Automatization and information technologies development for monitoring and evaluation of penitentiary healthcare facilities efficiency

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Abstract. The article presents an algorithm for developing a software package for evaluation of penitentiary healthcare facilities efficiency. The algorithm is based on the data of penitentiary healthcare facilities of the Volga Federal District. To create a computer program algorithm there were chosen indicators and criteria for evaluation of penitentiary health facilities efficiency. Mathematical processing of indicators based on the Analytic Hierarchy Process allows to present the formula for calculating the total integral indicator, which is calculated automatically. The results of calculation are presented in the window interface of the computer program in the form of color charts. In this way it forms a rating of healthcare facilities, where green indicates high level of efficiency, yellow indicates its medium level, red indicates its low level.

1. Introduction

Currently, one of the most important issues that provides effective monitoring and quality management of health care is becoming big data analysis. Qualitative analysis of medical big data, as well as its collection, storage and transmission can be resolved by applying information technologies [1].

In Russia in the late 60s for the first time it has been given the focused attention to the development of computer technologies of health management in public health in general, and at the regional level, in particular [2]. Now, automated information systems are implemented in the daily work of the healthcare system facilities throughout the country. The Concept of creating a Unified State Information System in the Healthcare Sector (USISHS) for the period until 2020 developed in 2011 determines the main goals and principles of this process, as well as the expected socioeconomic impact.

According to the main provisions of the concept, the USISHS provides informational and technological support for such significant processes as monitoring of health indicators of the population in the regions, evaluation of healthcare facilities efficiency based on the developed criteria, monitoring of the health facilities logistics, staff monitoring, cost estimation of medical care, as well as comprehensive analysis of the impact of management decisions and predicting the development of public health [3].
Thus, the development of an automated system for evaluation of healthcare facilities efficiency as a tool of healthcare quality management seems to become an important way to improve the healthcare system on the whole.

2. Research objectives
The main objective of the research is a development of the automated monitoring system of healthcare facilities efficiency in the field of cardiac care (based on the experience of penitentiary healthcare institutions and facilities).

3. Materials and methods
5 criteria and 23 indicators evaluating the efficiency of regional healthcare institutions of the Federal Penitentiary Service (RHI of FPS of Russia) were developed to create the automated monitoring system. Mathematical synthesis using Analytic Hierarchy Process (AHP) based on the method of expert assessments gave the possibility to weight significance of each obtained criteria and indicator. The result of using AHP has become the formula of total integral index (TII) reflecting the healthcare facilities efficiency. The formula includes the sum of the products of the weight value of each indicator by its quantitative value.

The numerical values of healthcare facilities efficiency for 2017 from 13 RHI of FPS of Russia in the Volga Federal District (VFD) were received by the means of electronic communication system "Electronic document management system of the Federal Penitentiary Service." The obtained data were used to form a unified electronic database of healthcare facilities efficiency indicators.

To automate the calculation of TII it was developed a computer program “The program for automated monitoring of penitentiary healthcare facilities efficiency in the field of cardiac care” (certificate of state registration of computer programs No. 2018620069 from 01/09/2018), which forms the rating of the RHI of FPS of Russia.

The program is created in the Delphi 7 environment and based on the Object Pascal programming language. The environment also includes a graphical interface that allows the computer to interact with the user. Also, thanks to the unique combination of language simplicity and code generation, the program allows the user to interact directly with the operating system. The developed program is independent of third-party software. Allocation and release of RAM is controlled mainly by the user code. On the one hand, it tightens the quality requirements of the code, but on the other hand, makes it possible to create complex computer applications with high responsiveness requirements (real-time work). The computer program runs in the MS Windows environment, which requires the availability of the appropriate technical material means.

Thou, for the correct operation of the software package standard office personal computers with the following system requirements are sufficient:

- Windows 2000 Service Pack 4, Windows 7, Windows Server 2003, Windows Server 2008, Windows Server 2008 R2, Windows Vista, Windows XP;
- a personal computer compatible with Intel Pentium III 500 MHz or faster (1 GHz or faster recommended);
- at least 192 MB of RAM (512 MB or more recommended);
- 600 MB of free disk space.

In the process of developing a software package special attention was paid to the visualization aspect of the obtained data. Visualization rules were based on the use of a classic window interface containing diagrams, graphs, and elements of a geographic information system (GIS).

4. Results
Efficiency of any healthcare facility involves a complex task of social, medical and economic performance [4,5]. In this case, according to the researchers a significant part of the efficiency structure
of any activity makes the proper evaluation of healthcare quality [6]. According to the model of A. Donadebian, it includes three main categories: structure, process and result of healthcare [7,8].

Based on the above provisions there were formed 5 criteria and the corresponding indicators to evaluate penitentiary healthcare facilities efficiency: for the criteria "equipment" - 5 indicators characterizing the licensing of medical practice and the availability of hardware and diagnostic systems for cardiac care; for the criteria “staff” - 4 indicators, including evaluation of the actual medical staffing; the criteria “financing” - 2 indicators evaluating the rate of funds for medicines and payment for high-tech types of cardiac care from the total funds of RHI of FPS of Russia; the criteria “diagnostic and treatment process” - 8 indicators reflecting the compliance of the prescribed treatment with the protocols and standards for the management of patients with circulatory system diseases (CSD), the state of preventing healthcare in RHI of FPS of Russia, defects in healthcare and patient complaints about the refusal or poor quality of healthcare; the criteria “outcomes” - 4 indicators, including indicators of prevalence, disability and mortality due to CSD in inmates (figure 1).

![Diagram of the hierarchical structure of the mathematical model for evaluation of penitentiary healthcare facilities efficiency for patients with CSD.](image)

Using AHP, the elements of each hierarchy level (criteria and indicators) are compared in pairs by experts on a 9-point scale. The experts were specialists from the Department of Organization of Health Care of the Federal Penitentiary Service of Russia, employees of RHI-18 of FPS of Russia, chief supernumerary cardiologist of the Federal Penitentiary Service of Russia.

Through matrix synthesis, taking into account the agreed opinion of experts weighting coefficients were obtained for each indicator. This allowed us to develop formulas for the final indicators (FI) of penitentiary healthcare facilities efficiency for each criterion and total integral index (TII) of the efficiency of RHI of FPS of Russia considering all 5 criteria. For this, the products of final weighting coefficients of indicators and actual data of RHI of FPS of Russia for these indicators were summed (formulas 1-6).

\[
FI_1 = 0.017X_1 + 0.004X_3 + 0.007X_3 + 0.008X_3 + 0.017X_5 \\
FI_2 = 0.127X_6 + 0.074X_7 + 0.040X_8 + 0.040X_9 \\
FI_3 = 0.060X_{10} + 0.018X_{11}
\]
\begin{align*}
FI_4 &= 0.003X_{12} + 0.015X_{13} + 0.011X_{14} + 0.021X_{15} + 0.007X_{16} + 0.058X_{17} + 0.043X_{18} + 0.002X_{19} \\
FI_5 &= 0.122X_{20} + 0.020X_{21} + 0.051X_{22} + 0.233X_{23} \\
TII &= FI_1 + FI_3 + FI_4 + FI_5
\end{align*}

where \(FI_1\) – the final indicators of penitentiary healthcare facilities efficiency for the criterion "equipment"; \(FI_2\) – the final indicators of penitentiary healthcare facilities efficiency for the criterion “staff”; \(FI_3\) – the final indicators of penitentiary healthcare facilities efficiency for the criterion “financing”; \(FI_4\) – the final indicators of penitentiary healthcare facilities efficiency for the criterion “diagnostic and treatment process”; \(FI_5\) - the final indicators of penitentiary healthcare facilities efficiency for the criterion “outcomes”; \(TII\) – total integral index \((TII)\) of the healthcare facility efficiency.

The developed formulas became the algorithmic platform of the computer program “The program for automated monitoring of penitentiary healthcare facilities efficiency in the field of cardiac care”. A database was formed to conduct program monitoring of the efficiency of cardiac care in RHI of FPS of Russia. The database contained the necessary data about cardiac care from 13 RHI of FPS of Russia: RHI -12 (Mari EL Republic), RHI -13 (Republic of Mordovia), RHI -16 (Republic of Tatarstan), RHI -18 (Udmurt Republic), RHI -21 (Chuvash Republic), RHI -43 (Kirov region), RHI -52 (Nizhny Novgorod region), RHI -56 (Orenburg region), RHI -58 (Penza region), RHI -59 (Perm region), MSC-63 (Samara region), MSC-64 (Saratov region), NFM-73 (Ulyanovsk region).

Data entry automatically generates the rating of RHI of FPS of Russia, which is based on the value of FI for each criterion and TII of the efficiency of RHI of FPS of Russia. The results are displayed in the form of color charts and GIS on the map of the Volga Federal District, where green indicates high level of efficiency, yellow indicates its medium level, red indicates its low level (figure 2).

![Figure 2](image.png)

**Figure 2.** The program interface of the results of monitoring efficiency of RHI of FPS of Russia in the Volga Federal District in cardiac care of 2016 in the geographic information system.

Taking into account the values of the entire set of criteria, it was found out that the prevailing part of RHI of FPS of Russia has a medium degree of efficiency (46%), 15% of RHI of FPS of Russia has a low degree, 39% of RHI of FPS of Russia has a high degree of efficiency (Table 1).

| Criteria       | low degree, % | medium degree, % | high degree, % | Total, % |
|----------------|---------------|------------------|----------------|----------|
| Equipment      | 8             | 69               | 23             | 100      |
| Staff          | 8             | 46               | 46             | 100      |
Diagnostic and treatment process  15  62  23  100
Financing  54  31  15  100
Outcomes  8  62  30  100
Total integral index of the efficiency of RHI of FPS of Russia  15  46  39  100

Thus, the developed program allows conducting automated monitoring of the healthcare facilities efficiency, to identify RHI of FPS of Russia with sufficient and insufficient healthcare efficiency, to conduct a comparative analysis of their work and to make effective management decisions.

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