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# DIGITAL DECISION-MAKING TOOLS IN THE FIELD OF PUBLIC ADMINISTRATION OF HEALTHCARE

## ABSTRACT

The purpose of the research is to develop a mathematical core of the decision-making preparation system (DSS) and an integral DSS algorithm in the field of public health care management. The urgency of the research is determined by the need to coordinate economic and social issues, the urgency and importance of which is increasing all the time, and the growing need for effective use of financial, budgetary, and other resources in times of economic crises and military operations. The goals that should be achieved by the implementation of digital health care management tools and the tasks that should be solved for this are defined. Factors that affect the effective implementation of DSS and results that are achieved by eliminating negative factors of influence are systematized. Possible indicators of the effectiveness of decisions made are specified. It is indicated that the implementation of DSS technologies in the field of health care and the integration of information resources for this purpose in this area should in the future be oriented to the implementation of an effective integrated national model of Digital Health Records, which is the main structural element of a digital system aimed at health care of every individual. For the analysis of data and the preparation of decision options in the field of health care, a multidimensional system for managing cloud resources of super-large data is proposed and the need to introduce specific digital tools is indicated, in particular data lake house, which allows the implementation of a multi-scenario version of the management solution, which is important for economic and social problems. A mathematical model and an algorithm of DSS in the field of public health care management, which uses the approach of multi-dimensional multi-extreme optimization and the introduction of "nested" one-dimensional solutions on the data hypercube, are developed. This will make it possible to solve complex multi-parametric economic and social problems with the effective use of computing system resources.

**Keywords:** public administration, digital tools, health care, mathematical model, economic and social problems, decision-making risks

**JEL Classification:** E27, C61, C82, I15, I18

## INTRODUCTION

Today, the need for digital transformation of the sphere of public health care management, in particular, the need to implement modern decision-making preparation systems is growing under the following conditions: an increase in the amount of data needed for decision-making; the need to agree on various social and political issues, the number, urgency and importance of which is constantly increasing; the growing need for effective use of state budget funds during economic and political crises and military actions, etc. An integrated decision-making support system can use the potential, including an economic one, by increasing the efficiency of management and the effectiveness of operating available resources: personnel, finances, production of medical equipment and pharmaceutical products, infrastructural, etc. (Msosa and Khuboni, 2023; Pokataiev et al., 2023; Kubalskyi, 2022; Nitsenko, 2021). This is especially relevant because according to the Ministry of Finance spending on health care has been decreasing in recent years. Thus, expenditures in 2022 amounted to UAH 215300 million, including state

budget expenditures together with transfers of ~ UAH 187200 million. In 2023, expenditures were reduced to UAH 206800 million, including state budget expenditures together with transfers to UAH 176100 million (Ministry of Finance of Ukraine, 2023).

Other countries are intensively implementing digital technologies in the field of health care. In particular, the European Union is implementing the "Digital Europe Programme", which is aimed at five main technological areas ("High-Performance Computing", "Cloud, Data and Artificial Intelligence", "Cybersecurity", "Advanced Digital Capabilities", "Accelerating the best uses of technology"). But even in the EU countries, whose institutional structures contribute to the digital transformation of public health care management and the implementation of modern decision-making training systems, this creates a number of problems related to the need to create a technological infrastructure, ensure public support, and provide equal social conditions for access to information and medical services, organizational restructuring of institutional approaches, inclusion in the management process of citizens and commercial structures, whose interests should also be taken into account when making decisions (Lytvyn et al., 2022; Mulka et al., 2022). The introduction of digital technologies in Ukraine also leads to the emergence of new problems, in particular, those affecting the sphere of national security. It should also be taken into account that the conditions of hostilities reduce the transparency of the decision-making system in the field of public health, require additional attention to the assessment of the consequences of decision-making in this field, and shape other peculiarities of information support for healthcare management in Ukraine. Difficulties in implementing the decision-making training system in the field of public healthcare management also lie in the lack of financial resources for its implementation. This determines the need for cooperation with potential investors - domestic and international companies in the field of production of medical equipment and pharmaceuticals.

## LITERATURE REVIEW

Various aspects of the digital transformation of public healthcare management are the focus of the attention of Ukrainian and foreign researchers. This is evidenced, in particular, by detailed reviews of scientific works in this field: Stoumpos et al. (2023), Angelis et al. (2023), Pooran (2022), and Gannedahl et al. (2018).

Caumanns (2019) indicate that the unsatisfactory pace of digitization of the healthcare industry is due to difficulties in implementing "both the integrated management of electronic health care and the sustainable implementation of digital transformation." That is the study by Caumanns (2019) and Krupskiy et al. (2022) state that the driving force behind digitalization should be a unified healthcare management system.

Stoumpos et al. (2023) point out that "digital transformation is defining personal and institutional health care" and the importance of the thesis "there is a great need to explore the managerial implications of digitalization by various stakeholders".

Andrews et al. (2019) introduce the concept of New Public Management (New Public Management, NPM) and argue for the need for a configuration of reforms for its implementation aimed at "improving the efficiency, effectiveness and equity of health care." The necessary tool for this is determined by the digitization of the healthcare industry.

Polyakov and Kovshun (2021) investigated the structural changes brought about by digital tools, in particular e-Health, using the example of which the role of the diffusion of digital innovations as a key driver of development is substantiated. The need to create portals for discussing solutions and knowledge management platforms is indicated. This approach is developed in the presented article for the introduction of a decision support system and the creation of a single national data space.

Ricciardi et al. (2019) while studying information support systems for management decisions indicated the perspective of the TAPIC framework. Using the TAPIC framework as an example, Ricciardi et al. (2019) identify five categories of public healthcare management: "transparency, accountability, participation, integrity, and capacity" on the basis of which public institutions in the field of healthcare should make management decisions. An important peculiarity of the digital healthcare system is indicated: "There is a constant conflict between the protection of privacy and the interests of data use." It is also indicated that information support systems for management decisions allow to increase the efficiency of the use of budget resources. These recommendations were used in the presented study.

Hermes et al. (2020) propose the introduction of an "ecosystem" of digital health management and indicate the need to develop a regulatory framework for the sharing of private, commercial and public data flows. This approach has certain disadvantages, since the new goal is not the goal of each of the "actors" in the field of healthcare, but the "ecosystem of shared values". Hermes et al. (2020) also point out that "current research on information systems has not yet taken into

account the inter-organizational perspective of the digital transformation of healthcare" which leads to the segmentation of groups of "actors". This is considered in the presented study.

Rios-Zertuche et al. (2020) analyze digital health decision support tools in Mexico for the provision of equipment and medicines to district health facilities. These tools use iterative data integration methods. Unfortunately, these methods are limited by the processing capabilities of only small data sets.

Lu et al. (2021) indicated that the growing array of primary medical information necessitates the use of digital tools for its processing. Lu et al. (2021) also studied the impact of barriers to the digitization of medical information for the use of the so-called "importance-resistance analysis model (IRA)" to develop a strategy for overcoming persistent factors. The impact of digitalization barriers on the result of its implementation is considered in the presented article.

Sokolenko and Lynnyk (2021) investigated the results of the implementation of the Health24 medical information system that uses cloud resources. This system significantly simplified the document flow and improved the quality of services in the field of healthcare. Its implementation proves the effectiveness of the use of cloud technologies and in the future provides the possibility of integrating its databases into a single system of management and preparation of solutions in the specified field.

Krinichko and Motailo (2021) substantiated the need for the introduction of information systems for the management of the healthcare industry and information and computer technologies as a tool for providing information to citizens and state structures. It is indicated that "in modern conditions, the effectiveness of management ... depends on the quality of information support of management bodies", but it is not indicated which mathematical models and algorithmic methods are necessary for the implementation of these tasks.

Vasiuk and Kuziuk (2022) studied in detail the peculiarities of designing a single electronic healthcare system eHealth for its use for the purpose of public management. It's advantage of overcoming the "non-transparency of the management mechanisms of the healthcare system" is pointed out. Unfortunately, in the works of Krinichko and Motailo (2021) and Vasiuk and Kuziuk (2022) mathematical models capable of providing "investment-innovation, financial, organizational, legal mechanisms" of state administration have not been studied.

The conclusions of Demikhov (2021) complement the conclusions of Krinichko and Motailo (2021) and Vasiuk and Kuziuk (2022), regarding the need to introduce a unified system of preparation and decision-making in the field of healthcare, since the main factors slowing down the mechanisms of the use of digital control tools are due to insufficient coordination of institutional structures.

Alolayyan et al. (2020) indicate that the use of Health Information Technologies (HITs) reduces economic costs even at the level of primary care and proves an increase in cost savings in the healthcare system at the level of the state of Ceará (Brazil) by integrating data from different levels. This is considered in the presented study. Wang et al. (2021), examining the experience of using preparedness and decision-making systems to combat the pandemic in China, point to their main elements of vulnerability: "data delays and fragmentation, the level of private privacy, and data security vulnerabilities." This is confirmed by the work of Rotaru and Tașcă (2021) on the experience of public management in the fight against the pandemic in Romania. Rotaru and Tașcă (2021) also pointed out the problems of managing the provision of a large number of medical devices and consumables. This was taken into account when preparing the recommendations in the presented article.

Vanagas et al. (2019) compared different approaches to mathematical modelling to prepare decision-making with the aim of directly using the results in the interests of patients: "predictive modelling, simulation modelling and decision analysis" and their use "for planning, performance and outcome evaluation, healthcare financing and assessment of impact on the budget, economic assessment of healthcare, surveillance of infectious diseases, etc. The necessity of improving the mathematical apparatus of these models is indicated. However, the locality of the considered problems limits the use of the proposed mathematical apparatus for complex management problems. Dash and others (2019) investigated the use of super-big data for public health management. It is indicated that the peculiarities of the healthcare system require specialists in a new speciality - the so-called "bioinformatics". A comparative analysis of different big data platforms is provided and Hadoop and Apache Spark are recommended. With this in mind, the presented research focuses on the unification of data and their processing systems. Paul et al. (2023) investigated the implementation of various digital technologies in the field of healthcare. It is indicated that the reliability of digital tools of public healthcare management depends on the success of transferring unstructured data into standardized sources, which requires both adaptive primary data processing systems and high-quality mathematical models for "high-precision rule-based systems". This is considered in the presented study.

Makarenko (2021) investigated the results of the implementation of the eHealth system. It is indicated that "transformational changes in the field of healthcare are designed to improve the making of effective management decisions through the use of electronic systems in the provision of medical services and the processing of large arrays of information, the volume of which is constantly increasing," but no mathematical and algorithmic methods of implementing these tasks are indicated. Zaporozhets (2019) indicated that "the introduction of medical information systems provides managerial, analytical and statistical accounting, performs quality management in real-time, improves the effectiveness of managerial decision-making at all levels of the healthcare industry." The importance of the interoperability of the information system in the field of healthcare with other state information resources is rightly noted. But, unfortunately, the necessity and importance of the creation of a single national data space are not indicated, and recommendations regarding mathematical methods and algorithms for the implementation of these tasks are not provided. Korobchynska and Khaletsk (2023) on the basis of the analysis of the experience of developed countries indicated the need for "adjustment of the management process in the field of healthcare based on monitoring and control algorithms using digital technologies" but, unfortunately, no recommendations were given regarding models and the indicated digital technologies were not specified.

A review of the scientific literature on a specific issue indicates the need to implement a national system of training and decision-making in the field of healthcare. This requires the development of a mathematical core (basic mathematical model) of the decision-making preparation system and decision-making algorithm in the field of public healthcare management. According to the experience of other countries, as indicated by the scientific studies of domestic and foreign authors, this will require the definition of the goals to be achieved by the implementation of digital healthcare management tools in Ukraine.

## AIMS AND OBJECTIVES

The purpose of the research is to develop the mathematical core of the decision-making preparation system and the integral decision-making algorithm in the field of public healthcare management.

The tasks of the research are: determination of the goals to be achieved by the implementation of digital healthcare management tools in Ukraine, and the tasks to be solved for this; identification of factors that influence the implementation of the decision-making preparation system in the field of public healthcare management, identification of ways and results of solving problems related to the influence of these factors.

## METHODS

General and special methods of cognition were used during the research. When introducing the method of content analysis, a study of the scientific literature was carried out according to the definition of the direction. The use of the generalization method made it possible to determine the purpose and tasks of the presented research. The application of the method of logical abstraction made it possible to determine the goals that should be achieved by the implementation of digital healthcare management tools and to identify the range of tasks that should be solved for this. The use of the method of induction and deduction made it possible to indicate the factors that influence the implementation of the decision-making preparation system in the field of public healthcare management, to determine the ways and results that should be achieved under the conditions of solving problems related to the influence of these factors. The application of the method of mathematical analysis contributed to the development of the mathematical core of the decision-making preparation system. The system convergence method made it possible to develop an integrated decision-making algorithm in the field of public health care management.

## RESULTS

The digital transformation of the healthcare sector has so far been carried out according to the diffusion principle (Polyakov and Kovshun, 2021). But nowadays, healthcare management needs systemic approaches that should cover all areas related to healthcare problems: technological, organizational, and resource ones; solve problems not only in the named field but also in related ones - in the production of medical equipment, pharmaceuticals, etc. The peculiarity of the digitization of healthcare management is also that this sphere affects not only social security issues of great importance to the country, as indicated by Nabhan and Moiseenko (2021), and national security - both directly, for example, in view of the need to make decisions regarding the epidemiological protection of the population, and indirectly, since, in particular, it affects the functioning of the country's economy, determines the effectiveness of achieving the main macroeconomic results.

Given the fact that the preparation of decisions for public healthcare management requires taking into account a significant number of economic, political, social and national security factors and involving representatives of institutional, international, industrial, financial, and commercial structures in the process of making and agreeing on decision options, public organizations and individual citizens, the goals that must be achieved by the implementation of digital healthcare management tools in Ukraine are indicated:

- to increase the efficiency of the overall management of the healthcare system and its resources;
- to ensure the effective achievement of the country's sustainable development goals, first of all, the goal of "Strong health and well-being", further promotion of the development of society's well-being and the formation of a sustainable healthcare system;
- to achieve compatibility with the programs of the European Union, in particular, such as Horizon Europe, Digital Europe, Europe4Health, and Shaping Europe's digital future;
- involve citizens in decision-making in the field of public healthcare management, promote awareness among citizens of common interests and joint responsibility for the effectiveness of decisions;
- implement a data management policy that ensures effective interaction of various parties in making quality decisions;
- create a national space of data related to public healthcare management and a unified knowledge base on ensuring the health of citizens;
- provide management of the evolution of public information and communication systems to discuss the issues of decisions in the field of public healthcare management and direct this evolution to the personalization of citizens' participation in this area;
- generate decisions on projects that are accelerators of sectoral restructuring, which have a structural nature, and contribute to the coordinated, consistent and multidimensional development of the healthcare system;
- to accelerate the development of the industrial sector, first of all, the production of medical equipment and the pharmaceutical industry;
- implement healthcare management based on 5P healthcare (Population, Preventive, Predictive, Personalized, Participatory).

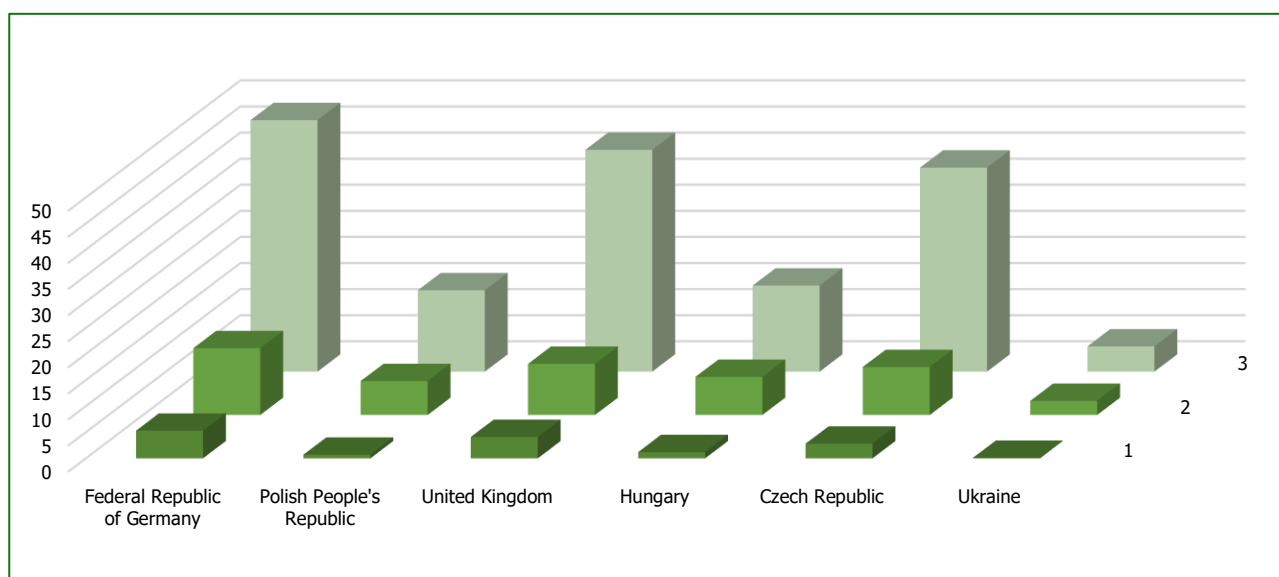
For this, the following tasks must be solved:

- under the digital transformation of healthcare, the formation of a decision-making environment by public sector structures, various institutions related to the field of healthcare, and also institutions related to innovations in this field, public organizations individual citizens, etc.;
- ensuring the standardization of the unified semantics of development of the decisions, standardization of the methodology of their making, giving access to information, exchange of data arrays and their relevant analysis;
- formation of mechanisms to ensure compatibility of information, including medical and economic ones, principles of FAIR (findable, accessible, interoperable and reusable) (David et al., 2020) data necessary for public health care management;
- formation of tools for monitoring threats to the healthcare system and risks to the health of citizens and directing monitoring results into a unified national information system in real-time;
- introduction of tools for evaluating proposed solutions in view of their economic, social, legal, and political consequences;
- implementation of data platforms and technological infrastructures based on modern digital tools: artificial intelligence, cloud technologies, etc. (Andriushchenko, 2022);
- information coordination with international structures: the United Nations; Directorate General of the European Commission for Health Care, World Health Organization, etc (Mitchell et al., 2019);
- information coordination of actions of institutional structures and subjects and organizations of the healthcare system.

Indicators of the effectiveness of the decisions taken can be both economic indicators and the dynamics of life expectancy in absolute terms and in relative terms - the ratio of life expectancy to budget expenditures or the average citizen's healthcare expenditures; dynamics of disability and mortality from diseases; changes in the proportion of the vaccinated population, etc. Unfortunately, the necessary statistical data are not provided by the State Statistical Service. Therefore, to evaluate the effectiveness of digital tools, an indicative method was used based on a survey of citizens according to the Health Index of Ukraine (2023). Thus, digital tools, in particular, the use of cloud technologies by Ukrainian drug manufacturers and the introduction of digital documentation and accounting tools made it possible to implement the "Affordable

Medicines" program. Year by year, the number of those who received all necessary medicines under this program is increasing: 2018 - 43.8%; 2019 - 47.2%; 2020 - 62.4%. In 2016, the assessment of the efficiency of registration in the reception department was 9.4%; 2017 - 18.0%; 2018 – 16.1%; 2019 - 16.2%; 2020 – 18.8%, that is, in 2020, compared to 2016, this indicator improved twice, primarily due to the introduction of digital documentation and accounting tools. The assessment of treatment effectiveness in general also has an upward trend in 2017 - 42.7%; 2018 – 47.1%; 2019 - 50.1%; 2020 – 54.5% (Health index of Ukraine, 2023). The results of the expert survey "How do you assess Ukraine's development processes in the field of electronic healthcare?" conducted by the Polish International and Regional Research Fund (Zaporozhets, 2019) were a demonstrating indicator of the effectiveness of digitization of the healthcare sector. The expert survey showed that positive assessments prevailed over negative in both 2019 and 2020 more than twice.

A comparison of the indicators of expenditures on the health care system in Ukraine and the countries of the European Union for 2021 is shown in Figure 1. Much lower indicators of Ukraine prove the need to implement a decision-making support system in the field of health care to increase the level of effective use of budget resources.



**Figure 1. Demonstrating indicators of expenditures on the healthcare system in Ukraine and the countries of the European Union.** Note: 1 - specific expenditures on the health care system, thousands of USD per person; 2- share of expenditures on the health care system in GDP, %; 3- specific GDP, thousand USD per person. (Source: own calculations based on data (State Statistics Service of Ukraine, 2023; Eurostat Statistics Expanded, 2023a; Eurostat Statistics Expanded, 2023b; Healthcare expenditure, 2023; UK Budget, 2023)

The implementation of digital decision-making technologies in the field of health care and the integration of information resources for this purpose in this field will further contribute, with the growth of GDP and budget opportunities, to the implementation of an effective integrated nationwide HSD (Digital Health Record) model, which is the main structural element of a digital system aimed at protecting the health of every individual.

Factors that affect the effective implementation of the decision-making preparation system in the field of public health care management are listed in Table 1.

The decision-making support system in the field of public health care management should provide access of all parties to the discussion of the proposed decision options (representatives of the Ministry of Health of Ukraine, other state and regional institutions, research institutes, business structures) through a digital cloud platform for storage, archiving large arrays of data, their processing and analysis. This digital tool - a cloud platform must be designed taking into account compatibility, expandability, quality, and data protection. It should also be segmented and allow the connection of other, in particular, commercial (with the consent of their owners) data repositories, and form aggregated and consolidated data.

**Table 1. Factors affecting the implementation of the decision-making training system in the field of public healthcare management.**

Factors	Current situation and negative consequences	Ways and results of problem-solving
Normative and legal	The legal framework does not meet the conditions for the introduction of modern health information technologies. Regulatory frameworks for the use of digital tools are needed, such as the creation of "data lakes" for large data sets and rules for the use of health data, including RWD sources	Regulatory and legal clarification of the formation and handling of extremely large volumes of data of the healthcare system and the de-personalization of RWD sources, the integration of other, in particular, commercial data repositories can contribute to the faster implementation of analytical systems, decision-making systems, creating the prerequisites for the effective use of resources and the formation of a sustainable environment for improvement of the healthcare system
Financing, investments	Budget revenues are decreasing, which limits the possibilities of financing decision-making support systems in the field of healthcare.	Funding of decision-making support systems in the field of healthcare requires institutional support for the formation of public-private partnerships for investment in the digital transformation of the healthcare system.
Data security measures	Data security measures can delay the implementation of digital health tools.	The regulatory and legal coordination of the balance of tasks of a security nature and the need to involve a wide range of individuals and organizations in decision-making will allow to stimulate public management in the field of healthcare. Standardized implementation of differentiated access to data lakes is recommended.
Institutional barriers	Fragmentation of solutions to the problems of implementation of healthcare and its resource and financial provision between different institutional structures leads to irrational use of resources and ineffective and delayed solutions of urgent problems.	Improved interaction between institutional structures at the stage of preparation and decision-making and during their implementation will contribute to the rational use of resources and effective solutions of healthcare system problems in a short period of time.

These recommendations are supported by the existing experience of using cloud technologies to implement the tasks of one's economic activity in areas related to the healthcare system (see Table 2). The use of cloud technologies in the indicated areas is practised much more than in other areas, as shown by a comparison of the data in Table 2. This indicates the presence of appropriate infrastructure and specialists in areas related to the healthcare system. At the same time, it should be noted that the share of pharmaceutical companies using cloud technologies has decreased in recent years. This, in particular, leads to a reduction in the amount of relevant information in this area, which can be used in the future for making decisions in the field of health care.

**Table 2. Share of enterprises using cloud technologies in the total number of enterprises, %.** (Source: State Statistics Service of Ukraine, 2023)

By types of economic activity	Years			
	2018	2019	2020	2021
An integral indicator for all sectors of the economy	9.8	10.3	10.2	9.8
Production of basic pharmaceutical products and pharmaceutical preparations	14.5	20.0	17.9	15.1

The information system must support structured or unstructured data, in particular, sources of RWD (Real-world data). This is a peculiarity of healthcare information systems for which RWD sources are a widespread source of data provided they are de-identified according to rules similar to HIPAA (Health Insurance Portability and Accountability Act) or GDPR (General Data Protection Regulation) (Girardi et al., 2020), which must be introduced into the Ukrainian legal field for the effective application of information systems.

Qualitative improvement of healthcare management will allow the introduction of a modern system of support and management decision-making. Since this area has peculiarities, the effectiveness of the support system and management decision-making is conditioned by the need to develop specialized mathematical tools and algorithms.

For data analysis and preparation of solutions in the field of healthcare, a multidimensional system for managing super-big data cloud resources is offered. Since the use of heterogeneous (including commercial) data repositories is expected to effectively use the potential of cloud computing, the data lake house architecture is proposed, which allows the implementation of a multi-scenario version of the management solution, which is important for economic and social problems. This determines the use of OLAP technologies ("online analytical processing"). As it is known, the concept of OLAP is based on the multidimensional representation of information, i.e., processing of data hypercube. For complex economic and social problems, it is advisable to apply modelling of multidimensional multi-extremal optimization.

The solution of such a problem on the data hypercube is proposed to be considered as a set of "nested" one-dimensional solutions:

$$f(\vec{x}) = \dots \cdot f(\vec{x}_1 \dots \vec{x}_n), D \ni [a_1 \dots z_1], [a_n, \dots z_n] \tag{1}$$

where  $\vec{x}$  is a vector of parameters of a multidimensional problem,  $f(\vec{x})$  is a function whose extreme value is the solution of the problem,  $\vec{x}_1 \dots \vec{x}_n$  are vectors of parameters of subextremal functions,  $D$  is the area of hypercube chambers whose data are needed to solve the problem,  $[a_1, \dots z_1], [a_n, \dots z_n]$  are subareas of hypercube chambers.

Then the solution of the multidimensional problem (1) is reduced to the solution of the one-dimensional problem:

$$f^* \equiv f(\vec{x}) = f_1^*(\vec{x}_1) \tag{2}$$

where

$$f_i^*(\vec{x}_i) = f_i(\vec{x}_1 \dots \vec{x}_n) = f_{i+1}(\vec{x}_1 \dots \vec{x}_i \dots \vec{x}_{i+1}), 1 \leq i \leq n \tag{3}$$

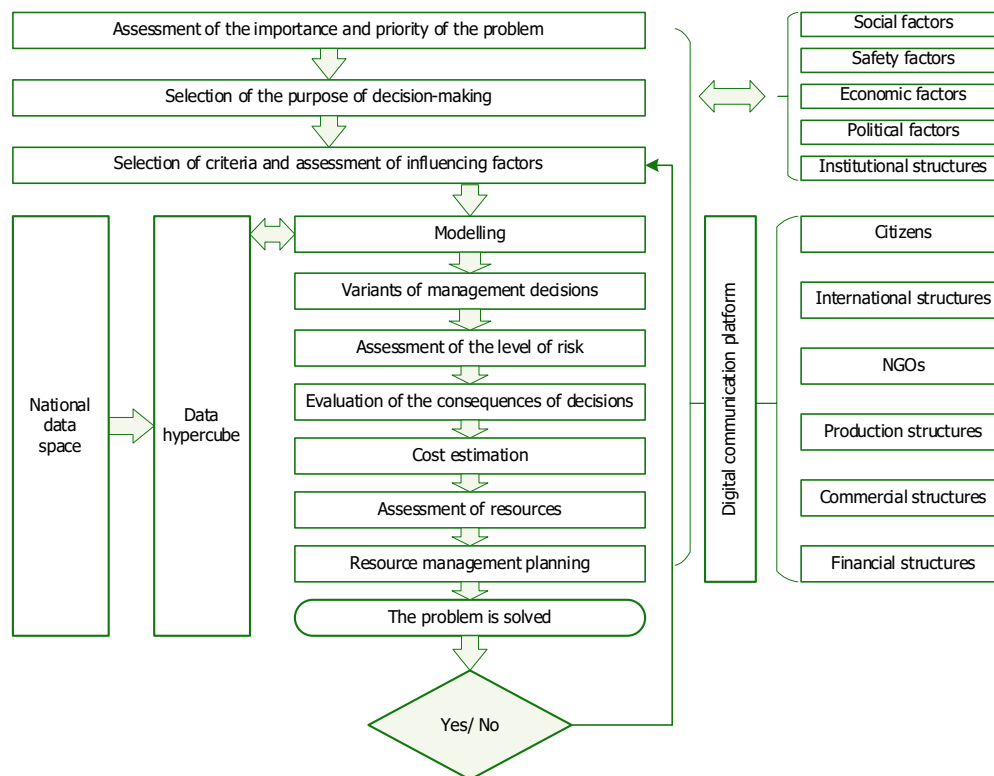
The one-dimensional function  $f_1^*(\vec{x}_1)$  is formed according to the recurrent principle, that is, for its calculation to determine the vector of the variable  $\vec{x}_1 = \vec{x}_1^*$  it is necessary to successively optimize the functions  $f_2^*(\vec{x}_2)$  and  $f_2^*(\vec{x}_1 \dots \vec{x}_2 \dots \vec{x}_3)$

If the extremum regions of the functions  $f(\vec{x}_1), f(\vec{x}_2), \dots f(\vec{x}_n)$  do not coincide in the region of admissible values of the specified functions, a subregion of compromise values is searched for in the multidimensional region of the definition of all functions with a step-by-step clarification of this subregion:

$$A \rightarrow \min \in (A_1, A_2 \dots A_n), \text{opt} f_1(\vec{x}_1) \in A_1, \text{opt} f_2(\vec{x}_2) \in A_2, \text{opt} f_n(\vec{x}_n) \in A_n \tag{4}$$

where  $A$  is the domain of the function  $f(\vec{x})$ ;  $A_1, A_2 \dots A_n$  are the domains of the functions  $f_1(\vec{x}_1), f_2(\vec{x}_2), f_n(\vec{x}_n)$ .

A mathematical model was developed for use as a mathematical basis for the formation of, first of all, the "Modeling" block and, in general, the implementation algorithm of the "Digital Communication Platform" - the core of the integral decision-making algorithm in the field of public healthcare management, presented in Figure 2. The integral decision-making algorithm in the field of public healthcare management is presented in Figure 2. in a generalized, skeletal way, since its detailing is not possible in the framework of this article.



**Figure 2. An integral decision-making algorithm in the field of public healthcare management.**

This algorithm systematically takes into account the peculiarities of public healthcare management, contributes to the achievement of the above-mentioned goals and allows for solving the mentioned tasks. Coordination of the functioning of other components of the algorithm is determined precisely by the peculiarities of the mathematical core, which should implement a multidimensional, multi-criteria automated decision-making preparation system in the field of public healthcare management. The multi-criteria nature of decision-making preparation is taken into account by connections with blocks of economic, social, political factors and, even, security factors and institutional, international, and public structures and, even, individuals who have the right to formulate tasks and identify problematic issues that should be solved by the proposed system of support and decision-making in the field of public healthcare management. There is a significant difference in the groups of influencing factors and the interests of the specified parties, which is illustrated by Figure 2. Thus Figure 2 proves the need to take into account and compromise agreement of the target functions that formalize the tasks and problems formulated by the named structures. The need for interaction with other information resources of the state and the condition of ensuring fast processing of data from the specified resources for health management tasks determine the formation of the proposed National data space for the use of cloud technologies, which is illustrated in Figure 2. It is the proposal for the creation of the National Data Space that, firstly, will form the prerequisites for public management by opening wide access to significant arrays of information with proper provision of data security measures without delaying the implementation of digital healthcare tools, secondly, the common data space will speed up and facilitate primary processing of data in the field of healthcare management and will ensure data exchange between various state structures.

The mathematical model and algorithm developed during the research, the results of which are given in the presented article, will allow to implement an effective system of preparation for decision-making in the field of healthcare, to improve the results of the industry and to use financial resources in a rational way.

## DISCUSSION

In the scientific literature, it is often indicated that "public administration in the field of healthcare is a component of the social security of the state" (Nabhan and Moiseenko, 2021), but sometimes it is overlooked by researchers that in modern conditions of ensuring the proper level of social security tasks, digital tools of public administration are needed. Unfortunately, the mathematical models of decision-making in this field are also largely ignored by researchers. The modelling of the management process in a complex economic and social system, which is represented by the healthcare management system, requires specialized tools of multidimensional multi-extreme optimization. The use of digital tools for healthcare decision-making also requires special knowledge, and the formation of a specialized infrastructure, as indicated by Dash et al. (2019), that will even need specialists in a new speciality - the so-called "bioinformatics". This statement by Dash et al. (2019) is debatable. But, of course, the implementation of digital tools in the field of healthcare management will require both trained specialists and significant financial resources. At the same time, according to Ricciardi et al. (2019), Hermes et al. (2020), and Rios-Zertuche et al. (2020), direct use of the experience of other countries in Ukraine is impossible. It should be taken into account that there are groups of factors that negatively affect the introduction of an effective Ukrainian national decision-making support system in the field of healthcare. This is confirmed by the experience of implementing the Health24 medical information system, which, contrary to the opinion of Sokolenko and Lynnyk (2021), did not go smoothly. The experience of implementing Health24 also confirms that without the use of cloud technologies, the implementation of a healthcare decision-making preparation system will require much more financial costs.

Conclusions by Demikhov (2021) that the main factors slowing down the mechanisms of application of digital control tools are at the regional level require additional research. The main factors that, according to the authors, influence the implementation of the decision-making preparation system in the field of public healthcare management are listed in Table 1. It should also be noted that although the conclusions of Ricciardi et al. (2019) that digital management tools with the appropriate level of transparency in their use are able to ensure the objectification and transparency of management in a complex economic and social system of healthcare, to achieve social justice in the provision of medical services and to realize the rational economic use of available resources, are generally true, it is difficult to ensure full management transparency in the Ukrainian conditions with the need to strengthen security measures.

## CONCLUSIONS

It is indicated that the implementation of digital tools in the field of healthcare has so far been carried out according to the diffusion principle. This led to certain improvements, which are particularly indicated by the results of public opinion polls and expert surveys. But today, healthcare management needs systemic approaches that should cover all areas related

to healthcare: technological, organizational, and resource ones; to solve problems not only in the named field but also in related ones. Therefore, the preparation of decision-making for the public management of healthcare requires taking into account a significant number of economic, political, social and national security factors and involving representatives of institutional, international, industrial, financial, commercial structures, and public organizations in the process of making and agreeing on decision options. The goals that should be achieved by the implementation of digital healthcare management tools in Ukraine are specified. It is indicated that the achievement of the specified goals will require solving a number of problems and a list of problems that need to be solved is provided.

A comparison of the essential indicators of expenditures on the health care system in Ukraine and the countries of the European Union is provided, and it is indicated that the significantly lower essential indicators of Ukraine prove the need for the implementation of a decision support system in the field of health care for the effective use of budgetary resources. It is indicated that the implementation of digital decision-making technologies in the field of healthcare and the integration of information resources for this purpose in this area should be oriented in the future to the implementation of an effective integrated national model of the Digital Health Record, which is the main structural element of a digital system aimed at the healthcare of every individual.

Factors that affect the effective implementation of the decision-making training system in the field of public healthcare management and the results that will be achieved by eliminating negative factors of influence are systematized.

It is indicated that the decision support system in the field of public healthcare management should support both structured and unstructured data. First of all, this applies to Real-world data. It is indicated that for this purpose it is necessary to approve the possibility of their de-identification according to rules similar to the General Data Protection Regulation.

For data analysis and preparation of solutions in the field of health care, a multidimensional system for managing super-big data cloud resources is offered. Since the use of heterogeneous (including commercial) data repositories is expected to effectively use the potential of cloud computing, the data lake house architecture is proposed, which allows the implementation of a multi-scenario version of the management solution, which is important for economic and social problems.

A mathematical model and an integrated decision-making algorithm in the field of public healthcare management were developed. This algorithm systematically takes into account the peculiarities of public healthcare management. The multi-criterion of decision-making preparation is taken into account by connections with blocks of economic, social, political factors, and even security factors and institutional, international, and public structures. The need for interaction with other information resources of the state and the condition of ensuring fast processing of data from the specified resources for the tasks of healthcare management determine the need for the National Data Space using cloud technologies. The creation of the National Data Space, firstly, will form the prerequisites for effective public management of the wide access to large amounts of information with proper provision of data security measures without delaying the implementation of digital healthcare tools, secondly, the common data space will speed up and facilitate the initial processing of data in the field of healthcare management.

The mathematical model and algorithm developed during the research will allow to implement an effective system of preparation for decision-making in the field of healthcare, improve the results of the industry and rationally use financial resources.

Future research will be aimed at adapting the proposed model and algorithm to the organizational peculiarities of the healthcare sector, developing specialized processing algorithms, checking the relevance and systematization of primary data. The implementation of a comprehensive information and communication system for providing information to a wide range of interested parties requires attention.

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## ADDITIONAL INFORMATION

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### AUTHOR CONTRIBUTIONS

*All authors have contributed equally.*

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## **ЦИФРОВІ ІНСТРУМЕНТИ УХВАЛЕННЯ РІШЕНЬ У СФЕРІ ПУБЛІЧНОГО УПРАВЛІННЯ ОХОРОНОЮ ЗДОРОВ'Я**

Метою дослідження є розроблення математичного ядра системи підготовки ухвалення рішень та інтегрального алгоритму ухвалення рішень у сфері публічного управління охороною здоров'я.

Актуальність дослідження обумовлюється необхідністю узгодження економічних, суспільних, політичних питань, нагальність і важливість яких повсякчас збільшується, і зростанням потреб ефективного використання фінансових, бюджетних та інших ресурсів у часи економічних криз та воєнних дій.

Визначено цілі, які мають бути досягнуті впровадженням цифрових інструментів управління охороною здоров'я, та завдання, які мають бути виконані для цього. Систематизовані фактори, які впливають на ефективне впровадження системи підготовки ухвалення рішень, і результати, які будуть досягнуті за усунення негативних чинників впливу. Указано на можливі індикаторами ефективності ухвалених рішень. Указано, що впровадження цифрових технологій ухвалення рішень у сферу охорони здоров'я та інтеграція для цього інформаційних ресурсів у цій царині мають надалі бути орієнтовані на реалізацію ефективної інтегрованої загальнонаціональної моделі Digital Health Record, яка є основним структурним елементом цифрової системи, спрямованої на охорону здоров'я кожного громадянина.

Для аналізу даних і підготовки варіантів рішень у сфері охорони здоров'я запропонована багатовимірна система управління хмарними ресурсами надвеликих даних та вказано на необхідність запровадження конкретних цифрових інструментів, зокрема data lakehouse, які дозволяють реалізувати багатосценарний варіант управлінського рішення, що є важливим для економіко-соціальних проблем.

Розроблена математична модель ядра й алгоритм системи підтримки ухвалення рішень у сфері публічного управління охороною здоров'я, яка використовує підхід багатовимірної багатоекстремальної оптимізації та запровадження «вкладених» одновимірних рішень на гіперкубі даних. Це дозволить виконувати складні багатопараметричні економіко-соціальні завдання за ефективного використання ресурсів обчислювальних систем.

**Ключові слова:** публічне управління, цифрові інструменти, охорона здоров'я, математична модель, економіко-соціальні задачі, ризики ухвалення рішень

**JEL Класифікація:** E27, C61, C82, I15, I18