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System of Project Management at a Medical Hub as an Instrument for Implementation of Open Innovation

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Abstract: Globalization activates qualitative changes in multiple economic entities and requires the development of alternative forms of business organization. At present, one of the most promising development tracks is represented by the implementation of network structures, aimed at achieving common goals and obtaining a win-win outcome via joint effort. Business structures that invite dynamic and consistent transformations on a wide scale prove to be able to successfully compete in the market. In this regard, a project management system at a medical hub serves as a vital tool for implementation of open innovation. Participation in the medical hub allows coordinating intentions and establishing aligned communication between all stakeholders, suppliers and private institutions. In modern sectors of the economy, a developing hub becomes a unique structure, because it unites the contributions of the most important healthcare specialists in a single framework. This research examines the structure of healthcare business process models, and scrutinizes the communication between suppliers, partners and consumers of medical services. It also defines the main directions and outlines strategic goals. Assessment of performance of a project management system at a medical hub proves to be the issue of particular relevance, due to the fact that its tasks should be primarily aimed at increasing the share of successful projects and implementing only those ones that comply with the strategy. Based on the latter, a model for the project management system at a medical hub was designed. As a result, the authors developed an assessment mechanism for innovative projects using SNA methods that align with intra-communication interactions (transactions) between the participants in a medical hub. The conducted research allows concluding that in the current era of cutting-edge technologies, the project management system should be considered the most effective management tool for coordinating the actions of a corporate structure at a medical hub.

Keywords: medical hub; information technology; business model; open innovation; vaccine life-cycle; architecture model

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1. Introduction

As part of digital transformation, innovation management becomes an urgent task. Primarily, it serves as a fundamental factor in ensuring sustainable development and increasing competitiveness. The most important challenge for modernizing healthcare is to create a more efficient system managing financial resources, and thereby significantly improving the quality of medical services provided to the population. In the field of economic globalism and market expansion, business processes go far beyond an individual company. That is why structural networks are being actively shaped to engage stakeholders from different national economies.

Due to the current development trends, medical organizations, manufacturers and suppliers of medical equipment, and pharmaceutical companies are forced to accumulate and strengthen their competitive advantages. The largest competing manufacturers face new challenges created by the digital transformation. In these conditions, the internal reserves of enterprises are drained, resulting in the applied business model being considered as the subject of optimization, instead of the expected resource potential of an enterprise.

Development of automation imposes new requirements. As a result, the radical optimization of management becomes the only way to reduce costs in the medium term. At the moment, a new structure—the medical hub—is gaining attention in healthcare. A medical hub is a group of geographically adjacent interconnected companies and related organizations that function in a certain area of activity, which is beneficial for all parties involved.

The significance of a medical hub boils down to the fact that most of its participants do not compete with each other, but produce goods and services in different sectors of the medical industry. They have common opportunities and, at the same time, deal with common challenges. Participation in a medical hub makes it possible to share goals and establish interaction between the participants, the suppliers and the government. In modern economic conditions, a medical hub becomes a unique structure, capable of uniting a wide range of healthcare stakeholders for the sake of their common goals. Another important aspect is that hubs are typically characterized by the territorial localization of most organizations, stability and priority of economic ties between the participants, and a long period of coordination of common goals and actions between the stakeholders. The advantage of medical hubs is the effectiveness of innovative development within this form of interaction of organizations. Innovations need constant communication between the participants, in order to adjust and make changes in development, research and production processes in a short time. This form of interaction, on the one hand, allows small and medium-sized enterprises to comfortably carry out their activities. On the other hand, it is the small- and medium-sized organizations that are the most flexible and adaptive to external changes. In addition, the development of an effective business model for a medical hub becomes an effective mechanism for protecting domestic manufacturers and creating conditions for the emergence of a new, transparent system of planning, development, production and introduction of medical devices into medical practice.

The main goals of creating a medical hub include the development of a single resource base to reduce the costs of its operation:

- The formation of a common knowledge base, the exchange of necessary competencies and the ability to offer the market a more attractive product value;
- The distribution of risks between partners;
- The maximization of total revenues due to the emergence of a network synergetic effect (system effect).

The sustainability and efficiency of the medical hub business model is determined by the strength of information links (the presence of a common network of rapidly replenishing information resources), the coordination of actions between the network participants (as a rule, in case of a merger of equal companies, coordination councils are created to solve significant issues, or a network broker is hired to coordinate their activities), the availability and implementation of in-network standards (business processes related to customer service, information processing, decision-making, motivation, innovation, etc. must be clearly spelled out and controlled) and trust between stakeholders and the development of a network corporate culture.

In these conditions, the medical hub management system deserves close attention, especially in the context of project management systems, since at present it is an effective project management system that is becoming a key element of the medical hub business model and must necessarily correspond to the strategic goals of its formation. The project management system is a process of planning, organizing, directing and controlling work of all departments at the medical hub, using all available resources to achieve certain goals.

The choice and development of necessary tools for project management and performance control (regulatory framework, methods, corporate culture, scorecards and management decisions) is an urgent task and a fundamental success indicator, which determines the relevance of this research.

2. Literature Review

As part of the digital transformation of economic systems, the management of open innovations is an urgent task, as it serves as a fundamental factor in ensuring sustainable development and increasing competitiveness. Since this research presents the project management system of a medical hub as a tool for implementing the concept of open innovation, the theoretical basis of the work was research in the field of network forms of business organization and in the field of evaluating the effectiveness of project management of medical organizations. In accordance with the existing theoretical framework, the network form of interaction includes a specific pattern of cooperation and interdependence between stakeholders which is characterized by at least two traits:

- The network involves two or more enterprises whose activities are aimed at achieving common goals and solving problems in the long run;
- Partner companies coordinate their functions, but do not combine them.

Dubois [1] offers a simple model of an interorganizational network that includes three related components: network participants, resources and activities. In accordance with the Dubois model, enterprises (agents) carry out certain types of activities, have the necessary competencies to do it, possess information about network resources and control the state of their own resources. As a result of repeated transactions between the network participants for a long time, a system of mutual relations develops and links the resources and activities of the network participants.

Stamps and Lipnack [2] identified five basic principles of inter-organizational network structures, which are listed below.

1. A single goal ensures the stability of the network;
2. The independent performance of the network participants also allows benefiting from their position in the network structure;
3. Pooling the resources and efforts of the network participants takes place on a voluntary basis;
4. The functional uniqueness of each member of the network makes it possible to achieve greater success for the entire organization. The presence of several leaders gives the organization stability and flexibility;
5. Network organizations are multi-level structures.

Webster [3] defines inter-organizational networks as "complex multi-stakeholder organizational structures that arise from strategic alliances, usually combined with other forms of organization, such as branches, departments or value-added resellers". He also emphasizes that the main characteristic of a network organization is its confederate structure. Hakanson [4] believes that the network is defined by a set of entities that are institutionally independent, but carry out certain interdependent actions and control resources. In his opinion, there is some agreement between the entities of market interaction regarding the existence of this dependence.

Sheresheva [5] offers a definition in which the inter-organizational network is defined as a system of contracts between formally independent economic agents in order to optimally combine and use resources. As a result, the network organization copes more successfully with the competition in global markets by focusing on a limited number of functions, and cooperating with other organizations to maintain the necessary technological level, increase operational efficiency and reduce its own costs. Thus, the advantages of network organizations include:

- Adaptability and rapid response to changes in the market;

- The ability to concentrate the activities of each participant on the best competencies and unique processes, which allows achieving high quality production and distribution of goods and services;
- Significant reduction of costs and rational allocation;
- The possibility of attracting optimal partners to joint activities within the network, excluding the use of incompetent performers.

Existing approaches and methods are normally based on processing, generalization and integration of existing results in the field of business modeling and system analysis. However, the processes of developing and implementing architectures in large systems, such as a medical hub, are currently only emerging, which clearly indicates that the problem is not sufficiently developed.

At present, the development of methodology for improving healthcare management is gaining higher theoretical and practical significance. It becomes more and more urgent to continue reforms in healthcare, research in the methodology of medical IT and the formation of optimal solutions to economic problems in healthcare. Under these conditions, the particular challenge of project management in medical organizations is explained by insufficient practical experience in this area, and the need for competent adaptation of such experience gained in the business environment. It is believed that changes in the management processes of medical organizations can serve as both a catalyst and a serious obstacle for the development and establishment of a new, qualitative level of functioning of the entire healthcare system. Adapting a modern health care management system to new challenges involves both the revision of experience already gained in applied organizational decisions and the scientific credibility of new technologies, forms, methods and models of management. An important tool for managing open innovations is project management [6–8]. Its traditional approaches are limited to methods and techniques for project execution control and are associated with Gantt diagrams, the Critical Path Method on a network graph (Critical Path Method, CPM), a group of methods for evaluating and reviewing plans (Program/Project Evaluation and Review Technique, PERT), a graphical evaluation and analysis technique (Graphical Evaluation and Review Technique, GERT), a streaming method and a network planning and management method. However, effective project management (as discussed in the works by [9–14]) requires that the interconnection between project executors is considered. With the development of methods of social network analysis (SNA), the authors take into account the dynamics of communications between project participants so as to analyze the efficiency of project implementation. Mead [15], Toomey [16] and other researchers [17–19] use social network metrics that reflect communication between performers as an indicator of project success. Plokhov et al. [20] and further research [21–25] use network analysis to identify conflict situations based on the balance of networks in the process of the dynamics of decision-making. These techniques have been widely applied in industries such as transport, retail or banking. However, in medicine, they are insufficiently implemented.

Results of the literature review show that these problems are severely underrepresented in the literature on the topic.

3. Materials and Methods

The authors analyzed the experience of participation of various small and medium-sized organizations in the medical hub and identified prerequisites for successful integration of medical hub participants into project activities. It was a profound experience of analyzing a sufficient amount of data with the selection of adequate research methods. At the same time, the research apparatus chosen by the authors allowed the drawing of interesting conclusions, namely, finding out the impact of intra-communication interactions of participants in the project activities of the medical hub on the mechanism for assessing the success of innovative projects.

In this study, a number of analytical methods were used, including description, data grouping, causal analysis, evaluation and business architecture modeling methods. Im-

plementation of these methods made it possible to connect independent facts about the current situation in the field of development and assessment of performance of medical hub business models in an environment where project management is used to solve unique and large-scale business problems. However, the prevalence of the project approach remains low. The methodological basis of the study contains theoretical provisions of the economics of the public sector and management and data from official sources of state authorities of the health care system, and includes methods of critical analysis, theoretical modeling and formalization.

In the presented study, the authors considered the structure of the medical hub business model, and analyzed the interface for interaction with suppliers and partners as well as the interface for interaction with consumers of healthcare services. At a high level of detail, the reference operating business model of a medical hub is presented at two levels: the resource level and the key capability level. Based on the theoretical results of the study, confirmed by the expert community in healthcare, the authors considered the project management system as a tool for implementing strategic goals of the medical hub. As a result, a mechanism for evaluating the project management system using SNA methods was developed, taking into account intra-communication interactions (transactions) between the participants of a medical hub. To implement this idea, the authors propose to identify the relationship between project performance indicators and indicators of intra-project communications. In this work, a study was made of the relationship between project success indicators and intra-project communications; however, a limited number of structural characteristics were used. Based on the results of the data obtained, an analysis of the factors that positively and negatively affect the results of project activities was carried out. Approbation of the results of the study was carried out on the data of a medical organization engaged in the development of IT solutions in the field of medicine. To develop solutions, the company used a project approach and took an active position within the medical hub.

4. Results and Discussion

4.1. Structure of the Medical Hub Business Model

The digital transformation of economic systems cannot but affect the logic of a company's business processes, which indicates the need to adapt business models to changing market conditions. Today, the improvement of business models is becoming a necessity. At the same time, this process cannot be considered without optimizing IT services. Meanwhile, the main condition for the effective use of IT services for management purposes is a properly constructed system of business processes. What is more, business is forced to adapt to new conditions, in order to ensure compliance with new legislative requirements. Consequently, medical organizations require constant development of automated process management systems. On the one hand, it entails additional costs, while on the other hand, it opens up new opportunities for optimization, reducing labor intensity, and increasing the efficiency of business processes.

The introduction of a process approach in the development of business models is quite widespread in foreign companies, but in the Russian segment it has not immediately proven its effectiveness. First of all, this is explained by the lack of a methodological framework that would take into account the specifics of this approach in certain industries and spheres of activity [26,27].

According to the presented structure (Figure 1), at the conceptual level, the business model of the medical hub consists of three key elements: the interface of interaction with suppliers and partners, the interface of interaction with customers (value proposition) and the operational model. Such a representation of the business model will make it possible to define critical points and strengths, as well as determine the framework for strategic management.

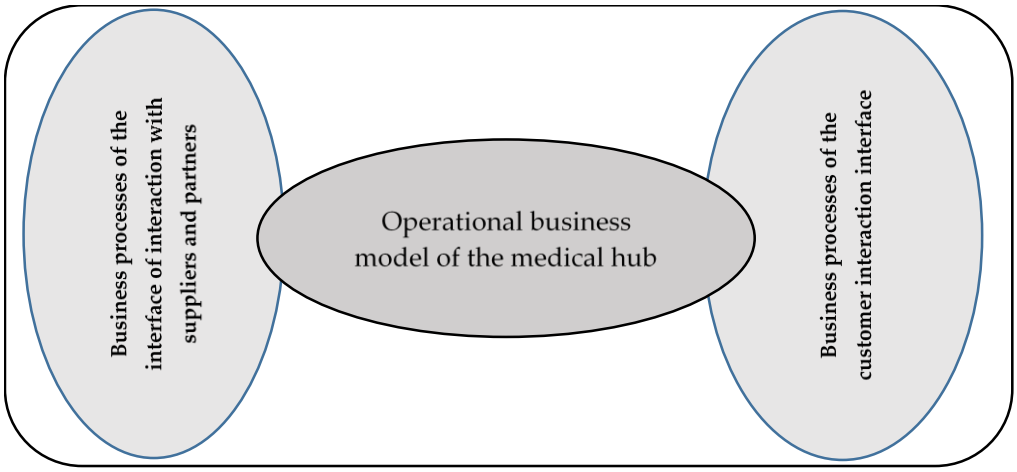


Figure 1. Structure of the medical hub business model.

At the same time, it depends on the chosen strategy. In other words, for the majority of large companies, the focus of strategic management is on the left side—the interface of interaction with suppliers and partners. For local companies, the focus is put on the right side of the business model—the value offered. Any company interacts with suppliers and partners in three main areas and has certain established obligations, as presented in Figure 2.

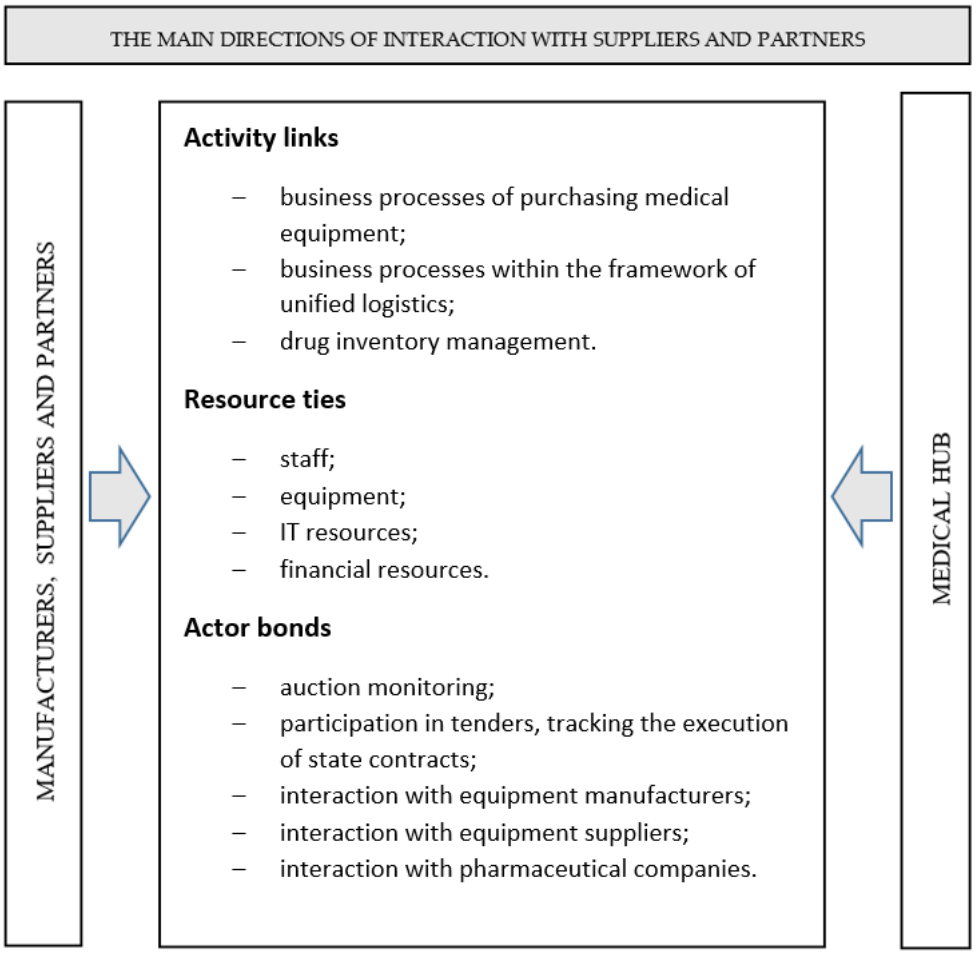


Figure 2. Main directions of interaction with manufacturers and suppliers.

To be more specific, Activity links mean business processes for the purchase of medical equipment, business processes within a single logistical framework, inventory management of medicines, and project management. Resource ties represent all types of resources that take part in joint business processes. Actor bonds are contractual terms and personal relationships that develop between employees of medical organizations and suppliers.

In addition to the interface for interaction with suppliers and partners, the key areas of interaction between participants of the medical hub and external clients should be considered. To optimize the interaction between all participants of the medical hub, as well as to increase patient satisfaction with the treatment process, it is necessary to complete the following tasks: ensure that patients' rights are implemented; predict the potential effectiveness of medical services; control the dynamics of disease through follow-up contacts with patients; inform patients about the proposed methods and means of treatment, especially when using risk-associated methods; and develop preventive measures for pathological conditions. The main activities within the key areas of interaction between the participants of the medical hub and external clients are shown in Figure 3 below.

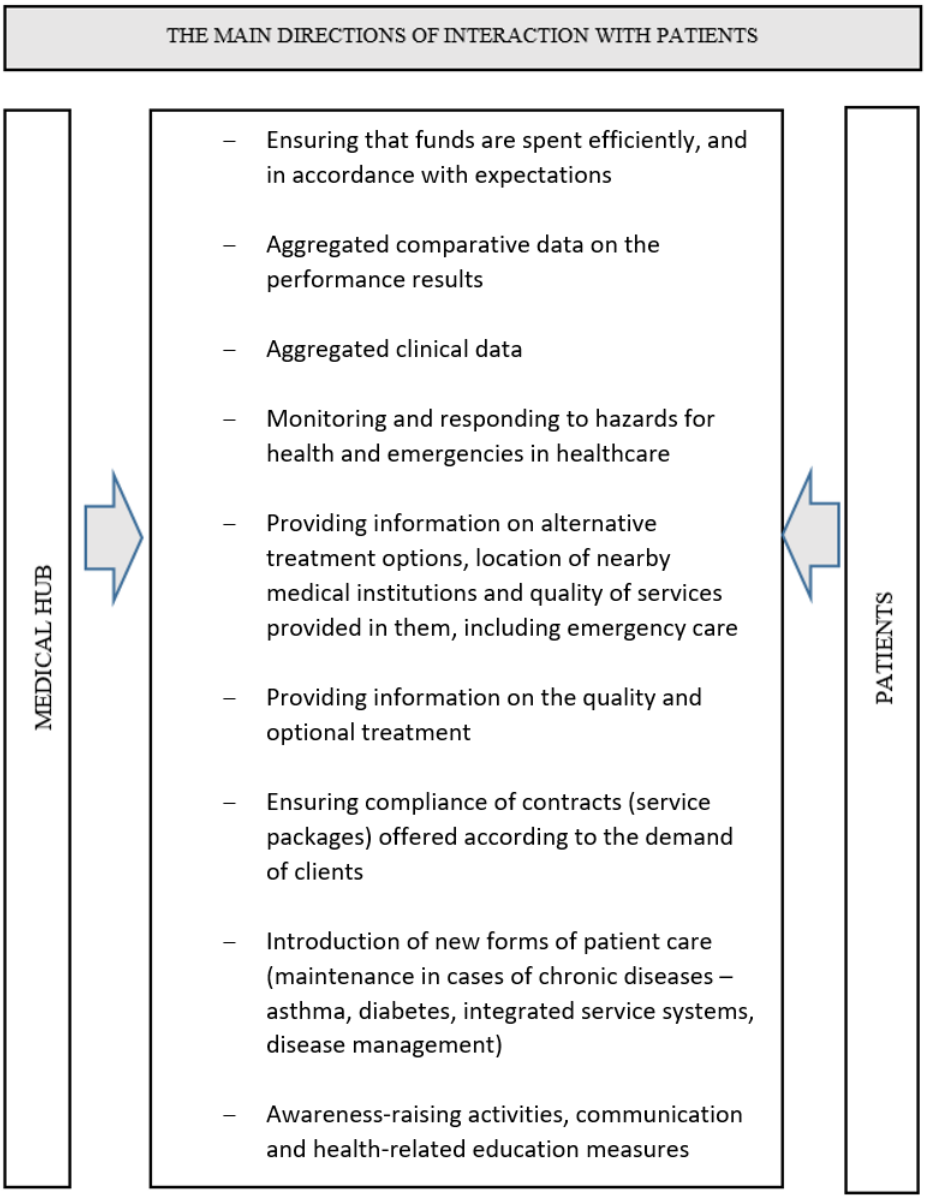


Figure 3. Main directions of interaction with customers.

Due to the changes that consumers of medical services are going to face, the list of personal characteristics of clients that need to be taken into account is expanding, in order to improve the efficiency of the medical hub. Considering the integration of offline and online patient records, it should be noted that medical organizations already have a fairly large database of consumers [28–30]. The most difficult task at this stage is to integrate the system and CRM into a new online platform, since the omnichannel business must be managed using a single technological platform.

When studying the satisfaction level of patients, attention should be paid to key aspects of reforming the industry: increasing the availability and quality of medical care, improving personnel policy, strengthening the material and technical base, disseminating information technology, protecting patient rights, and taking into account public opinion in addressing current health issues. What is more, it should be remembered that each country has its own unique model of healthcare system, and patients' opinions about their satisfaction with its work depend on a combination of cultural, political and economic factors.

4.2. Structure of the Operational Business Model of the Medical Hub Business Processes

A medical hub should be seen as a system that is being constantly transformed. Participants in this system, in their aspirations to be successful and viable, are constantly looking for ways to improve their activities. Here, one of the most successful ways of development is organizational design. Most of the projects implemented by the participants of a medical hub are related to business automation, the opening or modernization of medical organizations, and expanding the range of services provided to the population. However, strengthening the material and technical base does not completely solve the problem of quality and accessibility of medical care.

The use of modern project management methodology, according to the research by the International Project Management Association (IPMA), can reduce project time by 20–30% and its budget by 15–20%. Given the scale of the medical hub and its multitasking, it makes all the difference. Calculations show that in the following 2–3 years, investments in technology not only pay off economically, but also allow staying afloat in a rapidly changing world. The medical industry has always been one of the most technologically advanced sectors of the Russian economy. In terms of infrastructure, large medical hubs have already implemented digital business transformation and are now looking at new niches for growth. They improve existing products and develop new directions that are considered promising. For example, the innovations that the entire market is talking about were among the first to be introduced by the medical industry. These include artificial intelligence, the internet of things, machine learning, neural networks and robotization. The first step towards digital transformation is the automation of a company's business processes, which should lead to a reduction in labor costs, obtaining operational and reliable analytics for making important management decisions. An integrated project management system is a tool for achieving business results and for implementing both the development and transformation strategies at medical hubs.

The specified company operating model connects the interface with consumers (the value and format offered) with the interface with suppliers and partners. It is a system of business processes through which goods and services are delivered to the final consumer, that is, the chain of consumer value formation. In the operating model, it is important to distinguish two levels, which are presented in Figure 4. These levels are:

1. Level of operations and key abilities;
2. Resource level.

The level of operations and of key capabilities includes a business process map and, most importantly from the point of view of formulating a competitive strategy, the organizational capabilities of the medical hub. Among them, it is important to highlight the key differentiating abilities, i.e., what a medical hub can do much better and faster than competitors. The resources of the medical hub include all the assets that the association can use to create value for patients and perform business processes. At the same time, being an

important element of the operating model, they cannot be considered competitive advantages, unlike business processes and key organizational abilities, since similar resources may be at the disposal of competitors.

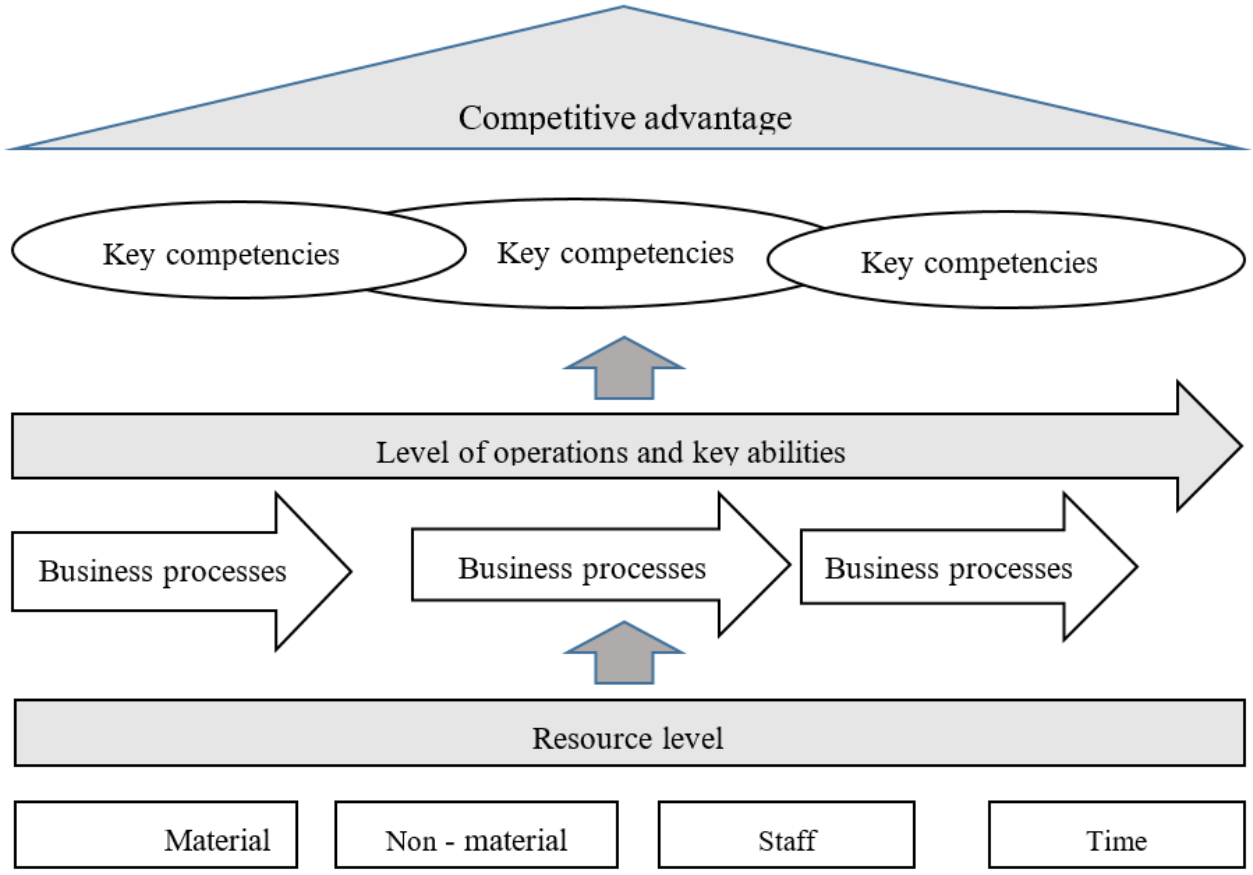


Figure 4. Structure of the operating model of the business processes of the medical hub.

When analyzing business processes and key organizational abilities, in addition to the traditional division into main, supporting and development processes, it is important to highlight current business processes that directly create consumer value and strategic business processes that create future value [31–33]. For example, current processes should include replenishing stocks of medicines and the placing of orders to suppliers of medical equipment, and operational management. Strategic business processes include the development of new services, innovations, and staff training. It is these business processes that will further optimize the business model of the medical hub.

4.3. Project Management System as a Tool for Implementing Strategic Goals of the Medical Hub

The improvement of the business model of the medical hub can be carried out in three different areas, presented in Figure 5.

When analyzing the factors hindering the improvement of business models of medical hubs, special attention should be paid to the following:

- Optimizing a medical hub's business model may require systems, processes and assets that are quite costly;
- In medicine, project management is used to solve unique and large-scale business problems, but the degree of prevalence of the project approach is still low;
- There is a degree of impenetrability in the medical hub's business model, which makes it difficult for competitors to reproduce it;
- There are unique resources, such as a brand, an organizational system and a network of partners that have a certain static nature.

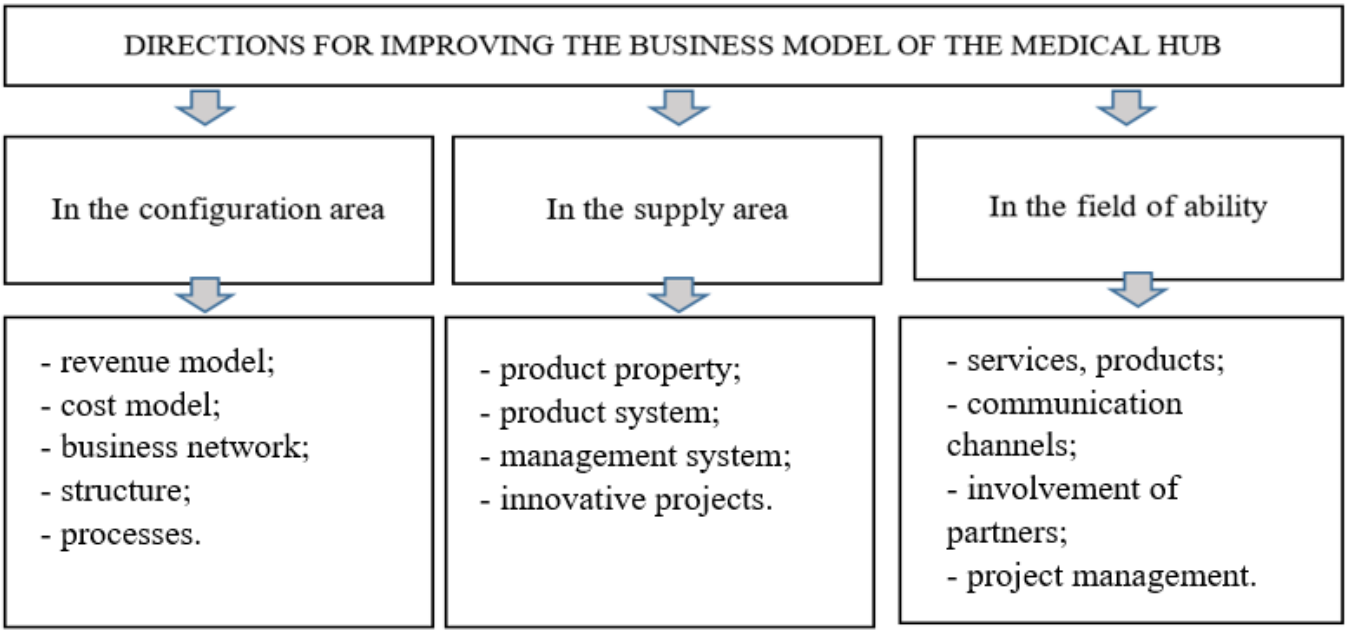


Figure 5. Main directions of optimization of the medical hub business model.

There is no generally accepted methodology for assessing the success of a project management system that takes into account intra-communication interactions (transactions) between participants in a medical hub. Currently, a unified approach to the implementation and evaluation of the project management system in the activities of the companies participating in a medical hub has not been developed. Individual companies use different business models in their activities, while the efficiency of their activities also varies significantly. It should be taken into account that any innovation or expansion should not have a significant impact on the sequence of business processes and, since any change in business processes entails very costly changes to IT services—that is, in the process of improving the business model—it is advisable to use a bimodal management structure, in which, in addition to the current management structure, structures are created to search for new innovative solutions [34–36].

Based on the foregoing, it is advisable to present the strategic goals of the formation of a medical hub (Figure 6).

Since the tasks of the project management system should primarily include increasing the share of successful projects and implementing only those projects that comply with the strategy, the assessment of the success of the project management system of the medical hub is of particular relevance.

4.4. Efficiency Assessment of the Medical Hub Business Model

In this situation, effective project management becomes one of the key components of successful business within the medical hub. As a research hypothesis, it is proposed that there is a statistical relationship between project indicators (budget, deadlines, quality) and network metrics (Dimension, Density, Diameter, Average degree, Centrality by mediation, Centrality by degree, Centrality by proximity, Clustering coefficient, Maximum clique, K-core) evaluating intra-project communications between project executors.

Intra-project communications are mechanisms for managing information flows within an organization within a specific project, used by managers to create a basis for effective working relationships between employees. Intra-project communications are divided into formal and informal [37–40]. It is assumed that deviations from the project indicators will be caused by inefficient communications and accompanied by changes in the communication network, which can be fixed by SNA methods.

To build a social network, we will use only formal intra-project communications. Data collection of formal intra-project communications can be obtained through the use of automated project management information systems from the task tracker. To do this, a time interval is selected and information is collected on the intensity of interactions. A model of this kind of interaction within a team is a graph (network), where the number of vertices (nodes) corresponds to the number of project participants, and the edges are identified communications taking into account a given intensity. The model of the network of intra-project communications is presented in the form of an ordinary graph. Figure 7 shows 20 selected projects in the form of graphs G1–G20.

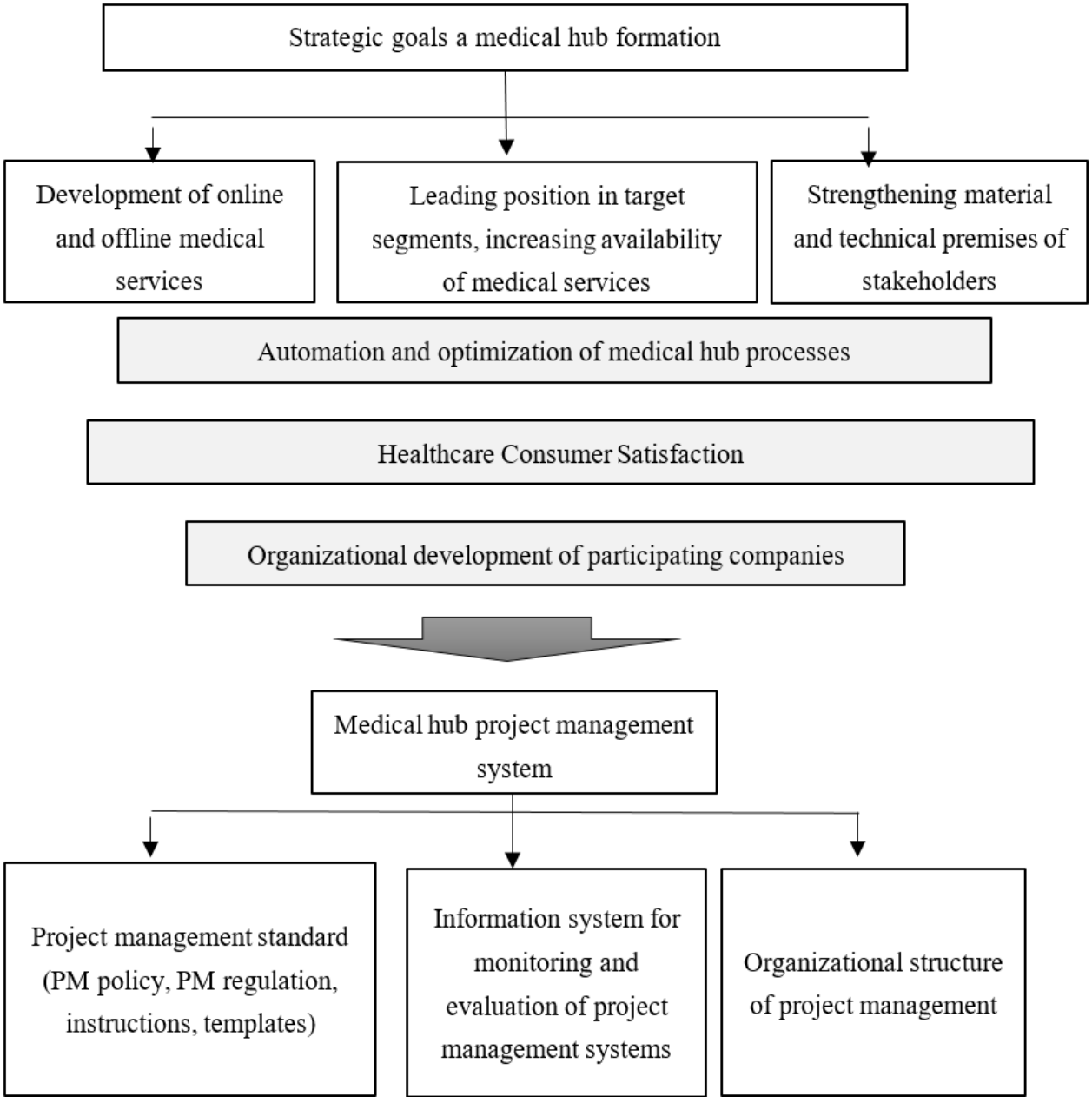
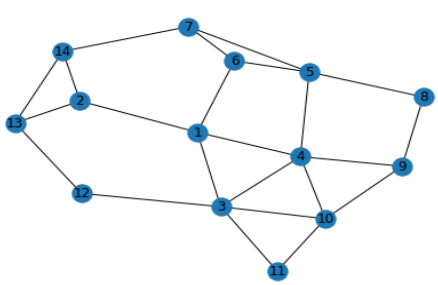
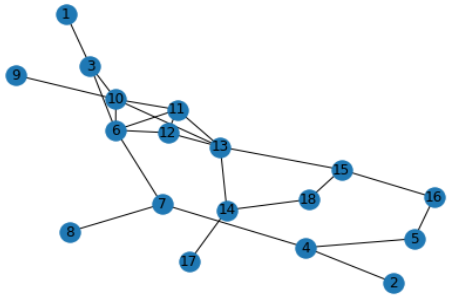


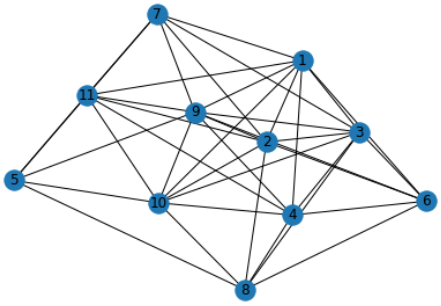
Figure 6. Medical hub project management system.



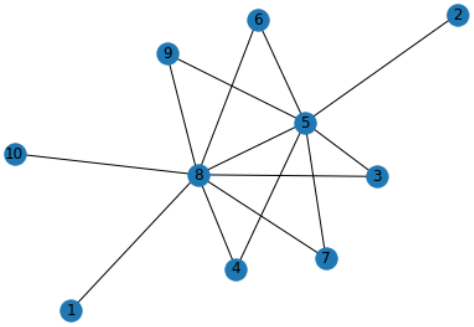
(**a**) G1



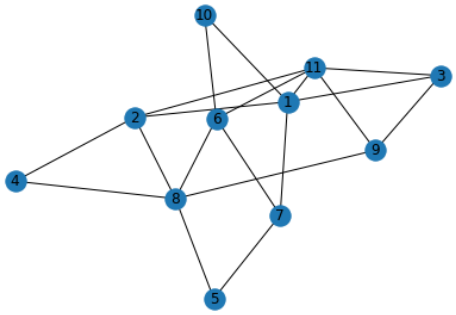
(**b**) G2



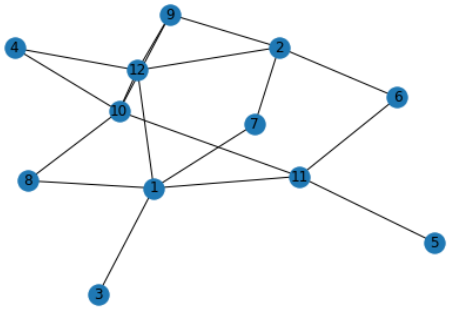
(**c**) G3



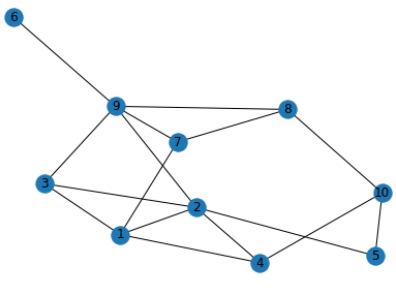
(**d**) G4



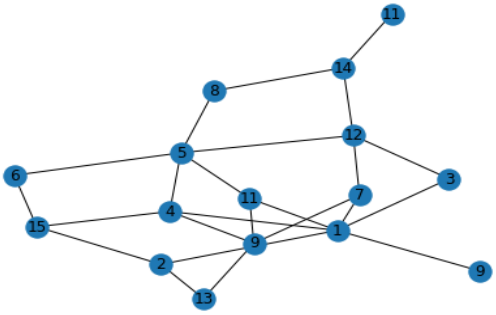
(**e**) G5



(**f**) G6

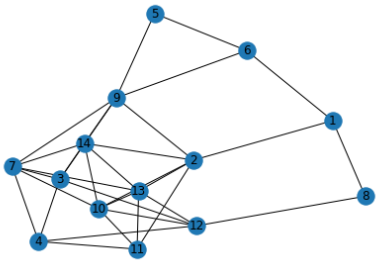


(**g**) G7

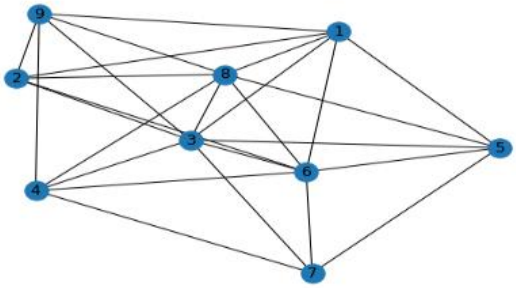


(**h**) G8

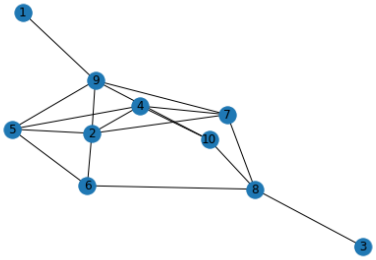
Figure 7. *Cont.*



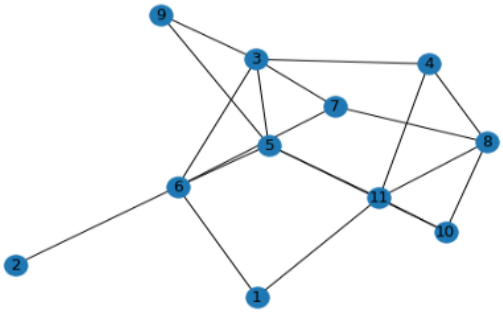
(**i**) G9



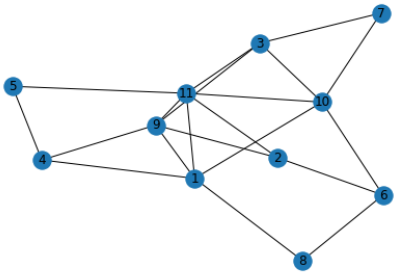
(**j**) G10



(**k**) G11



(**l**) G12



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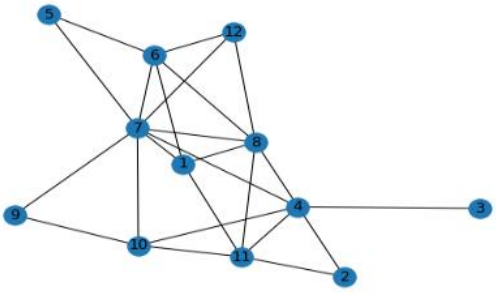
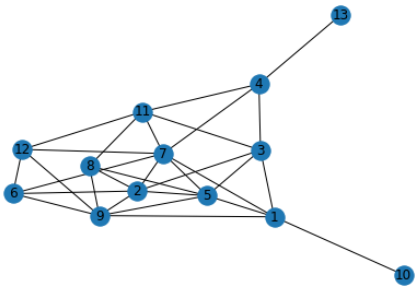
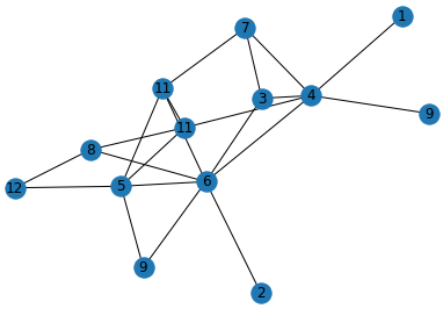


(**n**) G14

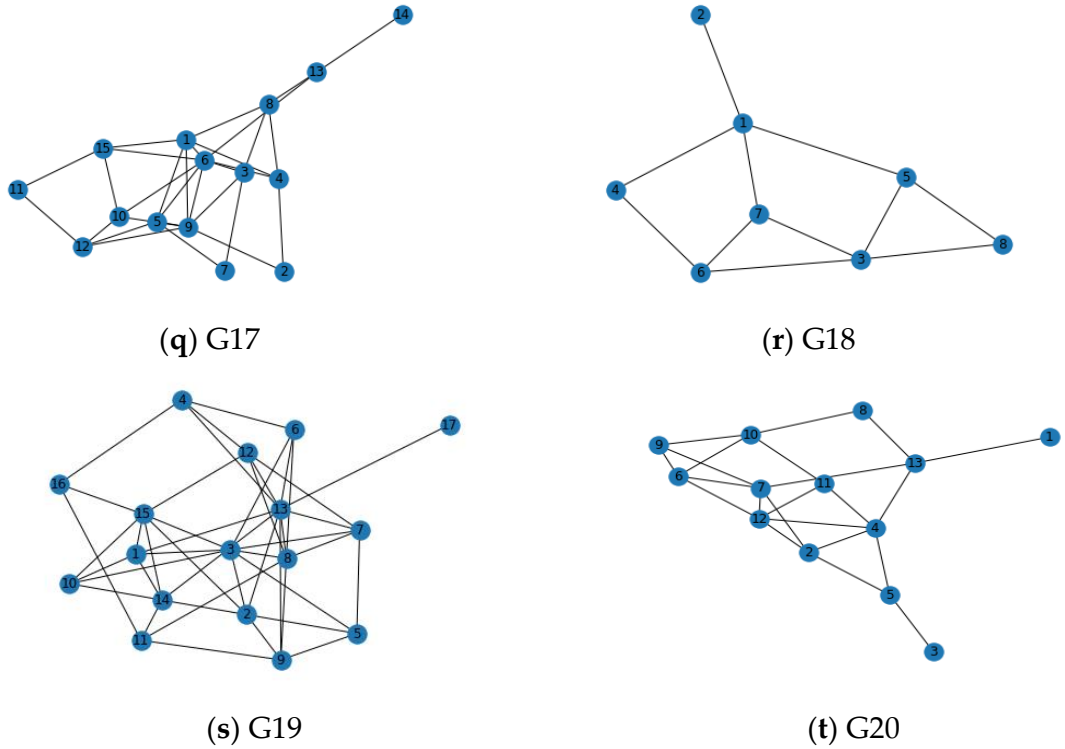


(**o**) G15



(**p**) G16

Figure 7. *Cont.*



(**q**) G17 (**r**) G18

(**s**) G19 (**t**) G20

Figure 7. Model of communication interactions between the participants of the medical hub within the framework of the selected project, presented in the form of graphs G1–G20 (**a**–**t**).

The study sample included 20 projects with a number of participants from 10 to 30 people, similar in content, timing, budget and labor intensity. Data on formal communication between project executors were recorded from the database of the corporate project management system and represented an informational message. Informal communications between the project executors were not used. When collecting data, information about the receiving and sending parties, as well as the time and number of messages, was recorded. Not only were messages used, but also accepted, completed, assigned and reassigned tasks.

The data model is represented by a graph or a social network in which the project participants corresponded to the nodes, and communication between the nodes was established when messages were recorded between the participants during a given period of time. In other words, if at least one message per day was recorded between two employees during the entire project, then an edge (connection) was carried out in the data model between the corresponding nodes of the social network.

To assess the success of the projects, information was taken about deviations from the budget and the planned deadlines of the project. To assess the quality of the project, two quantitative indicators were used: customer satisfaction and the level of communication. Customer satisfaction is determined based on the methodology developed in the company at the completion of any project and is determined on a scale from 1 (lowest satisfaction) to 10 (highest satisfaction). The level of communication is determined upon completion of the project in the form of testing of project participants and is evaluated on a scale from 1 (lowest) to 10 (highest).

Based on the analysis of the presented innovative projects, it can be concluded that there are really different communication structures in the projects.

To assess the impact of intra-project communications on the effectiveness of the project, it is proposed to use network metrics such as:

- Dimension;
- Density;
- Diameter;

- Average degree;
- Centrality measures (centrality by mediation, centrality by degree and centrality by proximity);
- Clustering coefficient;
- Maximum click;
- K-core.

Size is the main characteristic of a network that determines the number of participants, usually called nodes or vertices. The density of the graph G (V, E) is calculated as the normalized number of edges.

$$den(G) = \frac{2|E|}{|V|(|V|-1)} \quad (1)$$

where $|E|$ is the number of existing edges and $|V|$ is the number of vertices of the graph *G*. Density is a measure of involvement of all members of the project team in the overall system of intra-project communications.

The diameter of the network *G* is the maximum distance between two nodes in the network:

$$d(G) = \max\rho(v, w)$$

The diameter of the network determines the minimum path along which a message passes between the two most distant nodes of the network from each other. The degree of a vertex is the number of edges attached to the vertex. The average degree of vertices is the average value of the degrees of vertices of the graph *G*.

$$\overline{deg}(G) = \frac{\sum_{v \in V} \deg(v)}{|V|}$$

The average degree of vertices determines the average number of connections of network participants. Centrality measures allow us to assess the importance of network participants. The degree centrality is the simplest measure of centrality to calculate, based on the degree of the node, which allows for the determination of the most significant network participants. To calculate the centrality by degree, the following formula is used:

$$C_d = \frac{1}{(|V|-1)(|V|-2)} \sum_{i=1}^{n} (deg_{max} - deg_i)$$

where C_d is the centralization of the network by degree, deg_{max} is the maximum degree of the network, deg_i is the degree of participant *I* and $|V|$ is the number of network participants. A large $C_D(i)$ value indicates a large number of links belonging to node *i*.

Closeness centrality is a way of detecting agents that are able to distribute information very efficiently over the network. Proximity is an indicator of how close (and correspondingly more significant) a given participant is to all others and how easy it is, using direct or indirect connections, to establish communication with him or her. The formal representation of centrality by proximity is:

$$C_c = \frac{(2|V|-3)}{(|V|-1)(|V|-2)} \sum_{i=1}^{n} (C_{max} - C_i)$$

where C_{max} is the maximum proximity of the network participant, C_i is the proximity of the participant *I* and $|V|$ is the number of network participants. The centrality of the proximity of a node measures its average distance (inverse distance) from all other nodes. Nodes with a high proximity score have the shortest distances to all other nodes.

The coefficient of centrality is a coefficient that tells you how many times a node is an intermediary between all the shortest paths of all the other nodes. Nodes with a high coefficient of centrality by mediation are important structural elements that potentially

connect its substructures; they are connecting links. To calculate this metric, the following formula is used:

$$C_b = \frac{2}{(|V|-1)^2(|V|-2)} \sum_{i=1}^{n} (B_{max} - B_i)$$

where C_b is the centralization of the network by the median, B_{max} is the maximum indicator of the median in the network, B_i is the median of the participant i, and $|V|$ is the number of network participants.

The clustering coefficient of vertex i in graph $G\ (V, E)$, denoted by C_i, shows to which part of its neighbors vertex i is connected. Formally, the clustering coefficient has the following form:

$$C_i = \frac{2e_i}{k_i(k_i-1)}$$

where e_i denotes the number of edges between the neighbors of vertex i, and k_i is the number of neighbors of vertex i.

When the clustering coefficient is high, it means that the network is extremely densely grouped around several nodes; however, when it is low, it means that the connections in the network are relatively evenly distributed among all nodes. The average clustering coefficient of the graph $G(V, E)$, denoted by $\overline{C}$, is defined as the average value of the clustering coefficients of all vertices $v \in V$. Formally, the average clustering coefficient is determined by the following expression:

$$\overline{C} = \frac{1}{|V|} \sum_{i=1}^{|V|} |V| C_i$$

The clustering coefficient shows the tendency of participants in intra-project communications to form closer subgroups, i.e., clusters. One of the ways to study the subgroups of the intra-project communication network is to study social cohesion. Cohesive subgroups are sets of network participants connected to each other through numerous strong and direct connections. The simplest method of analyzing cohesive subgroups is the identification of clicks. In terms of graph theory, it is a maximal complete subgraph that includes at least three vertices. Partly because of the rarity of clicks, alternative definitions of social cohesion have been proposed. The most popular of them is the k-kernel, a maximal subgraph in which each vertex is connected to at least k other vertices of the same subgraph.

Network metrics are a complex characteristic of the network as a whole, and not its individual elements, so they can be used as characteristics of communication structures that have formed in project teams. The density and the average degree show how fully all project team members are involved in communication. Various metrics of network centralization show the degree of importance of participants in intra-project communications. The evaluation of the cohesion of project participants involves metrics evaluating clicks and k-cores of communication structures. Table 1 shows the calculated network metrics of internal communications for selected projects of the company.

The success of innovative projects of the medical hub was analyzed on the basis of data on deviations from the budget and planned deadlines, as well as on the basis of the customer satisfaction index used in the company and the level of communications. The deviation of the actual budget from the planned one, as a percentage of the planned one, was determined as an indicator of budget compliance. The budget was considered as the internal budget of the project, i.e., the sum of all the costs of the company for the implementation of the project for the customer, including the costs of purchasing equipment and services from third parties. A negative value means saving the project budget, a positive value means overspending. As an indicator of compliance with the planned timing of the project, the deviation of the actual completion dates of the project from the previously planned ones, as a percentage of the planned deadlines, was used. The planned timing was understood as the internal planned deadlines for the implementation of the project by the company, which are always less than the deadlines specified in the

contract. The customer satisfaction index was left unchanged, as it was calculated according to the corporate methodology. In addition to the project success indicators, the survey also obtained group assessments of the quality of communications within each project.

Table 1. Network metrics of intra-project communications of selected projects.

	Number of Vertices	Average Degree	Density	Centrality by Degree	Centrality by Proximity	Centrality by Mediation	Max. Click	Diameter	Clustering of Networks	K-Cores
G1	14	3.285714	0.252747	0.153846	0.236272	0.149244	3	4	0.316667	2
G2	18	2.666687	0.156863	0.154412	0.236166	0.265552	3	7	0.137037	3
G3	11	7.090909	0.709091	0.233333	0.297580	0.033937	5	2	0.695455	5
G4	10	2.800000	0.311111	0.722222	0.707302	0.515432	3	3	0.541657	2
G5	11	3.454545	0.345455	0.188889	0.235913	0.160926	3	3	0.266667	2
G6	12	2.833333	0.257578	0.236364	0.334830	0.274380	3	4	0.211111	2
G7	10	3.200000	0.355558	0.250000	0.281675	0.249486	3	3	0.250000	2
G8	16	3.333333	0.238085	0.919780	0.236433	0.161041	3	4	0.164444	2
G9	14	4.000000	0.307692	0.179407	0.246911	0.123356	3	4	0.264266	3
G10	9	5.777778	0.722222	0.357143	0.494589	0.080580	5	2	0.761905	4
G11	10	3.400000	0.377778	0.666666	0.182893	0.189300	3	4	0.220000	3
G12	10	3.090909	0.309091	0.233333	0.238305	0.179830	3	4	0.324242	2
G13	11	3.636361	0.363636	0.288889	0.325007	0.134630	3	3	0.318182	3
G14	12	3.83333	0.348485	0.345455	0.390876	0.231405	4	3	0.600000	3
G15	13	4.153846	0.346154	0.181818	0.191651	0.102553	4	4	0.330769	3
G16	13	3.500000	0.318182	0.381818	0.422747	0.273719	3	4	0.298810	3
G17	8	4.133333	0.295238	0.318601	0.407802	0.242487	4	4	0.243651	3
G18	15	2.750000	0.395827	0.238095	0.288357	0.319728	3	3	0.291667	2
G19	17	4.588235	0.286765	0.241667	0.196923	0.149053	4	4	0.327731	3
G20	13	3.384615	0.282051	0.159091	0.242684	0.173632	3	4	0.269231	3

The customer satisfaction index was left unchanged, as it was calculated according to the corporate methodology. Customer satisfaction was measured at the completion of any project and is measured on a scale from 1 (lowest satisfaction) to 10 (highest satisfaction). In addition to project success indicators, the survey also provided group assessments of the quality of communications within each project. The level of communication is determined at the end of the project in the form of testing of project participants and is assessed on a scale from 1 (lowest) to 10 (highest). Indicators of success and quality of communications for each of the company's studied projects are presented in Figure 8.

To analyze this connection between project success indicators and intra-project communications, linear paired correlation-regression models were used (Table 2).

Table 2. Results of correlation and regression analysis between project indicators and intra-project communications of medical hub participants.

	Number of Vertices	Average Degree	Density	Centrality by Degree	Centrality by Proximity	Centrality by Mediation	Max. Click	Diameter	Network Clustering	K-Cores
Budget	0.29	−0.25	−0.28	0.26	0.25	0.17	−0.26	−0.019	0.0078	−0.37
Deadlines	−0.23	0.57	0.54	−0.43	−0.3	–0.7	0.45	−0.28	0.34	0.42
Customer satisfaction	0.39	−0.53	−0.51	−0.12	−0.11	0.36	−0.38	0.48	−0.44	−0.27
Communication level	−0.074	0.14	0.026	−0.17	−0.062	–0.011	0.16	0.11	−0.067	0.19

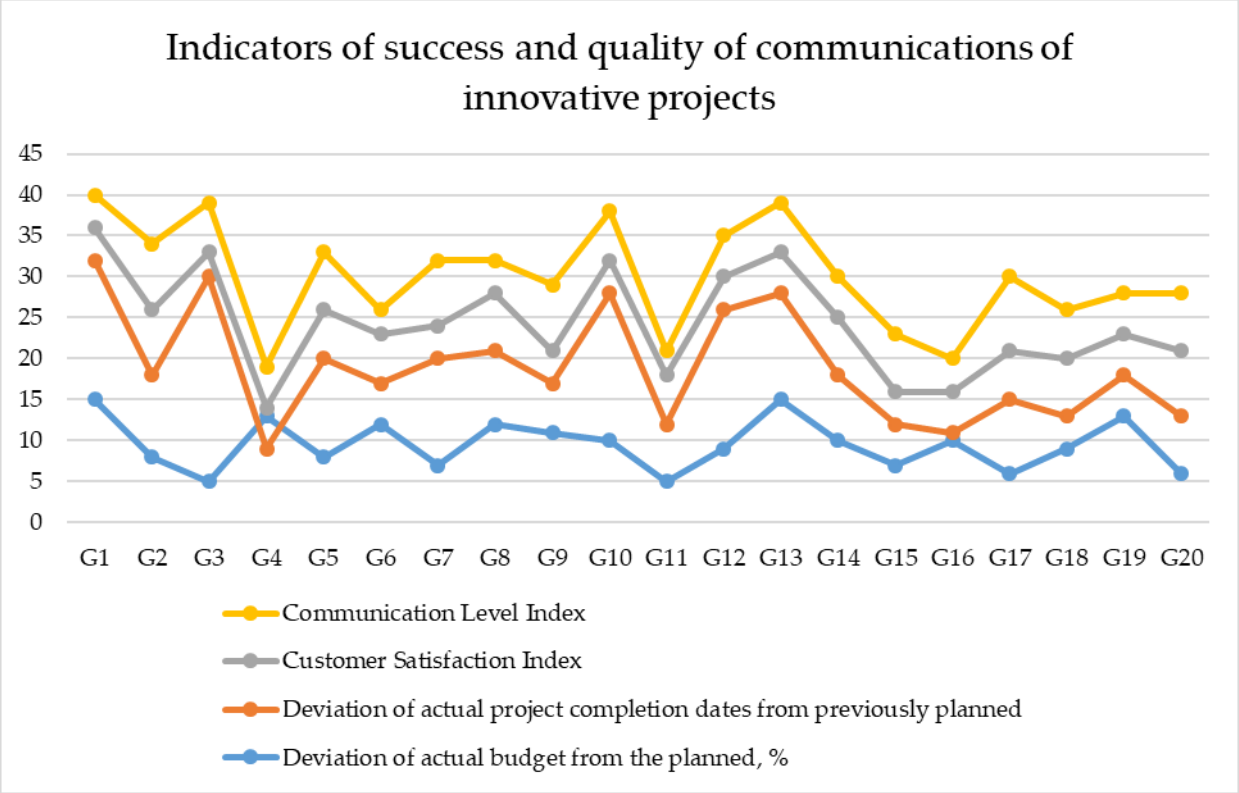


Figure 8. Indicators of success and quality of communications of innovative projects.

Taking into account the ratio of Chaddock [41], we can say that there is a noticeable connection between the centralization of mediation and deviation from the deadlines of projects. Also, a moderate relationship was recorded between the average degree of nodes of the network structure and deviation from the project deadlines. The nature of the model suggests that the higher the centralization of mediation, the less violation of project deadlines occurs. Increasing centralization of intra-project communications is accompanied by a greater tendency to meet deadlines. A moderate relationship can be traced between the average degree of nodes and the timing of project execution. In this case, an increase in the average degree of intra-project communications is accompanied by an increase in the deadlines for the execution of projects.

In all other cases, it is extremely difficult to talk about the presence of statistically significant links between the structure of intra-project communications and the success of the project. In particular, there is no connection between the deviation from the budget and the indicators of the structure of intra-project communications. There are also no significant links between the quality of communications and quantitative indicators of the communication network.

Since the projects under consideration are characterized by a certain similarity in all indicators, it can be noted that the difference found in the structures of intra-project communications is largely due to the preferences of the team members themselves and their interconnections, both professional and socio- psychological. Among other aspects that matter, we can see the impact on the communication system on the part of the project managers, their degree of cooperation and their style of organizing work on the project. Some characteristics of intra-project communication structures turn out to be closely related to the success of innovative projects. This confirms the position present in the theory of innovation project management that communications are directly and/or indirectly related to the results and efficiency of projects. At the same time, the conducted study confirms this position on the basis of empirical material. In particular, there is a connection between the degree of centralization and such indicators of project success as deviation from deadlines.

It is difficult to say with complete certainty that it is a higher level of centralization that is the reason for better performance in terms of timing. It is quite possible that the identified relationship is due to the influence of some other factors that remained outside the scope of the study. However, some assumptions can be made.

The relatively high centralization of mediation of intra-project communications indicates that, within the framework of projects, there is a small number of participants through whom the main flow of information passes. It becomes easier for these members of project teams to access important information within highly centralized communication networks. They can make decisions faster, and distribute information among other members of project teams. What is more, the presence of participants with a high centrality facilitates the external communications of the project. It is often easier to interact with the project team through one or two members who act as the main points of access or contact centers.

An interesting connection was found between the indicators of density and the average degree of communication networks, and the deviation from the timing. The increase in density and increase in the average degree reflect the amount of communication links within the project team. It turns out that increasing communication links does not always have a positive effect on the success of the project, although it is generally accepted that an increase in the number of communications indirectly reflects the degree of cooperation and interaction between project participants and should be accompanied by an increase in the effectiveness of communications and the effectiveness of the project as a whole. It is difficult to assume that the reduction in the number of communication links is accompanied by a higher success of the project; in that case, the most effective communication structure would be a network in which all participants were isolated from each other and there were no connections between them. Apparently between the number of communications and the success of the project there is a more complex relationship than a linear one. It can be assumed that, up to a certain limit, an increase in the number of significant communications leads to an increase in the effectiveness of communications. But a further increase in communications can lead to a complication of the communication network and a decrease in efficiency. More research is needed to analyze the relationship between the number of communication links and project success in a more informed manner.

The absence of any connection between the indicators of the structures of intra-project communications and the indicator of budget execution can be explained in the organization under consideration by the fact that project team members do not take an active part in either the formation of the budget or its control. This is done by specialists from the financial departments. Moreover, a significant share of the budget of the projects under consideration is associated with the purchase of equipment and services from third parties. In organizing these procurements, project teams do not play an important role, and, accordingly, they cannot influence the implementation of the budget for these items of expenditure.

No links were found between the quality of communications and the characteristics of the structures of intra-project communications. This may be due to the fact that the quality of communications is a rather complex phenomenon, which is associated not so much with the formal characteristics of the structure of communications as with the content characteristics of communications. It is possible that the quality of communications is also affected by a large number of other factors that are not directly detected using formal methods of studying communication networks. Such factors include socio-psychological relations between project team members, with communications external to the project with representatives of the customer and departments of the company, and with the progress of the project (the perception of the potential success of the project may arise long before the completion of the project and influence on the quality of communications). To analyze the links between the quality and indicators of the communication network, additional research is required, with specific focus on the content and socio-psychological aspects of communication, rather than the formal ones.

5. Conclusions

As a result of the present study, a mechanism for efficiency assessment for the implementation of innovative projects of a medical hub was developed. The SNA methods were used, taking into account intercommunication interactions between participants of the medical hub. To implement this idea, the relationship between project performance indicators and indicators of intra-project communications was revealed.

As a result of the conducted study, a number of conclusions can be suggested. Despite the similarity of data used as a sample for the projects being carried out, the structure of communications in them differs significantly. The structure of some projects differs significantly in all network characteristics. Major differences are revealed in the density of links of the project structure. If we consider the characteristics of the structure from the point of view of centralization of communications, then some projects are classified by a fairly uniform distribution of communication links, without participants with a pronounced central position, whereas, in other projects, there are fairly obvious communication centers, which corresponds to the presence of project team members who play a more important role in managing project communications.

The theoretical significance of the study has repeatedly been discussed and confirmed by the expert opinion of the academic and medical community [42,43], namely research and commercial organizations [44–46], and has also received the support of public authorities in the field of health care. It should be noted that confirmation of the validity of practical results requires the collection of a large amount of data, the receipt of which is associated, among other things, with the following challenges, such as the lack of a legislative framework, medical and commercial secrets, the lack of regulation of data exchange in the ecosystem and the lack of a single digital platform. Work on these issues is the subject of further developments in this area.

The following practical recommendations can be made for managers of innovative projects implemented within the framework of medical hubs:

- Pay increased attention to optimizing the business model of the medical hub in the field of configuration;
- Update in a timely manner the interface for interaction with suppliers and partners and/or the interface for interaction with external clients, depending on the chosen strategy for the development of the medical hub;
- The quality of medical care can be solved primarily by introducing modern management systems into medical institutions, in particular, a quality management system based on international standards;
- It is necessary to develop management rules and procedures that ensure optimal management of each of the types of projects of the company participating in the medical hub, as well as to obtain a trained project management team with a separate analytical service;
- Each project participant needs to know all the steps to complete the tasks of each sprint, so participants need access to the standard operating procedures of the companies participating in the medical hub so that they can do their job efficiently and reliably.

It is necessary to qualitatively determine the value of the business, which is necessary to meet the needs of customers and achieve the goals of the company. It should be noted that the implementation of project management systems and the use of the proposed method of their evaluation will provide the following advantages:

- Avoiding losses from the provision of services of inadequate quality, the share of which in the health care system is, according to a number of experts, 30–60%;
- Application of the process approach at the initial stage of the implementation of the project management system will allow you to look at the medical organization from the outside and clearly define the responsibility, authority, resources, information and management communications. This approach does not reject the existing management

system, but determines ways to improve it and gradually transition to a process management system;
- Thanks to the many built-in self-improvement mechanisms (internal audits, management analysis, feedback from consumers, etc.), the implementation of a project management system will ensure timely changes in the system in response to changes in the external and internal environment, as well as continuous improvement in the activities of a medical organization;
- The involvement of personnel in project management activities enables the medical organization to more effectively use the abilities, knowledge, skills and abilities of its employees;
- When building a project management system within the framework of a medical hub, the costs of a medical organization are reduced, mainly due to streamlining activities, eliminating unnecessary or inefficient processes and external and internal losses caused by defects and inconsistencies;
- An effective project management system within the medical hub also reduces management costs.

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