

DOI: 10.15838/esc.2025.4.100.10
UDC 303.094.7, LBC 87.256.631.0
© Natsun L.N.

Substantiating the Choice of Regional Healthcare Effectiveness Indicators



Leila N. NATSUN

Vologda Research Center, Russian Academy of Sciences

Vologda, Russian Federation

e-mail: leyla.natsun@yandex.ru

ORCID: 0000-0002-9829-8866; ResearcherID: I-8415-2016

Abstract. In the context of modern demographic trends related to population aging, as well as due to the ongoing pro-natalist policy, new challenges arise for healthcare, coupled with an increasing contradiction between the growing demand for medical services from the population and the limited available human, material and financial resources. Consequently, the choice of criteria for evaluating the effectiveness of healthcare becomes crucially important from the practical perspective. Russian and foreign researchers propose various approaches to the development of such criteria and to the way in which the assessment procedure itself is carried out. However, so far, there is no well-established list of criteria for evaluating healthcare effectiveness. The aim of this work is to substantiate the indicators for assessing the effectiveness of the regional healthcare system, applicable to solving optimization problems. The information base of the study includes Russian and foreign research on the topic in question, and statistical data characterizing the functioning of regional healthcare and the state of public health. We consider approaches to determining the effectiveness of healthcare at the levels of individual medical technology, medical organization, and the industry as a whole and reveal strengths and weaknesses of existing approaches to measuring healthcare effectiveness. Special attention is paid to the analysis of current approaches to assessing the effectiveness of management decisions in the healthcare sector. It is proved that the correlation of “input” and “output” is the most relevant method for solving optimization problems simulating variants of management decisions in the healthcare sector. Theoretical novelty

For citation: Natsun L.N. (2025). Substantiating the choice of regional healthcare effectiveness indicators. *Economic and Social Changes: Facts, Trends, Forecast*, 18(4), 184–198. DOI: 10.15838/esc.2025.4.100.10

of our research lies in substantiating a number of indicators for assessing the effectiveness of regional healthcare. Based on the analysis of data from Russian and foreign studies, as well as taking into account the correlation analysis, we propose to consider life expectancy at birth, mortality of the population over the working age, mortality from diseases of the circulatory system and one-year mortality of patients with malignant neoplasms as the resulting indicators of the functioning of regional healthcare. In the future, these indicators will be used as target parameters for solving optimization problems in the field of regional healthcare using its agent-based model. The proposed approach to assessing the effectiveness of regional healthcare can serve as a theoretical basis for an automated management decision support system in this area, which determines the practical significance of the research findings.

Key words: regional healthcare, effectiveness criteria, public health, healthcare resources.

Acknowledgment

The research was supported by Russian Science Foundation grant 24-28-01783 (<https://rscf.ru/project/24-28-01783/>).

Introduction

The most acute modern challenges facing the healthcare system at the regional level are demographic aging; high levels of premature mortality; a significant gap between life expectancy and healthy life expectancy; the fact that people have to use paid medical services due to lack of resources to provide free medical care in the public healthcare system (Morozova et al., 2022); lack of funding for territorial programs of state guarantees for providing free medical care to the population (Grishin et al., 2021). These challenges bring to the fore the issue of improving the efficiency of the healthcare system. Addressing this issue largely determines the prospects for maintaining public health. Since there is a growing demand for the development of automated management decision support systems, research in this area is particularly in demand.

Materials and methods

The aim of the study is to substantiate indicators for evaluating the effectiveness of the regional healthcare system, applicable to solving optimization problems.

To achieve this goal, a critical analysis of existing approaches to assessing the effectiveness of healthcare at various levels was carried out, with an emphasis on the macro level. Since the quality of management and the competence of decision makers is of particular importance in the current socio-economic conditions, a review of the available methods for evaluating the effectiveness of management decisions in the healthcare sector was conducted.

At the next stage of the work, based on the analysis of the results of Russian and foreign studies, a number of principles for selecting indicators that can reflect the effectiveness of the functioning of regional healthcare were proposed and substantiated. When formulating the selection principles, the initial judgment was the thesis about the need to search for such indicators, the levels of which mainly depend on the work of the health system, but at the same time directly characterize the state of public health. Next, a correlation analysis was conducted for the direct selection of performance indicators. The final list of indicators

for assessing the effectiveness of the functioning of regional healthcare, therefore, was formed on the basis of logical selection conditions, as well as taking into account the assessment of their correlation with the indicators of resource availability of the industry.

The resulting set of performance indicators at subsequent stages of the study will be used to assess the effectiveness of the regional healthcare system using the cost–effectiveness method using an agent-based model. In particular, when solving optimization tasks, a comparison of the target and actually achieved levels of each of the selected performance indicators and the cost of resources to achieve them will be carried out.

Results

There is often an equal sign between the concepts of “effectiveness” and “performance efficiency”, but this is not entirely correct. We rely on the approach proposed in (Uiba et al., 2012). Performance efficiency is considered as the achievement of planned results, regardless of how much resources were used for this purpose, effectiveness is a broader concept, a comprehensive description of the potential and actual results of the functioning of the system, taking into account the degree to which these results correspond to the main goals. In other words, effectiveness is considered as “the property of the system to achieve the ultimate goal”. The applicability of this approach in assessing the effectiveness of the healthcare system is explained by the fact that it belongs to the ergatic system, that is, it has a given target function (Uiba et al., 2012).

In the work mentioned above, it is also proposed to decompose the concept of “effectiveness” into a number of narrower categories, highlighting external functional (target) effectiveness, internal functional effectiveness, economic effectiveness and resource conservation, management effectiveness and social effectiveness. Denoting the logical

relationship of the proposed categories, the authors point out that the quality and reliability of the functioning of the economic system are its procedural properties, and effectiveness is the resulting property. The authors also talk about the fundamental difference between the meanings of the categories “result” and “effect”: “effect” is a manifestation of the effect of a result obtained in a given system on a neighboring system (Uiba et al., 2012).

We should note that the categories “effect” and “result” are not always distinguished. Thus, in the work of A.Yu. Sokolov and co-authors (Sokolov et al., 2018), the concept of “effect” is considered as a synonym for a specific result of actions, and effectiveness is assessed as the degree to which planned end results are achieved based on the “end results model”, which includes a set of indicators of planned effects (in absolute numbers) or a set of criteria (relative values) of effectiveness.

Effectiveness can be determined at various levels: individual medical technology, medical organization, and the sector as a whole. At the same time, each level has its own effectiveness criterion (*Tab. 1*).

To assess the effectiveness of testing individual medical technologies, one is guided by the requirements of the “Clinical and economic research. General provisions”¹ standard. The effectiveness criteria for any of the methods recommended in the Standard for conducting clinical and economic analysis are based on the ratio of the results of medical care and the costs of their implementation. The approved methods include: “cost–effectiveness” analysis, “cost minimization” analysis, “cost–benefit” analysis, and “cost–profit” analysis.

¹ Clinical and economic research. General provisions: Industry standard. Standardization system in healthcare of the Russian Federation. Available at: <https://docs.cntd.ru/document/1200123394?ysclid=m7u7dqmkp9861869310>

Table 1. Criteria for evaluating effectiveness at different levels

Type of effectiveness in healthcare	Effectiveness criterion	Level of effectiveness assessment
Performance efficiency	Probability of achieving a given result	Separate nosology, doctor, prevention program, etc.
Medical effectiveness	Probability of achieving a certain effect from achieving the goal	Healthcare sector as a whole
Medical and economic effectiveness	Probability of achieving the optimal “cost–effect” ratio	Healthcare sector as a whole
Socio-economic effectiveness	Probability of achieving a certain “cost–socio-economic effect” ratio	Social systems
Note. The single criterion for all levels is the probability of achieving the set goal. Compiled according to: (Uiba et al., 2012).		

The concepts of “risk” and “security” are widely used in assessing the effectiveness of anti-epidemic preventive measures. The main criterion for effectiveness is a reduction in the incidence rate in the context of the implementation of the measure compared to the previous period when it was not used².

Foreign studies devoted to assessing the effectiveness of the healthcare system consider this concept as a ratio of resource expenditure to the result obtained. In the work of T.H. Wagner and co-authors, it is noted that healthcare effectiveness can be divided into two types: allocative effectiveness, i.e. related to the search at the macro level for the best way to allocate limited resources to achieve public goals, such as public health or social security, and production effectiveness, which is considered as the ability of a medical organization to maximize the production of results using available limited resources and technologies (Wagner et al., 2025). In the first case, the most common method of evaluating effectiveness is cost-effectiveness analysis (CEA), and in the second case, budget impact analysis (BIA). At the same time, the need to combine both approaches in practice when

solving managerial tasks in the field of healthcare is emphasized. According to the authors of the systematic review of healthcare effectiveness research at the national and subnational levels (Mbau et al., 2023), this area is still less developed compared to research on the effectiveness of individual medical institutions. The health system performance indicators used in the literature are classified by the authors of the mentioned review into three blocks: intermediate outputs of health services (for example, the number of visits to medical institutions), individual health outcomes (for example, infant mortality rate) or composite indices of any intermediate health outcomes (for example, healthy life expectancy). In macro-level studies, parametric and nonparametric methods are used to assess cost effectiveness, which make it possible to identify the “effectiveness boundary” of healthcare functioning (Joo, 2025). Discussion and comparative analysis of the advantages and limitations of various parametric and nonparametric methods is a developing area of research (Hollingsworth, Wildman, 2003; Şenel, Cengiz, 2016).

In the works of Russian authors devoted to the assessment of the effectiveness of healthcare, we are talking about medical, economic and socio-economic efficiency. The “cost–effect” method is more often used to evaluate effectiveness. In particular, industry resources can be compared

² Slobodenyuk A.V., Kosova A.A., An R.N. (2015). Epidemiological analysis: Textbook. Yekaterinburg: Publishing house of GBOU VPO UGMU of the Ministry of Health of Russia. 36 p.

with the results obtained. Demographic indicators (mortality, life expectancy) and their derivatives are considered as the resulting indicators, reflecting the cost assessment of the population's health capital (GDP losses due to negative processes in public health).

A study by specialists from Vologda Research Center of the Russian Academy of Sciences (Ilyin et al., 2006) summarized the methods of complete economic analysis used to assess the effectiveness of healthcare at the regional and municipal levels. These include the cost minimization method, the "cost–effectiveness" method, the "cost–profit" method, and the "cost–benefit" method. At the level of assessing the effectiveness of regional healthcare, the "cost–effectiveness" and "cost–benefit" methods can bring the best results. In the first method, it is proposed to use general and primary morbidity, morbidity with temporary disability, primary disability, mortality, as well as the number of complaints from the population about the quality of medical services provided, as effective indicators of regional healthcare. For the second method, the resulting indicator will be quality-adjusted life years (QALY). However, its practical application is difficult due to a number of methodological constraints (Ilyin et al., 2006).

The conceptual basis for defining the target functions of the regional healthcare system in the work of A.V. Pepelyaeva and E.A. Tretyakova is the synthesis of institutional, evolutionary and functional approaches. When building their own methodology for assessing the effectiveness of regional healthcare, the authors carry out a multi-stage procedure for calculating integral indicators (Pepelyaeva, Tretyakova, 2018).

One of the options for assessing the effectiveness of regional healthcare is the correlation and regression analysis of statistical data. Thus, in the work of G.G. Rapakov and co-authors, methods

of correlation regression and cluster analysis were applied and it was proved that the territories of the Vologda Region differ in healthcare effectiveness, estimated through a comparison of the capacity of institutions and mortality rates (Rapakov et al., 2019).

The creation of integrated indicators of various design and content is one of the most common approaches to assessing the effectiveness of regional health systems. As a rule, the final value of such indicators is obtained by averaging the estimates of their individual components. Note that this approach is very easy to apply, but it has a limitation: in this case, the importance of each of the criteria used relative to the others is not evaluated, and when calculating the final rank, all of them are recognized as having equal significance.

An example of a study with such a design can be the work of V.I. Starodubov and co-authors, in which the assessment of regional health systems was carried out in two stages. At the first stage, average ranking estimates were obtained for individual thematic blocks of statistical indicators, and at the second stage, an average integral effectiveness estimate for each region was calculated. According to the results of the calculations, the lowest effectiveness ratings were observed in the northern and eastern regions of Russia (Starodubov et al., 2010).

Stability is an aspect that is relatively rarely given attention in the study of the effectiveness of regional healthcare systems. Methodological developments aimed at its assessment are presented in the work of V.A. Chereshev and co-authors. The design of this study included, among other things, a procedure for assessing stability criteria using the criteria importance theory (CIT). The regional healthcare effectiveness coefficient itself was calculated as the ratio of the integral coefficient of medical and social effectiveness and the coefficient of financing of the

territorial program of state guarantees. The novelty of the approach proposed by the authors is that its implementation produces a quantitative assessment of the dynamics of the effectiveness and stability of regional healthcare, as well as a conclusion about the mode of functioning of regional healthcare: whether it is located in a safe zone, a risk zone, or a disaster zone (Chereshnev et al., 2021).

N.P. Starykh and A.V. Egorova propose a list of indicators for assessing the effectiveness of regional healthcare, taking into account the objectives of the national project “Healthcare”. At the same time, such types of effectiveness as economic, medical and social are considered as criteria for the effectiveness of regional healthcare, and the targets contained in the national project are aligned with each of these criteria. Thus, to assess economic effectiveness, it is proposed to use an indicator of industry financing, to assess medical effectiveness – indicators of mortality and life expectancy, and to assess social effectiveness based on information about the staffing of outpatient clinics with paramedical personnel, the number of people who have undergone professional examinations, as well as the number of substantiated patient complaints. The final assessment of the effectiveness of regional healthcare is based on calculating the sum of their ranks according to the achieved levels of target indicators (a point score in accordance with the number of criteria used) (Starykh, Egorova, 2020).

A number of principles for building a system of criteria and indicators for assessing the quality and effectiveness of medical activities are substantiated by A.L. Lindenbraten et al. They note that the effectiveness of medical activity at the territorial level can be assessed by comparing indicators of its results with the amount of costs over a certain period of time. Indicators of the results of medical activity include the degree to which the target values of public health indicators are achieved, the

outcome of treatment, medical care satisfaction, coverage of the population with regular healthcare check-ups, preventive and rehabilitative measures (Lindenbraten et al., 2020).

Methodological limitations typical for traditional methods of assessing the effectiveness of healthcare, based on a comparison of achieved and regulatory levels of medical statistics, were identified in the study by A.V. Danilov. These restrictions include the following:

- 1) unreasonableness of the set of indicators used for the integrated effectiveness assessment;
- 2) redundancy of the set of indicators used;
- 3) lack of substantiation within the framework of the scaling theory for the correlation of qualitative indicators and their scores;
- 4) interpretation of arithmetic mean normalized values or scores of a set of indicators as an integral indicator³.

Russian experts draw attention to the fact that the healthcare system is stochastic in the sense that all external influences on it, as well as the interactions of the system’s elements with each other, are random; therefore, probabilistic statistical models, the theory of mathematical modeling of stochastic systems, the theory of probability and mathematical statistics, and the theory of operations research should be used to study them. A special role is assigned to the construction of mathematical models based on procedures for analyzing optimization problems using a “decision tree”, the mathematical Markov model, as well as simulation models (Uiba et al., 2012).

The development of agent-based models is one of the promising approaches in the field of studying the behavior of complex socio-economic systems.

³ Danilov A.V. (2021). Scientific substantiation of the use of innovative organizational technologies to improve the management efficiency of medical organizations at the regional level: Doctor of Sciences (Medicine) dissertation. Voronezh. 224 p.

In world practice, this method is widely used in modeling the work of medical services at various levels (Tracy et al., 2018; Aspland et al., 2019; England et al., 2021). The problems that can be solved using agent-based models include not only optimization tasks at the level of individual healthcare institutions, but also complex projects related to improving the functioning of the healthcare system as a whole.

Agent-based models simulating the regional healthcare system created earlier are focused on solving problems of optimizing the spatial location of medical infrastructure facilities (Dianov et al., 2021; Shvetsov et al., 2023). However, the potential for using models of this kind is much broader and may also include solving problems related to modeling patient queues and routing, optimizing the burden on medical personnel, and improving the work of emergency medical services.

In recent years, data envelopment analysis (DEA) has been widely used in healthcare effectiveness studies in Russia and other countries. The method is based on linear programming and is designed to assess the relative effectiveness of decision making units (DMUs) as the ratio of the goods and services produced (output parameters) to the resources used (input parameters). The comparative ease of using this method and the availability of specialized software products that automate calculations largely explain its popularity (Hollingsworth, 2003; Su et al., 2023; González-de-Julián et al., 2024).

The problem of determining the magnitude of lags in the development of mathematical models of regional healthcare systems effectiveness deserves special attention. A solution may be the use of the DEA method to assess the relative effectiveness of regional healthcare systems. Yu.V. Neradovskaya's work provides an algorithm for evaluating the effectiveness of healthcare in the regions of Russia

(Neradovskaya, 2022). The indicators of life expectancy at birth for a number of years preceding the reporting year are used as input parameters of the model, and the value of life expectancy at birth in a given year is used as the resulting indicator of the effectiveness of healthcare systems. The author explains the chosen design of the model by the fact that the indicator of life expectancy, although it reflects the result of the functioning of not only the healthcare system, but also a number of other factors, still remains the most comprehensive measure of public health in the territories; whereas it is the protection of public health that is the target function of the systems under consideration. The inclusion of the levels of life expectancy at birth for a number of previous years as factor variables in the model was explained by the fact that these values result from the impact of the entire set of factors that influenced the health of the population of the regions during the period under consideration. In this paper, the problem of determining the magnitude of the lag with which factor variables should be included in the model was solved by sequentially correlating the correlation coefficients of the ranks of performance indicators calculated with a complete and reduced set of factor variables. This approach allowed us to establish that with the relative stability of external (relative to the healthcare system) "shocks", a lag of one is sufficient.

Methods for assessing the quality of management decisions in healthcare

One of the subtasks in assessing the effectiveness of regional healthcare is to assess the effectiveness of management decisions. This procedure helps, among other things, to identify ineffective solutions that impede the work of medical organizations and negatively affect the industry as a whole. Also, using this procedure, it is possible to determine the reasons for non-fulfillment or improper

implementation of management decisions. At the same time, various methods can be used to directly assess the quality of management decisions. One of the most common is the expert assessment method.

A methodological problem when working with opinions of experts (including in the field of healthcare) is to identify the key criteria they use in practice to evaluate management decisions. Russian researchers have proposed to apply the criteria importance theory (CIT) to formalize the solution of multi-criteria problems. This is a branch of mathematical theory developed as an alternative to T. Saaty's analytic hierarchy process, the practical application of which is to support managerial decisions in various fields (Nekhoroshev et al., 2008; Podinovskaya, Podinovsky, 2014). The most significant difference between this theoretical direction and other methods of analyzing multi-criteria tasks is that it does not create a single generalizing indicator for evaluating managerial decision; instead, it develops formal definitions of the concepts of "relative significance of criteria" and their "significance coefficients". In the process of solving multi-criteria problems using CIT, a mathematical model of the problem situation and its solutions is compiled, a set of criteria for their assessment is set, and the preferences of decision makers are also included in the model in a formalized form (Podinovsky, 2019).

In the context of studying management decisions effectiveness, a number of diverse criteria are identified that describe the results of healthcare functioning after a particular management impact. A classification of the criteria used for evaluating solutions is proposed in the work of N. Tanios and co-authors. They grouped the criteria used at different levels of the healthcare system into 10 descriptive areas, and it was found that the most important criteria in making managerial decisions are clinical effectiveness/performance efficiency, safety, quality of evidence, severity of disease, and

impact on healthcare costs (Tanios et al., 2013). A systematic review of research on healthcare effectiveness assessment (Cromwell et al., 2015) identified 72 unique criteria that are used to evaluate management decisions in this area. A distinctive feature of this review is its focus on articles that described not only the procedure for assessing the solutions, but also contained information about their practical implementation. This suggests that the identified criteria do serve as guidelines for decision makers in the healthcare sector. The most common criteria were "economic impact and outcomes/benefits of intervention", "general context", "disease impact (burden)", and "priorities (equity)" (Cromwell et al., 2015).

The issue of evaluating the effectiveness of management decisions in the healthcare sector certainly includes studying the causes of "management failures". In the work of N.G. Korshever and S. N. Pomoshnikov, based on the data from a survey of experts from among healthcare organizers, a list of the main reasons for non-compliance with management decisions in medical organizations was obtained. It was found that the main contribution to the non-fulfillment of decisions was made by unforeseen phenomena, low performance discipline and flaws in managerial decisions themselves. The experts identified (in descending order of importance) the following flaws in the decisions taken and subsequently not implemented: the necessary conditions for completing the task were ignored; the task was ill-conceived from an industrial, economic, technological point of view; the tasks did not take into account the type of activity of the performers, their capabilities and professional skills; the tasks were given to an already overloaded performer; the tasks were vague and their result could not be verified ("take action", "strengthen", "pay attention"); the tasks had unrealistic deadlines, which later still have to be postponed (Korshever, Pomoshnikov, 2019).

These examples bring to the fore the need to design automated decision support systems in the healthcare sector, which can reduce the incidence of managerial errors.

At the same time, assessing the effectiveness of only recent or key management decisions, it is impossible to judge to what extent they have contributed to the achievement of the sector's objectives. The functioning of healthcare has certain inertia, since it is carried out according to the rules established in the past. In addition, it is difficult to single out and selectively assess the impact of narrowly focused solutions on the work of the entire industry as a whole. Assessment of the quality of management decisions in the healthcare system remains an important stage in the study of its functioning. Choosing the most correct method for assessing the quality of management decisions is also fundamentally important when creating mathematical models of the regional healthcare system. Only if there is a procedure for such an assessment, the developed model can be used as a full-fledged tool to support management decisions.

Substantiating the choice of effectiveness assessment criteria for building an agent-based model of the regional healthcare system

Based on the analysis of available methods and approaches, several general rules for selecting indicators for evaluating the effectiveness of regional healthcare can be identified. When performing an assessment using the "cost–effectiveness" method it is necessary to use such result indicators that: 1) characterize the fulfillment of the objective function of the healthcare system – to promote public health; 2) are not internal characteristics of the regional healthcare system itself; 3) correlate with indicators characterizing the resource provision and functioning of the regional healthcare system.

The first two characteristics correspond most closely to death rate indicators and mortality due to diseases, life expectancy, and medical care satisfaction.

Mortality is a traditional indicator based on which one can judge the health of the population of a given territory. The advantage of mortality indicator in comparison with morbidity rates is the reliability of statistical accounting of deaths and their causes, the availability of statistical data, and the unambiguous interpretation of the level and dynamics of the indicator. The main problem when using morbidity indicators is the difficulty of interpretation: the increase in the indicator may be due to both improved detection of diseases among the population and poor-quality prevention (including insufficient coverage of the population with preventive measures).

The indicator of medical care satisfaction reflects the quality of the results of obtaining medical care. The higher its level, the more services provided by medical organizations in the region correspond to the needs of the population in terms of quality and access. This indicator is also relatively easy to interpret. However, there are some limitations in its use related to the availability of the necessary sociological data. To obtain representative and comparable results, it is necessary to conduct sample surveys of the population in all regions of the country using a single methodology.

The indicator of life expectancy can be used to assess the effectiveness of healthcare in the region, taking into account certain limitations. First, life expectancy is largely determined not only by medical factors, but also by people's lifestyle factors. In this regard, the dynamics of this indicator only partially correlates with the situation in the healthcare system.

To check whether mortality rates and life expectancy correspond to the third indicated selection condition, a correlation analysis was performed. The values of mortality, death rate, and life expectancy were compared with indicators characterizing the resources of the Vologda Region healthcare system for the period from 2018 to 2023. The choice of this period was due to the availability of a continuous range of regional statistical data. EMISS data served as the source of the information⁴.

The calculation of Spearman's correlation coefficient showed that the strongest positive relationship is demonstrated by the indicators of life expectancy at birth and the proportion of patients with detected malignant neoplasms at stages I–II. At the same time, the latter indicator has a strong negative correlation with the mortality rate of the population over the working age, which indicates the importance of timely diagnosis of

oncological diseases for prolonging life in old age. The mortality rate of the working-age population did not show a significant correlation with any of the indicators of resource provision of regional healthcare (*Tab. 2*).

Discussion

The problem of choosing the resulting indicators in assessing the effectiveness of healthcare is widely discussed in the research of Russian and foreign authors. There exist two opposing points of view on its solution. The first involves analyzing the effectiveness of the healthcare industry by comparing its interim performance results with cost indicators. In this case, such interim results usually include indicators that directly characterize the functioning of medical institutions and the process of providing medical care to the population: the number of days spent in hospital, the number of examinations, consultations, etc. The second point of view is based on the fact that the resulting

Table 2. Coefficients of mutual correlation of variables

Indicator	1	2	3	4	5	6
Proportion of patients with detected malignant neoplasms at stages I–II	0.657	-0.371	-0.771	-0.200	-0.200	-0.029
Provision of hospital beds per 10,000 people	0.086	-0.371	0.200	0.543	-0.543	-0.600
Provision of doctors working in state and municipal medical organizations (people per 10,000 people)	0.030	-0.152	0.152	0.759	-0.273	-0.516
Provision of paramedical personnel working in state and municipal medical organizations (people per 10,000 people)	-0.086	-0.257	0.314	0.371	-0.486	-0.543
Funds spent during the reporting period by the regional compulsory insurance fund (thousand rubles), per 10,000 people	0.086	0.257	-0.314	-0.371	0.486	0.543

Notes: 1 – Life expectancy at birth, years; 2 – Mortality of the working-age population per 100 thousand people (people, the value of the indicator for the year); 3 – Mortality of the population over the working age (women aged 55 years and older, men aged 60 years and older) per 100,000 people; 4 – Mortality from neoplasms, including malignant ones, per 100,000 people (people, the value of the indicator for the year); 5 – Mortality from diseases of the circulatory system, per 100,000 people (people, the value of the indicator for the year); 6 – One-year mortality of patients with malignant neoplasms (percent).
Source: own calculation in SPSS Statistics.

⁴ EMISS State Statistics. Available at: <https://fedstat.ru/>

indicators directly characterize public health. Depending on the purpose of the research, it is possible to choose in favor of any of the approaches, taking into account the associated methodological limitations.

Expert survey is a common method for choosing indicators to assess the effectiveness of healthcare (both factors and outcomes). Thus, M. Dlouh and P. Havlik, based on an expert survey, selected healthcare costs as a percentage of GDP, the number of doctors and nurses per 1,000 people, and the number of hospital beds per 1,000 people as the most significant healthcare effectiveness factors in OECD countries; while life expectancy at birth, life expectancy, and infant mortality rate were chosen as the most significant resulting indicators. The authors of the cited work used these criteria when performing a comparative analysis of the effectiveness of healthcare systems in 27 OECD countries and Russia, using data envelopment analysis (DEA) and multi-criteria decision analysis (MCDA) (Dlouhý, Havlik, 2024).

Population mortality is often used as a result indicator in assessing (including comparative) effectiveness of regional healthcare systems. At the same time, S.A. Boytsov and I.V. Samorodskaya proved that non-standardized mortality rates cannot serve as criteria for evaluating the results of measures aimed at reducing mortality in regions, nor are they suitable for interregional comparisons and ratings, since differences in the gender and age structures of the population of regions and in mortality rates in individual age groups affect the actual recorded mortality. As an alternative, it is proposed to rely on mortality rates in certain age groups of the population (Boytsov, Samorodskaya, 2014).

Taking into account the experience of Russian and foreign studies, as well as the results of the

correlation analysis, such indicators as life expectancy at birth, mortality of the population over the working age, mortality of the population from diseases of the circulatory system and one-year mortality of patients with malignant neoplasms were selected as the resulting indicators of regional healthcare functioning. We did not include such a widely used indicator as infant mortality in the final list of resultant indicators, due to the fact that it had poorly correlated with the resource availability of healthcare and, on the contrary, strongly correlated with the region's GDP (Natsun, 2023). Nevertheless, when solving optimization problems related to the functioning of the obstetric service, including using simulation models, the infant mortality rate must be taken into account when evaluating healthcare effectiveness.

The resulting set of performance indicators at subsequent stages of the study will be used to assess the effectiveness of the regional healthcare system using the “cost–effectiveness” method and designing an agent-based model for the system. When performing computational experiments in an agent-based modeling environment using optimization tasks, the goal will be to minimize mortality or maximize life expectancy at birth with a given level of healthcare funding. To assess the effectiveness of the regional healthcare system, the resulting solutions will be compared not only by the level of target variables, but also by the magnitude of other output parameters of the model. Depending on the design of the optimization task and taking into account the priorities of regional policy in the field of healthcare management, indicators of medical care satisfaction, medical care access, burden on doctors, number of visits to medical organizations, and provision of material and technical resources to medical organizations can be taken into account as additional controlled

parameters. Various options for the spatial placement of medical organizations will also be analyzed as a variable parameter of the regional healthcare system.

The proposed approach will allow comparing the results of management decisions and choosing optimal scenarios (routing patients, optimizing the burden on doctors, choosing the spatial layout of medical infrastructure facilities, adjusting the resource provision of medical organizations).

Conclusion

The conducted research allowed us to summarize the existing approaches to assessing the effectiveness of the healthcare system. It is shown that the “cost–effectiveness” method is the most relevant in solving optimization problems, since it helps to establish a direct relationship between the cost of industry resources and the results achieved using them. Based on a critical analysis of data from Russian and foreign studies, as well as the performed correlation analysis, a number of resulting indicators were proposed that can be used to assess the effectiveness of regional healthcare using the “cost–effectiveness” method. When selecting indicators, preference was given to those that directly characterize the health of the population, and, accordingly, reflect the fulfillment of the target function of the healthcare system. The final list of indicators includes life expectancy at birth, mortality of the population over the working age, mortality of the population from diseases of the circulatory system, and one-year mortality of patients with malignant neoplasms.

As the current socio-economic conditions increase the “price” of possible management errors in the healthcare sector, the importance of quality management in this area comes to the fore. Accordingly, automated management decision support systems are becoming increasingly in demand, making it possible to assess the feasibility of various scenarios of impact on the resource availability of regional healthcare, as well as on existing functional interactions within it.

In modern research on healthcare effectiveness, the DEA method has become widespread, which is considered as the basis for creating a management decision support system. However, a significant disadvantage of this method is that it works like a “black box”, that is, it does not allow determining exactly how resources are converted into final results in the system. Since multiple interactions between elements in the healthcare system, as well as between the system and the external environment, are often random, simulation modeling is a suitable method for studying it. Management decision support systems that use agent-based modeling can be promising in terms of identifying and detailing potential areas of management impact.

The list of resultant indicators formed in this paper to assess the effectiveness of regional healthcare at subsequent stages of the study will be used to solve optimization problems with the help of agent-based modeling. These circumstances determine the prospects and practical significance of the conducted research.

References

- Aspland E., Gartner D., Harper P. (2019). Clinical pathway modelling: A literature review. *Health Systems*, 10(1), 1–23. Available at: <https://doi.org/10.1080/20476965.2019.1652547>
- Boytsov S.A., Samorodskaya I.V. (2014). Comparison of mortality rates in constituent entities of the Russian Federation: The role of the age structure of the population. *Menedzher zdavookhraneniya*, 4, 13–19 (in Russian).

- Chereshnev V.A., Krivenko N.V., Krylov V.G. (2021). Comprehensive assessment of the effectiveness and sustainability of the regional healthcare system. *Ekonomika regiona*, 17(1), 31–43. DOI: 10.17059/ ekon. reg.2021-1-3 (in Russian).
- Cromwell I., Peacock S.J., Mitton C. (2015). ‘Real-world’ health care priority setting using explicit decision criteria: A systematic review of the literature. *BMC Health Services Research*, 15, 164. Available at: <https://doi.org/10.1186/s12913-015-0814-3>
- Dianov S.V., Kalashnikov K.N., Rigin V.A. (2021). Search for ways of optimal spatial placement of healthcare infrastructure facilities: A review of methodological tools. *Problemy razvitiya territorii= Problems of Territory's Development*, 25(2), 108–127. DOI: 10.15838/ptd.2021.2.112.7 (in Russian).
- Dlouhý M., Havlík P. (2024). Efficiency evaluation of 28 health systems by MCDA and DEA. *Health Economics Review*, 14, 59. Available at: <https://doi.org/10.1186/s13561-024-00538-y>
- England T., Harper P., Crosby T. [et al.] (2021). Modelling lung cancer diagnostic pathways using discrete event simulation. *Journal of Simulation*, 17(1), 94–104. Available at: <https://doi.org/10.1080/17477778.2021.1956866>
- González-de-Julián S., Vivas-Consuelo D., Barrachina-Martínez I. (2024). Modelling efficiency in primary healthcare using the DEA methodology: An empirical analysis in a healthcare district. *BMC Health Services Research*, 24, 982. Available at: <https://doi.org/10.1186/s12913-024-11420-2>
- Grishin V.V., Ragozin A.V., Itselev A.A., Glazunova S.A. (2021). Financing of the Program of state guarantees of free medical care: How to solve the problem of shortage? *Zdravookhranenie Rossiiskoi Federatsii*, 65(6), 514–521. DOI: <https://doi.org/10.47470/0044-197X-2021-65-6-514-521> (in Russian).
- Hollingsworth B. (2003). Non-Parametric and parametric applications measuring efficiency in health care. *Health Care Management Science*, 6, 203–218. Available at: <https://doi.org/10.1023/A:1026255523228>
- Hollingsworth B., Wildman J. (2003). The efficiency of health production: Re-estimating the WHO panel data using parametric and non-parametric approaches to provide additional information. *Health economics*, 12(6), 493–504. Available at: <https://doi.org/10.1002/hec.751>
- Ilyin V.A., Kolinko A.A., Duganov M.D. et al. (2006). *Effektivnost' zdravookhraneniya regiona* [Effectiveness of Region's Healthcare]. Vologda: Vologodskii nauchno-koordinatsionnyi tsentr Tsentral'nogo ekonomiko-matematicheskogo instituta Rossiiskoi akademii nauk.
- Joo Y. (2025). Comparative efficiency analysis of OECD health systems: FDH vs. machine learning approaches with efficiency analysis trees (EAT and RFEAT). *Cost Effectiveness and Resource Allocation*, 23, 4. Available at: <https://doi.org/10.1186/s12962-025-00607-x>
- Korshever N.G., Pomoshnikov S.N. (2019). The study of manageability of medical organizations. *Problemy sotsial'noi gigieny, zdravookhraneniya i istorii meditsiny=Problems of Social Hygiene, Public Health and History of Medicine*, 27(6), 1075–1079. DOI: 10.32687/0869-866X-2019-27-6-1075-1079 (in Russian).
- Lindenbraten A.L., Grishina N.K., Serdyukovskii S.M., Kolomiichenko M.E., Ludupova E.Yu. (2020). The basic principles of building a system of criteria and indicators for assessing the quality and effectiveness of medical activities. *Byulleten' Natsional'nogo nauchno-issledovatel'skogo instituta obshchestvennogo zdorov'ya imeni N.A. Semashko*, 2, 30–35. DOI: 10.25742/NRIPH.2020.02.004 (in Russian).
- Mbau R., Musiega A., Nyawira L. [et al.] (2023). Analysing the efficiency of health systems: A systematic review of the literature. *Applied Health Economics and Health Policy*, 21, 205–224. Available at: <https://doi.org/10.1007/s40258-022-00785-2>
- Morozova T.V., Belaya R.V., Kozyreva G.B. (2022). Differentiation of consumer behavior of the population of Republic of Karelia in the market of socially significant commercial services. *Narodonaselenie=Population*, 25(2), 52–65. DOI: 10.19181/population.2022.25.2.5 (in Russian).

- Natsun L.N. (2023). Assessing the influence of medical, demographic and economic factors on the dynamics of infant mortality in Russia's regions. *Ekonomicheskie i sotsial'nye peremeny: fakty, tendentsii, prognoz*=*Economic and Social Changes: Facts, Trends, Forecast*, 16(3), 265–283. DOI: 10.15838/esc.2023.3.87.14 (in Russian).
- Nekhoroshev S.N., Podinovskiy V.V., Potapov M.A. et al. (2008). The use of the theory of multicriterial choice in the decision support system of the National Center for Managing Crisis Situations of the Emercom of Russia. *Tekhnologii grazhdanskoi bezopasnosti*, 5(1-2)(15-16), 128–130 (in Russian).
- Neradovskaya Yu.V. (2022). Evaluation of effectiveness of regional health care systems. *Ekonomika i upravlenie: nauchno-prakticheskii zhurnal*, 1(163), 125–132. DOI: 10.34773/EU.2022.1.24 (in Russian).
- Pepelyaeva A.V., Tretyakova E.A. (2018). Synthesis of institutional and evolutionary and functional approaches to assess the efficiency of the regional health care system functioning. *Vestnik Permskogo universiteta. Ser. "Ekonomika"*=*Perm University Herald. Economy*, 13(1), 58–74. DOI: 10.17072/1994-9960-2018-1-58-74 (in Russian).
- Podinovskaya O.V., Podinovskiy V.V. (2014). Analysis of hierarchical multi-criteria decision-making tasks by methods of criteria importance theory. *Problemy upravleniya*, 6, 2–8 (in Russian).
- Podinovskiy V.V. (2019). *Idei i metody teorii vazhnosti kriteriev v mnogokriterial'nykh zadachakh prinyatiya reshenii* [Ideas and Methods of Criteria Importance Theory in Multi-Criteria Decision-Making Tasks]. Moscow: Nauka.
- Rapakov G.G., Banshchikov G.T., Gorbunov V.A., Kharakhnin K.A., Revelev I.M. (2019). Computer simulation of regional public health efficiency using statistical analysis methods. *Vestnik Cherepovetskogo gosudarstvennogo universiteta*=*Cherepovets State University Bulletin*, 2, 56–68. DOI: 10.23859/1994-0637-2019-2-89-5 (in Russian).
- Şenel T., Cengiz M.A. (2016). A Bayesian approach for evaluation of determinants of health system efficiency using stochastic frontier analysis and beta regression. *Computational and Mathematical Methods in Medicine*, 2801081. Available at: <https://doi.org/10.1155/2016/2801081>
- Shvetsov A.N. et al. (2023). A service-based approach to designing agent-based models for optimal spatial placement of healthcare infrastructure facilities. *Vestnik Cherepovetskogo gosudarstvennogo universiteta*=*Cherepovets State University Bulletin*, 1(112), 79–99. DOI: 10.23859/1994-0637-2023-1-112-6 (in Russian).
- Sokolov A.Yu., Shchavaleva M.V., Kulpanovich O.A. (2018). Essential characteristics of the category of efficiency in healthcare. *Zdravookhraneniye*, 3, 5–9 (in Russian).
- Starodubov V.I., Son I.M., Leonov S.A., Sterlikov S.A. (2010). Assessment of the effectiveness of regional healthcare systems. *Menedzher zdravookhraneniya*, 3, 15–25 (in Russian).
- Starykh N.P., Egorova A.V. (2020). Target indicators of the national Health project in determining the effectiveness of regional healthcare. *Srednerusskii vestnik obshchestvennykh nauk*=*Central Russian Journal of Social Sciences*, 15(1), 143–161. DOI: 10.22394/2071-2367-2020-15-1-143-161 (in Russian).
- Su W., Hou Y., Huang M. [et al.] (2023). Evaluating the efficiency of primary health care institutions in China: An improved three-stage data envelopment analysis approach. *BMC Health Services Research*, 23, 995. Available at: <https://doi.org/10.1186/s12913-023-09979-3>
- Tanios N., Wagner M., Tony M. [et al.] (2013). Which criteria are considered in healthcare decisions? Insights from an international survey of policy and clinical decision makers. *International Journal of Technology Assessment in Health Care*, 29(4), 456–465. Available at: <https://doi.org/10.1017/S0266462313000573>
- Tracy M., Cerdá M., Keyes K.M. (2018). Agent-based modeling in public health: Current applications and future directions. *Annual Review of Public Health*, 39, 77–94. Available at: <https://doi.org/10.1146/annurevpublhealth-040617-014317>

Uiba V.V., Chernyshev V.M., Pushkarev O.V., Strelchenko O.V., Klevasov A.I. (2012). *Ekonomicheskie metody upravleniya v zdravookhranении* [Economic Management Methods in Healthcare]. Novosibirsk: OOO “Al’fa-Resurs”.

Wagner T.H., Hoomans T., Salloum R.G. [et al.] (2025). Efficiency in health care: Connecting economic evaluations with implementation objectives. *Implementation Science Communications*, 6 (77). Available at: <https://doi.org/10.1186/s43058-025-00763-4>

Information about the Author

Leila N. Natsun – Candidate of Sciences (Economics), Senior Researcher, Vologda Research Center, Russian Academy of Sciences (56A, Gorky Street, Vologda, 160014, Russian Federation; e-mail: leyla.natsun@yandex.ru)

Received March 27, 2025.