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FUNCTIONAL SIMULATION OF MEDICAL ORGANIZATION MANAGEMENT SYSTEM

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Abstract

Key stages in the process of providing medical services to population were considered. Treatment and prophylactic institution financial, economic and accounting services (departments) operation were studied. Functional model of medical organization management system was formalized and developed, which appeared as a set of diagrams describing all aspects of the system under study. When creating the functional model, structural approach to design, IDEF0 methodology (Structured Analysis & Design Technique subset) and *AllFusion* toolkit were used. Functional cost analysis role was noted in the process of reliable determination of costs in providing medical services and improving financial performance of the medical institutions. Medical institution management system role in organizational and functional structure of a medical institution was revealed. Composition and sequence of procedures were determined for application of economic and mathematical models in managing the tariffs optimal distribution and the financial result of a medical organization operation. Separately, recommendations are provided on implementation of medical savings accounts in the activities of treatment and prophylactic institution and integration thereof with the patient medical treatment record. Analysis of the designed system was carried out as a toolkit in improving quality of the patient medical care and increasing the treatment and prophylactic institution income. Developed integrated medical organization management system is relevant for the medical institution financial and economic units and is aimed at improving their operation effectiveness

Keywords

Functional simulation, SADT, IDEF0, AllFusion, medical saving accounts, electronic medical treatment card, medical organizations management system, structured approach, design

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Introduction. Despite high social significance of the primary health care element, medical organization management processes nowadays could be characterized as extremely ineffective, since any integral scientific and methodological

approach to making informed management decisions based on functional and economic mathematical models and integrated into everyday medical practice is missing. Problems of the management processes low efficiency in treatment and prophylactic institutions (TPI) are associated with fragmentation and imperfection of the mathematical apparatus used in practice and of the functional simulation tools. As a result, approaches to effective medical care and making justified management decisions are not fully implemented.

Article objective is to develop a functional model for medical organization management system, which actually is a set of diagrams formalizing all aspects of the system under study.

Design and creation of a comprehensive and reliable model of the economic information system that takes into account external and internal relations, information flows and medium management processes was carried out using the IDEF0 (Integration Definition for Function Modeling) functional modeling methodology based on the SADT (Structured Analysis & Design Technique) structural approach to design and was developed for block simulation of the organization business processes [1, 2].

In the course of our study, the following main problems were solved: IDEF0 methodology introduction as a means of functional modeling was considered; key stages in the process of providing services to patients of medical institutions were identified; role of functional cost analysis was determined in the process of identifying the real cost of providing medical services and improving financial performance of the medical institutions operation; management system functional model was developed; function ability of the created model to improve medical care for patients and to increase the medical organization efficiency was evaluated.

Literature review. The problems of managing financial resources of medical organizations are the subject of research conducted by many scientists and health care professionals, for example, O.A. Latukha [3–5], D.V. Karas [6, 7], O.E. Karpov [8, 9], L.I. Kaspruk [10, 11], L.L. Kvachakhiya [12], P.F. Kiku [13], E.Yu. Kitchatova [14], L.N. Kiyanitsina [15] and others. It should be noted that they are investigating the TPI management problems from the standpoint of improving operation thereof and achieving high quality indicators of medical activity.

Mathematical simulation and tools for managing the medical organizations resources are introduced in the works by V.V. Igolkina [16] and I.V. Ilyin [17–19]. However, these mathematical and instrumental tools are focused on increasing the TPI economic efficiency, analyzing financial and economic activities, managing stocks and costs, introducing advanced technologies in medi-

cal care provision using new information means and systems and implementing thereof in everyday medical practices, which should improve quality services to the population and reduce the cost of providing medical services.

Influence of the medical services volume on the quality of medical care and profitability of the in-patient operation was considered by foreign researchers in [20]. A three-stage model was constructed using the least squares method, which reflected both the influence of the number of patients on the quality of medical care in the in-patient department and the economic efficiency of its operation. Importance of internal control over the health status of individuals for creating optimal and effective ways to strengthen physical and mental health of the population is analyzed in [21]. Impact of income inequality and budgetary decentralization in Chinese public health is discussed in [22], and it is concluded that higher income inequality provides a significant negative effect on the public health indicators. As for the modern functional models of the medical organization management system, work [23] is of interest. The work illustrates simulation modeling of the medical organization personnel and patients' evacuation based on the modified cellular automats, and it defines the centers of responsibility for management decisions. As the present study, work [24] considers the actual problem of effectively managing the patient queue in medical organizations. However, these problems were solved in different ways. In this study, the authors propose to more actively use the electronic outpatient cards, automated queue management systems and medical savings accounts as the most promising reduction systems and, most importantly, queue management means. At the same time, work [24] proposes mechanism and tools to ensure interaction between medical personnel and patients, which are based on the controlled process of the medical personnel working operations dynamic regrouping in order to reduce non-operation time costs and to increase labor productivity. Work [25] is devoted to the analysis of special software products and their use in medical organizations. In particular, it is proposed to more widely use the medical information databases for intensive therapy in order to identify the most significant factors influencing mortality projections on weekends in the in-patient hospitals. Nevertheless, the authors missed functional models of the medical organization management systems and possibility of their integration with the MIMIC III system (medical information databases for intensive care), which could significantly expand the scope of the MIMIC III models implementation.

Consequently, this literature review demonstrated the lack of works aimed at reengineering the business processes as a tool in the medical organization

management, as well as developing and introducing functional models of a TPI management system into everyday medical practice. Since at present there is no unified theoretical and methodological approach to the medical organization management system functional simulation, the need to search for a scientifically substantiated concept of building functional models in the TPI management appears to be an extremely urgent task. Scientific novelty of the results obtained in this work consists in solving the scientific problem of creating a functional model of the TPI medical services management system, which increases efficiency of these organizations.

Research methodology. *IDEF0 methodology introduction for functional simulation*. IDEF0 methodology is used to create a hierarchical multi-level model, which appears to be the structured mapping of the system under study functions including data flows (information) and material objects that connect these functions [1].

Each diagram consists of blocks (boxes) and arrows. Each block (*Activity*) is a separately executable process, function or operation and expresses the executed action (for example, patient registration). The arrow (*Arrow*) describes the object, which is exposed to action in the box. Arrow direction relative to the box (point, where Arrow and Activity connect) determines the type of interaction: block input on the left (*Input*) indicates input information intended to be used in the process and to ensure the result; input from above (*Control*) indicates data control operation (work), which govern the operation; output on the right (*Output*) indicates the result of work performed (for example, processed information); bottom entry (*Mechanism*) defines the mechanism (resources) to carry out the required work (responsible executive, department, service, automated system).

Functional blocks are connected by arrows forming a hierarchy of objects, which results in forming a diagram that describes a certain process executed in the system.

SADT methodology distinctive feature is the principle of diagram decomposition (detailing). This means that each diagram details (expands) the corresponding functional block in the parent (overlying) diagram [26]. By adding new detailing levels to the set of diagrams, it becomes possible to formalize (describe) in sufficient detail the current or the designed system. This simplifies not only system construction, since there is no need to display the entire system at once, but also its substantive understanding (information is provided in small parts on each subsequent diagram). This is how all aspects of the system are examined in turn. IDEF0 model design and development is based on the

AllFusion class toolkit, which is characterized by complete and accurate description of subject area and organization of data collection, storage and classification. It is convenient to use the *AllFusion Process Modeler 7* software product as such a toolkit, which provides conceptual and logical design of business models, supports high level of information and procedures integration and contains mechanisms for constructing logical and semantic data models.

Key stages in the process of providing medical services to population. Let us list six key stages in the process of providing medical services to population.

1. Registration. Any TPI patient is provided with medical services from the moment he turns to specialists of a medical institution until obtaining results of diagnostics and appointment of additional medical examination in the institution itself or referral to another TPI and provision of other medical services: prophylactic appointment; treatment; rehabilitation; medical manipulations and procedures; medical interventions and operations [11].

Patient initial acquaintance with a TPI starts in the registry. Speed and efficiency of the registry staff operation determine the result of the entire medical institution work. Long queues are the main problem of the registry, primarily due to significant time it takes to find an outpatient card and prepare the necessary documents. Reduction of queues by increasing the number of service personnel is associated with growing costs, sometimes not only for attracting additional personnel, but also for capital expenses (expanding the material and technical base, opening additional offices). This accompanied by low revenue growth rates leads to a decrease in labor productivity and, accordingly, to deteriorating financial performance. In other words, expanding the number of medical personnel is economically feasible, if the number of visits grows enough to cover these costs. For institutions that are at their limit or are not experiencing significant growth in attendance, a queue management approach is more preferable. The idea of queue management lies in solving a complex problem: firstly, to make the flow more predictable and organized, and secondly, to make the queuing patients so comfortable that the queue becomes invisible to them.

The queue is regulated in accordance with the doctor's appointment schedule. To improve the quality of service, appointment with a doctor could be made by phone (for example, through the Electronic Reception), using the queue management automated systems (terminals), at the entrance to a medical institution and via the Internet.

2. Waiting for appointment. Waiting time for patients to be invited to a doctor's office could also be reduced by organizing the outpatient cards

movement in the electronic form [27]. Currently, Russian regions are in transition to the electronic medical cards. During the transition period, paper ambulatory cards could be used in parallel with electronic cards. Average delay from the moment the card is ordered at the registry until it is delivered to the doctor's office in some clinics could range from 5 to 15 minutes. This negatively affects the patients and introduces additional confusion to the organized patient queue. Keeping outpatient cards in the electronic form and storing them in a unified database with distributed access would accelerate their transfer from one office to another, solve the problems of finding an outpatient card and of the costs for keeping it. Results of all analyzes, established diagnoses and prescription forms an integral part of the outpatient card electronic version should be available to doctors in a regulated manner excluding violation of medical secrecy and medical ethics. This requires introduction of additional protection and information security system in a TPI [11].

3. Payment for medical services. Significant progress in improving the quality of patient services, especially in organizing appointments and visiting a doctor and in reducing queues at the registry, could be achieved by introducing the chip plastic cards (CPC) in a medical institution. These cards are able to solve the problems of the accounting information multiple entry, search for necessary information about a patient, automatic data substitution, acceleration of accounting and redirection of results. In addition, there appears a possibility to store the required amount of information on the CPC. In this regard, plastic card could play the role not only of the owner identifier, through a system of accessing databases automatically provide required information for making an appointment and receiving medical treatment, but also perform an important function of a payment instrument ensuring possibility of payments for medical services provided by monetary funds from the medical savings accounts (MSA) [28]. In this case, any patient deposits funds in advance on a special card account through the medical institution cash desk. And using the MSA funds, the patient is able to pay with his CPC at the doctor's office eliminating the need to waste time and effort to pay for each service prescribed at the cash desk in cash. In addition, this approach significantly contributes to solving the problems of paying for services not included in the patient medical insurance program, thereby reducing risks of claims from insurance companies, and also allows the patient to control the state of his account and to pay only for services actually provided to him. It is possible to connect this card to the Mobile Bank system by analogy with banking services, i.e., a CPC could simultaneously be a medical insurance policy, a means of payment and an electronic outpatient card.

4. Doctor appointment. In case paid medical services are provided, the patient is given a receipt at the registry to pay for services at the cash desk or through a payment terminal. Then, the patient visits a specializing doctor with outpatient coupon, paper or electronic outpatient card and paid receipt. The doctor examines the patient, asks him about the disease development, performs the required medical diagnostic procedures (manipulations) and comes to one of the possible conclusions: establishes the patient's diagnosis; sends the patient to instrumental and (or) functional studies, or prescribes additional medical examination at another TPI. Diagnosis made and record of admission issued to the patient are registered in the outpatient card.

5. Questionnaire. Patient questionnaires could be used to improve the TPI operation, raise the quality of patient services, simplify collection and increase amount of the patient information. When contacting the registry, a patient, in addition to the documents listed above, receives a questionnaire with questions. Questionnaires differ in their form depending on the reason for seeking medical assistance. The patient after filling out the questionnaire might go to the appointment. Such a scheme improves the patient's interaction with a doctor and makes him an accomplice in his health, which affects the results of treatment, as well as the diagnosis accuracy.

6. Patient additional examination. If necessary, the doctor uses the laboratory and diagnostic room services. At the end, he receives an ECG or a MR tomogram, conclusion of a laboratory assistant, examination results on photograph, paper or digital carrier, which is registered in the patient's outpatient card. Modern medicine is increasingly often using the DICOM format to transfer, store and receive images of radiation diagnostics (MR tomograms, CT tomograms, X-ray images).

Role of functional cost analysis in determining the cost of providing medical services and improving financial performance of a medical organization. Functional cost analysis (FCA) makes it possible to estimate real cost of the process and is used to collect and register costs associated with the work performed. Functional cost simulation (Cost analysis) is based on the item-by-item distribution of parameterized (digitized) time and financial resources expenditure connected to implementation of certain stages in the process of providing medical services to population [2]. Functional cost analysis is based on the work model, since quantitative evaluation of processes is impossible without detailed understanding of the organization activities.

As a rule, FCA is used in reorganization or fundamental reengineering (redesign) of the organization business processes in order to determine the sources of

costs and to facilitate selection of the required work model (Business Process Reengineering, BPR). Cost analysis makes it possible to determine real cost of providing medical assistance and support to a client, identify the most expensive services and those requiring prioritized improvement of work, provide managers with information on the required amount of funding for the proposed changes [9].

FCA data would be correct only, if the work model is consistent (corresponds to syntactic rules of the IDEF0 methodology), reliable (correctly reflects business process in providing medical care to patients), comprehensive (covers the entire area under consideration) and stable (is not changing during the examination cycle), i.e., when design and development of the work model is completed. The work total cost is calculated by summing all the cost centers. When calculating the costs of superior (parent) work, first the product of costs of the child work by the number of cycles of its execution is determined, when the parent work is carried out, and then the results are summed up.

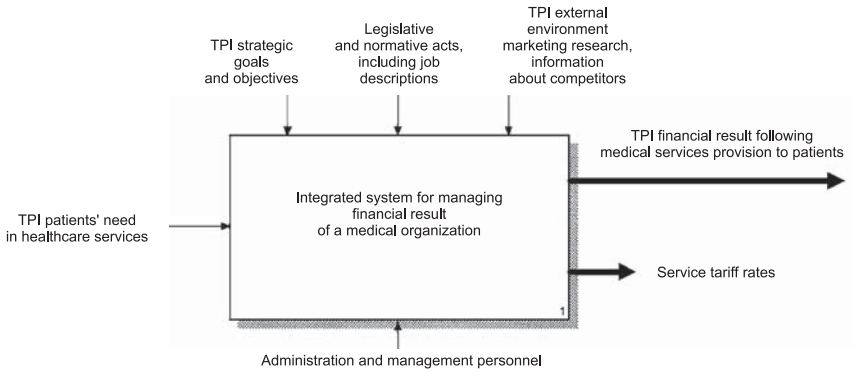
Data collected and processed using the *AllFusion Process Modeler 7* software product toolkit serve as analytical material for marketing and economic services of the organization, reflect demand for various types of services and statistics on the population disease rate. For example, the quality of public services could be determined by the time the patient actually spends in a queue. Analysis of this indicator would reveal the reasons for the TPI ineffective operation associated with late delivery of outpatient cards, absence of medical personnel in their places during working hours, etc., which makes it possible to optimize processes of providing services.

Financial and Economic Service (FES) sets tariffs for medical services and distributes the profit received by a TPI. FES is responsible for solving the problem of determining the sources, from which the payment for services rendered to the patient would be made. Such sources could include budgetary funds, payments from compulsory medical insurance (CMI) or voluntary medical insurance (VMI) funds and the patient proprietary financial resources.

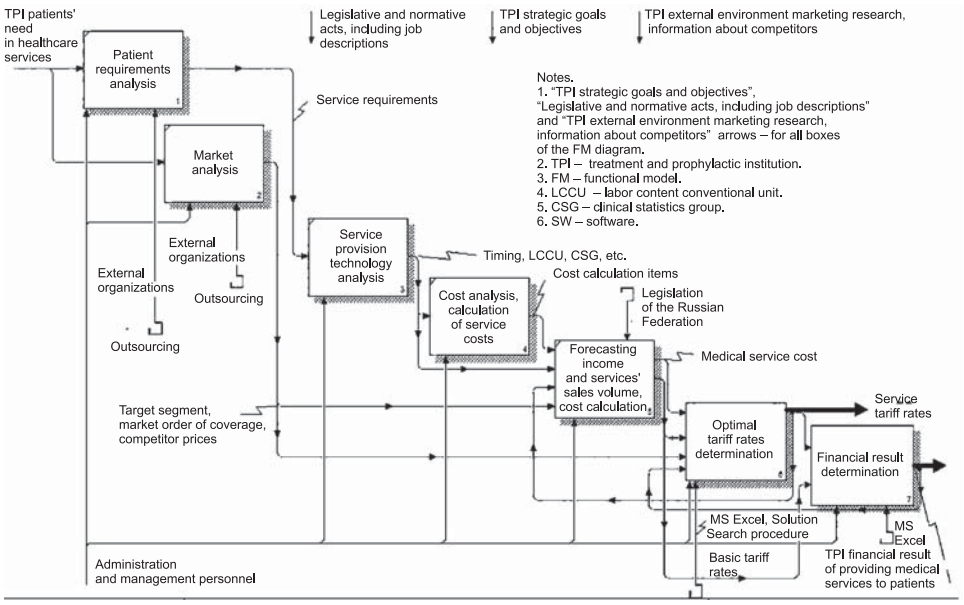
Functional simulation of the medical organization management system. Let us consider the medical organization management system in accordance with the IDEF0 methodology requirements. The medical organization management process could be divided into several enlarged modules. In accordance with requirements to the SADT methodology, division into modules was carried out on the basis of the incoming and outgoing resources (material and information flows) analysis, control actions (regulatory and normative data) and resources performing the process. In accordance with this methodology and the *AllFusion* class toolkit, the functional model under development

consists of a set of diagrams, each of which is described on a separate sheet and appears to be a more detailed decomposition of the (*Activity*) block top-level diagram, i.e., the *Parent* diagram. Each subsequent diagram details one of the top-level diagrams [26].

TOP-diagram (or A0-diagram) is the beginning of any functional model in *AllFusion*, and it consists of a single functional block. All subsequent diagrams are decompositions of the A0-diagram. The A0-diagram describing the TPI financial and economic service is presented in Fig. 1 *a*.



a



b

Fig. 1. A0-diagram (*a*) describing the TPI Financial and Economic Service and diagram of an integrated system managing the medical organization financial result (*b*)

Integrated system for managing the TPI financial result is a set of measures aimed at redistributing financial result between patients and the medical institution in such a way as to maximally take into account interests of the parties in terms of financial results and to attract new visitors [2]. It consists of the following blocks (Fig. 1 *b*): patient requirements analysis; market analysis; analysis of services provision technology; expenses analysis, cost calculation for provision of services; forecasting income and volumes of services rendered, cost calculation; optimal tariff amount determination; financial result determination.

At this stage, calculation and analysis of costs for design, development, implementation, maintenance and provision of medical services is carried out. Market segmentation and study of the target audience is performed, for which the service is intended, capacity and elasticity of the market segment and market conditions are determined, life expectancy for each service is being forecasted, sales volume, fixed and variable costs are planned, breakeven indicators are analyzed, and based on all of the above, cost of the developed service is calculated. Further, in accordance with the organization goals and objectives in the market and the absence of legislative restrictions, recommended tariff rate for the service is formed and brought to attention of all TPI interested services and personnel. The final tariff rate is determined based on peculiarities of relationship between the organization and the patient.

Technical support in decision-making by the responsible employee is based on the economic mathematical model for determining the optimal tariffs and the TPI financial result management, which are parts of Optimal Tariff Determination and Financial Result Determination blocks diagram decompositions, respectively (Fig. 2). Any software could become the basis for decision-making algorithms based on the economic mathematical model, if it is possible to use such software in solving mathematical programming problems, including the Solution Search procedure of the *MS Excel* software product.

Functional model diagram was designed and developed using the listed key stages in the process of providing medical services to population in order to increase the medical services efficiency to population and to ensure informed management decisions (Fig. 3). The model formalizes the process of providing medical assistance to a patient from the moment he or she goes to a medical organization to the moment of establishing a diagnosis or referral for additional research, including examination in another TPI.

Conclusion. Functional simulation of the medical organization management system is a comprehensive and consistent reflection of the process of the integrated system functioning in effective management of the financial result

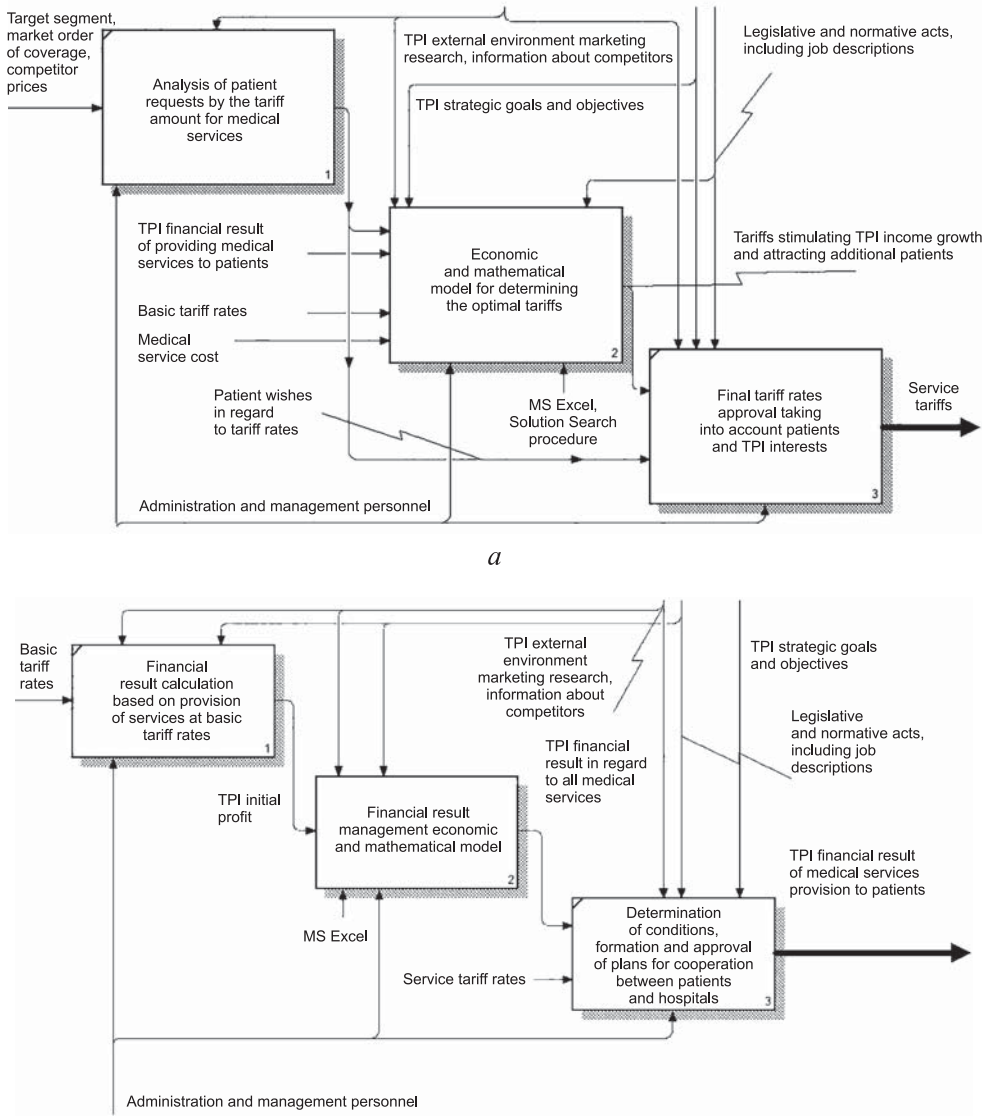


Fig. 2. Diagrams for determination of the optimal tariff rate (*a*) of the financial result (*b*)

of providing medical services to the TPI patients. In contrast to the known approaches to structural system analysis and design [1, 23, 26], using the elaborated functional model in medical organizations makes it possible to establish mutually unambiguous correspondence between functions, information and objects in the process of interaction between patient, doctor and medical organization, as well as to identify centers of responsibility for decisions made in the departments of a medical institution.

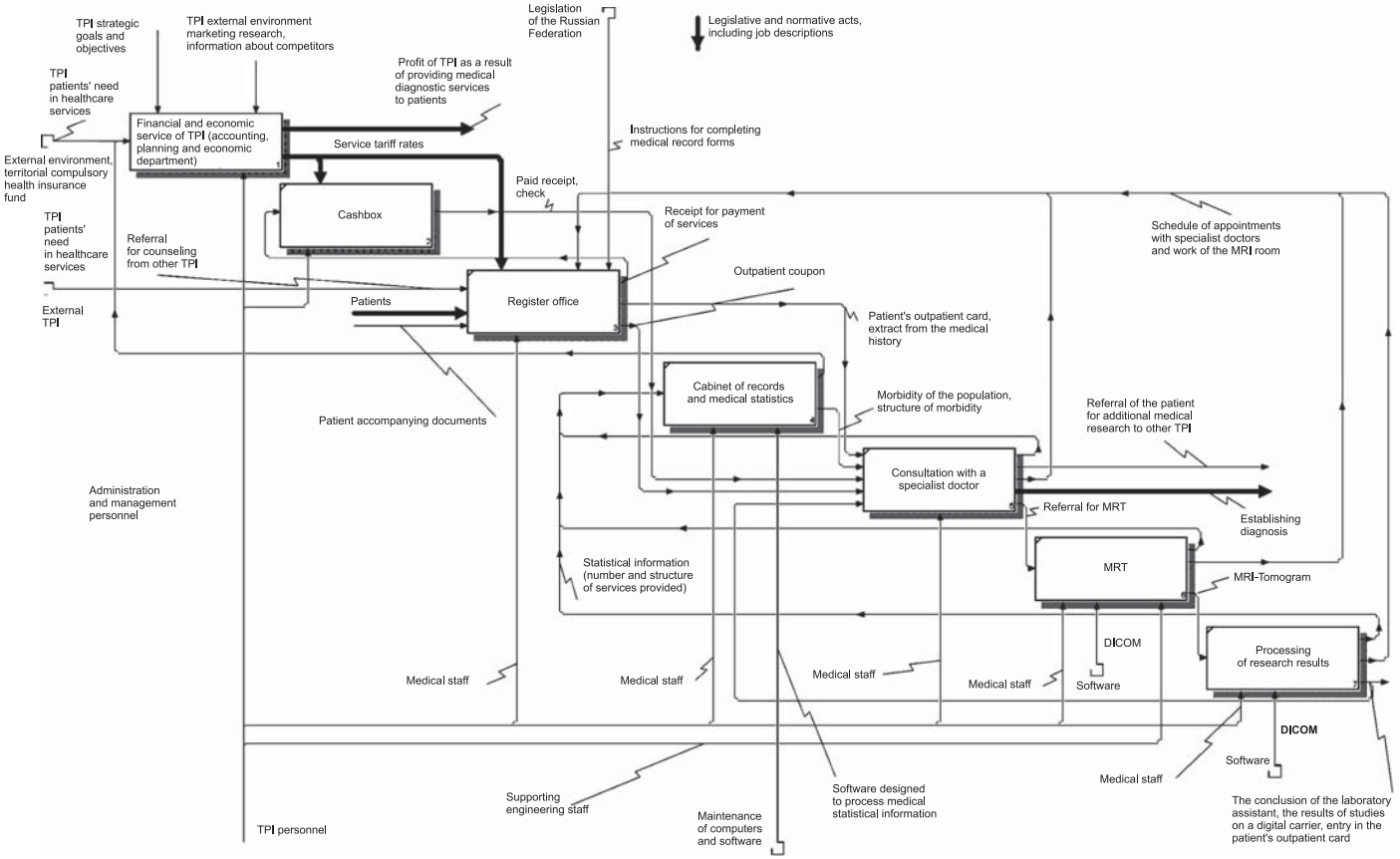


Fig. 3. Key stages in the process of providing medical diagnostics services to population

The model under consideration also makes it possible to identify areas for improving medical services to patients and increasing the efficiency of TPI operation, to unambiguously determine structure and functions of each of its elements. This would allow eliminating errors at the stage of system design and development, significantly simplify implementation and reduce the cost of support and provision of medical services.

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