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Factor analysis of the digital transformation of healthcare in the Republic of Kazakhstan

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Abstract. This study analyzes the main drivers of healthcare digital transformation in Kazakhstan and provides recommendations to improve organizational and economic mechanisms for digital technology implementation. The purpose of the study is to analyze the impact of the factors of digital transformation of healthcare in the Republic of Kazakhstan on the dynamics of digitalization of the industry and, based on the results of multifactorial economic and statistical analysis and trend modeling, to develop sound organizational and economic mechanisms and practical recommendations for accelerated implementation of digital technologies in the healthcare system. The methodology combines economic and statistical analysis, logical evaluation of digital components, and a systems approach. Key methods include data grouping, synthesis, deduction, abstraction, comparative and factor analysis, and mathematical forecasting.

The findings highlight critical drivers: investment in information and communication technologies (ICT), digital literacy, medical research and development, and innovation activity. A multifactor regression model confirmed the strong impact of ICT spending and research on transformation levels. Trend-based forecasting showed favorable prospects for ICT investment growth in healthcare.

To accelerate digitalization, Kazakhstan should expand ICT investment, develop innovative healthcare infrastructure, and strengthen digital skills among medical staff and the public. Effective policy, regulatory improvements, and support for advanced technologies are essential to ensure sustainable modernization of the healthcare system.

Keywords: healthcare, digital transformation, digital technologies, innovation, digital literacy.

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Introduction

One of the key directions in modernizing social infrastructure in Kazakhstan is the digital transformation of healthcare. It enhances the efficiency of medical services through increased investment in information and communication technologies (ICT), improved digital literacy, and the adoption of innovative solutions. A higher level of digitalization is expected to reduce administrative costs, improve the quality and accessibility of healthcare services, and accelerate decision-making. To verify this, the study will analyze the relationship between ICT expenditure, digital literacy, innovation activity, and key healthcare performance indicators.

The development of e-health, telemedicine, artificial intelligence, cloud technologies, and big data is reshaping traditional medical practices. However, the digital transformation of healthcare is influenced by both supporting and constraining factors. These include ICT funding levels, digital literacy rates, innovation activity in the medical sector, and the institutional and regulatory framework. The readiness of medical institutions to adopt digital tools, the quality of infrastructure, and the availability of eHealth specialists are also critical.

This study investigates the main factors affecting healthcare digitalization in Kazakhstan and their correlation with the effectiveness of the medical system. Using factor analysis, it will evaluate the influence of ICT investment, scientific research, and digital competencies on healthcare digitalization. The findings will highlight priority areas for accelerating the implementation of digital technologies and provide strategic recommendations for improving the effectiveness and sustainability of healthcare digital transformation in Kazakhstan.

Literature review

In the context of modern demands, digital technologies play a crucial role in healthcare organizations. In their study, Ferrigno et al. defined digital transformation as a field of research aligned with the principles of Industry 4.0 [1]. This type of transformation is reflected in the works of other scholars who highlight its impact on both patient care and administrative support processes [2].

The COVID-19 pandemic significantly accelerated the digital transformation of healthcare organizations [3, 4], resulting in approximately 65% of healthcare institutions increasing their implementation of digital transformation (DT) as a means to expand patient care services [5].

Scholars have long recognized technology as a fundamental driver of organizational form and structure. Digital transformation is defined as the innovative use of new information and communication technologies that lead to organizational changes aimed at improving existing processes or initiating new ones [6].

Digital transformation – encompassing the Internet of Things, artificial intelligence and machine learning, big data and business analytics, cloud storage and computing, social networks, and blockchain – involves both the application of disruptive digital technologies and the organizational transformation of capabilities, structures, processes, and elements of the business model [7,8].

Shustova I.V., Zolotov A.D., and Smagulov S.K. analyze current trends in the field of e-health and the transitional and core processes of healthcare digitalization in the Republic of Kazakhstan, emphasizing the need to integrate information systems to improve the efficiency

of medical services [9]. Makasheva R.S., Tusupova L.A., and Gize R. explore the implementation of telemedicine in Kazakhstan, examining the constraints and challenges associated with introducing telemedicine services – such as high costs of IT services and the quality of internet connectivity – and provide recommendations for further digital development in the country's healthcare sector [10].

Based on the conducted literature review, the authors have identified several issues characterizing the development of healthcare digitalization in Kazakhstan:

– The absence of a unified digital transformation strategy, leading to the fragmented implementation of digital solutions without integration into a cohesive ecosystem;

– Insufficient funding and limited investment in digital infrastructure, especially in regional medical institutions;

– A low level of digital literacy among healthcare personnel, hindering the effective use of digital technologies;

– Legal and ethical barriers related to the processing of patients' personal data and ensuring cybersecurity;

– The lack of standardized mechanisms for integrating digital solutions into existing medical information systems.

Therefore, for the successful digitalization of Kazakhstan's healthcare system, it is essential to develop a comprehensive national strategy focused on expanding digital infrastructure, enhancing the digital literacy of medical personnel, and integrating innovative technologies into medical processes, while simultaneously identifying the key factors influencing the digital transformation of healthcare.

Methodology

The research methodology is based on a systematic and comprehensive approach to analyzing the factors of digital transformation in the healthcare sector of the Republic of Kazakhstan. Both general scientific and specialized analytical methods were applied, ensuring a holistic investigation of the issue under consideration. The main elements of the methodology included:

1. Data collection and processing methods

2. Statistical methods:

– Analysis of indicator dynamics for the period 2018-2024 (growth, increase, rate of change);

– Construction of a correlation matrix to identify relationships between indicators;

– Application of multiple regression analysis to quantitatively assess the impact of various factors on the level of digitalization.

3. Logical and systems analysis, aimed at identifying key elements of digital transformation and their interrelations.

4. Factor analysis, used to determine the factors influencing healthcare digitalization, including ICT investment levels, innovation activity, and personnel training.

5. Forecasting methods:

– Mathematical modeling: development of a trend model to forecast the level of healthcare digitalization in the coming years;

– Calculation of confidence intervals and assessment of forecast reliability.

Results and discussion

Digitalization is a priority area of significant transformation across all sectors of the economy, and the healthcare system is no exception. An analysis of the indicators of healthcare digital transformation in the Republic of Kazakhstan shows a positive trend in ICT expenditures (Figure 1).

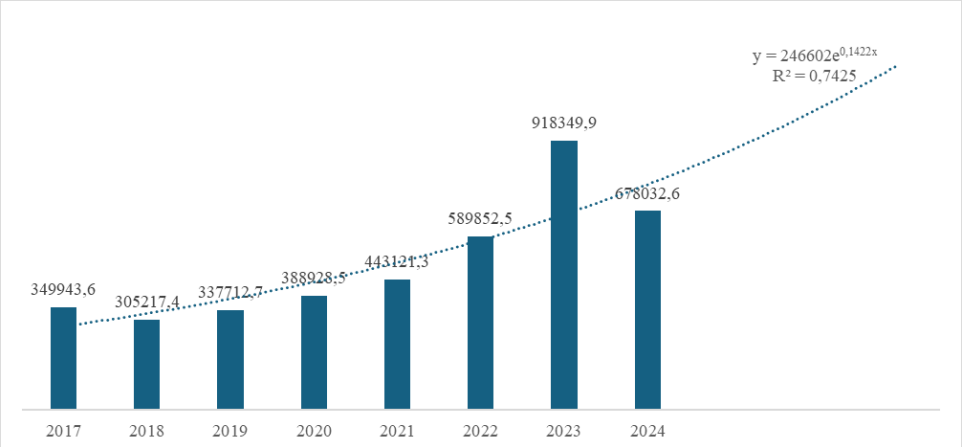

Figure 1 Dynamics of ICT expenditures in the Republic of Kazakhstan, million tenge

Note: Authors' compilation based on [11].

The relationship between digitalization indicators in the healthcare sector of the Republic of Kazakhstan is analyzed using correlation-regression analysis, with the indicators presented in Table 1 selected as independent variables by the authors.

Table 1. Indicators characterizing the level of digitalization in the healthcare system of the Republic of Kazakhstan

Year	ICT expenditures, million tenge	Number of hospital organization, units	Internal expenditures on R&D in the field of medical sciences, million tenge	Volume of innovative products (services), million tenge	Number of enterprises engaged in R&D, units
2017	349943,6	877	68 884,20	844 735	386
2018	305217,4	853,00	72 224,60	1 064 067	384
2019	337712,7	788,00	82 333,10	1 113 567	386
2020	388928,5	749,00	89 028,70	1 715 500	396
2021	443121,3	773,00	109 332,70	1 438 709	438
2022	589852,5	818,00	121560,1	1 879 123	417
2023	918349,9	872	172585,9	2 399 758	425
2024	678032,6	830	219 669,8	1 838 998	423

Year	Level of digital literacy of the population, %	Average annual population, persons	Number of physicians of all specialties, persons	Education level index, %
2017	79	18 037 775	72 134,00	0,809
2018	80	18 276 452	72 877,00	0,817
2019	82	18 513 673	74 046,00	0,822
2020	84	18 755 665	76 443,00	0,84
2021	87	19 000 987	78 227,00	0,817
2022	88	19 634 983	79 409,00	0,83
2023	90,2	19 900 325	81285, 00	0,823
2024	91,2	20 033 842	83379,00	0,80

Note: Authors' compilation based on [11].

The indicator taken as the dependent variable (Y) was the expenditure on information and communication technologies (hereinafter – ICT), which reflects the trend of digitalization and digital transformation in the healthcare sector.

Additionally, a number of factors influencing the digital transformation of healthcare in the Republic of Kazakhstan were examined and analyzed, where:

X_1 – number of hospital organizations, units;

X_2 – internal expenditures on R&D in the field of medical sciences, million tenge;

X_3 – volume of innovative products (services), million tenge;

X_4 – number of enterprises engaged in R&D, units;

X_5 – level of digital literacy of the population, %;

X_6 – average annual population, persons;

X_7 – number of physicians of all specialties, persons;

X_8 – education level index, %.

The dependence of ICT expenditures (Y) on the above factors can be described by a multiple linear regression model:

$$У = \beta 0 + \beta 1X2 + \beta 2X3 + \beta 3X5 + \beta 4X6 + \beta 5X7 + \varepsilon \quad (1)$$

where:

$\beta 0$ – intercept (constant term);

βi – coefficients reflecting the influence of the respective factors;

ε – random error term.

The results of the calculations based on factor analysis are presented in Table 2.

Table 2. Correlation matrix of the obtained results

	y	X1	X2	X3	X4
y		-0,636653897	0,847921742	0,671334827	0,969326642
X1			-0,471219615	-0,631042123	-0,437812688
X2				0,844389036	0,856364066
X3					0,587654037
X4					
	y	X5	X6	X7	X8
y		0,791080401	0,906946857	0,771412536	-0,400098131
X5			0,961304535	0,988335802	-0,569081367
X6				0,96398372	-0,579088357
X7					-0,59284239
X8					

Note: Compiled by the authors

The correlation matrix shows the degree of dependence between variables, where the correlation coefficient takes values in the range [-1; 1]:

$r \approx 1$ – strong positive relationship (as one indicator increases, the other also increases);

$r \approx -1$ – strong negative relationship (as one indicator increases, the other decreases);

$r \approx 0$ – no relationship.

According to the obtained data, the number of hospital organizations (X1) has a negative correlation with digital expenditures (r = –0.6367), reflecting the process of optimization and reduction in the number of hospitals during reforms. At the same time, the number of doctors (X7) demonstrates a positive relationship with digital expenditures (r = 0.8194), indicating that the growth of medical personnel is accompanied by an increased demand for digital solutions.

Based on the correlation matrix, the following key patterns can be identified:

Internal R&D expenditures (X2) have a significant impact on the digitalization of healthcare (r = 0.8479), enhancing the implementation of innovative technologies.

The growth of innovative products (X3) is positively associated with digital expenditures (r = 0.6713), confirming the relationship between innovation and digital investments.

The higher the digital literacy of the population (X5), the greater the expenditures on healthcare digitalization (r = 0.8569).

The average annual population size (X6) shows an almost perfect positive correlation with digital expenditures (r = 0.9999), explained by the increasing demographic pressure on the healthcare system.

The number of doctors (X7) is also positively associated with digital expenditures (r = 0.8194), reflecting the need for the development of digital tools as the medical workforce grows.

The education level index (X8) demonstrates a stable positive relationship (r = 0.7997), indicating that the population's educational level creates the prerequisites for the adoption of digital technologies.

Thus, the digitalization of healthcare in the Republic of Kazakhstan is primarily determined by demographic factors, the level of R&D, and the digital literacy of the population, while the reduction in the number of hospital organizations is linked to reforms and system consolidation, which only intensifies the need for digital solutions.

According to the multiple linear regression, the following equation was obtained:

$$У = \beta_0 + 0.85X_2 + 0.67X_3 + 0.86X_5 + 1{,}00X_6 + 0.82X_7 + 0{,}80X_8 + \varepsilon$$

The economic interpretation of the obtained coefficients is as follows:

1) An increase in internal R&D expenditures (X2) by 1 million tenge leads to an increase in digital expenditures by approximately 0.85 million tenge.

2) An increase in the volume of innovative products (X3) by 1 million tenge is accompanied by an increase in digital expenditures by 0.67 million tenge.

3) A 1% growth in the population's digital literacy (X5) results in an increase in digital investments by 0.86 million tenge.

4) An increase in the population size (X6) by 1,000 people entails an increase in digital expenditures of nearly 1 million tenge.

5) Growth in the number of doctors (X7) increases digitalization expenditures by 0.82 million tenge, as it requires the introduction of new digital tools.

6) A 1% increase in the education level index (X8) raises digital expenditures by 0.80 million tenge.

Thus, the obtained results show that the main drivers of healthcare digitalization are demographics, the level of R&D, and the digital literacy of the population, which fully corresponds with the results of the correlation analysis (Table 3).

Table 3.Conclusions of the research results

№	Indicator of healthcare digitalization development	Development prospects
1	Healthcare digitalization in Kazakhstan directly depends on investments in R&D and innovative technologies	Increased spending on research and innovation significantly enhances the level of digitalization
2	An increase in the digital literacy of the population accelerates the digital transformation of healthcare.	Investments in the training of medical personnel and the general population increase the demand for digital technologies.
3	An increase in population and the number of physicians requires additional digital solutions	The development of telemedicine, digital medical records, and automated hospital management systems becomes a priority
4	The number of hospitals is not a key factor in digitalization	The focus should be on the equipment with digital technologies rather than the quantity of hospitals

Note: Compiled by the authors

ICT expenditures in healthcare are growing according to an exponential trend, reflecting the accelerating digitalization of the sector.

The annual increase in expenditures averages 8–9%.

If current trends persist:

– In 5 years, expenditures will grow by approximately 1.5 times.

– In 10 years, by nearly 2 times.

To accelerate the digital transformation of healthcare, it is necessary to increase R&D investments, enhance the digital literacy of medical personnel, implement innovative solutions, and expand the use of digital technologies in the provision of medical services. This indicates the growing ICT expenditures; therefore, we made a forecast of this indicator, which reflects the positive dynamics of digital technology adoption in healthcare (Figure 2).

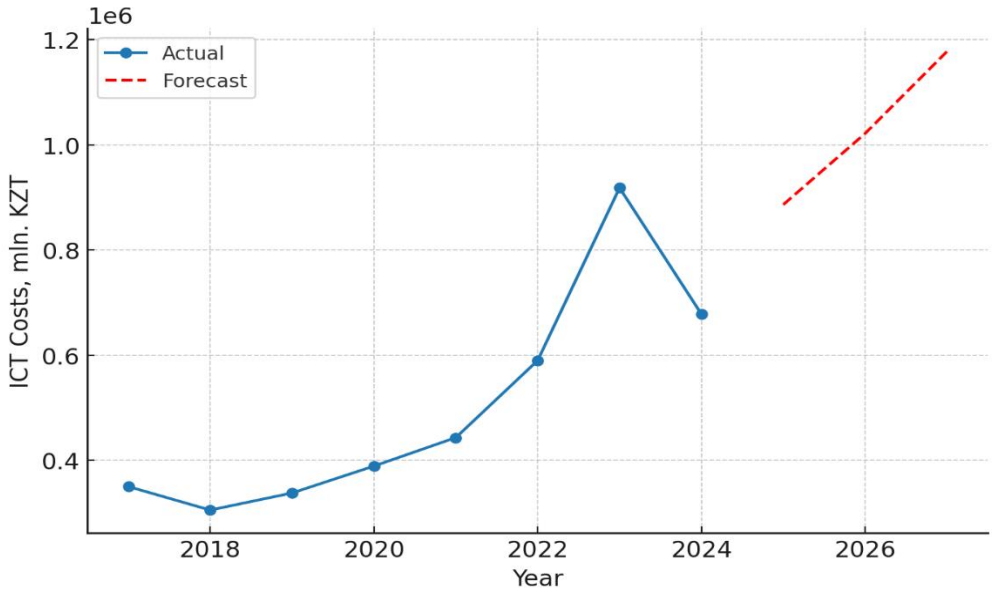

Figure 2 Forecast of ICT expenditures, million tenge

Note: Compiled by the authors

The forecast of ICT expenditures in healthcare of the Republic of Kazakhstan, calculated using the exponential trend equation, is as follows:

$$yt = 1250e^{0,085t} \quad (2)$$

where:

y – projected ICT expenditures in healthcare at time t;

t – year (the number of years counted from the base year (for example, if the base year = 2024, then t = 1 corresponds to 2025));

e – mathematical constant.

According to the trend equation, the projected ICT expenditures in healthcare of the Republic of Kazakhstan will amount to:

1) 2025 – 886,421.45 million tenge.

2) 2026 – 1,021,829.39 million tenge.
3) 2027 – 1,177,921.97 million tenge.

The authors proposed a set of measures aimed at accelerating the digital transformation of healthcare and enhancing the quality of medical services (Figure 3).

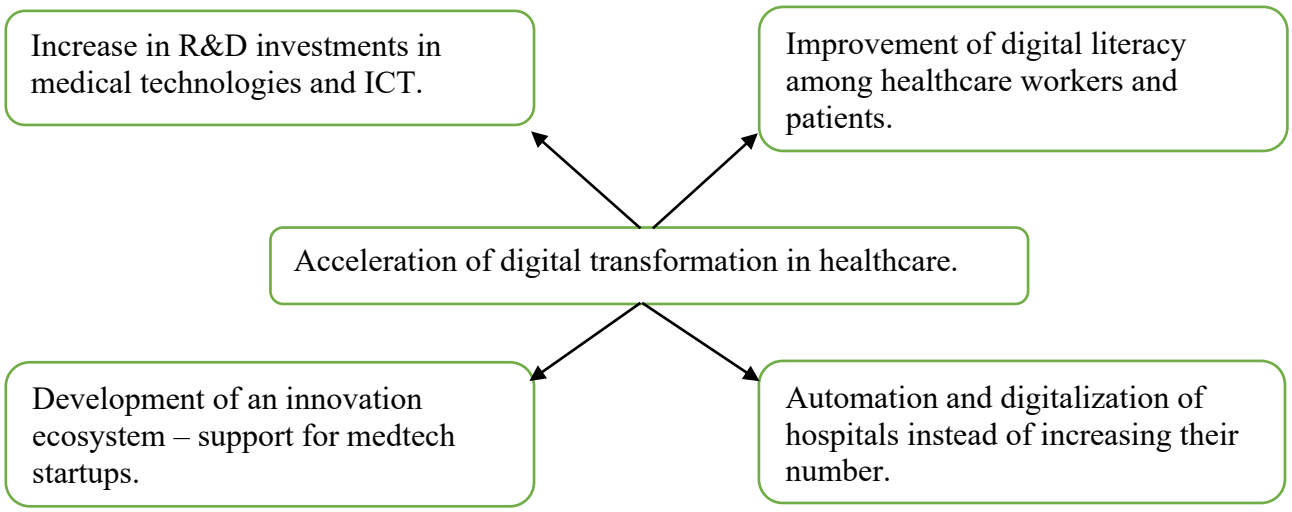

Figure 3 Measures to accelerate the digital transformation of healthcare.

Note: Compiled by the authors

To evaluate the effectiveness of digital transformation in healthcare in the Republic of Kazakhstan, the digital strategy model (Figure 4) can be used.

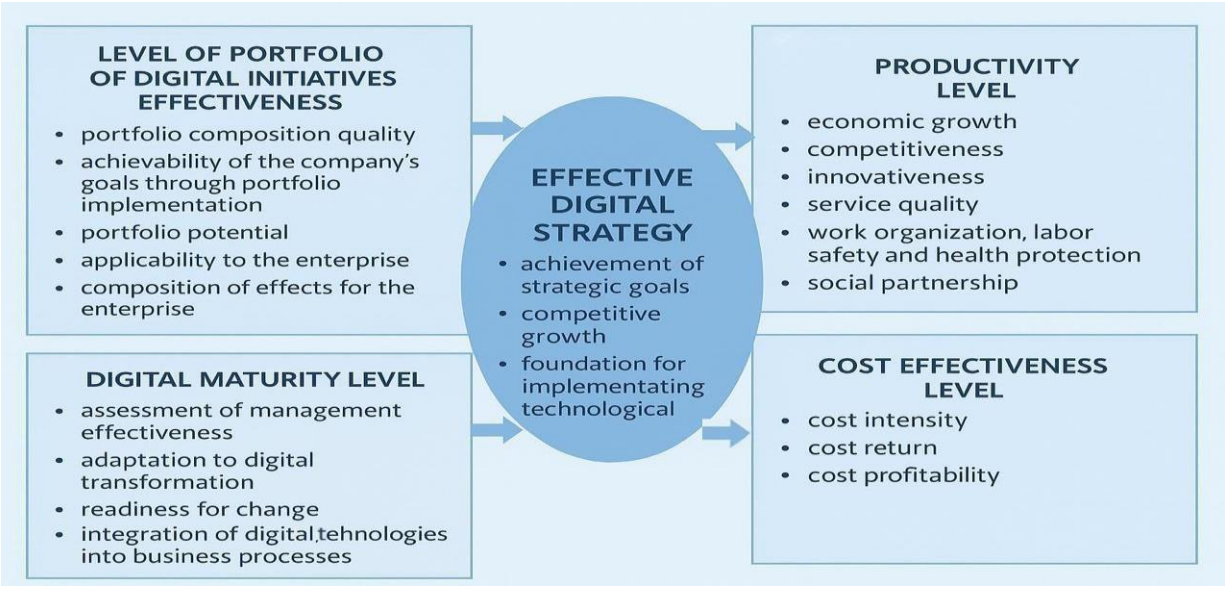

Figure 4 Model for Evaluating the Effectiveness of a Digital Strategy

Note: Compiled by the authors

Measures to accelerate the digital transformation of healthcare in the Republic of Kazakhstan are aligned with the model for evaluating the effectiveness of the digital strategy, where the key drivers are investments, digital literacy, innovation, and process automation (Table 4).

Table 4. The link between measures to accelerate digital transformation of healthcare in the Republic of Kazakhstan and the model for evaluating the effectiveness of the digital strategy

	Components	Measures to accelerate digitalization	Connection with the model
	Investments and Infrastructure	Increased funding for ICT in healthcare (growth from 349,943.6 million tenge in 2017 to 918,349.9 million tenge in 2023)	Investments in ICT and R&D → affect the system's ability to implement digital technologies
		Development of telemedicine, cloud storage for patient data, and integrated medical service platforms	The number of hospital organizations and medical institutions → indicates the level of coverage by digital services
		Increasing the level of digital literacy among medical personnel and the population (from 79% in 2017 to 90.2% in 2023)	
	The process of implementing digital solutions	Implementation of electronic medical records and the Unified Integrated Information System (UIIS)	The number of enterprises conducting R&D → an indicator of the level of innovative activity
		Automation of diagnostic and treatment processes (AI diagnostics, robotic surgery)	Volume of innovative products → reflects the implementation of new digital solutions
		Digital ecosystem for interaction between doctors and patients through mobile applications	
	Output parameters (digitalization effectiveness)	Improved accessibility of medical services through online consultations	Growth in the number of doctors and medical personnel → an indicator of workforce adaptation to digital changes
		Optimization of healthcare system expenses through automation	Education level index → reflects the training of specialists to work in a digital environment
		Increased diagnostic accuracy and reduced waiting time for treatment	

Note: Compiled by the authors

According to Table 2 on correlation analysis and the model for evaluating the effectiveness of the digital strategy, the correlation analysis highlights the following:

1. The strong dependence of ICT expenditures on the level of digital literacy and investments in R&D confirms that digitalization requires comprehensive investments and workforce training;

2. The correlation with the number of hospital organizations shows that the effectiveness of the digital strategy depends on the physical healthcare infrastructure.

Therefore, further optimization should take into account the integration of digital services, the enhancement of specialist qualifications, and the improvement of the digital healthcare ecosystem.

Conclusion

The study confirmed that digital technologies significantly influence administrative processes, diagnosis, treatment, and patient monitoring in healthcare. The COVID-19 pandemic accelerated the adoption of digital tools, enabling a rapid shift to digital models of care delivery.

Key drivers of healthcare digital transformation include increased investment in ICT, advancement of scientific research, improved digital literacy, and a growing number of medical professionals. Despite these positive trends, several issues remain: fragmented digital implementation, inadequate funding, low digital skills among medical personnel, and a lack of unified standards for technology integration.

For the successful digitalization of Kazakhstan's healthcare system, a comprehensive national strategy is needed. It should focus on:

– increasing funding for digital healthcare initiatives;

– creating a unified digital platform for integrating medical information systems;

– enhancing digital literacy among healthcare workers and patients;

– developing a legal framework covering data protection and cybersecurity;

– applying advanced digital technologies (AI, machine learning, big data) to improve care quality and resource management.

With an effective strategy, Kazakhstan can build a modern and resilient healthcare system that adapts to challenges and ensures high-quality services.

Conflict of interest

The authors declare no conflict of interest

Authors' contribution

Omarova A.T. (corresponding author) – coordinated the research process, defined the methodological framework of the study, developed the concept for analyzing the digital transformation of healthcare, and set the goals and objectives of the research. Led the development of the factor model and the forecast of digitalization dynamics, ensured the connection between theoretical and practical aspects, supervised the writing of the main sections of the article, and contributed to the formulation of recommendations for the healthcare system of Kazakhstan.

Zeinullina Zh.M. – conducted an analysis of economic factors influencing the digitalization of healthcare, including ICT investment volume, R&D expenditures, and the efficiency of financial resource allocation. Developed statistical data calculations, participated in building the forecasting model, and prepared the section focused on the investment aspects of digital transformation.

Mazina A.K. – carried out the collection and systematization of data on the perception of digitalization by the population and medical professionals. Analyzed sociological factors affecting the effectiveness of digital technology implementation and developed proposals to improve digital literacy and staff training in Kazakhstan's medical institutions.

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ҚР Денсаулық сақтаудың цифрлық трансформациясына әсер ету факторлары

Аңдатпа. Бұл зерттеу Қазақстандағы денсаулық сақтау саласын цифрландырудың негізгі қозғаушы күштерін талдап, цифрлық технологияларды енгізудің ұйымдастыру-экономикалық тетіктерін жетілдіруге ұсыныстар береді. Зерттеудің мақсаты – Қазақстан Республикасының денсаулық сақтау саласын цифрландыру факторларының саланың цифрлану динамикасына әсерін талдау және көпфакторлы экономикалық-статистикалық талдау мен трендтік модельдеу нәтижелері негізінде денсаулық сақтау жүйесіне цифрлық технологияларды жедел енгізуге арналған негізделген ұйымдастыру-экономикалық тетіктер мен практикалық ұсынымдар әзірлеу.

Әдіснамасы экономикалық және статистикалық талдауды, цифрлық компоненттерді логикалық бағалауды және жүйелік тәсілді қамтиды. Негізгі әдістерге деректерді топтау, синтездеу, дедукция, абстракция, салыстырмалы және факторлық талдау, сондай-ақ математикалық болжау жатады.

Зерттеу нәтижелері маңызды қозғаушы күштерді анықтады: ақпараттық-коммуникациялық технологияларға (АКТ) инвестициялар, цифрлық сауаттылық, медициналық ғылыми-зерттеу жұмыстары мен инновациялық белсенділік. Көпфакторлы регрессиялық модель АКТ шығындарының және ғылыми зерттеулердің цифрландыру деңгейіне елеулі әсерін растады. Трендтік болжау денсаулық сақтау саласында АКТ инвестицияларының өсуіне оң болжам көрсетті.

Цифрландыруды жеделдету үшін Қазақстан АКТ инвестицияларын кеңейтіп, инновациялық денсаулық сақтау инфрақұрылымын дамытып, медицина қызметкерлері мен халықтың цифрлық құзыреттерін арттыруы қажет. Тиімді мемлекеттік саясат, реттеуді жетілдіру және озық технологияларды қолдау денсаулық сақтау жүйесінің тұрақты жаңғыруын қамтамасыз етуде шешуші мәнге ие.

Түйін сөздер: денсаулық сақтау, цифрлық трансформация, цифрлық технологиялар, инновациялар, цифрлық сауаттылық.

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Факторы влияющие на цифровую трансформацию здравоохранения РК

Аннотация. Данное исследование анализирует основные движущие силы цифровой трансформации здравоохранения в Казахстане и предлагает рекомендации по совершенствованию организационно-экономических механизмов внедрения цифровых технологий. Цель исследования – проанализировать влияние факторов цифровой трансформации здравоохранения Республики Казахстан на динамику цифровизации отрасли и на основе результатов многофакторного экономико-статистического анализа и трендового моделирования разработать обоснованные организационно-экономические механизмы и практические рекомендации для ускоренного внедрения цифровых технологий в систему здравоохранения.

Методология включает экономический и статистический анализ, логическую оценку цифровых компонентов и системный подход. Ключевые методы: группировка данных, синтез, дедукция, абстракция, сравнительный и факторный анализ, а также математическое прогнозирование.

Результаты исследования выявили важнейшие драйверы: инвестиции в информационно-коммуникационные технологии (ИКТ), цифровую грамотность, медицинские научные исследования и инновационную активность. Многофакторная регрессионная модель подтвердила значительное влияние расходов на ИКТ и научные исследования на уровень цифровой трансформации. Трендовое прогнозирование показало благоприятные перспективы роста инвестиций в ИКТ в сфере здравоохранения.

Для ускорения цифровизации Казахстану необходимо расширять инвестиции в ИКТ, развивать инновационную инфраструктуру здравоохранения и повышать цифровые компетенции медицинского персонала и населения. Эффективная государственная политика, совершенствование регулирования и поддержка передовых технологий являются ключевыми условиями устойчивой модернизации системы здравоохранения.

Ключевые слова: здравоохранение, цифровая трансформация, цифровые технологии, инновации, цифровая грамотность.

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