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Translated Article†

THE FINANCING MODEL OF THE REGIONAL HEALTH SYSTEM

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Abstract

Subject The research devises the healthcare spending model in line with types and scope of medical aid, assesses indicators of the current and future planned periods.

Objectives The research is an attempt to optimize healthcare spending by improving the way it is earmarked in line with the region's demand for certain types of medical aid and reallocating financial resources.

Methods We use the conceptual modeling and Python 3.

Results We devised the model to optimize expenditures in order to increment resources available for health care purposes by reallocating them in accordance with the analysis of the financial situation, classes of patients. Our model builds on the type of total medical expenditures on patients with certain diseases and adjustment of healthcare spending against the current year's plans.

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Keywords: medical treatment, health care, resources, economic efficiency, cognitive modeling

Conclusions and Relevance Expenditures could be optimized through their reallocation in line with the type of total spending, financial effectiveness class and adequacy of their planning for promising and effective medical interventions.

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Introduction

Many countries model certain aspects of their healthcare systems [1–4]. They strive to make their national health systems more effective in light of the existing social needs and goals[1].

However, despite the highly elaborate approach to this issue as seen in the scholarly literature, there are still no versatile models allowing to plan and allocate healthcare resources as the region and/or country would really need. As a result, it is difficult to substantially upgrade the health system by lowering the public morbidity rates, curb a growth in medical spending [5–9]. The above effects are indispensable and unattainable without optimizing the mechanism for planning and allocating healthcare resources in line with the region's local distinctions. To ensure further development of the regional healthcare management theory and practices, resource planning and allocation processes should be modeled. In this respect, the appropriate methodological tools should be selected.

Looking through bibliographic sources, we found out that researchers from many countries had attempted to model some healthcare processes for the recent years. In particular, some of them suggested forming interdisciplinary teams and practicing systems approaches to chronic disease treatment [1, 2, 10, 11], analyzing the incidence of chronic non-infectious diseases and risks of their occurrence [12–14]; front-end medical assistance [15] and vertical equality [16], optimization of planning, designing and financing of health systems in accordance with the number of population. These models accommodate for socio-political circumstances and determinants of the health system [2, 17–21]; healthcare finance through the public-private partnership mechanism [22], spatial and time development of the health system [23–25]. The above studies involved correlation and regression analysis [13, 17, 19], Poisson lognormal mixed model in the Bayesian framework fitted to the INLA efficient estimation procedure [23], cost effectiveness estimation method [14], decision tree, Markov chain, micromodels, discrete and dynamic event modeling [24, 26], descriptive statistics, forecasting and simulation [19–21, 24, 25], market research [10].

Russia's health system is restructured to increase the cost effectiveness of medical aid to the public. The analysis reveals that optimization of resource planning, allocation and use is still pending in this sector [27–31]. Currently, human rights for health protection and medical aid are widely pronounced and specified. To exercise the declared rights, the State needs to form, effectively allocate and use as much financial resources as needed to perform specific tasks and attain healthcare goals. Accessible medical aid and its quality require to integrate various types of medical assistance. The health system shall be organized on the basis of a comprehensive approach to managing all its constituents [32].

Medical aid in case of a certain disease implies a combination of healthcare services varying by disease or a group of diseases. Available resources and financial resources, in particular, become a cornerstone of the quality and effectiveness of such medical care.

Nowadays healthcare services are financed in accordance with the State guarantee program for public healthcare and special-purpose programs for priority healthcare aspects. However, such finance is considered to be insufficient and unbalanced since funds are mainly spent on the priority needs.

The situation determines the purpose of this research. We devise and test an algorithm to build a healthcare spending model and optimize it by

[‡]For the source article, please refer to: Куликова О.М., Усачева Е.В., Шамис В.А., Нелидова А.В., Боуш Г.Д. Модель финансового обеспечения регионального здравоохранения. *Региональная экономика: теория и практика*. 2018. Т. 16. № 10. С. 1823–1840. URL: https://doi.org/10.24891/re.16.10.1823

[1] Dahabreh I.J., Chan J.A., Earley A. et al. Modeling and Simulation in the Context of Health Technology Assessment: Review of Existing Guidance, Future Research Needs, and Validity Assessment. Rockville, Agency for Healthcare Research and Quality (US), 2017. URL: https://www.ncbi.nlm.nih.gov/books/NBK424024/

– classifying types of medical care by level of financing;

– classifying patients by type and scope of medical care they need;

– estimation of indicators for the current and planned periods in accordance with the morbidity trend in the Russian regions, and analysis of observed scenarios.

Methodology

The research employs methods of logic and statistical analysis. We devised a special algorithm to optimize healthcare spending in the Russian regions. The regional healthcare spending algorithm is based on the assumption that the optimal structure of expenditures is the principal driver of healthcare effectiveness and high quality. In the Russian regions, the structure of healthcare funds is expressed with the set $CR = \{C_1, C_2,...C_m\}$, which encompasses financial expenditures $C_1, C_2,...C_m$ on various types of medical care. When planning and allocating financial resources of the national health system, authorities consider the delivery of primary health and sanitary care (outpatient clinics), specialized healthcare (inpatient and high-tech healthcare facilities), emergency and palliative care. Financial spending on the delivery of *i*-type of medical care is expressed with the formula:

$$C_i = c_i n_i \quad ,$$

where c_i is the unit cost of *i*-type of medical care, thousand RUB; n_i is the number of patients awaiting *i*-type of medical care in the region, people.

The following condition determines whether healthcare spending in the national health system is optimal or not: *CR* is optimal only if $C_i = C_i^{nd}$, where C_i^{nd} is healthcare institutions' needs for financial resources to deliver *i*-type of medical care. The needs are expressed with the following formula:

$$C_i^{nd} = c_i n_i^{nd} \quad ,$$

where n_i^{nd} is the number of patients who need *i*-type of medical care in the region.

As part of the model for optimizing healthcare spending in the Russian regions, healthcare financing is viewed from perspectives of public needs. Funds may be sufficient or scarce. Financial funds for healthcare can be classified into the following types by scarcity/insufficiency:

1) excessively funded (contributing constituents), where $C_i > C_i^{nd}$;

2) optimally funded (normal constituents), where $C_i = C_i^{nd}$;

3) insufficiently funded (recipient constituents), where $C_i < C_i^{nd}$.

Therefore, expenditures can be classified as follows depending on the structure of financial resources earmarked for medical care:

– *Sponsor set*: all respective constituents are excessively funded and can be viewed as potential sponsors of other types of total expenditures;

– *Optimum set*: the structure is optimal, i.e. all respective constituents are optimally funded and cannot be viewed as sponsors of other types, and recipients;

– *Chimera set*: there are both excessively and insufficiently funded items;

– *Recipient set*: all respective constituents are insufficiently funded.

The financing of the national health system is optimized by reallocating financial resources among types of medical care and hereby transforming ineffective spending schemes into effective ones. If it is impossible to generate the Optimum set, the financial priority is assigned to those types of medical care which are in the highest demand in terms of the risk and emergency theory.

In pursuit of optimization and more effective finance of medical care in the regional health system, patients can be classified by disease, severity and stability of their disease.

As part of a certain disease or a group of diseases, the model of healthcare spending and its optimization is built in the following coordinates:

– *X*-axis denotes *The ratio of finance needed to finance planned in the current year, percent,* determining to what extent the current expenditures correspond with the available (earmarked) funds;

– *Y*-axis denotes *The type of a set of medical care expenditures for a group of patients*.

The ratio of finance needed to finance planned in the current year, percent» (D_g) is assessed with the formula:

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$$D_g = \frac{\sum_{i=1}^{m} C_i^{nd}}{\sum_{i=1}^{m} C_i^{pl}} \cdot 100 \quad ,$$

where C_i^{pl} stands for funds earmarked for the delivery of *i*-type of medical care. Expenditures are expressed with the formula:

$$C_i^{pl} = c_i n_i^{pl} \quad ,$$

where n_i^{pl} indicates the number of patients who are eligible for *i*-type of medical care to be funded as part of the State guarantee program in the region.

When estimates concern those classes of patients who pertain to the same set in accordance with the analysis of the State guarantee program, n_i^{nd} is substituted with n_{gi} showing how many *g*-class patients need *i*-type of medical care in the region. The indicator is expressed with the following formula:

$$n_{gi} = k_{gi} \sum_{i=1}^{m} l_{gi} N_{gnos} \quad ,$$

where k_{gi} is the share of *i*-type of medical care within the overall medical care services, which are sought after by the analyzable class of patients; l_{gi} denotes the relative share of *i*-type of medical care services envisaged in the State guarantee program in the region; N_{gnos} is the number of patients in the analyzable set who have the analyzable disease or a group of diseases.

Moreover, when estimates accord classes of patients and State guarantee program, n_i^{pl} is substituted with n_{gi}^{pl} indicating the number of *g*-class patients who are eligible to *i*-type of medical care funded under the State guarantee program in the region. The indicator is expressed with the formula:

$$n_{gi}^{pl} = N_{gnos} l_{si} \quad .$$

If D_g is less than 100 percent, financial needs are below the planned amount; if D_g equals or approximates 100 percent, financial needs correspond with the planned finance; if D_g is higher than 100 percent, financial needs exceed the planned finance.

The metric, *Type of Medical Care Expenditures for a Group of Patients*, is inscribed into the ordinal scale and has the following values: 1 corresponds to *the Sponsor set*; 2 is for *the Optimum set*; 3 is for *the Chimera set*; 4 is for *the Recipient set*. The scale reflects the complexity of managerial decision on the optimization of healthcare spending.

The model can be configured *As–Is*/*To–Be*[2] with or without regard to classes of patients and the State guarantee program. Let us observe how the models are set. As part of the *As–Is* model, healthcare expenditures on each class of patients are indicated in the given coordinate system as a pie chart. In the case of the *As–Is* model, a table can be made to define what rules and results the optimization process shall produce. They shall be determined on combinatorial principles and optimization aspects. The table may provide for changes in the scope of healthcare services. Thus, patients may be reclassified. The *To–Be* model can take two forms:

– without overlapping with the *As–Is* model to reveal only optimized aspects of healthcare expenditures per each class of patients;

– overlapping with the *As–Is* model to show pre-optimization structures in addition to those ones which were optimized.

The healthcare spending optimization model in the Russian regions is built in accordance with the algorithm below.

1. Predetermining input parameters for modeling a disease class as per the International Classification of Diseases 10 (ICD-10) (one or several diseases); form of the model (*As-Is*, *To-Be* with or without overlapping).

2. Setting up the *As-Is* model.

2.1. Predetermining input parameters for setting the *As-Is* model.

2.2. Assessing values for the *As-Is* model.

2.3. Setting up the *As–Is* model.

2.4. Analysis of results from the model. If the healthcare spending structure is optimal, paragraph 2.6 is relevant. If the structure is not optimal, paragraph 2.5 shall be referred to.

[2] Modern Business Management Technologies. The *As-Is* Model. URL: http://piter-soft.ru/automation/more/glossary/process/as-is-model/ (In Russ.)

2.5. Determining aspects of healthcare spending structure to be optimized with respect to classes of patients.

2.6. Visualization of estimates through the graphical presentation of the model.

2.7. Conclusions on the modeling results.

If the healthcare spending structure is optimal with respect to classes of patients, paragraph 4 becomes relevant. If the structure is not optimal and the *As–Is* model is chosen only, paragraph 4 shall be referred to again. If the structure is not optimal and the *To–Be* model is chosen, paragraph 3 shall be referred to.

3. Setting up the *To–Be* model.

3.1. Setting the table of optimization opportunities (the table can be embedded into the algorithm and run by default).

3.2. Apply limits to modeling.

3.3. Optimization of the healthcare spending structure with respect to classes of patients through the exhaustive search method.

3.4. Setting up the *To–Be* model, with or without overlapping.

4. Cognitive visualization of results.

The algorithm is implemented via Python 3.

The model was tested while healthcare expenditures were structured and optimized with respect to patients with ischemic heart disease. The unit cost of a certain type and statutory scope of medical care is assessed per person holding a compulsory medical insurance policy by type and form of health care in accordance with the State guarantee program for free medical aid[3] as earmarked for 135 thousand patients with ischemic heart disease.

Results

The regional healthcare spending optimization model treats the finance of healthcare services in terms of the public needs. The State guarantee program sets forth statutory rates of healthcare services per person holding a compulsory medical insurance policy. The established rates and norms are used to plan and substantiate financial resources. If we refer to the statutory scope of healthcare services stipulated in under the Statutory guarantee program as a percentage, the breakdown below of key healthcare services will be the most cost effective per person holding a compulsory medical insurance policy:

– services of outpatient clinics (healthcare services delivered out of hospital due to a disease) – 78%;

– emergency healthcare – 13%;

– specialized healthcare in twenty-four hour hospitals (inpatient care) – 7%;

– high tech healthcare – 2%.

We point out four classes of patients by severity and stability of ischemic heart disease, specifics of their treatment, needs for some type of healthcare services.

Rosebush patients. Treatment is very effective and inexpensive as it results in a protracted remission of a disease so that patients may keep an ordinary lifestyle and continue working. Outpatient care prevails in the *rosebush* class spending. It is cost effective, very accessible and inexpensive.

Camelthorn patients. High-tech medical services are predominant in the *camelthorn* spending structure. The treatment is sustainably effective but it requires expensive medical interventions. Such patients seldom suffer from acute conditions of their chronic disease and continue to work given high-tech healthcare services are delivered to them. High costs of this healthcare type stems from the use of innovation and gradually rising indications.

Quicksand patients. Treatment efficacy is not stable, though being rather costly. The disease is severe, with frequently reoccurring acute conditions making patients unable to work as they used to and become physically limited in everyday life. Emergency care and twenty-hour inpatient care make the substantial part of expenditures on such patients.

Severe winter patients. This class is associated with the highest costs of twenty-four hour inpatient care and ambulance service. Unplanned costs for high-tech medical care are also incurred. The patients are mostly disabled, thus requiring additional payments for temporary or full loss of ability to work.

Table 1 and *2* present input data of the *As-Is* model in the case of patients with ischemic heart disease, which

[3] Resolution of the RF Government of November 28, 2014 № 1273, *On The State Guarantee Program for Free Healthcare Services for 2015 and the 2016 and 2017 Planning Period* (with amendments and additions). URL: http://base.garant.ru/70812574/ (In Russ.)

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we obtained as a result of the clinical test research and reassessed the entire population of patients with ischemic heart disease in the region.

Fig. 1 depicts the *As-Is* healthcare spending model, which is based on input data, with respect to classes of patients with ischemic heart disease.

Having analyzed the results, we concluded that the analyzable classes of patients with ischemic heart disease pertain to *the Chimera set* of healthcare expenditures since each class of financial efficiency has the sponsor constituents and recipient constitutes, namely:

- expenditures of the *Rosebush* class include ambulatory and outpatient care as the recipient constituent (additional funds of RUB 28.32 million are required) and sponsor constituents (excessive funds of RUB 563.8 million);
- expenditures of the *Camelthorn* class include such sponsor constituents as ambulatory and outpatient care and emergency care with excessive funding of RUB 3.9 and 13.9 million respectively, and two recipient constituents – inpatient care and high-tech medical care, which require additional RUB 53.5 million and RUB 348.4 million respectively;
- expenditures of the *Quicksand* class include the sponsor constituent – ambulatory and inpatient care – with excessive funding of RUB 6.1 million and recipient constituents – ambulance care (additional funding of RUB 1.42 million), inpatient care (additional RUB 74.85 million), high-tech medical care (additional funding of RUB 297.23 million);
- expenditures of the *Severwinter* class include the sponsor constituent – ambulatory and outpatient care (excessive funding of RUB 9.9 million) and recipient constituents – ambulance care (additional funding of RUB 247 million), inpatient care (additional funding of RUB 61.48 million), high-tech medical care (additional funding of RUB 302.38 million).

Therefore, healthcare spending on patients with ischemic heart disease cannot be considered as optimal. Hence, measures should be taken to qualify it as such. *Fig. 2* shows the healthcare spending optimization model without overlapping with respect to patient with ischemic heart disease (*To–Be* model). The utilization of financial resources was optimized by reallocating them among types of healthcare services within a class of patients.

As seen in *Fig. 2*, after financial resources were streamed from the sponsor constituent to recipient constituents within the same class, the *Rosebush* expenditures could be reclassified from *the Chimera set* into *the Optimum set*. The structure of the other classes remained unchanged. As the next step, all the sets of expenditures shall be brought to *the Optimum* type, which is feasible only if additional financial resources of RUB 1.12 billion are allocated annually. Most of the funds (RUB 948 million, i.e. 84,6%) should be earmarked for high-tech medical care. We should note that this regional healthcare development course is in accord with departmental special-purpose programs, *The 2014–2020 Health System Development*.

Discussion

The optimal structure of healthcare spending is modeled to get a more comprehensive and accurate view of resources needed to implement primary goals of healthcare, i.e. substantially reduce the morbidity and mortality rates, cut unplanned healthcare expenditures. Creating the effective mechanism for resource planning, allocation and use in health care, it is necessary to consider the volume and composition of resources needed to deliver healthcare services depending on a disease since the Russian regions have different morbidity trends.

The algorithm we propose allows to consider the morbidity trends in the region and subsequently configure healthcare spending in each region and Russia as a whole. If costs are planned in accordance the financial efficiency classes, there will be sustainable cash flows. Insufficient funding restricts the delivery of healthcare services as needed under the compulsory medical insurance program. In this respect, it is not enough to prioritize expenditures and choose the type, volume of free healthcare services and categories of citizens who are eligible to them. There should be understanding of possible rearrangement of financial flows within the sector. The proposed model has the following advantages.

1. It raises the public awareness about the existing financial situation with respect to every disease.
2. It shows how the financial situation may develop in the future.
3. It clarifies financial challenges and their causes.
4. It paves the way for increased efficiency of the regional health system.

5. It contributes to the regional allocation of healthcare resources.

6. It enhances the way expenditures are controlled.

Referring to these findings, regional authorities may enhance the management of the regional health system, deciding on each class of diseases and choosing those types of healthcare services which definitely reduce morbidity rates.

Conclusion

Regionally and nationally, challenges of the health system include not only lack of funds but also the effective use of available financial resources. Public healthcare, quality and timeliness of healthcare services will lower morbidity rates, prolong the ability to work and raise labor productivity. The above factors will foster a growth in the national income and public wellbeing.

Table 1

Baseline data on the classes and number of patients, and the need for medical care

Class of patients	Demand for outpatient care, %	Demand for ambulance care, %	Demand for inpatient care, %	Demand for high-technology medical care, %	Number of patients within the class
Rosebush	90	7	2.997	0.003	88,152
Camelthorn	75	12	10	3	27,124
Quicksand	65	15	15	5	13,562
Severwinter	50	20	20	10	6,781

Source: Authoring

Table 2

Baseline data on the key indicators of healthcare services

Indicators	Outpatient care	Ambulance care	Inpatient care	High-tech medical care
Statutory rate of key healthcare services per one policyholder, %	79.628	12.985	7.22	0.167
Unit cost of a healthcare type, thousand RUB	1.265	2.124	28.968	185.193

Source: Authoring

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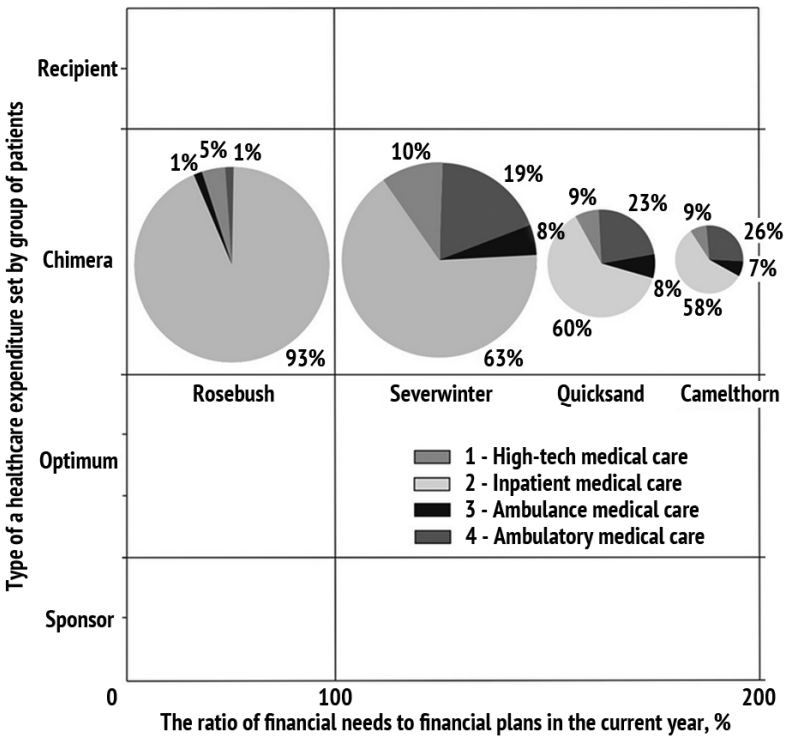
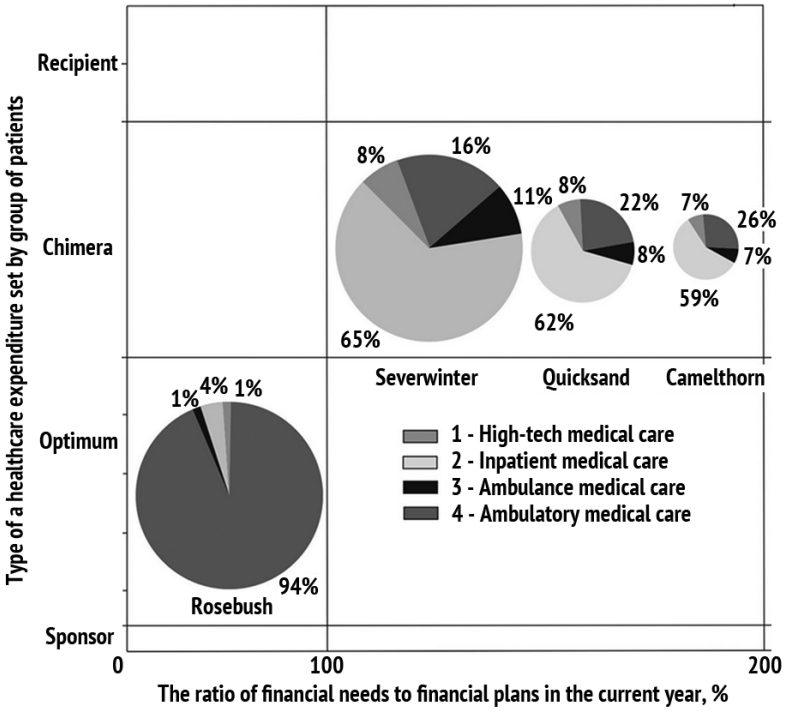
Figure 1
The healthcare spending model by class of patients and type of Expenditure set



Source: Authoring

Figure 2
The healthcare spending optimization model with respect to patients with ischemic heart disease, without overlapping (the *To–Be* model)



Source: Authoring

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Conflict-of-interest notification

We, the authors of this article, bindingly and explicitly declare of the partial and total lack of actual or potential conflict of interest with any other third party whatsoever, which may arise as a result of the publication of this article. This statement relates to the study, data collection and interpretation, writing and preparation of the article, and the decision to submit the manuscript for publication.

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