individuals and their provider teams for outcomes reporting through the journey of care. It is focused on the transformation of raw data into actionable insights to identify risk and most quality strategy of care.

This study adopts a structured desk research methodology based on mixed methods of analysis of the content of secondary data. It applies qualitative methodology approach to systematic policy and regulatory document content analysis as well as available sources to assess conformance to across set dimensions. The analytical matrix based on the adapted HIMSS DHI applies quantitative methodology approach, enabling a structured evaluation of Croatia's digital maturity across four core dimensions relevant to telemedicine and e-Health.

For every indicator a score scale has been setup to measure DHI conformity:

0 = not enabled,

1 = partially enabled,

2 = advanced and/or systemic.

For the Governance and Workforce dimension indicators include:

- existence of national policies, legislation and governance structures for digital health and telemedicine;
- public reporting of strategy, quality, safety and digital transformation outcomes;
- workforce training, HR strategy, digital skills and
- national policies and strategies for patient participation in governance.

The Interoperability dimension is assessed within following criteria:

- existence of national health information exchange infrastructure enabling telemedicine workflows;

- standardization of data formats, data models and coding systems;
- workflow integration of cross-sector providers and
- cross-border data exchange readiness.

The Person-Enabled Health dimension assess indicators:

- availability of patient records;
- digital tools supporting prevention and self-care;
- digital communication tools enabling individualized care pathways and
- population capacity to use digital health and digital literacy.

Finally, the Predictive Analytics dimension is scored through:

- clinical decision analytics;
- use of data to identify risk groups;
- use of real-time system performance data and
- infrastructure for secondary use of data.

To link results of DHI conformity with national digital maturity, the following categorization to four maturity levels is proposed: low (0–2), emerging (3–4), moderate (5–6) and high (7–8) to enable differentiation between early adoption, operational capability and systemic integration, which is particularly relevant for assessing telemedicine readiness and EHDS alignment.

Low level exhibits minimal or fragmented capability, characterized with pilot projects, strategy without implementation and isolated resources. Emerging level is characterized with early implementation stages where infrastructure exists, but there is uneven adoption. Operational, but still not full systemic maturity is distinctive for moderate level as national services are running, their interoperability is functional, but analytics is limited. Finally, high level of digital maturity is systemic and scaled one, with routine use of technology, integrated workflows, predictive governance and overall EHDS readiness.

So, selected DHI dimensions can serve as analytical indicators of the extent to which the Croatian healthcare system is prepared and aligned with the regulatory requirements of the EHDS. As the Governance and Workforce dimension reflects institutional readiness for harmonised data governance and cross-border health data exchange, interoperability constitutes a core requirement under the EHDS framework, followed by the Person-Enabled Health dimension that provides and secures citizens' access to and control over their personal electronic health data. Finally, predictive analytics is a backbone and prerequisite for data utilization that supports secondary use of health data for research and innovation as overall goal of EHDS.

Chapter 4 - Research Findings

4.1. Main strengths and challenges of Croatian health system

The Croatian health system is centralized, with most healthcare providers remaining under public ownership that are under the stewardship of the Ministry of Health, responsible for policy, planning, regulation and public health programs. It is primarily funded through mandatory health insurance contributions (80,26 % of revenue in 2024. by (Croatian Health Insurance Fund, 2024)), while state budget transfers rose to 13.14%. Patients also have the possibility of choosing the voluntary health insurance which market covers co-payments and accounted for 0.55% of total Croatian Health Insurance Fund (hrv. Hrvatski zavod za zdravstveno osiguranje, HZZO) income in 2024, that covers broad scope of preventive and curative health services not included in mandatory insurance.

Primary care serves as the entry point to the system as institutions are divided into four levels: primary, secondary, tertiary and the institute level, in accordance with Article 29 of the Health Care Act (Zakon o Zdravstvenoj Zaštiti, 2025). Secondary and tertiary levels provide hospital-based specialist and highly specialized services, while institute-level institutions, including the Croatian Institute of Public Health (hrv. Hrvatski zavod za javno zdravstvo, HZJZ) and the Croatian Institute of Emergency Medicine (hrv. Hrvatski zavod za hitnu medicinu, HZHM), play a key coordinating and surveillance role, particularly in public health monitoring, telemedicine coordination and registry management.

Most healthcare providers (especially in secondary and tertiary care) are remaining under public ownership, while the number of private providers, primarily in primary care, is growing (OECD/European Observatory on Health Systems and Policies, 2023).

Main challenges of Croatian healthcare are unmet medical needs by mandatory insurance and by public providers with rate of 8.9 per 100 inhabitants (Bobinac, 2023). The most common (59.55%) explanation for inaccessible care is a long waiting list due to challenges in the geographical distribution of health facilities (Džakula et al., 2021). Most hospitals are located in central Croatia, predominantly in the capitol city of Zagreb and the network of hospitals has not been substantial to meet requirements of the changing demographic structure of the population. Disparities persist particularly in rural and island regions. Also, self-reported unmet needs among older people are higher than the EU average (Ministarstvo zdravstva, 2021).

To address this issue the Government has established a network of public institutions (Mreža Javne Zdravstvene Službe, 2024) with maximum number of medical teams per county (21 of them). The overall number of medical teams in country is 2,445 for a population of 3,871,833 according to the 2021 census. Significant advancements in emergency medical response and healthcare accessibility are made also through the implementation of Helicopter Emergency Medical Services (hrv. Helikopterska hitna medicinske službe, HHMS) and telemedicine.

Launched on March 30, 2024, Croatia's civil HHMS operates from four strategic base sin Osijek, Rijeka, Split and Zagreb. This network ensures comprehensive national coverage, including remote, rural and island regions (Croatian Institute of Emergency Medicine, 2024). Each helicopter is staffed with a physician and a nurse (with at least a bachelor's or master's degree), while base locations were chosen based on aviation infrastructure, proximity to major hospitals and compliance with EU regulations.

Coordinated by HZHM and reinforced by regulatory framework (Health Care Act, Regulation on Telemedicine Conditions and Organization and Decision on the Telemedicine Centre Network) telemedicine is also integrated into the national healthcare system. Services are available from major clinical hospitals to local health centres through telemedicine Access Centres, where patients receive services and telemedicine Specialist Centres, where specialists provide consultations and appointment scheduling process is the same as for in-person specialist visits (Croatian Institute of Emergency Medicine, n.d.).

Importantly, National Public Health Information System (hrv. Nacionalni javnozdravstveni informacijski sustav, NAJS) has been integrated into the DARWIN EU platform (Croatian Institute of Public Health, 2024), enabling Croatia to contribute data to European real-world evidence projects under strict privacy controls. This inclusion signals significant progress toward meeting the EHDS objective of facilitating secondary use of health data, particularly standardization of data infrastructures and interoperability standards.

Operationally, the Ministry of Health's 2024 annual report highlights significant achievements in infrastructure modernization, emergency medical services and workforce development. Yet, it also reveals ongoing challenges in fully implementing strategic reforms, particularly in human resource management and administrative efficiency. While many targets were met or exceeded, such as the expansion to the mentioned helicopter emergency services, others, like the full integration of digital systems and regulatory updates, still remain in progress(Croatian Health Insurance Fund, 2024).

The SWOT analyses conducted within the National Health Care Development Plan for period 2021-2027 (Ministarstvo zdravstva, 2021)provides more structured overview of strengths, weaknesses, opportunities and threats derived from working group contributions and public consultation, reflecting both internal institutional dynamics and broader systemic conditions.

Internal strengths include the high level of professional expertise and accumulated experience of healthcare workers, as well as established coordination mechanisms among institutions within the system. There is also the existence of a direct managerial line between the Ministry of Health and healthcare institutions owned by the Republic of Croatia that enables centralized oversight and strategic alignment at the national level. On the other side, weaknesses are identified within limited

capacity to control and manage autonomous healthcare institutions, which may result in reducing the coherence of national policy implementation.

Also, there are structural limitations in rewarding high-performing and highly motivated healthcare professionals, that resulted in emigration of a significant number of healthcare workers immediately after accession to the EU. However, in recent years the trend of emigration has been decreasing. Long-standing neglect of investments in healthcare workers has led to a situation where some hospitals, and especially primary healthcare, are facing difficulties in filling open positions.

Further, the analysis also highlights insufficient expertise in health economics within the public administration, which constrains evidence-based financial planning and strategic resource allocation.

At the same time, the identified threat includes risk of prioritizing institutional or individual interests over broader national healthcare objectives.

Analysis against external factors include several strengths: the presence of highly skilled and professionally committed healthcare workers, a well-developed hospital network as well as a comprehensive public health infrastructure supported by regional institutes. This can relate to opportunity identified in strong consensus among stakeholders that the existing healthcare system requires substantial reform and that Croatia has the opportunity to leverage knowledge transfer and best practices from European countries that have already implemented successful healthcare reforms and advanced digital health systems. Also, alignment with EU regulatory and interoperability frameworks, particularly under the European Health Data Space, is recognized as an incentive for accelerated digital modernization.

On a challenges side, despite these strengths and opportunities, significant structural weaknesses persist.

The most critical is the insufficient number of healthcare professionals that, combined with an unfavourable age structure, increases vulnerability to workforce attrition and limits adaptability to digital innovation. Furthermore, the system lacks a sufficiently developed quality control and patient safety improvement framework, which weakens the integration of performance monitoring with digital health solutions.

There is also limited coordination among institutions involved in patient treatment pathways, due to fragmentation across providers and the deteriorated condition of parts of the healthcare infrastructure as a result of long-term underinvestment, that complicate the implementation of interoperable digital systems and integrated care models.

At the same time, fragmentation and particularistic interests of stakeholders (private, public) can bring threats and undermine reform efforts as resistance to change can discourage progress in achieving integrated digital health transformation and EHDS alignment.

4.2. Governance and Workforce dimension

4.2.1. Governance

Croatia demonstrates a formally established strategic governance structure for digital health in relation to data protection, accountability and transparency. However, empirical findings on privacy transparency (Alić, 2022) suggest that institutional-level compliance practices may not fully reflect the maturity of the legal framework.

Although three years had passed since the General Data Protection Regulation entered into force in 2018 and was transposed into the national legislation of EU Member States, a 2021 study on privacy transparency in Croatia (Alić, 2022) revealed concerning findings. Of the 148 public healthcare institutions listed on the Ministry of Health website, only 37% had published privacy policies, and in many cases these policies were difficult to locate.

The same study, which also included privately owned healthcare institutions, showed that most healthcare providers offered only partial information regarding their data processing practices, as required under the GDPR framework applicable in the Republic of Croatia. Furthermore, the language used in privacy policies was frequently complex and not easily understandable to the average individual or target audience, raising concerns about the substantive transparency of compliance practices.

One year after the GDPR implementation the Act on Healthcare Data and Information (Zakon o Podacima i Informacijama u Zdravstvu, 2019) entered into force in Croatia. This Act ensures the implementation of Regulation (EC) No 1338/2008 of the European Parliament and of the Council on Community statistics on public health and health and safety at work. It establishes the foundational legal framework for the management of health data in Croatia.

Based on key principles defined in Article 4 — lawfulness, accuracy, interoperability and traceability — the Act regulates institutional responsibilities for data processing and defines the national health information infrastructure of the Republic of Croatia. This infrastructure comprises of Central Health Information System of Croatia (hrv. Centralni zdravstveni informacijski sustav Republike Hrvatske, CEZIH), NAJS and other national and institutional health information systems.

Article 10 confirms the application of personal data protection regulations in relation to data subjects' rights by imposing obligations on data controllers and processors of health data to ensure the protection of personal data in all procedures involving access to and processing of such data. In this context, rights provided under Articles 3 and 4 of the EHDS regulation, concerning access and data portability, can be aligned with corresponding provisions of the GDPR and the Act on Healthcare Data and Information as:

- the right of individuals to access their personal health data (EHDS Art. 3) corresponds to Article 15 GDPR and Article 10 of the Act and
- the right to receive and transmit health data in a structured format (EHDS Art. 4) aligns with Article 20 GDPR and Article 8 of the Act.

Furthermore, Article 5 of the Act on Healthcare Data and Information (Zakon o Podacima i Informacijama u Zdravstvu, 2019) provides a legal basis for secondary use of health data for research, statistical and public health purposes.

Also, the provisions of the EHDS and the GDPR have also been incorporated into secondary legislation, including the Ordinance on the Method of Processing Health and Other Personal Data in National and Institutional Health Information Systems in Healthcare, the Method of Storing and Protecting Health Data and Creating Health Indicators, Standardized Forms and Registers and Records in Healthcare from 2024. This regulation governs the processing of health data within national systems such as CEZIH and NAJS, ensuring secure, standardized and interoperable handling of personal and public health data.

Articles 3 and 4 of the EHDS, which guarantee individuals the right to access and transmit their electronic health data, are operationalized through CEZIH and NAJS, as these platforms enable structured and secure retrieval and sharing of health information. Article 7 of the EHDS, mandating logging and traceability of data access, is reflected in Articles 2 and 3 of the Ordinance, requiring that every access to health data be recorded to ensure transparency and accountability.

From the perspective of the GDPR, Article 5, which establishes principles of lawful, fair and transparent processing, is embedded in the design and operational protocols of CEZIH and NAJS to ensure data minimization, purpose limitation and accuracy. Article 32 GDPR, requiring appropriate technical and organizational security measures, is implemented through safeguards within the CEZIH system, including encryption, access controls and audit trails.

The Ordinance on the Scope and Content of Data and the Management of Electronic Health Records (2023) further operationalizes EHDS provisions regarding patients' rights. Article 3 enables patients to access their data via the CEZIH Health Portal. Articles 5 and 6 regulate consent management within the system, aligning also with Article 7 GDPR requirements on consent.

Finally, the 2024 Ordinance on Process, Technical, Organizational and Semantic Standards for data processing for professional and business areas in healthcare defines interoperability and data exchange standards in healthcare. This regulation establishes the architectural foundations of Croatia's healthcare information infrastructure by specifying how health data must be structured, transmitted and interpreted across digital systems. It ensures consistency, reliability and semantic alignment between healthcare providers, institutions and national platforms such as CEZIH and NAJS.

The right to data portability under Article 4 EHDS is directly supported by this regulation through standardized data formats and communication protocols enabling cross-border exchange. Article 8 EHDS is operationalized through structured data and metadata requirements, mandating interoperable coding systems and semantic standards that enhance both machine readability and human comprehensibility of health information.

4.2.2. Workforce

In their survey from the perspective of healthcare professionals, Orešković and Benković (Orešković & Benković, 2024) found that 56% of respondents believe that the system is poorly managed and organized, while 66% believe that financial problems are the result of poor management of existing resources, rather than a lack of money. Furthermore, 89% of respondents seek greater autonomy for management from politics.

As National Health Development Plan for the period 2021-2027 puts human resource management as a key role in reform, analysis of the Action plan (Ministartvo zdravstva, 2021) results taken in the period from 2022. to 2025. shows that concrete measures aimed at long-term stabilization and modernization of the human resources.

The strategic framework for human resources development was published on 31.9.2022, with the aim of defining short-term and long-term needs for healthcare professionals at all levels and in all regions of the Republic of Croatia. This set the foundation for: planned management of shortage professions, regional distribution of personnel and a framework for the transfer of competences between professions as a measure that directly contributes to the flexibility of the system because it allows for the anticipation of needs instead of reactive management of personnel shortages.

Following, the guidelines for human resources management were published on 30.6.2023 that include salary increases in line with fiscal possibilities; professional development and career advancement based on objective, transparent, measurable criteria; an impartial dispute mediation system and

flexible working conditions. This measure tends to strengthen staff retention and increase the organizational stability of the system - a prerequisite for its effectiveness.

Also, there are implemented and planned measures within specialist training and lifelong learning (2023–2025) that included publication of standards for education abroad by 30.6.2023, completion of specialization of 215 family medicine doctors by 31.12.202 and specialist training of 375 Bachelors of Nursing in emergency medicine by 31.12.2025. These actions directly address the shortage of personnel at the primary level and in emergency medicine and increase the rationality of the system by strengthening competencies at lower levels of health care.

The observed measures show a shift from ad hoc human resource management towards strategic capacity planning and objective performance evaluation, strengthening the competencies and redistribution of knowledge. They can be linked to the medium-term measures of the National Plan of improving human resource management and education of public administration in healthcare in the field of health economics and successful models of development and expansion of healthcare workers' competencies.

Related to digital skills, the results based on a comprehensive analysis of higher education options on information and cyber security at universities and polytechnics in Croatia, with reference to the selection of courses, modules and teaching topics on information and cyber security in university and polytechnic curricula and programs for the education of health and medical professionals (Belani, 2023), show that Croatia does not have a formal study program in biomedical informatics, nor a systematic personnel strategy for digital health experts. This represents a structural limitation for sustainable digital transformation, as Croatia remains the only EU Member State without a dedicated educational program in this field.

And digital transformation is a central pillar of healthcare reforms such as National Development Strategy 2020 - 2030 and the National Health Care Development Plan 2021 - 2027 for connected, data-driven healthcare system. As improvements to the existing CEZIH platform integrating health data across care levels, and recent reforms aim to improve care integration, quality and efficiency to support clinical decision-making and public health monitoring, risks were also identified including resistance to change by stakeholders, lack of IT professionals and the need for sustained political and financial support.

4.2.3. DHI conformity

Croatia has a comprehensive regulatory framework including the Act on Healthcare Data and Information, multiple ordinances governing interoperability and data exchange, the National Health Care Development Plan and the Telemedicine Framework. Governance structures defining institutional responsibilities are clearly established. There is only partial public reporting of strategy, quality, safety and digital transformation outcomes strategic documents and implementation programmes are publicly available and the introduction of the Health System Performance Assessment (HSPA) framework indicates movement toward systematic monitoring, but overall routine outcome transparency and standardized reporting remain limited.

Workforce readiness is identified as one of the main maturity constraints as national plans recognize workforce shortages, digital skills gaps and the need for new professions (biomedical health informaticians). Although training initiatives exist, they are not systematically scaled and only partially enabled.

Finally, although patient rights are mentioned as part of governance and built in framework, through Health Portal infrastructure, structured patient co-governance mechanisms remain limited and without systemic policies.

DHI scoring results are shown in Table 4.1.

Table 4.1 DHI conformity scoring for Governance and Workforce dimension

indicator	score
existence of national policies, legislation and governance structures for digital health and telemedicine	2
public reporting of strategy, quality, safety and digital transformation outcomes	1
workforce training, HR strategy, digital skills	1
national policies and strategies for patient participation in governance	1

4.3. Interoperability dimension

In Croatian healthcare, digitalization began in last third of twentieth century with the computerization of the Croatian Cancer Registry in Zagreb, automated data processing in outpatient and occupational medicine in Varaždin and the Remetinec Health Center, as well as the application of telemedicine through telephone line signal transmission (e.g., ECG) in the 1970s and 1980s (Kurjak & Richter, 2001). Even during the early days of the Croatian War of Independence, wireless communication technology was implemented in the Emergency Situations Information System. In the 1990s, numerous local IT solutions were developed for hospitals, polyclinics, clinics, laboratories and other facilities across different platforms. Their incompatibility, coupled with global advancements in information technology, highlighted the need for a systematic approach to create a unified health information system in Croatia.

In 2002, a scientific research project marked the beginning of the CEZIH as central national healthcare information system. The first contract for system delivery was signed with the Croatian Government in 2003, followed by agreements for maintenance and continuous upgrades with Ericsson Nikola Tesla. Since 20.2.2007 CEZIH has been operational, connecting healthcare providers across all levels of healthcare.

Today, CEZIH is a central system for health data storage and for their standardized processing at the primary, secondary and tertiary levels of healthcare. According to the 2019 Act on Health Data and Information, all exchange of health information must go through CEZIH.

Over the years, CEZIH has digitized and transformed various processes in healthcare and made the healthcare system more accessible to patients. A significant part of the system's services is integration interfaces that enable communication between other systems and their users, and from this perspective, CEZIH represents a national integration platform for all other information systems and applications in the Republic of Croatia.

An integral part of CEZIH are applications that are available to end users:

- the Electronic Health Record (hrv. e-Karton) application allows a single view of a patient's medical data generated in different parts of the healthcare system for authorized healthcare professionals and
- the Health Portal (hrv. Portal zdravlja), which provides citizens with access to their own medical data and data for minors in their care, enabling them diverse services such as sending requests for the extension of chronic therapy, exchanging messages with selected doctors, managing orders etc.

Almost all healthcare professionals in the Republic of Croatia use CEZIH on a daily basis, while according to recently available open data (Korištenje E-Usluga u Sustavu e-Građani, 2026), the average number of applications (total number of applications/number of unique users) to the Health Portal e-service is 21 in the period from 01.06.2014 to 31.12.2025.

One of the most popular services of the CEZIH system is the electronic prescription (e-Prescription), whose launch in 2010 was the first truly national implementation of electronic prescribing and dispensing of medicines in the world. Just a month later, the e-Referral system for biochemical laboratories was also launched into full implementation, completely digitalizing this business process.

In the background, CEZIH offers a number of other services:

- electronic sick leave reporting,
- electronic reporting of malignant neoplasms,
- electronic notification of infectious diseases,
- reporting of adverse events following immunization,
- electronic ordering (hrv. e-Naručivanje) in specialist care,
- integration with laboratory information systems (LIS).

Since the dimension of legal interoperability was analysed in the previous chapter under Governance section of previous chapter, the following sections focus on the organizational, semantic and technical aspects of interoperability in relation to the described system.

4.3.1. Organizational Interoperability

Organizational interoperability refers to the alignment of institutional roles, processes and responsibilities that enable coordinated data exchange across healthcare actors.

As CEZIH functions as a central integration platform connecting various stakeholders in Croatian healthcare system (Figure 4.1): primary healthcare providers, secondary and tertiary hospitals, pharmacies, laboratories, Croatian Health Insurance Fund, Croatian Institute of Public Health and telemedicine centers, it enables for system to operationalize standardized workflows at national level. For example, the e-Prescription lifecycle goes from physician to pharmacy and to CHIF for billing purposes and e-Referral process sends data from primary care to specialist/lab and reports back the results.

Organizational interoperability is explicitly structured through the Ordinance on the Scope and Content of Data and the Management of Electronic Health Records. Articles 12–15 define who creates the EHR (upon the assignment of unique number of insured person), who enters data (selected general practitioner doctor and other providers), who is responsible for data accuracy and how data are transmitted via CEZIH. Also, Article 16 defines access rights across professional categories, while Article 17 operationalizes patient access and audit logging through the Health Portal.

This establishes formalized process flows, role-based access governance, accountability and traceability as well as distributed service provision with centralized coordination.

Within Ordinance on Process, Technical, Organizational and Semantic Standards for data processing for professional and business areas in healthcare from 2024 organization standards (Article 2) are set to regulate inter-sectoral cooperation, relationships between providers and users, infrastructure project governance and service availability requirements. As Article 7 further defines organizational preconditions for software implementation, governance of health information infrastructure and security management rules, Croatia has a formally regulated organizational interoperability layer, including compliance control mechanisms for healthcare software.

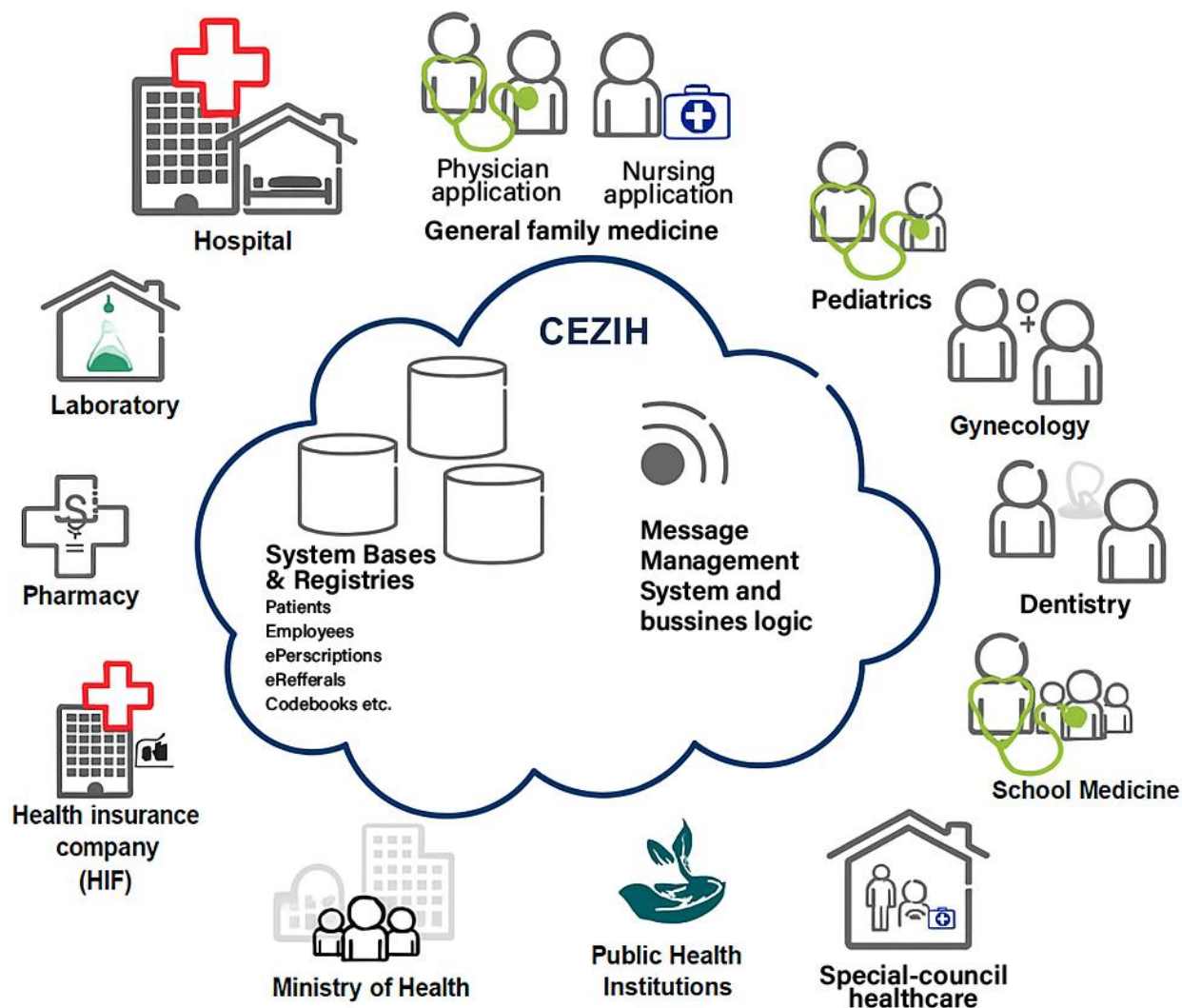


Figure 4.1 CEZIH system

Adapted from CEZIH - Function specification by Author, 2026
Copyright 2013 by Ministry of Health, Croatia

However, according to the results of the National Plan, information systems are still not "fully complete and integrated to enable integrated patient-centered healthcare delivery, nor have sufficient professional human resources been developed to develop and manage these systems, and the health system lacked the flexibility to absorb all necessary changes and possible improvements given the rapid advancement of technology" (Ministarstvo zdravstva, 2021).

In reality, healthcare institutions and primary healthcare practices in the Republic of Croatia largely function as separate silos. For example, IT systems do not enable full data exchange and coordination at all levels of healthcare, and family physicians are not equipped with the appropriate tools to effectively and efficiently manage care. Patient pathways that include acceptable waiting times and define all necessary steps in the treatment of a disease, from diagnosis to cure or dignified death, have not yet been defined.

Overall, organizational interoperability challenges can be summarized as uneven digital maturity across providers as well as workforce digital competency variability, factors that can directly influence the effectiveness of technical and semantic interoperability.

4.3.2. Semantic interoperability

Semantic interoperability ensures that exchanged data preserve consistent meaning across different systems and institutional contexts.

In Croatian healthcare infrastructure it is implemented within CEZIH's structured message validation and the use of standardized coding lists as system incorporates automated validation mechanisms that verify compliance with predefined data structures and mandatory elements, automatically rejecting messages that do not conform to specified coding (Gvozdanović, 2020). Semantic consistency is further reinforced through standardized electronic workflows, including e-prescriptions, e-referrals, laboratory reporting and registry submissions.

The EHR contents is defined under the Ordinance on the Scope and Content of Data and the Management of Electronic Health Records from 2023 and represents a harmonized subset of longitudinal patient data collected across healthcare providers and it is structured in accordance with European Patient Summary specifications that are developed within the eHDSI framework (Belani et al., 2024), enabling compatibility with cross-border exchange initiatives.

Articles 5–9 define standardized clinical content using:

- ICD diagnostic codes,
- procedure codes,
- vaccination codes,
- implant classification codes,
- structured therapy elements,
- structured allergy and intolerance fields,
- Patient Summary for cross-border care (Art. 10).

Moreover, the 2024 Ordinance on Process, Technical, Organizational and Semantic Standards formally establishes requirements for structured data models, standardized terminology systems and interoperable coding frameworks across CEZIH and NAJS.

A case study on Croatia's implementation of secure, interoperable health data exchange, starting from the 2013 epSOS pilot to full production in 2019 for e-prescriptions and patient summaries using HL7 CDA standards (Belani et al., 2024) shows Croatia's leadership in EU cross-border e-health services via the eHDSI (MyHealth@EU) infrastructure. Described eHDSI architecture, including core EU services for interoperability, cybersecurity and terminology, connected via National Contact Points (NCPeH) enables two-way exchange of data as Croatian e-prescriptions are dispensable in Finland, Estonia, Portugal, Spain, Poland with patient summaries accessible too.

Despite, the implementation of full semantic harmonization at the institutional level seems incomplete due to variability in legacy systems across hospital information systems and limited transparency regarding nationwide implementation.

4.3.3. Technical Interoperability

Technical interoperability refers to the infrastructure and communication mechanisms that facilitate secure data exchange between systems. As the CEZIH architecture is based on centralized message exchange using standardized communication protocols, the infrastructure relies on (Ministry of Health, 2013):

- secure VPN connectivity,
- digital certificates for healthcare professionals,
- smart card authentication,
- SSL/TLS encrypted communication,
- role-based access control,
- centralized audit logging and
- HL7-based message exchange architecture.

This architecture enables real-time electronic prescription validation, automated referral routing, laboratory result exchange and billing communication with CHIF. By utilizing standardized interfaces rather than bilateral system connections, CEZIH reduces fragmentation and supports scalable national connectivity.

Integration with the NAJS further strengthens technical interoperability for epidemiological surveillance, cancer registry reporting and preventive programme monitoring.

According to Croatian IS implementation analysis, the 2021 case study (Osvaldić, 2021) highlights several technical barriers:

- incompatibility of certain hospital information systems,
- incomplete interconnection of all hospitals,
- paper-based transfer in some inter-hospital scenarios,
- limited research database accessibility,
- insufficient IT staff capacity and
- public procurement delays affecting infrastructure upgrades.

Thus, while foundational technical interoperability exists at national level, full seamless exchange across heterogeneous platforms remains incomplete.

4.3.4. DHI conformance

CEZIH provides nationwide infrastructure, supporting e-Prescriptions, e-Refferal and registry reporting workflows to integrate primary care, hospitals, pharmacies and public health institutions as a strong technical interoperability foundation for telemedicine, reducing fragmentation and ensuring timely access to longitudinal patient information across providers.

Yet, care pathways remain fragmented and siloed in practice. As regulations mandate standardization of data formats, models and coding through EHR (e-Karton and registries), securing semantic interoperability, there is unclear state of its adoption within hospital systems due to the variability of legacy systems and overall digital transformation at organizational level.

In contrast, cross-boarder data exchange via the eHDSI infrastructure show advanced and/or systemic level of maturity.

DHI scoring results are shown in Table 4.2.

Table 4.2 DHI conformity scoring for Interoperability dimension

indicator	score
existence of national health information exchange infrastructure enabling telemedicine workflows	2
standardization of data formats, data models and coding systems	1
workflow integration of cross-sector providers	1
cross-border data exchange readiness	2

4.4. Person-Enabled Health dimension

Within the DHI framework dimension of Person-Enabled Health seeks to evaluate the extent to which individuals are empowered to access, understand and use digital and health information for managing their own health. This includes patient access to records, engagement tools, digital literacy as well as health literacy as a prerequisite for meaningful and active participation.

Empirical evidence for Croatia indicates structural limitations in this domain, as nationally representative study (Bobinac, 2023) shows that more than half (53.1%) of the Croatian population has limited or problematic health literacy. Only 46.9% of them demonstrate adequate health literacy.

At the same time EU Digital decade report results show that Croatia achieved 59 % of its population aged 16–74 with at least basic digital skills in 2024. This share is slightly above the EU average of 55.6 %, but still below the EU 2030 target of 80 % (Kralj, 2024).

As digital access alone does not ensure effective patient engagement if individuals lack the cognitive and interpretative capacity to use health information meaningfully, Croatia's challenge is not only digital infrastructure maturity but also population readiness to utilize digital health tools.

Through the Health Portal integrated within the e-Citizens (hrv. e-Građani) platform, patients are able to access their electronic health record (e-Karton) on computer and mobile phones and review laboratory results, prescriptions, referrals, discharge letters and other clinical documentation. The system also enables patients to monitor access logs and verify which healthcare professionals have viewed their data, thus operationalising principles of transparency, accountability and data traceability.

Also, from a cross-border perspective, as already mentioned as a part of interoperability conformance, Croatia has been fully integrated into the eHDSI since 2019 (Belani et al., 2024), enabling the exchange of electronic prescriptions and patient summary documents with other EU Member States. This integration allows Croatian citizens to obtain prescribed medicines abroad and enables foreign healthcare providers to access structured patient summaries when treating Croatian patients, demonstrating a relatively advanced level of digital maturity within the Person-Enabled Health dimension as well.

But despite the established infrastructure for accessing personal data, the SWOT analysis of the National Health Care Development Plan (Ministarstvo zdravstva, 2021) identifies weaknesses that directly intersect with the Person-Enabled Health: weak results of health promotion and prevention measures, insufficient monitoring of outcome indicators, poor coordination of care pathways as well as general pain point - geographic inequalities in access to care.

In DHI terms, this signals moderate to low maturity in citizen engagement enablement, particularly in proactive health management and prevention, although National Plan introduces establishment of digital solutions to promote disease prevention and healthy lifestyles, envisioning digital applications that stimulate preventive behaviour and monitor patient health routines in order to support for self-care plans of patients. Besides reminders for appointments, medication intake and measurements, it will also provide feedback mechanisms and interactive communication between patients and providers.

Telemedicine also represents a critical component of citizen-centered digital health in Croatia as the Telemedicine Framework for Expansion of Emergency Medical Services (Ministarstvo zdravstva Republike Hrvatske, 2022) sets telemedicine as a formally integrated part of national emergency and specialist healthcare services. It operationalizes teleconsultations between emergency teams and specialists, remote diagnostic support, structured telemedicine access centres, integration with CEZIH workflows and standardized referral procedures identical to in-person care.

In order to reduce geographical disparities, particularly in rural and island regions, telemedicine services are available via patient-facing channels as Telemedicine Access Centres and provider-facing channels operationalized through Telemedicine Specialist Centres. However, the framework remains primarily oriented toward emergency and specialist consultation rather than longitudinal patient self-management.

Within mobile health solutions in Croatia two solutions stand out. EmERGE Health 3.0 is developed to support modern clinical monitoring of patients living with HIV/AIDS as the application enables patients access to complete laboratory results (including biochemical parameters, viral load and CD4 lymphocyte counts) via mobile devices and to retrieve historical laboratory data stored in the database of the University Hospital for Infectious Diseases “Dr. Fran Mihaljević” (from 1997 onwards), view graphical representations of CD4 and viral load trends over time. Also, they can receive physician comments on the most recent results.

Another case includes Continuous Glucose Monitoring Systems (CGM) systems (including sensor, a transmitter and a mobile application interface) that have been included on the basic reimbursement list of the Croatian Health Insurance Fund (HZZO) since 2021. The systems allow patients to monitor real-time glucose levels via mobile devices, track glucose trends over time and receive predictive alerts about rising or falling glucose levels up to 60 minutes in advance.

4.4.1. DHI conformance

Through the Health Portal there is systemic availability of patient records as patients are able to review core components of their electronic health record, including prescriptions, referrals, laboratory results, vaccination data and records of healthcare encounters.

However, patients' enablement in self-care do not extends beyond this „one sided “engagement. At least for now, as the National Health Care Development Plan envisions the expansion of digital tools that support prevention, self-management and continuous patient engagement. While there are some pilot initiatives and solutions of digital tools supporting prevention and self-care, their implementation remains fragmented and more programme-specific rather than systemic.

On the other, patient side, results of DESI and national studies show gaps in digital literacy affecting full patient engagement and representing an additional limiting factor for translation of available infrastructure into effective patient empowerment tools, as these disparities affect patients' ability to interpret and navigate digital health information and meaningfully participate in digitally-enabled healthcare.

DHI scoring results are shown in Table 4.3.

Table 4.3 DHI conformity scoring for Person-Enabled Health dimension

indicator	score
availability of patient records	2
digital tools supporting prevention and self-care	1
digital communication tools enabling individualized care pathways	1
population capacity to use digital health and digital literacy	1

4.5. Predictive Analytics dimension

The predictive analytics dimension in DHI framework assesses the overall capacity of a health system to transform collected data into actionable insights that support public health surveillance, enable system performance monitoring, research, policy-making and predictive modelling. It upgrades from mere data exchange toward structured analytics, outcome measurement and anticipatory governance.

A crucial structural shift in Croatian health data governance relevant for predictive analytics concerns the transition from aggregated annual reporting toward individual-level, real-time data extraction via CEZIH in 2021 (Draušnik et al., 2021). Primary care practitioners (family medicine, pediatrics, gynecology and dental medicine) began to transmit data directly to the Croatian Health Insurance Fund and subsequently to the Croatian Institute of Public Health (HZJZ), oppose to data being collected through predefined annual aggregated reports submitted by primary care practices to county public health institutes.

This shift fundamentally changes the analytical capacity of the system. Instead of retrospective annual summaries, the new model offers comprehensive coverage as all providers connected to CEZIH transmit data, higher accuracy of data and timeliness.

After every patient contact (including in-person visits, telephone consultations and e-mail consultations), a standardized electronic message titled “Report after each examination” is transmitted containing: visit metadata (date, time, provider, specialty code), patient identifier, diagnostic-therapeutic procedures, primary and secondary International Classification of Diseases (ICD) diagnoses, prescription and referral data.

More importantly, the HZZO system performs semantic validation before acceptance, including verification of mandatory elements, validation against official code lists, digital signature verification and authorization checks.

From a predictive analytics perspective, this architecture supports incidence and prevalence calculation, service utilization modelling, pathway reconstruction, early signal detection and health system performance monitoring.

Despite, the National Plan (Ministarstvo zdravstva, 2021) explicitly acknowledges that Croatia currently does not collect and analyze sufficient health system performance indicators compared to other EU Member States. This gap complicates outcome-based monitoring and evidence-based policymaking. As part of the technical assistance project implemented through the Structural Reform Support Programme, in cooperation with technical assistance providers, the Ministry of Health has initiated the process of developing a framework for measuring the effectiveness of health care (Health System Performance Assessment, HSPA), which will contribute to the establishment of key indicators for measuring effectiveness according to the established methodology, related to the process of linking measures to objectives set in national strategic planning acts and reforms, timeliness of data, and improve monitoring of health outcomes. This will enable the integration of policy and reforms into an overall performance review, which will enable the Ministry of Health and key stakeholders in the health system to monitor the implementation of reforms and design better evidence-based policies.

The availability of individual-level CEZIH data provides the necessary infrastructure for HSPA implementation as structured encounter-based datasets, performance assessment would remain limited only to financial or aggregate utilization indicators. In addition, the integration of NAJS and CEZIH enables real-time infectious disease notifications, structured cancer registry reporting and preventive programme monitoring.

However, as highlighted in the analysis by (Draušnik et al., 2021), certain data fields (e.g., case status for incidence calculations) still show quality inconsistencies, particularly when they are not clinically decisive for treatment, but crucial for epidemiological modeling, which underscores a key

maturity challenge of predictive analytics reliability depending not only on infrastructure, but on data entry culture and clinical coding discipline. Variability in data entry practices affects epidemiological accuracy.

Within CEZIH and NAJS, infectious disease notifications are processed electronically, enabling real-time or near real-time reporting from healthcare providers to public health authorities. Physicians and laboratories submit structured notifications of communicable diseases directly into the system, which are automatically transmitted to the Croatian Institute of Public Health and regional public health institutes.

Cancer registry reporting is integrated through standardized electronic data submission to the Croatian National Cancer Registry. Healthcare providers transmit structured oncological data (diagnosis codes, staging, treatment data) via interoperable channels, enabling systematic and continuous population-level monitoring of cancer incidence and outcomes.

Finally, preventive programmes, including national cancer screening initiatives and immunization programmes, are also digitally supported through CEZIH and NAJS integration as centralized data collection enables tracking of screening participation rates, identification of regional disparities, monitoring of follow-up compliance, automated reminders and coordination, policy adjustments based on measurable indicators.

The integration of appointment scheduling (hrv. e-Naručivanje) within the same workflow logic as in-person specialist visits reduces system fragmentation and improves continuity of care data flows.

So, these digital workflows reflect a transition from passive record storage toward outcome-oriented monitoring. However, the transition toward predictive modelling (e.g. outbreak forecasting supported by artificial intelligence) remains limited.

Structured electronic notification allows aggregation of standardized datasets suitable for national and EU-level monitoring as through DARWIN EU participation (HZJZ, 2025), Croatia contributes real-world evidence datasets under strict privacy controls to European-level observational research platforms.

4.5.1. DHI conformance

As structured datasets generated through CEZIH, NAJS and national health registries provide standardized, longitudinal and population-level information, the Croatian healthcare system possesses key technical preconditions for clinical decision analytics. Nevertheless, current evidence suggests that the systematic deployment of clinical decision support systems, artificial intelligence applications or advanced predictive models remains limited as existing digital infrastructure is primarily oriented toward data collection, reporting and administrative coordination.

Extensive network of disease registries and prevention programmes enables continuous epidemiological surveillance and the identification of high-risk population groups, showing strong systemic level of deployment of relevant indicator, although the operational use of real-time system performance data remains underdeveloped. The ongoing emergence of the HSPA framework represents a significant step toward systematic monitoring of key performance indicators, but real-time feedback loops and predictive performance analytics are still not fully embedded, constricting the transition from retrospective reporting to proactive system governance.

Contrary, Croatia's participation in the DARWIN EU network indicates advanced readiness for secondary use of health data.

DHI scoring results are shown in Table 4.4.

Table 4.4 DHI conformity scoring for Predictive Analytics dimension

indicator	score
clinical decision analytics	1
use of data to identify risk groups	2
use of real-time system performance data	1
infrastructure for secondary use of data	2

Conclusion

This thesis set out to assess the digital maturity of the Croatian healthcare system using the HIMSS Digital Health Indicator (DHI) as an analytical framework in order to evaluate national readiness to support telemedicine and e-health services within the scope of the European Health Data Space (EHDS).

By operationalising DHI into an analytical matrix for examining strategic and regulatory documents, implementation reports as well as other publicly available evidence, the research provides a structured digital maturity assessment across four core dimensions (governance and workforce, interoperability, person-enabled health and predictive analytics) and levels (low, emerging, moderate and high).

The findings indicate that the overall digital maturity of the Croatian healthcare system can be characterised as moderate as Croatia demonstrates strong foundations in centralized governance, national infrastructure and registry-based data generation, but limited systemic integration due to variability in workforce capacity, uneven patient enablement and limited routine use of advanced analytics. Although this results suggest substantial structural alignment with the EHDS framework, they show only partial operational readiness for sustainable telemedicine and e-health services.

So, to answer the main research question (*to what extent digital maturity of the Croatian healthcare system is in alignment with the European Health Data Space to support sustainable telemedicine and e-Health services?*) findings suggest that Croatia's digital maturity corresponds to an intermediate stage of EHDS alignment; foundational components have been established, but systemic integration has not yet been fully achieved. That reflects telemedicine and e-health services, whose sustainability depends on workforce skills, workflow (re)design, patient engagement and advanced analytics capacity. Therefore, Croatia can be characterised as EHDS-compatible but not yet EHDS-mature.

And to assess more specifically specific research questions the results should be viewed on the basis of the conducted DHI conformance analyses.

Croatia's policy and legal framework aligns well with EHDS, covering health data management, patient rights, standards and secondary use. Centralized platforms like CEZIH and NAJS enable federated interoperability, creating solid institutional foundations for scalable digital and cross-border services. Yet workforce readiness is uneven with persistent shortages of healthcare professionals, limited digital skills development and insufficient integration of health informatics roles as the main constraints to scaling telemedicine and digital transformation.

In terms of interoperability, Croatia exhibits very strong maturity. Nationwide exchange infrastructure supports e-prescriptions, referrals, registries and telemedicine services, directly

matching EHDS primary data needs. eHDSI participation proves cross-border readiness, while standardized models ensure semantic consistency. However, inconsistent hospital system integration prevents complete operational maturity.

In the Person-Enabled Health dimension, alignment is emerging rather than systemic. Citizens access health data via the Health Portal, supporting EHDS empowerment goals, but fragmented digital tools for prevention and self-management, plus digital literacy barriers, limit person-centered care. As a result, telemedicine services risk reinforcing inequalities without stronger patient engagement.

Predictive analytics reveals the clearest divergence between current maturity and EHDS expectations. As Croatia possesses extensive registries and surveillance datasets that support population-level monitoring and secondary data use, routine integration of analytics into clinical decision-making, system performance management and predictive governance remains limited. The emerging Health System Performance Assessment framework and participation in initiatives such as DARWIN EU signals movement toward EHDS data-driven governance and infrastructural readiness, but this transition is still in progress.

Study contributions and limitations

The study, through a systematic examination of the relationships and significance of the identified digital maturity indicators across DHI dimensions, at a theoretical level, contributes to digital maturity research by operationalization of maturity frameworks to assess telemedicine and e-health service delivery levels. Also, findings have direct methodological, as well as practical implications, for healthcare practitioners, policymakers and organisations managing digital transformation processes providing a structured approach for evaluating digital maturity and identifying gaps in conformity between requirements and operational implementation.

This research is limited by its reliance on secondary sources, through document analysis and publicly available evidence, rather than primary data from healthcare institutions, especially in telemedicine adoption, for which utilisation metrics should be more specific. As DHI operationalisation at national level required interpretative scoring from multiple sources, results may introduce subjectivity despite the structured methodology.

So, future research could extend this research through more surveys and comparative cross-country analyses of EHDS implementation at institutional level. Using more detailed metrics and indicators of workforce digital competencies, patient engagement models and real-time analytics adoption, these research would improve results in clarifying the gaps and pathways toward higher digital maturity levels in Croatian healthcare.

Overall, Croatian healthcare can be described as a system with strong digital foundations and established operational services that is still progressing toward systemic integration. Although telemedicine and e-health are technically feasible and strategically prioritised, their full potential depends on development of workforce capacity, patient enablement and predictive analytics governance. As digital maturity is not a fixed state, but a dynamic process where infrastructure, institutions and users should co-evolve, this study offers a strong foundation for steering Croatia's next steps in digital transformation of healthcare.

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