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Beyond Direct Savings: Administrative Productivity, Dual Workflows and Risk-Adjusted Assessment of Healthcare Digitalization in Kazakhstan

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Abstract. Digital health investments are often justified by the expectation of direct cost savings, faster administrative processing and lower paper-based document flows. Hospital-level evidence from transition economies, however, may show a more complex pattern: digital systems expand, service volumes grow, technical support costs increase and paper-based procedures continue. This article analyses healthcare digitalization in the University Hospital of NJSC Semey Medical University in Kazakhstan for 2019-2025 as a public-sector digital transformation case. The study uses aggregated institutional data and separates three types of evidence: observed accounting shifts, observed administrative productivity and scenario-based monetization of potential staff time savings. Administrative productivity increased from 460 to 670 treated cases per administrative employee, while electronic medical records, laboratory tests and diagnostic examinations also expanded. At the same time, the accounting data do not support a simple claim of direct financial savings: total administrative expenditures, archive expenditures, registry expenditures and paper-based document-flow costs increased during the observation period. This mixed pattern is interpreted as a dual-workflow effect, where digital and paper-based processes coexisted rather than fully replacing one another. Total IT and digitalization expenditures amounted to KZT 182.6 million. The modelled value of potential staff time savings is KZT 240.1 million under baseline assumptions, but it is treated strictly as a scenario estimate, not as audited savings. The baseline scenario produces a conditional ROI of 31.5%, whereas risk-adjusted and pessimistic scenarios become negative. The article contributes to digital health governance by showing that hospital digitalization may improve administrative productivity without immediately producing direct budgetary savings.

Keywords: healthcare digitalization; hospital economics; total cost of ownership; administrative productivity; dual workflow; Kazakhstan; ROI; NPV; scenario analysis; digital health investment.

1. Introduction

Digital transformation has become one of the central directions in the modernization of healthcare systems. Hospitals increasingly rely on electronic health records, medical information systems, digital administrative platforms, electronic document management, laboratory information systems, telemedicine tools, clinical decision-support systems and data-driven management instruments. At the global level, digital health is usually discussed as a way to strengthen healthcare systems, improve access to care, enhance data governance and support more sustainable models of healthcare delivery (World Health Organization, 2021; OECD, 2019). In hospital practice, however, digital technologies are expected to do more than improve clinical quality. They are also expected to influence workflows, administrative coordination, the use of staff time, resource allocation and the reliability of managerial information (Chaudhry et al., 2006; Buntin et al., 2011). Recent reviews of healthcare digital transformation also emphasize that technology adoption must be analysed together with acceptance, organizational readiness and the ability of health systems to use data for performance management (Stoumpos et al., 2023; OECD, 2023).

The international literature links hospital digitalization with several possible economic effects. These include lower administrative costs, reduced duplication of clinical and managerial procedures, faster access to patient information, improved accounting accuracy, better use of diagnostic and laboratory capacity, and higher labour productivity. Early systematic reviews showed that health information technologies can improve the quality, efficiency and cost structure of medical care, although the size and direction of the effect depend on the type of technology, the

level of implementation, interoperability and organizational readiness (Chaudhry et al., 2006; Goldzweig et al., 2009; Buntin et al., 2011). Modelling studies on the adoption of electronic medical records have also demonstrated a substantial potential for savings when systems are interoperable and introduced at scale (Hillestad et al., 2005). At the same time, later studies have made the picture less straightforward. They show that the economic effect of electronic medical systems is neither immediate nor automatic: costs may rise during the initial period, and positive outcomes usually depend on complementary organizational changes, staff adaptation and process redesign (Dranove et al., 2014; Agha, 2014).

This distinction is especially important for transition economies. In such contexts, hospitals may introduce electronic systems while continuing to maintain paper files, printed forms, archive procedures and parallel reporting channels. As a result, digitalization may increase IT and support costs before it produces visible financial savings. A hospital can process more patients, maintain more electronic records and expand digital reporting, but still report growing administrative, registry, paper-based and archive-related expenditures. Therefore, the economic question is not only whether digital systems exist, but how their consequences should be interpreted when digital and paper-based workflows coexist.

For Kazakhstan, this issue has practical and policy relevance. The country has been moving from fragmented medical information systems towards a more integrated digital architecture for healthcare. According to the WHO European Observatory, digital health in Kazakhstan is an important instrument for strengthening the national health system and requires coordinated national-level action (Abishev & Spatayev, 2019). Recent studies also show that Kazakhstan has moved from a predominantly paper-based model of medical information towards the gradual introduction of digital data, electronic processes and medical information systems, while problems of standardization, interoperability and uneven data collection remain unresolved (Nurgaliyeva et al., 2024).

In 2026, Kazakhstan announced a course towards consolidating existing information systems, developing the Unified State Medical Information System, creating the Smart Data Healthcare repository and integrating healthcare services with QazTech and eGov platforms. These measures are intended to support end-to-end analytics, forecasting, data-based managerial decisions and the principle that data should follow the patient (Government of the Republic of Kazakhstan, 2026). Official statements by the Ministry of Health also emphasize that the Unified State Medical Information System should become the basis of a single digital architecture in the sector, replacing fragmented interfaces and providing physicians with a single digital workspace (Ministry of Health of the Republic of Kazakhstan, 2026).

The relevance of this problem is reinforced by the fact that healthcare digitalization in Kazakhstan is no longer limited to electronic medical records and document flows. It is increasingly associated with artificial intelligence, biometric identification, electronic prescriptions, digital monitoring of healthcare quality and big data analytics. According to UNDP Kazakhstan, the country has 17 national healthcare information systems; more than 1,800 medical organizations use a digital patient identification system; and more than 75% of prescriptions are issued electronically. At the same time, insufficient connectivity between information systems remains a key constraint that limits the full managerial and economic value of digital health infrastructure (UNDP Kazakhstan, 2026; World Health Organization Regional Office for Europe, 2023). Thus, the main research problem is not the formal presence of digital solutions, but the extent to which they are transformed into measurable organizational and economic results at the hospital level. The COVID-19 period also demonstrated that digital technologies can rapidly become part of public-health response and service delivery, but their institutional effects depend on governance, data infrastructure and implementation capacity (Budd et al., 2020).

Kazakhstani studies emphasize that healthcare digitalization includes electronic medical records, clinical decision-support systems, digital medical documentation and artificial intelligence tools. Expected effects include faster clinical decision-making, lower administrative workload, better quality of care and improved resource use. At the same time, researchers point to barriers related to system integration, personal data protection, digital literacy of medical staff and continuous monitoring of digital solutions (Sabigolla & Golovacheva, 2025). These barriers are important because they explain why the economic effect of digitalization may be delayed, partial or difficult to measure through direct financial indicators alone.

The presence of digital infrastructure does not guarantee an immediate economic return. Digital projects often require additional expenditures on implementation, technical support, staff training, data integration, software maintenance, licences, cybersecurity and organizational adaptation (Kellermann & Jones, 2013; Gomes et al., 2022; Gentili et al., 2022). International research shows that the positive effect of healthcare digitalization depends on system interoperability, the quality of organizational integration, staff readiness and the evaluation horizon. Electronic health records and medical information systems may reduce costs and improve efficiency, but in the short term they may also

increase costs and create a J-curve effect, where economic returns become visible only after a period of adaptation (Hillestad et al., 2005; Dranove et al., 2014; Agha, 2014).

This problem becomes even more complex in university hospitals. Such organizations combine clinical, educational, research and managerial functions. Their information flows are more intensive than in many standard medical organizations because they include patient care, teaching processes, clinical training, departmental coordination, reporting to public authorities and interaction with external digital platforms. From the perspective of transaction cost economics, the economic value of digitalization lies in reducing the costs of searching, transmitting, verifying and coordinating information between participants in organizational processes (Williamson, 1985). From the perspective of IT complementarity theory, however, digital capital produces sustainable returns only when it is combined with organizational change, staff competence development, process redesign and managerial innovation (Brynjolfsson & Hitt, 2000; Dranove et al., 2014). This means that a hospital may invest in digital systems but fail to achieve direct savings if old paper-based routines continue to operate in parallel with electronic systems.

The case of the University Hospital of NJSC Semey Medical University illustrates this tension. During 2019–2025, the hospital increased the number of treated cases, electronic medical records, laboratory tests and diagnostic examinations. Administrative productivity also improved, as the number of treated cases per administrative employee increased. At the same time, the hospital's accounting data show that several expenditure lines associated with administration, registry work, archiving and paper-based document flows increased rather than decreased. This creates an important empirical puzzle. Digitalization appears to be associated with higher operational intensity and administrative productivity, but the available accounting data do not support a simple claim of direct cost reduction.

This article therefore does not treat digitalization as a self-evident source of financial savings. Instead, it separates three types of evidence. The first is observed accounting data, including IT expenditures, administrative expenditures, registry costs, archive costs and paper-based document flow costs. The second is observed operational and productivity data, including treated cases, electronic medical records, laboratory tests, diagnostic examinations and administrative productivity. The third is scenario-based estimation of potential staff time savings, which is used to calculate conditional ROI, NPV and payback indicators. This distinction is necessary because modelled time-value benefits are not the same as audited financial savings.

Despite the importance of this issue, Kazakhstan still lacks hospital-level studies that evaluate healthcare digitalization not merely as a technological reform, but as an investment process with costs, potential benefits, risks and implementation constraints. International research on the economic evaluation of digital health emphasizes the need to consider not only direct financial results, but also the time horizon, organizational readiness, implementation quality, sensitivity to risks and the specific methodological challenges of evaluating digital health solutions (Gomes et al., 2022; Gentili et al., 2022; Drummond et al., 2015). For transition economies, such hospital-level studies are particularly important because they show how digital investments operate in real institutional settings, where electronic and paper-based processes may coexist for a long period.

Against this background, the present study develops a risk-adjusted assessment of healthcare digitalization using the case of the University Hospital of NJSC Semey Medical University. Unlike a narrow efficiency assessment, the proposed approach does not assume that all digital activity automatically generates financial savings. It examines whether digitalization is associated with operational productivity gains, whether these gains are reflected in accounting expenditures, and how sensitive the modelled investment results are to assumptions about staff time savings, system use and implementation risks. This approach treats digitalization as an investment process under uncertainty, where the economic result depends not only on IT infrastructure, but also on the degree of organizational integration and the ability of the hospital to reduce duplicate paper-based procedures.

The purpose of this study is to assess the economic consequences of healthcare digitalization in a Kazakhstani university hospital by distinguishing between observed accounting data, observed operational productivity indicators and scenario-based estimates of potential staff time savings. This formulation avoids claiming direct financial savings where the accounting data do not support such a conclusion.

To achieve this purpose, the study sets the following objectives: (1) to systematize theoretical approaches to the economic evaluation of healthcare digitalization; (2) to justify the use of a risk-adjusted approach to digital investment in healthcare; (3) to construct a system of financial, operational and digital indicators for a university hospital; (4) to compare the dynamics of digital activity, administrative productivity and administrative expenditure indicators; (5) to estimate conditional ROI, NPV and payback indicators on the basis of scenario-based staff time savings; and (6) to identify managerial implications for healthcare organizations operating under conditions of incomplete substitution of paper-based processes.

The scientific novelty of the study lies in developing and empirically applying a risk-adjusted framework for assessing healthcare digitalization under conditions where digital and paper-based workflows coexist. The article contributes to the literature not merely by applying ROI and NPV to hospital digitalization, but by separating three analytically different outcomes: accounting savings, administrative productivity and modelled time-value benefits. This separation helps avoid treating potential staff time savings as realized budget savings and shows that a positive modelled ROI can coexist with rising administrative and paper-related expenditures.

2. Literature Review and Hypothesis Development

2.1. Digital Health, Hospital Efficiency and the Attribution Problem

The literature treats healthcare digitalization as the integration of information and communication technologies into the clinical, administrative, financial and managerial processes of medical organizations (World Health Organization, 2021; OECD, 2019; Chaudhry et al., 2006). At the hospital level, digitalization includes electronic health records, medical information systems, digital patient registration, electronic document management, laboratory and diagnostic information systems, electronic archives, billing platforms and integration with public digital systems (Hillestad et al., 2005; Buntin et al., 2011; Adler-Milstein & Jha, 2017).

International studies usually associate hospital digitalization with several channels of economic value creation. The first channel is the reduction of administrative and transaction costs. Electronic systems may reduce the need for repeated data entry, accelerate access to patient information, improve the accuracy of accounting and reduce errors in documentation and reporting (Chaudhry et al., 2006; Goldzweig et al., 2009). The second channel is higher productivity of medical and administrative staff. By automating routine operations, staff can process documents more quickly, generate reports, access patient histories and coordinate activities across departments (Buntin et al., 2011; Agha, 2014). The third channel is better use of hospital resources, including beds, diagnostic equipment, laboratory capacity and staff working time (Hillestad et al., 2005; Drummond et al., 2015).

However, these channels should not be interpreted as automatic evidence of direct financial savings. The central methodological problem is attribution. A reduction in processing time does not necessarily lead to a reduction in payroll expenditures. Similarly, an increase in administrative or paper-related expenditures does not automatically mean that digitalization has no value, especially if the hospital simultaneously treats more patients, processes more electronic records and increases diagnostic or laboratory activity. Therefore, digital health evaluation should distinguish between three categories of results: audited financial savings, observed productivity gains and modelled potential benefits.

Audited savings are reflected in accounting records and can be observed through actual changes in expenditures. Productivity gains are reflected in operational ratios, such as treated cases per administrative employee or the number of electronic medical records processed by existing staff. Modelled potential benefits are estimated through assumptions about staff time saved and the monetary value of released working time. These categories answer different research questions and should not be merged into one undifferentiated efficiency claim. This distinction is particularly important in hospital-level studies, where digital systems may improve throughput without immediately reducing budget lines.

International evidence confirms that the economic effect of digitalization depends on the scale of implementation, the maturity of digital infrastructure, the quality of system integration, staff readiness and the time horizon of evaluation (Dranove et al., 2014; Kellermann & Jones, 2013; Nguyen et al., 2014). Economic results are largely shaped by institutional readiness, managerial capacity, implementation quality and the organization's ability to redesign internal processes around new digital tools (Brynjolfsson & Hitt, 2000; Gomes et al., 2022). For transition economies, this issue is especially relevant because digital projects are often implemented under resource constraints, incomplete interoperability and uneven organizational readiness.

2.2. Transaction Cost Economics and the Hospital-Level Value of Digitalization

Transaction cost economics provides a useful theoretical explanation of why digitalization may improve the economic performance of hospitals (Williamson, 1985; Williamson, 1998). In medical organizations, a significant share of costs is connected not only with the direct delivery of healthcare services, but also with coordination: patient registration, document preparation, information exchange between departments, retrieval of medical records, referral processing, reporting, billing and interaction with insurance or public authorities.

Digital systems can reduce transaction costs by accelerating information exchange, reducing data duplication, standardizing procedures and improving the transparency of managerial decisions (Williamson, 1985; Hillestad et al., 2005; Goldzweig et al., 2009). For example, electronic health records may reduce the time required to search for patient information; electronic document management may reduce delays in preparing and transmitting documents; and

integration with financial and accounting systems may improve billing accuracy and reduce repeated data processing (Chaudhry et al., 2006; Buntin et al., 2011).

At the same time, transaction costs do not disappear simply because a hospital has introduced a digital system. They may change their form. Costs previously associated with paper handling and manual coordination may be replaced or supplemented by costs for technical support, software maintenance, user assistance, data integration, licences and cybersecurity. Therefore, the reduction of one type of transaction cost may coexist with the growth of another type of organizational or technological cost.

For a university hospital, transaction costs are especially important because its activities include not only patient care, but also education, research, clinical training, interaction with the university, public authorities and insurance institutions. Digitalization can therefore create economic value not only through direct financial savings, but also through better manageability of a complex organizational system (Dranove et al., 2014; Nguyen et al., 2014; Gomes et al., 2022). In such organizations, a narrow focus on accounting savings may underestimate the role of digital systems in supporting higher service volumes and more intensive information flows.

2.3. Total Cost of Ownership and Dual Workflows in Hospital Digitalization

Hospital digitalization is not limited to the purchase of software. It also requires hardware, integration with external systems, technical support, licences, subscriptions, staff training, cybersecurity, user assistance and continuous adaptation of organizational processes. These elements form the total cost of ownership of digital health infrastructure. In early or transitional stages, total cost of ownership may grow faster than measurable savings, especially when old procedures remain in place.

This is one of the reasons why the economic outcomes of digital health projects are often mixed. International research shows that the introduction of electronic systems may increase costs at the initial stage and produce positive results only later, after organizational adaptation and stable system use (Dranove et al., 2014; Agha, 2014; Kellermann & Jones, 2013). Digital health interventions may therefore look inefficient if they are evaluated only through short-term expenditure dynamics. Conversely, they may look too optimistic if potential time savings are treated as audited financial savings.

The dual-workflow effect is particularly relevant in hospitals. For legal, clinical, managerial or organizational reasons, electronic records may coexist with paper documents. Staff may enter data into information systems while also printing, signing, storing or archiving physical documents. In this situation, digitalization can improve transparency, speed of information access and throughput, but it will not immediately reduce paper or archive costs. Instead, the hospital may temporarily bear the costs of both digital and paper-based processes.

This issue is especially important for transition economies, where digital transformation often occurs in stages. Medical organizations may connect to national platforms and introduce electronic records while still maintaining physical archives and printed documentation. Therefore, a hospital-level assessment should explicitly account for the possibility that digitalization increases operational capacity before it produces direct expenditure reductions.

2.4. IT Productivity Paradox, Complementarity Theory and J-Curve Logic

One reason why the outcomes of digitalization are difficult to measure is the so-called productivity paradox of information technology. The paradox suggests that substantial IT investments do not always immediately translate into higher productivity or financial returns (Solow, 1987; Brynjolfsson, 1993; Brynjolfsson & Hitt, 2000). In healthcare, this issue is particularly visible because digital systems require staff training, process adaptation, data integration and changes in professional routines (Kellermann & Jones, 2013; Dranove et al., 2014).

IT complementarity theory explains that digital capital creates economic value only when it is combined with complementary organizational changes: process redesign, improved digital competences, management analytics, better data quality and appropriate incentives for system use (Brynjolfsson & Hitt, 2000; Dranove et al., 2014). If a digital system is introduced without changing work processes, it may fail to reduce costs and may instead create additional workload for medical and administrative staff (Kellermann & Jones, 2013; Gomes et al., 2022).

The J-curve concept is also important for analysing healthcare digitalization. It assumes that returns on IT investment may appear with a time lag. Costs increase first because organizations must configure systems, purchase equipment, provide technical support, train staff and adapt processes. Benefits appear later if systems are used consistently and if electronic procedures replace, rather than merely duplicate, manual procedures (Brynjolfsson & Hitt, 2000; Dranove et al., 2014; Agha, 2014).

For the present study, this means that the evaluation of digitalization in a university hospital should consider not only current costs and modelled benefits, but also the time dynamics of economic returns. A positive baseline ROI may

indicate potential economic value, but it should not be interpreted as definitive evidence of audited savings if administrative, paper-based or archive-related expenditures continue to grow.

2.5. Investment Risk and Risk-Adjusted Evaluation of Digital Health Projects

The digitalization of a medical organization is an investment project characterized by considerable uncertainty. Unlike the purchase of standard equipment, digital transformation affects organizational processes, staff behaviour, data structures, financial accounting, document flows and interaction with external platforms. Therefore, the assessment of digitalization should include risk analysis.

The main investment and organizational risks include higher actual costs compared with planned costs, delays in implementation, low staff readiness, incomplete integration with existing processes, duplication of paper-based and electronic document flows, technical failures, system downtime, insufficient use of system functionality, rising costs of support and licences, cybersecurity requirements and the absence of managerial accounting for the economic effects of digitalization.

A risk-adjusted assessment is therefore more suitable than a single baseline ROI. It allows researchers to test whether a positive result remains stable when benefits are lower, support costs are higher or duplicate paper-based processes persist. This is especially important for university hospitals, where digital systems are implemented in a complex organizational environment and may have different effects on clinical, administrative, educational and financial processes.

In the present study, ROI and NPV are interpreted as scenario indicators rather than as definitive proof of audited financial savings. The modelled monetized value of staff time savings is treated as a potential economic benefit, while accounting data are used separately to assess whether direct expenditure reductions are observed. This separation is necessary to avoid methodological circularity and to prevent potential time savings from being confused with realized budget savings.

2.6. Hypothesis Development

Based on the theoretical arguments above, the study formulates four hypotheses. Unlike a conventional approach that assumes digitalization automatically leads to efficiency, the present study distinguishes between productivity effects, direct expenditure effects and scenario-based investment results.

H1. Expansion of digital systems is associated with higher administrative productivity in a university hospital.

This hypothesis is based on the assumption that electronic document management, digital patient registration, medical information systems and electronic archives reduce the time required to process, store, retrieve and transmit information. As a result, a medical organization may be able to serve a larger number of patients and process a greater volume of medical documentation without a proportional increase in administrative staff. This hypothesis can be tested using treated cases and administrative staffing data.

H2. Digitalization leads to direct reductions in administrative, paper-based and archive-related expenditures.

This hypothesis reflects the conventional expectation that digital systems reduce paper document flows, archive costs and administrative expenditures. However, this expectation requires direct accounting evidence. If administrative, paper-based or archive-related expenditures increase during the study period, the hypothesis should not be supported, even if operational productivity improves.

H3. Potential staff time savings can generate a positive modelled ROI under baseline assumptions.

This hypothesis recognizes that digitalization may release staff time even when direct budget savings are not visible in accounting records. The monetized value of released time can be used to calculate conditional ROI, NPV and payback indicators. However, this hypothesis can only be conditionally supported because modelled time savings are not equivalent to audited financial savings.

H4. Risk-adjusted efficiency is sensitive to incomplete substitution, support costs and dual workflows.

This hypothesis is based on the logic that digital investment results depend on implementation quality. If system use is incomplete, support costs increase or paper-based procedures continue in parallel with digital processes, risk-adjusted ROI and NPV may deteriorate. The hypothesis is supported if risk-adjusted or pessimistic scenarios produce substantially weaker or negative results compared with the baseline scenario.

3. Institutional Context and Case Description

3.1. Digital Healthcare in Kazakhstan: Policy and Institutional Background

Healthcare digitalization in Kazakhstan has developed as part of a broader public policy agenda aimed at modernizing public services, increasing governance transparency and developing the digital economy. The informatization of the healthcare system has gone through several stages: from the introduction of individual

information systems and electronic services to the gradual digital transformation of processes, data flows and sectoral governance mechanisms (Ministry of Health of the Republic of Kazakhstan, 2020). According to the WHO European Observatory, digital health in Kazakhstan is an important instrument for health system development and requires coordinated national-level action (Abishev & Spatayev, 2019). Digital solutions have supported the transition from paper-based processes to electronic accounting, improved access to medical information, integration of medical organizations with public platforms and the development of management analytics (Ministry of Health of the Republic of Kazakhstan, 2020; UNDP Kazakhstan, 2026).

The key directions of healthcare digitalization in Kazakhstan include the implementation of medical information systems, the development of electronic health records, digitalization of document flows in medical organizations, integration with Ministry of Health information systems, interaction with the compulsory social health insurance system, the development of electronic services for patients, centralized medical data storage and the expansion of digital reporting and monitoring (Abishev & Spatayev, 2019; Ministry of Health of the Republic of Kazakhstan, 2020; Government of the Republic of Kazakhstan, 2026). In 2026, Kazakhstan announced a transition towards consolidating existing information systems, developing the Unified State Medical Information System and creating the Smart Data Healthcare repository. These initiatives are intended to bring together data from public and private medical information systems and to enable end-to-end monitoring of financial flows, quality and volumes of medical care (Government of the Republic of Kazakhstan, 2026; Ministry of Health of the Republic of Kazakhstan, 2026).

Patient-oriented digital services are another important direction of reform. According to the Government of Kazakhstan, the electronic health passport was already available to citizens through the eGov and mGov platforms at an earlier stage of sectoral digitalization (Government of the Republic of Kazakhstan, 2019). Later, the national digital health agenda expanded to include eHealth.kz, electronic prescriptions, digital patient identification, biometric confirmation of visits and the use of artificial intelligence in monitoring healthcare quality (Government of the Republic of Kazakhstan, 2026; UNDP Kazakhstan, 2026). UNDP Kazakhstan reports that the country has 17 national health information systems, more than 1,800 medical organizations using digital patient identification, and more than 75% of prescriptions issued electronically (UNDP Kazakhstan, 2026).

However, the presence of national digital infrastructure does not automatically mean that the economic effect of digitalization is fully realized at the level of each medical organization. Incomplete connectivity between information systems remains an important constraint. In practice, medical organizations may be connected to public digital platforms while still maintaining internal paper-based procedures, printed forms, local archives and parallel reporting practices. Therefore, the hospital-level effect of digitalization depends not only on national policy and technical availability, but also on institutional readiness, managerial accounting, staff adaptation and the ability of the organization to replace old routines rather than merely add new digital ones.

Kazakhstani studies also emphasize that healthcare digitalization affects not only clinical processes, but also the professional activity of medical specialists, quality of care and patient satisfaction. Digitalization includes electronic medical records, clinical decision-support systems, digital medical documentation and artificial intelligence tools. Expected effects include faster clinical decision-making, reduced administrative workload, better quality of care and improved resource use. At the same time, the barriers remain substantial: system integration, personal data protection, digital literacy of medical staff and continuous monitoring of the effectiveness of digital solutions (Sabigolla & Golovacheva, 2025).

For this reason, Kazakhstan still lacks hospital-level studies that assess healthcare digitalization from the perspective of investment efficiency, total cost of ownership and risk-adjusted economic results. Most existing approaches focus on describing digital reforms, technical solutions, electronic records, artificial intelligence and system-wide outcomes (Abishev & Spatayev, 2019; Sabigolla & Golovacheva, 2025; UNDP Kazakhstan, 2026). International methodology for the economic evaluation of digital health solutions, however, stresses the need to analyse costs, benefits, evaluation horizons, sensitivity to risks and organizational context (Drummond et al., 2015; Gomes et al., 2022). The case of a university hospital in Semey therefore helps address an important research gap by showing how national digital health policy is reflected in the operational and financial indicators of a specific medical organization.

The findings are also relevant to the Sustainable Development Goals (SDGs). Healthcare digitalization directly supports SDG 3 by improving the organizational capacity of medical institutions and indirectly contributes to SDG 9 through digital infrastructure and innovation. In the context of public administration, risk-adjusted assessment of digital investments is also linked to SDG 16, as it strengthens transparency, accountability and evidence-based decision-making in public healthcare organizations. In this sense, the proposed assessment is not only an economic calculation, but also a tool for aligning digital health investments with sustainable public-sector performance.

3.2. Case Description: University Hospital of NJSC Semey Medical University

The object of the study is the University Hospital of NJSC Semey Medical University. The hospital is a multidisciplinary medical and teaching organization that combines inpatient, outpatient, diagnostic, educational and research functions. This institutional profile makes it a relevant case for analysing healthcare digitalization because university hospitals operate with more complex information flows than many standard medical organizations. These flows include patient records, laboratory results, diagnostic examinations, inpatient documentation, outpatient referrals, reporting, educational documentation, clinical training materials and interaction with national healthcare platforms. According to information from NJSC Semey Medical University, the University Hospital is a multidisciplinary medical and teaching institution with 465 beds (Semey Medical University, n.d.). Its structure includes an adult inpatient unit with 319 beds and a paediatric inpatient unit with 146 beds. The adult inpatient unit includes cardiology, surgery, neurosurgery, neurology, gastroenterology, otolaryngology, cardiovascular and maxillofacial surgery departments, as well as an anaesthesiology, resuscitation and intensive care department. The paediatric unit includes paediatrics, surgery, otolaryngology, neurology, maxillofacial surgery, intensive care and resuscitation departments (Semey Medical University, n.d.).

In addition to round-the-clock inpatient care, the hospital has a 60-bed day hospital, 12 paraclinical diagnostic and treatment departments, an X-ray endovascular laboratory, a computed tomography room and its own consultative and diagnostic polyclinic covering a wide range of specialties. The presence of inpatient, outpatient, diagnostic and high-technology medical services increases organizational complexity and generates a substantial volume of administrative, clinical and financial data. This makes digitalization not only a technical issue, but also a factor of manageability, coordination and institutional transparency.

The hospital provides specialized and high-technology medical services in areas such as cardiac surgery, neurosurgery, interventional cardiology and angiosurgery. According to the order of the Ministry of Health of the Republic of Kazakhstan dated 8 December 2020 No. KR DSM-238/2020 on the approval of rules for providing specialized, including high-technology, medical care, 10 of the 13 approved technologies were implemented in the X-ray endovascular laboratory of the University Hospital in 2022. This confirms the high clinical and technological level of the organization and underlines the importance of accurate digital accounting of medical interventions, patient pathways, costs and treatment outcomes.

A specific feature of the University Hospital is its connection with the educational and research activities of NJSC Semey Medical University. Thirteen of the university's 23 departments are located at the hospital, allowing students to combine theoretical training with practical clinical skills. This structure increases the role of digital systems because electronic information is used not only for patient care, but also for educational processes, clinical training, research, reporting and communication between departments.

Hospital staff regularly master and introduce new treatment methods, including radiofrequency ablation for degenerative spinal diseases, minimally invasive brain and spinal cord surgeries using a modern operating microscope, and endovascular methods for treating vascular pathologies. Such high-technology medical areas increase the need for reliable medical information, digital document flows, coordination of treatment processes and managerial control over costs.

3.3. Digital Systems Implemented in the Hospital

The study covers the period from 2019 to 2025. The year 2019 is not treated as a non-digital baseline because the hospital already reported the use of core digital systems. According to the supplementary institutional data, the medical information system / HIS / MIS, electronic health records, the laboratory information system and integration with SHIF, eGov and Ministry of Health systems were implemented and fully launched in 2019. These systems were reported as used across the relevant departments, including all departments for the HIS/MIS and national platform integration, the polyclinic for electronic health records and the laboratory for the laboratory information system.

This means that the article does not assess a transition from zero digitalization. Instead, it examines the expansion, maintenance and economic consequences of digital system use in a hospital where the basic digital architecture was already functioning at the beginning of the observation period. This point is methodologically important because 2019 is used as the baseline year of observation, not as a period without digital technologies.

Telemedicine was reported from 2024 and was used for medical consultations and consilia in clinical departments, but its use was not quantified in the available institutional data. Therefore, telemedicine is treated as part of the institutional context rather than as a separate measurable driver in the economic calculations. This avoids overstating its contribution to ROI, NPV or staff time savings.

Kazakhstan represents a transition-economy case where national digital health platforms are expanding, but institutional-level substitution of paper workflows remains incomplete.

The hospital case is also important because the existence of digital systems did not automatically eliminate paper-based and archive-related processes. The supplementary data show that electronic systems were already in place, but administrative, registry, paper-based and archive-related expenditure lines continued to exist and, in some cases, increased during the study period. This confirms that the hospital operated under conditions of incomplete substitution, where digital and paper-based workflows coexisted. For this reason, the case is suitable for testing a risk-adjusted approach rather than a simple claim that digitalization directly reduced costs.

Thus, the University Hospital of NJSC Semey Medical University represents a relevant institutional case for analysing digitalization in a transition-economy healthcare system. It combines national digital health integration, a complex university hospital structure, high-technology medical services and persistent paper-based procedures. This combination makes it possible to examine not only the potential benefits of digitalization, but also the implementation risks, total cost of ownership and dual-workflow effects that shape the real economic outcomes of digital health projects. value benefits under dual-workflow conditions.

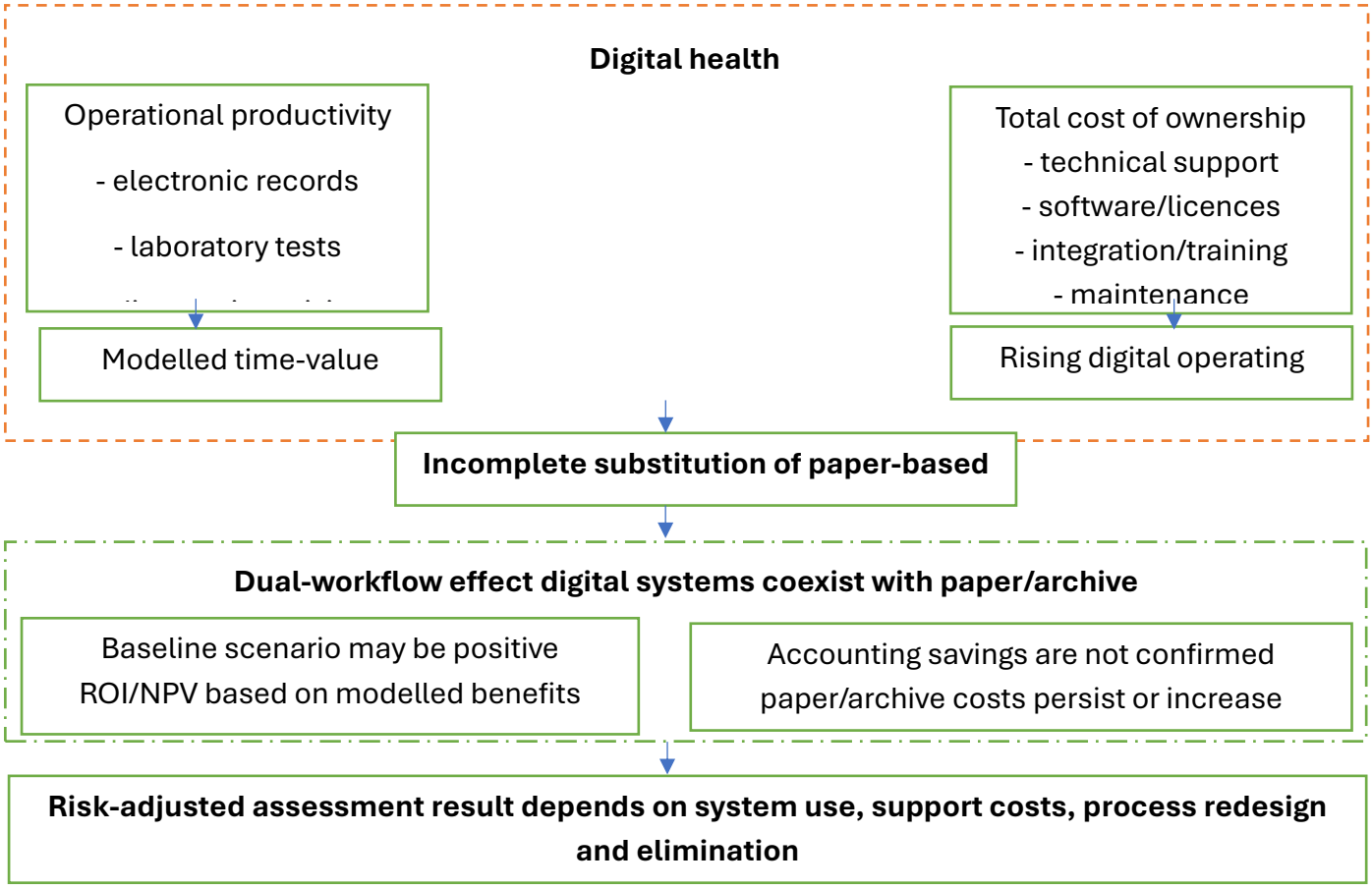


Figure 1. Conceptual framework for assessing healthcare digitalization outcomes in a university hospital

Note: developed by the authors to separate observed accounting evidence, observed productivity evidence and modelled time-value benefits under dual-workflow conditions.

Figure 1 presents the conceptual framework of the study. The model shows that digital health infrastructure may generate two simultaneous and partly conflicting pathways. The first pathway is operational: digital systems support the growth of electronic medical records, laboratory tests, diagnostic examinations and treated cases, which may increase administrative productivity and create modelled time-value benefits. The second pathway is cost-related: digital infrastructure requires technical support, software, licences, integration, maintenance, user assistance and staff training, which together form the total cost of ownership.

The central condition in the model is incomplete substitution of paper-based processes. If electronic systems do not fully replace paper documentation and archive procedures, the hospital operates under a dual-workflow effect. In this situation, digital and paper-based processes coexist. As a result, administrative productivity may improve, while paper-based and archive-related expenditures do not decline. This explains why modelled time-value benefits and rising accounting expenditures can appear at the same time.

The final block of the framework is risk-adjusted assessment. A positive baseline ROI may indicate potential efficiency under stated assumptions, but it should not be interpreted as audited financial savings. If system use is incomplete, support costs increase or duplicate paper procedures persist, risk-adjusted and pessimistic scenarios may become negative. Therefore, the model links digitalization outcomes to three analytically different results: observed productivity effects, observed accounting expenditure dynamics and scenario-based investment indicators.

4. Data and Methodology

4.1. Data Source and Empirical Base

The empirical base of the study consists of aggregated institutional records of the University Hospital of NJSC Semey Medical University for 2019–2025. The use of aggregated hospital-level data is appropriate for the purpose of this article because the study does not aim to conduct a patient-level cost-effectiveness analysis. Instead, it assesses how healthcare digitalization is reflected in the hospital's operational activity, administrative productivity, IT expenditures, administrative expenditure dynamics and scenario-based investment indicators.

The cleaned supplementary dataset includes several groups of indicators: general hospital activity indicators; staffing indicators; capacity and utilization indicators; IT and digitalization expenditures; implemented digital solutions; digital activity and system use indicators; administrative and operating expenditures; time indicators related to document and patient processing; author-calculated staff time savings; and scenario assessment of ROI, NPV and net effect. These data should be interpreted as aggregated institutional records rather than patient-level microdata or audited confirmation of financial savings.

The study covers the period from 2019 to 2025. The year 2019 is used as the baseline year of observation, but it is not treated as a non-digital or pre-digital year. This distinction is methodologically important. According to the institutional data, the medical information system / HIS / MIS, electronic health records, the laboratory information system and integration with SHIF, eGov and Ministry of Health systems had already been implemented and fully launched in 2019. Therefore, the article does not assess a transition from zero digitalization. It assesses the expansion, maintenance and economic consequences of digital system use in a hospital where the core digital infrastructure was already functioning at the beginning of the observation period.

The supplementary data are used in a strict way. Observed data are used to analyse hospital activity, staffing, IT expenditures, digital activity and expenditure dynamics. Time-saving parameters are used only for scenario modelling. Therefore, the calculation of ROI and NPV is explicitly conditional and should not be interpreted as evidence that the hospital actually saved KZT 240.1 million in its accounting records.

4.2. Case-Specific Data Groups and Variables

The first group of variables reflects the scale and intensity of hospital activity. It includes the number of beds, average annual number of employees, physicians, nursing staff, administrative staff, treated patients / cases, hospitalizations, outpatient visits, average length of stay, bed turnover, bed occupancy, laboratory tests and diagnostic examinations. These indicators are used to assess whether the hospital's operational workload increased during the period under review.

The second group characterizes staffing and administrative capacity. Particular attention is paid to administrative staff because one of the central questions of the study is whether digitalization is associated with higher administrative productivity. Administrative productivity is calculated as the number of treated cases per administrative employee. This is the main observed productivity indicator in the article because it is based on actual activity and staffing data, not on assumed time savings.

The third group includes IT and digitalization expenditures. These expenditures consist of total IT and digitalization costs, software costs, equipment costs, integration with external systems, technical support, licences and subscriptions, staff training, trained employees and workstations connected to the system. These indicators are used to estimate the total cost of ownership of hospital digitalization. This is important because digital transformation is not limited to a one-time purchase of software. It also requires technical support, integration, equipment renewal, licences, user assistance and organizational adaptation.

The fourth group describes implemented digital systems and digital activity. It includes the medical information system / HIS / MIS, electronic health records, the laboratory information system, integration with SHIF, eGov and Ministry of Health systems, telemedicine, electronic medical records, electronic referrals, online appointments / electronic registrations and registration employees working in the system. These indicators are used to assess the scope and intensity of digital system use.

The fifth group consists of administrative and operating expenditures. It includes total administrative expenditures, registry expenditures, archive expenditures, paper-based document flow costs, stationery and printed materials, and administrative expenditures per treated case. These indicators are used to test whether digitalization was accompanied by direct reductions in administrative, paper-based and archive-related expenditures. This is a key methodological safeguard: direct cost reduction is not assumed, but tested against accounting data.

The sixth group includes time indicators and staff time-saving parameters. The reported time indicators include average patient registration time, average time to retrieve a medical record / case history, average time for physician documentation, discharge preparation time, referral processing time, laboratory result processing time, reporting preparation time and processing time for one insurance / financial case. Since several of these indicators remain unchanged across the observation period, they are not treated as evidence of annual empirical variation. Instead, they are interpreted as reported standard processing-time indicators.

Staff time-saving parameters are used only for scenario-based calculations. They include assumed time savings for physicians, nursing staff, the registration office and archive-related processes. These parameters are combined with activity drivers and an assumed labour cost of KZT 2,500 per hour to estimate the potential monetary value of released working time. This value is not equivalent to audited financial savings and should not be interpreted as a reduction in payroll or administrative budgets

4.3. Methodological Separation of Evidence

To avoid methodological circularity, the study separates three types of evidence: observed operational data, observed accounting data and scenario-based assumptions.

Observed operational data include treated cases, electronic medical records, laboratory tests, diagnostic examinations, outpatient visits and administrative staffing. These indicators are used to analyse hospital activity, workload and administrative productivity. They answer the question of whether the hospital processed a larger volume of medical and administrative activity during the period under review.

Observed accounting data include IT and digitalization expenditures, administrative expenditures, registry expenditures, archive expenditures, paper-based document flow costs and stationery costs. These indicators are used to assess whether direct financial savings occurred. If these expenditure lines increase, the study does not claim that digitalization directly reduced such costs.

Scenario assumptions include time-saving parameters and the assumed average labour cost of KZT 2,500 per hour. These assumptions are used to estimate potential time-value benefits. They answer a different question: what monetary value could be attached to released working time under specified assumptions?

Scenario outcomes include conditional ROI, NPV, net effect and payback indicators. These outcomes are used for sensitivity analysis and risk-adjusted evaluation. They should be interpreted as modelled investment indicators rather than audited financial savings.

This separation is important because digitalization may improve productivity without immediately reducing accounting expenditures. Conversely, rising administrative expenditures do not necessarily mean that digitalization has no operational value if the hospital simultaneously treats more patients and processes more medical information. The purpose of the methodology is therefore not to force all indicators into a single efficiency claim, but to compare different types of evidence.

4.4. Calculation Methodology

The economic assessment was conducted using a combination of observed operational indicators, observed accounting indicators and scenario-based investment indicators. The formulas below distinguish real accounting data

from modelled time-value benefits. This distinction is important because the monetized value of released staff time is not the same as audited financial savings recorded in the hospital accounts.

First, total digital costs were calculated as the cumulative amount of IT and digitalization expenditures over the observation period:

$$C_{digital} = \sum_{t=2019}^{2025} C_t \ , (1)$$

where $C_{digital}$denotes total IT and digitalization costs for 2019-2025, and $C_t$denotes IT and digitalization expenditures in year t.

Second, administrative productivity was calculated as the number of treated cases per administrative employee:

$$AP_t = \frac{TC_t}{AS_t}, (2)$$

where AP_t denotes administrative productivity in year t, TC_t denotes treated cases in year t, and AS_t denotes the number of administrative staff in year t. This is the main observed productivity indicator in the study.

Third, administrative expenditure per treated case was calculated to check whether administrative costs decreased in relative terms after accounting for hospital workload:

$$AEC_t = \frac{AE_t}{TC_t} \ , (3)$$

where AEC_t denotes administrative expenditure per treated case, AE_t denotes total administrative expenditures in year t, and TC_t denotes treated cases in year t.

Fourth, total saved working hours were estimated as the sum of assumed time savings across the main staff categories and processes included in the supplementary dataset:

$$H_{saved,t} = H_{phys,t} + H_{nurse,t} + H_{reg,t} + H_{arch,t} \quad , (4)$$

where $H_{saved,t}$ denotes total estimated hours saved in year t; $H_{phys,t}$, $H_{nurse,t}$, $H_{reg,t}$ and $H_{arch,t}H_{arch,t}$ denote estimated hours saved by physicians, nursing staff, registration office and archive-related processes, respectively.

Fifth, the potential time-value benefit was calculated by multiplying estimated saved hours by the assumed average labour cost per hour:

$$B_{time,t} = H_{saved,t} * LC \quad , (5)$$

where $B_{time,t}$ denotes the modelled value of released working time in year t, $H_{saved,t}$ denotes estimated hours saved in year t, and LC denotes the assumed labour cost per hour. In this study, LC is KZT 2,500 per hour. This amount is an assumption for scenario modelling and is not treated as audited financial savings.

The total modelled time-value benefit for the whole period was calculated as follows:

$$B_{time,total} = \sum_{t=2019}^{2025} B_{time,t} \ , (6)$$

where $B_{time,total}$ denotes the cumulative modelled value of potential staff time savings over 2019-2025.

The conditional net economic effect was calculated as the difference between the total modelled time-value benefit and actual IT/digitalization expenditures:

$$NE = B_{time,total} - C_{digital} \ , (7)$$

where NE denotes the conditional net effect. This indicator compares modelled potential benefits with observed cumulative IT and digitalization expenditures.

Return on digital investment was calculated as follows:

$$ROI = \frac{NE}{C_{digital}} \times 100\% \quad , (8)$$

In this article, ROI is interpreted as a conditional scenario indicator. It shows whether the modelled value of released staff time exceeds actual IT and digitalization expenditures under stated assumptions. It does not prove that the hospital reduced its administrative budget by the same amount.

Net present value was calculated using a 12% baseline discount rate:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - I_0 \ , (9)$$

where CF_t denotes net cash flow in period t, r denotes the discount rate, and I_0 denotes initial digital investment. The baseline discount rate of 12% was used as an analytical assumption reflecting the opportunity cost of capital, inflationary expectations and the risk profile of digital projects in an emerging economy. Additional sensitivity checks use alternative rates of 8% and 16%.

The simple payback period was calculated as the ratio of total digital costs to the average annual modelled time-value benefit:

$$PP = \frac{C_{digital}}{B_{time,average}}, (10)$$

where PP denotes the payback period and $B_{time,average}$ denotes the average annual modelled time-value benefit. This indicator is descriptive and should be interpreted together with the scenario results.

For the risk-adjusted scenario, the modelled benefits were adjusted for actual system use and implementation risk:

$$B_{risk} = B_{time,total} \times K_{use} \times (1 - R) \text{ , (11)}$$

where B_{risk} denotes risk-adjusted modelled benefits, $B_{time,total}$ denotes baseline modelled benefits, K_{use} denotes the coefficient of actual digital system use, and R denotes the integrated implementation risk coefficient.

The risk-adjusted net effect was then calculated as:

$$NE_{risk} = B_{risk} - C_{digital} \text{ , (12)}$$

where NE_{risk} denotes the risk-adjusted net effect.

The risk-adjusted ROI was calculated as:

$$ROI_{risk} = \frac{NE_{risk}}{C_{digital}} \times 100\% \text{ , (13)}$$

This correction is important because implementation risk reduces modelled benefits. The formulas therefore keep the distinction between observed costs, modelled benefits and risk-adjusted outcomes.

Table. Notation used in the formulas

Interpretation in this study	Meaning	Symbol
Observed accounting indicator	Total IT and digitalization costs	$C_{digital}$
Observed annual cost	IT and digitalization expenditures in year t	C_t
Observed operational indicator	Treated cases in year t	TC_t
Observed staffing indicator	Administrative staff in year t	AS_t
Observed productivity ratio	Administrative productivity	AP_t
Observed accounting indicator	Total administrative expenditures in year t	AE_t
Relative expenditure indicator	Administrative expenditure per treated case	AEC_t
Scenario-based estimate	Estimated hours saved in year t	$H_{saved,t}$
KZT 2,500 per hour	Assumed labour cost per hour	LC
Not audited savings	Modelled value of released time in year t	$B_{time,t}$
Scenario-based benefit	Total modelled time-value benefit	$B_{time,total}$
Modelled benefit minus observed digital costs	Conditional net effect	NE
Conditional scenario indicator	Return on digital investment	ROI
Used for NPV calculation	Net cash flow in period t	CF_t
12% in the baseline case	Discount rate	r
Initial digital investment	Initial investment	I_0
Descriptive scenario indicator	Payback period	PP
Risk-adjustment parameter	Coefficient of actual digital system use	K_use
Risk-adjustment parameter	Integrated implementation risk coefficient	R
Benefits after system-use and risk adjustment	Risk-adjusted modelled benefits	B_{risk}
Risk-adjusted benefits minus observed digital costs	Risk-adjusted net effect	NE_{risk}

4.5. Scenario Design

Scenario analysis was used to test the stability of the investment results. Four scenarios were considered: optimistic, baseline, risk-adjusted and pessimistic.

The optimistic scenario assumes higher potential benefits while costs remain unchanged. This scenario reflects a situation in which digital systems are used effectively, staff time is released more fully and duplicate paper-based procedures are reduced.

The baseline scenario uses the estimated potential time-value benefits and actual IT and digitalization expenditures. It reflects the central modelled estimate based on the assumptions stated in the supplementary dataset.

The risk-adjusted scenario reduces potential benefits by taking into account implementation risks, incomplete system use and the persistence of dual workflows. This scenario reflects the possibility that digital systems are formally implemented but do not fully replace manual or paper-based procedures.

The pessimistic scenario assumes lower benefits and higher costs. It reflects an unfavourable implementation environment in which support costs rise, organizational adaptation is incomplete and paper-based procedures continue in parallel with digital systems.

The scenario design is intended to prevent overinterpretation of the baseline ROI and NPV. A positive baseline result is meaningful only if it remains robust under less favourable assumptions. If risk-adjusted or pessimistic scenarios become negative, the study interprets this not as a failure of digitalization in general, but as evidence that the economic effect is sensitive to implementation quality, total cost of ownership and the degree of substitution of paper-based processes.

5. Results

5.1. Hospital Activity, Staffing and Digital Use

Table 1. Hospital activity, staffing and service intensity, 2019-2025

Indicator	2019	2020	2021	2022	2023	2024	2025
Beds	490	465	465	465	465	465	465
Administrative staff	36	34	38	38	40	43	30
Treated patients / cases	16,563	14,353	17,638	17,393	19,195	20,163	20,087
Outpatient visits	28,175	21,919	43,385	35,867	35,867	37,434	39,268
Average length of stay, days	8.9	8.4	8.5	8.9	8.3	8.4	8.1
Bed turnover, times	33.8	30.9	37.8	37.4	41.3	43.4	43.2
Laboratory tests	807,035	506,266	870,828	807,140	1,051,002	1,163,455	1,232,611
Diagnostic examinations	134,489	122,872	130,102	150,743	163,052	170,306	181,258

Note: compiled/calculated by the authors based on aggregated institutional hospital data.

Table 1 shows that the hospital did not become a smaller or less complex organization during the observation period. Treated cases increased from 16,563 in 2019 to 20,087 in 2025, while the number of beds decreased from 490 to 465. Laboratory tests increased from 807,035 to 1,232,611, and diagnostic examinations rose from 134,489 to 181,258. These dynamics indicate higher operational intensity and a larger volume of clinical and administrative information processed by the hospital.

The staffing dynamics should be interpreted cautiously. Administrative staff did not decline steadily every year: it decreased in 2020, increased to 43 employees in 2024 and then fell to 30 in 2025. Therefore, the article should not present a simplified narrative of continuous administrative downsizing. The more defensible result is the end-period improvement in administrative productivity. Treated cases per administrative employee increased from approximately 460 in 2019 to 670 in 2025. This is the main observed productivity indicator used in the article, because it is based on actual activity and staffing data rather than on assumed time savings.

5.2. IT and Digitalization Expenditures

The annual structure and cumulative amount of IT and digitalization expenditures are presented in Table 2.

Table 2. IT and digitalization expenditures, 2019-2025

Indicator, thousand KZT	2019	2020	2021	2022	2023	2024	2025	Total
Total IT and digitalization expenditures	6,852	11,535	14,974	37,392	26,273	59,848	25,734	182,608
Software	0	400	720	0	0	29,630	0	30,750
Equipment	0	3,413	5,353	26,399	12,544	7,610	0	55,319
Integration with external systems	0	0	0	649	840	954	1,149	3,592
Technical support	6,852	7,722	8,901	10,344	12,889	21,054	24,051	91,813
Licences and subscriptions	0	0	0	0	0	600	134	734
Staff training	0	0	0	0	0	0	400	400

Note: compiled/calculated by the authors based on aggregated institutional hospital data.

Total IT and digitalization expenditures amounted to KZT 182.6 million over 2019-2025. The largest component was technical support, which reached KZT 91.8 million. Equipment accounted for KZT 55.3 million, while software accounted for KZT 30.8 million. The peak of digital spending occurred in 2024, when total IT and digitalization expenditures reached KZT 59.8 million, mainly due to software and technical support costs.

This expenditure structure supports the total-cost-of-ownership interpretation. Hospital digitalization was not a one-time purchase of software or equipment. It created recurring obligations for technical support, maintenance, system integration, licences and user assistance. This is why the economic evaluation should not compare only initial investment with potential benefits; it should include the continuing costs required to keep digital systems operational.

5.3. Digital Activity and Implemented Systems

The dynamics of the main digital activity and system-use indicators are presented in Table 3.

Table 3. Digital activity and system use indicators, 2019-2025

Indicator	2019	2020	2021	2022	2023	2024	2025
Electronic medical records	15,841	19,515	18,495	18,763	21,444	24,011	26,219
Electronic referrals	28,175	21,919	43,385	35,867	35,867	37,434	39,268
Online appointments / electronic registrations	15,000	10,000	21,248	12,356	15,896	14,852	13,456
Registration employees working in the system	4	4	4	4	4	4	5

Note: compiled/calculated by the authors based on aggregated institutional hospital data.

Digital activity expanded, but not uniformly across all channels. The number of electronic medical records increased from 15,841 in 2019 to 26,219 in 2025, which represents a 65.5% increase. Electronic referrals generally followed the dynamics of outpatient activity. By contrast, online appointments and electronic registrations fluctuated and were lower in 2025 than in 2019. This unevenness is important because it prevents an overly linear interpretation of digitalization as a uniform annual expansion in every digital indicator.

The institutional data show that the core medical information system, electronic health records, the laboratory information system and integration with national platforms were already functioning from 2019. Therefore, the observed period should be interpreted as a phase of expansion, maintenance and more intensive use of digital infrastructure rather than as a transition from zero digitalization. This point prevents the observed period from being misinterpreted as a transition from a non-digital baseline.

5.4. Administrative and Operating Expenditures: No Direct Saving Effect

Table 4. Administrative and operating expenditures, 2019-2025

Indicator	2019	2020	2021	2022	2023	2024	2025
Total administrative expenditures, thousand KZT	4,195,158.8	4,217,192	5,453,446	6,404,505	7,419,035	7,896,803	8,723,279
Registry expenditures, thousand KZT	1,449,756	1,449,756	552,884	854,350	1,286,448	2,435,525	2,349,368
Archive expenditures, thousand KZT	1,800,545	1,589,422	1,436,223	2,345,210	3,049,132	4,156,442	7,945,033
Paper-based document flow costs, thousand KZT	3,487	4,279	6,595	6,968	3,758	14,009	20,772
Stationery and printed materials, thousand KZT	3,887	4,496	4,980	7,711	6,709	9,144	14,114
Administrative expenditures per treated case, KZT	253,285	293,820	309,187	368,223	386,509	391,648	434,275

Note: compiled/calculated by the authors based on aggregated institutional hospital data.

Table 4 is central to the empirical interpretation of the study. The accounting data do not show a direct reduction in administrative expenditures. Total administrative expenditures increased from KZT 4.20 billion in 2019 to KZT 8.72 billion in 2025. Administrative expenditures per treated case also increased, from KZT 253,285 to KZT 434,275. Archive

expenditures increased markedly, and paper-based document-flow costs rose from KZT 3.49 million to KZT 20.77 million.

These findings reject the simple hypothesis that hospital digitalization directly reduced administrative, paper-based and archive-related expenditures during the observation period. This does not mean that digitalization had no value. Rather, it means that the value cannot be claimed as audited budgetary savings. The more plausible interpretation is that digitalization operated alongside existing paper and archive procedures. This is the dual-workflow effect: electronic processes expanded, but the older paper-based and archival infrastructure was not eliminated.

This interpretation strengthens the internal consistency of the study. The article does not claim that digitalization reduced paper-based document flows or administrative costs when the accounting data show the opposite. Instead, the increase in paper and archive-related costs is treated as an empirical result that explains why risk-adjusted assessment is necessary.

5.5 Time Indicators and Scenario-Based Staff Time Savings

The hospital provided standard processing-time indicators for patient registration, medical record retrieval, physician documentation, discharge preparation and insurance / financial case processing. These indicators are presented in the Supplementary Materials as Table S6. They are not included in the main text because several values remain unchanged across the observation period. In this study, these indicators are therefore not interpreted as annual measured empirical variation.

This methodological distinction is important. The table is therefore reported in the supplementary file as a set of standard benchmarks rather than as a time series of independently measured annual values. For this reason, the analysis treats these indicators as reported standard processing-time benchmarks rather than as year-by-year measured operational observations. The article also does not use these indicators to claim observed annual reductions in processing time.

Instead, time-related information is used only for scenario-based estimation of potential staff time savings. The calculation relies on activity drivers, reported time-saving assumptions and an assumed labour cost of KZT 2,500 per hour. The resulting monetized value should therefore be interpreted as a modelled time-value benefit, not as audited financial savings and not as a direct reduction in payroll, administrative expenditure or paper-related costs. The annual scenario-based estimates of staff time savings and their monetized time-value benefit are presented in Table 5.

Table 5. Scenario-based staff time savings and monetized time-value benefit

Year	Total hours saved	FTE equivalent	Monetized benefit, million KZT
2019	14,862.1	8.4	37.2
2020	12,861.6	7.3	32.2
2021	15,778.8	9.0	39.4
2022	11,701.6	6.6	29.3
2023	13,239.0	7.5	33.1
2024	13,815.1	7.8	34.5
2025	13,798.3	7.8	34.5
Total	96,056.5	54.6	240.1

Note: calculated by the authors based on aggregated institutional hospital data, activity drivers, reported time-saving assumptions and an assumed labour cost of KZT 2,500 per hour. These values should be interpreted as modelled potential time-value benefits, not as audited financial savings.

According to the author calculations, the total estimated staff time savings for 2019–2025 amounted to 96,056.5 working hours, equivalent to 54.6 full-time equivalent positions. The monetized value of this released working time was estimated at KZT 240.1 million. This figure is used only as the benefit side of the scenario model. It does not mean that the hospital actually reduced its budgetary expenditures by KZT 240.1 million.

This interpretation avoids methodological circularity. The modelled benefit should not be read as if the hospital had actually saved KZT 240.1 million. Rather, it reflects the economic value of released staff time under explicit assumptions. In a hospital setting, released staff time may support higher throughput, faster processing or better workload distribution, but it does not automatically appear as a reduction in accounting expenditure.

5.6. Scenario Analysis

Scenario analysis was used to assess whether the modelled economic result remains stable under different assumptions about benefits, costs and implementation risks. Four scenarios were considered: optimistic, baseline, risk-adjusted and pessimistic. The assumptions and results of the four digitalization scenarios are summarized in Table 6.

Table 6. Scenario assessment of hospital digitalization, 2019-2025

Scenario	Assumptions	Benefits, million KZT	Costs, million KZT	Net effect, million KZT	ROI, %	NPV, million KZT
Optimistic	Benefits +20%; costs unchanged	288.2	182.6	105.6	57.8	82.3
Baseline	Estimated benefits and actual IT costs	240.1	182.6	57.5	31.5	50.8
Risk-adjusted	Benefits adjusted for system use and risk	147.7	182.6	-34.9	-19.1	-9.8
Pessimistic	Benefits -25%; costs +15%	180.1	210.0	-29.9	-14.2	-4.5

Note: calculated by the authors based on aggregated institutional hospital data for 2019–2025. Benefits are estimated through the monetized equivalent of potential staff time savings. The results should be interpreted as scenario-based investment indicators rather than audited financial savings.

The baseline scenario produces a positive conditional ROI of 31.5% and a positive NPV of KZT 50.8 million. However, this result depends on the assumption that released staff time can be valued economically and translated into process benefits. It should therefore be interpreted as a conditional scenario result, not as evidence of audited financial savings.

When the model is adjusted for lower realized benefits and implementation risks, the result becomes negative. The risk-adjusted scenario produces an ROI of -19.1% and an NPV of KZT -9.8 million. The pessimistic scenario is also negative. This confirms that the efficiency conclusion is not robust under unfavourable assumptions.

The main implication is that digitalization cannot be assessed only by the presence of information systems or by a single baseline ROI. Its economic result depends on system use, total cost of ownership, organizational adaptation and the degree to which digital procedures replace rather than duplicate paper-based workflows.

The sensitivity of NPV to alternative discount rates is reported in Table 7.

Table 7. Sensitivity of NPV to alternative discount rates, million KZT

Pessimistic	Risk-adjusted	Baseline	Optimistic	Discount rate
-10.7	-16.0	53.0	88.9	8%
-4.5	-9.8	50.8	82.3	12%
0.1	-5.1	48.6	76.6	16%

Note: calculated by the authors from annual scenario net flows. The sensitivity check changes only the discount rate; it does not remove implementation and dual-workflow risks.

5.7. Hypothesis Assessment

The empirical results were compared with the hypotheses formulated in the literature review. The assessment distinguishes between productivity effects, direct expenditure effects and scenario-based investment results. The evidence and final assessment for each research hypothesis are summarized in Table 8.

Table 8. Summary of hypothesis assessment

Hypothesis	Evidence	Result
H1	Administrative productivity increased from 460 to 670 treated cases per administrative employee.	Supported as association
H2	Administrative, archive, registry and paper-based document-flow expenditures increased.	Rejected
H3	The baseline scenario gives positive ROI, but only through modelled time-value benefits.	Conditionally supported

H4	Risk-adjusted and pessimistic scenarios become negative.	Supported

Note: compiled/calculated by the authors based on aggregated institutional hospital data

The hypothesis assessment shows why the article avoids an overly positive interpretation. H1 is supported only as an association: digital expansion coincided with higher administrative productivity, but the aggregated data do not allow a strict causal claim. H2 is rejected because the accounting data show increases in administrative, archive, registry and paper-based document-flow expenditures. H3 is conditionally supported because the positive ROI is based on modelled time-value benefits, not audited savings. H4 is supported because risk-adjusted and pessimistic scenarios become negative.

Overall, the results indicate that healthcare digitalization in the University Hospital of NJSC Semey Medical University was associated with higher operational intensity and improved administrative productivity, but not with direct reductions in administrative or paper-related expenditures. The main empirical contribution is therefore not a simple proof of economic efficiency, but a more cautious finding: positive productivity effects and modelled time-value benefits can coexist with rising accounting expenditures when digital and paper-based workflows operate simultaneously.

6. Discussion

The findings provide a cautious but more convincing interpretation of hospital digitalization. The case of the University Hospital of NJSC Semey Medical University shows that digitalization was associated with a larger volume of digital records, higher clinical and diagnostic activity, and higher administrative productivity by the end of the observation period. These are meaningful operational results. However, the accounting data do not confirm direct reductions in administrative, paper-based or archive-related expenditures. This mixed pattern is important because it shows that the economic consequences of digitalization cannot be reduced to a simple statement that digital systems automatically generate savings.

The results are consistent with the broader international literature, which shows that health information technologies may improve quality, efficiency and access to information, but that their economic effects depend on the type of technology, implementation quality, interoperability and organizational readiness (Chaudhry et al., 2006; Goldzweig et al., 2009; Buntin et al., 2011). Earlier modelling studies suggested that electronic medical records may generate substantial savings when systems are introduced at scale and become interoperable (Hillestad et al., 2005). However, later studies showed that the financial effects of health information technologies are not immediate and may remain limited when digital systems are implemented without complementary organizational changes (Dranove et al., 2014; Agha, 2014).

The present case supports this more cautious interpretation. Digitalization in the hospital did not operate as a simple cost-cutting mechanism. Instead, it appears to have supported higher operational intensity and administrative productivity while the hospital continued to maintain paper-based and archive-related processes. This finding is consistent with the logic of transaction cost economics. Digital systems can reduce the costs of searching, transmitting, verifying and coordinating information, but these costs do not disappear completely. They may be transformed into other types of costs, including technical support, user support, system maintenance, integration and data management (Williamson, 1985; Williamson, 1998).

The most important empirical contribution of the study is the identification of a dual-workflow effect. The hospital appears to have operated in a transitional mode in which digital systems were used while paper-based and archive procedures continued. This explains why administrative productivity may improve without immediate budgetary savings. It also explains why technical support became the largest IT expenditure item. Once digital systems become part of everyday hospital work, support and maintenance become recurring costs rather than temporary implementation expenses.

From the perspective of IT complementarity theory, this result is expected. Digital capital produces sustainable economic returns only when it is combined with complementary organizational changes, including process redesign, staff training, improved digital competences, management analytics and better data quality (Brynjolfsson & Hitt, 2000; Dranove et al., 2014). If electronic systems are introduced but old routines remain in place, the organization may bear the cost of both digital and paper-based workflows. In such circumstances, digitalization can improve throughput and information availability, but it may not immediately reduce administrative or paper-related expenditures.

The findings also correspond to the J-curve logic of IT investment. At the initial and transitional stages, digital expenditures may rise because the hospital needs software, equipment, technical support, system integration, licences,

user assistance and staff adaptation. Benefits may appear later, once digital systems are used consistently and replace, rather than merely duplicate, manual procedures. Therefore, rising IT and support costs should not automatically be interpreted as project failure. At the same time, they should not be ignored when calculating economic efficiency. This is why total cost of ownership is a necessary part of digital health investment evaluation.

The results also show why ROI and NPV must be interpreted carefully. A positive baseline ROI does not mean that the hospital saved money in its accounting records. It means that, under stated assumptions, the modelled value of released staff time exceeds IT and digitalization costs. If those assumptions are weakened, or if duplicate paper procedures persist, the result becomes negative. This interpretation is more consistent with the J-curve and IT complementarity literature than a simple claim of direct cost reduction (Dranove et al., 2014; Agha, 2014; Kellermann & Jones, 2013).

The interpretation also addresses a methodological issue that is often underestimated in studies of digital health efficiency. Staff time savings and audited financial savings are not the same. A hospital may release staff time through faster access to records, simplified documentation or electronic referrals, but this does not automatically reduce payroll or administrative expenditures. Released time may instead be absorbed by higher patient volumes, additional reporting requirements, more complex clinical work or quality-control procedures. For this reason, the monetized value of staff time savings in this study is treated as a modelled time-value benefit rather than as audited savings.

6.1. Comparison with International Evidence

International evidence on the economic effects of healthcare digitalization remains mixed. Some studies emphasize the potential of electronic medical records and medical information systems to reduce duplication, improve access to data, lower administrative costs and improve the accuracy of managerial accounting (Chaudhry et al., 2006; Goldzweig et al., 2009; Buntin et al., 2011; Hillestad et al., 2005). These studies provide an important theoretical and empirical basis for expecting positive economic effects from digital health investments.

At the same time, other studies show that such effects depend strongly on implementation conditions. The introduction of electronic systems may increase costs in the short term, and the expected benefits may not be realized if digital systems are poorly integrated, staff are not ready to use them, or paper-based procedures continue in parallel (Dranove et al., 2014; Agha, 2014; Kellermann & Jones, 2013). Economic evaluations of digital health interventions also emphasize the importance of methodological transparency, sensitivity analysis, clearly stated assumptions and careful distinction between observed outcomes and modelled benefits (Drummond et al., 2015; Gomes et al., 2022).

The findings of the present study are closer to the second group of studies. The hospital case does not show a clean pattern of direct financial savings. Instead, it shows a combination of higher operational productivity, increased digital activity, rising IT support costs and persistent paper-related expenditures. This combination is typical of organizations that are in the middle of digital transformation rather than at the stage of complete digital substitution.

Therefore, the results should not be interpreted as evidence against digitalization. Rather, they show that digitalization produces economic value only under certain organizational conditions. The key issue is whether electronic systems replace manual and paper-based procedures or whether they are added on top of existing routines. If replacement does not occur, the hospital may experience higher workload capacity and better data availability without achieving direct reductions in administrative expenditure.

6.2. J-Curve Interpretation and Risk-Adjusted Results

The scenario analysis confirms the importance of the J-curve interpretation. In the baseline scenario, the modelled value of potential staff time savings exceeds IT and digitalization expenditures, producing a positive conditional ROI and NPV. However, this result is not robust under less favourable assumptions. In the risk-adjusted and pessimistic scenarios, the economic effect becomes negative. This means that the conclusion about digital efficiency depends on implementation quality, actual system use, support costs and the degree of substitution of paper-based procedures.

This finding is important for two reasons. First, it prevents overinterpretation of the baseline ROI. A positive baseline result should be seen as a potential efficiency outcome under stated assumptions, not as direct proof of actual budgetary savings. Second, it shows why risk-adjusted evaluation is necessary for digital health projects. Digitalization is not a standard investment with stable and easily measurable returns. It is an organizational transformation process affected by technical, managerial, institutional and behavioural risks.

For a university hospital, such risks are especially important. The organization combines clinical, educational, research and managerial functions. This increases the value of reliable digital information but also makes process redesign more difficult. Digital tools must support not only patient care, but also reporting, clinical training, research coordination, interaction with public platforms and communication across departments. Under these conditions, digitalization may improve manageability before it produces direct savings.

6.3. Managerial and Policy Implications for Kazakhstan

The findings have several managerial and policy implications for healthcare digitalization in Kazakhstan. First, hospitals should clearly distinguish between productivity gains and audited financial savings. Treated cases per administrative employee is a useful productivity indicator, but it should not be presented as direct cost reduction unless the accounting data confirm an actual decline in expenditures.

Second, digitalization projects should include a clear plan for eliminating duplicate paper-based procedures. If electronic systems are introduced while paper files, printed forms and archive procedures continue unchanged, hospitals may face the costs of both digital and paper-based workflows. In such cases, digitalization may improve data availability and operational capacity, but its financial effect will be delayed or weakened.

Third, total cost of ownership should be monitored annually. Software, equipment and initial implementation costs represent only part of digital investment. Technical support, system integration, licences, software updates, cybersecurity, user assistance and staff training are not secondary costs; they are core components of digital health infrastructure. Without regular monitoring of these costs, the economic assessment of digitalization may be incomplete.

Fourth, ROI and NPV should be reported as scenario indicators with explicit assumptions. A baseline ROI should not be presented as final proof of economic efficiency. It should be accompanied by risk-adjusted and pessimistic scenarios, especially when benefits are based on modelled staff time savings rather than audited financial savings.

Fifth, future digital health policy in Kazakhstan should link system implementation with process redesign, staff training and managerial accounting for digital effects. The number of implemented systems is not sufficient for evaluating success. Medical organizations need to know whether digital systems actually reduce duplicate work, improve productivity, lower paper-related costs and support better managerial decisions.

Thus, the practical implication of this study is that healthcare digitalization should be managed not only as a technological project, but also as an organizational and economic transformation. Its success depends on whether hospitals are able to convert digital infrastructure into redesigned processes, lower duplication and more transparent cost management.

The hospital did not experience digitalization as a single replacement event. Rather, digital systems became embedded in everyday work while older reporting and archiving routines continued. This is important because administrative productivity and accounting savings moved in different directions.

7. Conclusions

This article reassessed healthcare digitalization in the University Hospital of NJSC Semey Medical University by distinguishing between three types of evidence: observed accounting data, observed operational productivity indicators and scenario-based estimates of potential staff time savings. This separation was central to the study, because the empirical evidence does not support a simple claim that digitalization automatically produces direct financial savings.

The results show that, during 2019–2025, the hospital increased the volume and intensity of medical activity while also expanding digital activity. Treated cases increased by 21.3%, electronic medical records by 65.5%, laboratory tests by 52.7% and diagnostic examinations by 34.8%. At the same time, administrative staff decreased from 36 to 30 employees by the end of the period, while administrative productivity increased from 460 to 670 treated cases per administrative employee. These findings indicate that digitalization was associated with higher administrative productivity and greater operational capacity.

At the same time, the accounting data do not confirm direct reductions in administrative, registry, archive or paper-based document-flow expenditures. On the contrary, these expenditure lines increased during the observation period. Therefore, the hypothesis that digitalization directly reduced administrative and paper-related costs was not supported. The most plausible explanation is the dual-workflow effect: digital systems expanded, but paper-based and archive procedures continued to operate in parallel.

Total IT and digitalization expenditures over the observation period amounted to KZT 182.6 million. The largest expenditure items were technical support, equipment and software, which confirms that hospital digitalization should be evaluated through the total cost of ownership rather than only through initial investment costs. Once digital systems become part of everyday hospital operations, support, maintenance, integration and user assistance become recurring components of digital expenditure.

The modelled time-value benefit of potential staff time savings was estimated at KZT 240.1 million. Under the baseline scenario, this produced a conditional net effect of KZT 57.5 million, ROI of 31.5% and NPV of KZT 50.8 million. These indicators should not be interpreted as audited financial savings. They show only that, under stated assumptions, the estimated monetary value of released staff time exceeds actual IT and digitalization expenditures. When

implementation risks, incomplete substitution and lower realized benefits are taken into account, the risk-adjusted and pessimistic scenarios become negative.

The practical significance of the study lies in showing that digital health investments should not be evaluated only by the number of systems implemented or by a single baseline ROI. Medical organizations and healthcare authorities need to distinguish between direct accounting savings, productivity effects and modelled potential benefits. This distinction can improve expenditure transparency and reduce the risk of overestimating the economic efficiency of digital projects.

The study is limited by its single-hospital design, aggregated data, lack of patient-level microdata, absence of detailed department-level cost allocation and reliance on scenario-based time-saving assumptions. Therefore, the results should be interpreted as an institutional economic assessment rather than as a full patient-level health economic evaluation. Future research should expand the sample of medical organizations, include several regions of Kazakhstan, compare university and non-university hospitals, and use department-level data and independent time-motion measurements.

Overall, the article shows that healthcare digitalization in a university hospital can improve administrative productivity and operational capacity without immediately reducing administrative or paper-related expenditures. This finding does not weaken the value of digitalization. Rather, it shows that its economic effect depends on whether digital systems replace old paper-based routines or merely coexist with them.

8. Limitations and Future Research

This study has several limitations that should be taken into account when interpreting the results. First, the analysis is based on data from one university hospital. The University Hospital of NJSC Semey Medical University is a complex medical, educational and research organization, and its institutional profile may differ from non-university hospitals, regional hospitals or private medical organizations. Therefore, the findings cannot be directly generalized to all healthcare organizations in Kazakhstan.

Second, the study uses aggregated institutional data rather than patient-level microdata. Aggregated data make it possible to assess general trends in hospital activity, digital use, IT expenditures, administrative productivity and scenario-based investment indicators. However, they do not allow the analysis of differences between departments, patient groups, clinical pathways or types of medical services. Future studies should therefore include department-level and patient-level data where possible.

Third, the study does not use audited financial savings as the main measure of digitalization benefits. The accounting data show that administrative, registry, archive and paper-based document-flow expenditures increased during the observation period. For this reason, the article does not claim that digitalization directly reduced these expenditures. The monetized value of staff time savings is treated only as a modelled time-value benefit based on explicit assumptions, not as a confirmed reduction in payroll or administrative budgets.

Fourth, some time-related indicators are based on reported standard processing-time values and time-saving assumptions. Since several of these indicators remain unchanged across the observation period, they should not be interpreted as measured annual empirical variation. This limitation is important because time-saving parameters affect the scenario-based calculation of ROI, NPV and payback period. Future research should use independent time-motion studies, system logs or workflow analytics to measure actual changes in processing time more precisely.

Fifth, the period 2019–2025 includes external factors that may have influenced hospital activity and expenditure dynamics. These include the COVID-19 pandemic, changes in healthcare financing, inflationary pressure, institutional reforms, changes in reporting requirements and the gradual expansion of national digital health platforms. These factors may affect patient flows, staffing, administrative workload and expenditure levels independently of hospital digitalization.

Sixth, the study does not fully separate the effects of digitalization from broader organizational and managerial changes. The increase in administrative productivity may be associated with digital system use, but it may also reflect changes in staffing policy, workload distribution, financing rules, reporting procedures or hospital management practices. Therefore, the observed relationship should be interpreted as an association rather than as strict causal evidence.

Future research should expand the sample of medical organizations and compare university hospitals, regional hospitals, outpatient organizations and private clinics. A multi-hospital dataset would make it possible to test whether the dual-workflow effect observed in this case is typical for Kazakhstan's healthcare system or specific to the studied hospital.

Further research should also develop comparative regional models of healthcare digitalization in Kazakhstan. Such models could include indicators of digital system use, IT expenditures, administrative productivity, paper-based procedures, staffing, patient flows and financial sustainability. Panel data would allow researchers to assess differences between regions and identify the institutional conditions under which digitalization produces stronger economic effects.

Another important direction is the development of more precise methods for measuring staff time savings. Future studies should combine managerial accounting data with time-motion observations, digital system logs, process mining and staff surveys. This would make it possible to distinguish more clearly between actual time savings, potential time-value benefits and audited financial savings.

Future research should also examine the quality-of-care effects of digitalization. The present article focuses on economic and administrative indicators, but digital health may also influence patient safety, waiting time, continuity of care, diagnostic accuracy, treatment coordination and patient satisfaction. Including these outcomes would provide a broader assessment of digitalization beyond ROI and NPV.

Finally, further development of risk-adjusted models for evaluating digital health investments is particularly important. Such models should take into account not only direct financial effects, but also total cost of ownership, technical support, staff training, cybersecurity, process redesign, dual workflows, organizational risks and institutional readiness. This approach can improve the justification of digital investments and build a stronger evidence base for the sustainable development of digital healthcare in Kazakhstan.

Declarations:

Author contributions: A.R., G.D. and Zh.R. conceptualized the study; G.D., D.B. and Zh.R. developed the methodology; A.D., N.S., T.A. and D.B. supported data validation and formal analysis; A.R., G.D., T.A. and Zh.R. wrote the original draft; all authors reviewed and approved the final manuscript.

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Data availability: The aggregated data supporting the findings are provided in the Supplementary Information. Additional clarifications are available from the corresponding author upon reasonable request.

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Supplementary Information

Supplementary Tables S1-S10 provide the aggregated institutional dataset and author calculations used in the article. The supplementary file includes general hospital activity indicators, IT and digitalization expenditures, implemented digital solutions, digital activity indicators, administrative and operating expenditures, reported standard processing-time indicators, scenario-based staff time-saving calculations, diagnostic examination data and scenario assessment results.

The supplementary data are aggregated institutional records of the University Hospital of NJSC Semey Medical University for 2019-2025. They should not be interpreted as patient-level microdata or audited confirmation of financial savings. Reported processing-time indicators are treated as standard benchmarks used only as supporting information for scenario modelling.

The full supplementary dataset is provided as a separate file: Supplementary_Data_Hospital_Digitalization_Clean_HSSC.docx.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

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