

# Methodological approaches to optimizing innovation networks in housing and communal services within digital transformation

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**Abstract.** The digitalization and networkization of the economy leads to the need to apply a subject-oriented approach to the development and implementation of innovations, including in the field of housing and communal services. The paper shows the possibility of accelerating the introduction of innovative digital technologies in the housing sector through effective management of the subjective structure of innovation. The main areas of innovative activity in the housing and communal services within the framework of digitalization are identified. A methodological toolkit for effective management of innovative activities in housing and communal services based on a subject-oriented approach is proposed.

## 1 Introduction

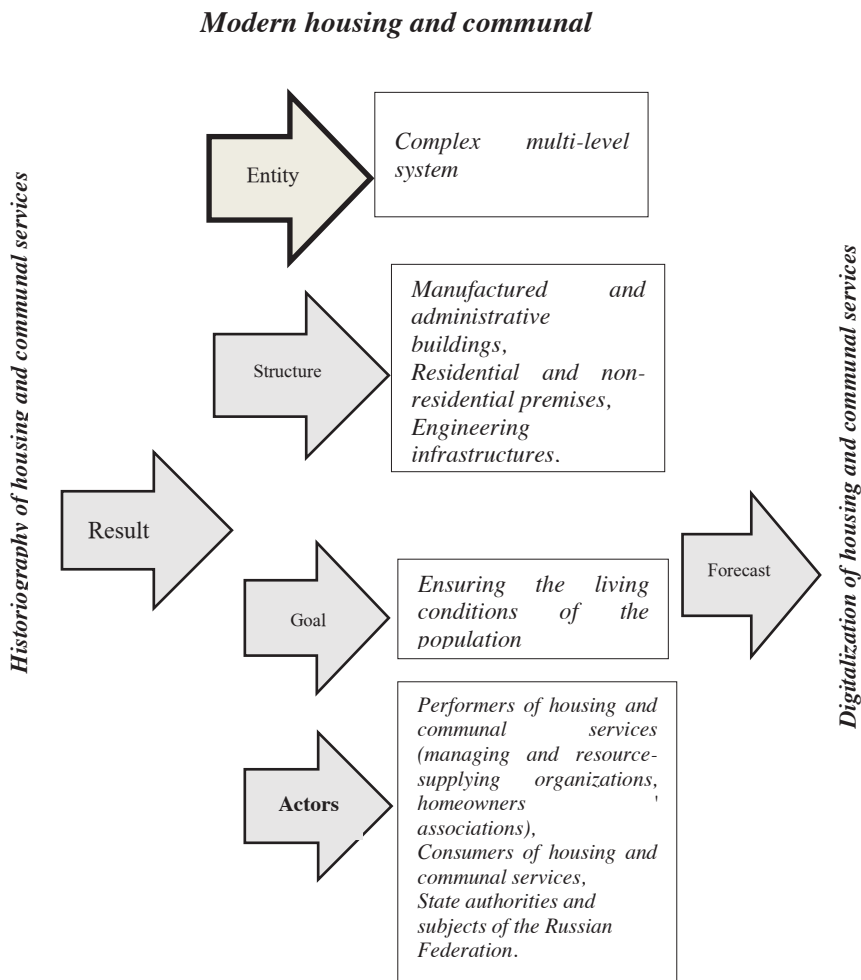
The transition to an innovative way of development reflects the essence of modern transformation processes taking place in the national economy. An important role in the formation and development of the innovation system is played by the involvement of participants in the innovation process in the form of heterarchical network associations, since it is networking that is the most common feature of the digital innovative economy [1].

The formation of network interactions in the innovation process is of particular importance when implementing innovations as part of the digital transformation of the economy and its individual industries. Despite the orientation of the domestic economy to innovative development, most of the activities are related to low- and medium-tech industries (LMT-industries), in which insufficient attention is paid to innovation. However, innovation in LMT industries has a significant impact on economic growth due to the total weight of these industries in the economy. For LMT industries, so-called diffuse innovations are usually typical - improving and borrowing innovations. An important aspect of innovations in these industries is the fact that they are more complex than simply borrowing new technologies, and also require a certain level of competence [2]. In many cases, innovative activities in LMT industries include the use of high-tech products and technologies [3]. The authors understand digital technologies as high-tech technologies. When justifying the need for networking, the specifics of industry participants and

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stakeholders should also be taken into account. The housing and communal sector considered in the paper, based on its complex historiography and the specifics of the regulatory and legal framework, has a rather complex structure and subject composition (Fig. 1).



**Fig. 1.** Author's interpretation of the concept of housing and communal services

According to the State Information System of Housing and Communal Services (SIS HCS), in the Russian Federation, there are more than 19 million residential buildings, more than 1.3 million apartment buildings, and more than 108 thousand organizations that operate in the field of HCS [4], including:

- organizations that manage apartment buildings;
- management companies;
- associations of real estate owners;
- housing cooperative and other cooperative;
- resource supplying organization;
- government body of the constituent entity of the Russian Federation;
- local government body;

- regional operator of capital repairs;
- regional operator for solid municipal waste management.

Digitization of housing and communal services will provide consumers with transparency and correct charging of payments for utilities used. This can be achieved by increasing the accuracy of metering consumption based on IoT technologies, integrating information systems of different levels, increasing the efficiency of horizontal and vertical communications between market participants through an open architecture and API.

Highlighting the use of information systems, Internet of Things technology, cloud data management platforms, information technologies and digital platforms as the main areas of digitalization of housing and communal services, researchers note a number of bottlenecks, including low density of the institutional environment, lack of a unified information environment, and multidirectional interests of stakeholders [5,6]. Accordingly, the formation of an effective innovation network in the implementation of innovations as part of the digital transformation of housing and communal services, the optimization of subject interactions, and the reduction of transaction costs and risks are an important scientific and practical task.

## **2 Materials and Methods**

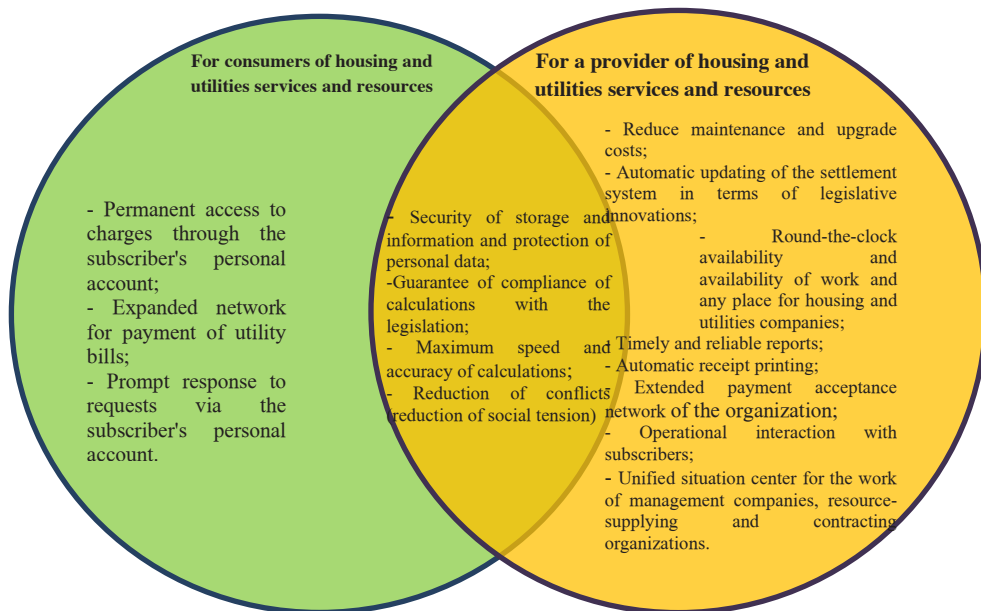
Let us consider in more detail the innovative portfolio of the housing and communal services industry in the projection of the applied digital technologies [7-9].

Firstly, a billing system based on a SaaS platform (Software as a Service).

SaaS technology in the field of housing and communal services is a system of interaction in which companies serving consumers and making payments for housing and communal services get access to software through a web interface for a monthly fee. That is, SaaS is a software outsourcing option. This means that HCS companies may not install software on their computers, but will simply access it via the Internet. SaaS-based solutions have become an innovation in the housing and communal sector, since they provided much more freedom of activity, help to avoid problems with software for payments for HSC and at a much lower cost, since the costs for using a billing system on a SaaS platform are transparent and easily predictable.

Figure 2 shows the main benefits of using a billing system on a SaaS platform.

### BENEFITS OF USING THE SAAS PLATFORM BILLING SYSTEM



**Fig. 2.** Benefits of using a billing system on a SaaS platform for consumers and providers of utilities and resources

Secondly, information systems, the main of which are the State Information System for Housing and Communal Services (SIS HCS) and the Federal Information Fund for Ensuring the Uniformity of Measurements of Federal Technical Regulation and Metrology Agency (Rosstandart) (FSIS ARSHIN).

Nowadays, the formation of a single information space for housing and communal services as an environment for a housing management system is carried out using SIS HCS working in conjunction with information systems of several types, including information systems that use cloud technologies and devices of the Internet of Things to manage housing and communal services.

The main advantage of SIS HCS for consumers and providers of utilities and resources is the general openness and accessibility of a single information space for housing and communal services, as well as the transparency, completeness and reliability of all posted information.

Thirdly, these are smart meters. Unlike conventional metering devices, smart meters carry out automatic remote transmission of current readings of individual metering devices, as well as the mode of consumption of electricity, water, gas and heat to the supplier. In the event of an accident or unauthorized intervention, smart meters send a signal to the network.

Digitization of housing and communal services is a huge prospect for the development of this industry and obtaining benefits for all its participants. Participants in the innovation network of digitalization of housing and communal services are characterized by differences in the intensity of interaction, the degree of independence within the framework of individual stages of the process, as well as belonging to the internal or external environment of the industry. This fact made it possible to identify the main types of

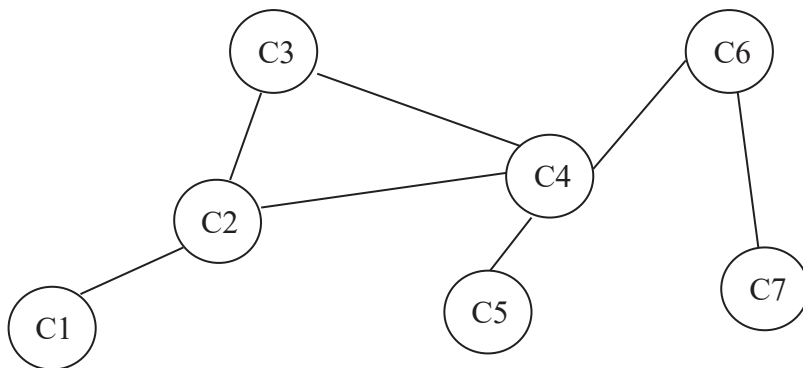
intersubjective interaction, their main advantages and disadvantages, as well as to identify the specific risks of interaction.

### 3 Results

Since innovation resources are distributed asymmetrically between the subjects of the HCS industry, they have to carry out joint activities to implement an innovative project, achieving such a subject composition and building the structure of relations in such a way that, on the one hand, to fully meet the requirements of the project for its successful implementation, and on the other hand - to meet the requirements of the subjects to achieve a sufficient level of profitability from their participation in the innovation network.

The structures for managing innovative activities in the housing and communal services industry form the interaction of management subjects with the help of complex inter-subject connections. Based on the well-grounded multi-subject nature and non-linear nature of the innovation process, we consider it expedient to represent the subject structure in the form of an innovation network represented in the form of a graph. The description of subject interactions in the structure of innovation management in the form of a graph realizes the possibility of analytical assessment of the effectiveness of the implementation of interactions, i.e. the efficiency of the functioning of the management structure of a multi-subject innovation process.

An innovation network is a polycentric set of independent subjects of innovation, united by communication links and resource flows, providing, through the exchange of resources, technology transfer and/or diffusion of innovations, contributing to the emergence of a network effect as a consequence of the economic effect of increasing returns [1]. Graphically, the innovation network in the housing and communal services industry can be represented in the form of a following non-directed graph (Fig. 3)



**Fig. 3.** Representation of an innovation network as a non-directed graph

The vertices (nodes) represent the subjects of the innovation process, and the edges (arcs) - the connection in the process of interaction between the subjects during the implementation of the innovation project (process stage). In this case, the resulting non-directed graph reflects the number of the main subjects of the innovation process (internal or external ones) and their interactions - connections (direct or indirect ones; decentralized - heterarchical or centralized, hierarchical).

From the standpoint of the proposed approach, based on traditional indicators for assessing graphs [1], a system for assessing the subject composition of innovative activity by methods of graph theory and their interpretation for the purposes of this study is formed:

1. The degree of connectivity. The graph connectivity assessment is based on the condition:

$$\frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n a_{ij} \geq n - 1 \tag{1}$$

where  $a_{ij}$  – elements of the adjacency matrix of the graph (characterizing the presence or absence of communication between the vertices);  $n$  – number of vertices in the graph.

From the standpoint of the approach proposed in this work, connectivity characterizes the structural relationships of the subjects of the innovation process (their presence or absence), and also reflects the presence of a single innovation center.

2. Structural redundancy of the graph is determined by the formula:

$$R = \frac{m}{n-1} - 1 \tag{2}$$

where  $m$  - set of graph communications:

$$m = \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n a_{ij} \tag{3}$$

By the value of this indicator, one can judge the level of efficiency and reliability of the structure of the subjects of an innovative project: the higher the redundancy, the higher the reliability (due to the possible transfer of functions), but less efficiency. On the basis of redundancy, one can also draw conclusions about the existence of duplication of the functions of the subjects.

3. Graph diameter.

$$d = \max(d_{ij}), i \neq j \tag{4}$$

where  $d_{ij}$  - distance from element  $i$  to element  $j$ .

Characterizes the independence of the subjects of the innovation process. Consequently, the larger the diameter of the graph, the more independent and detached the participating subjects.

4. Centrality (coefficient of centralization). Determined by formulas:

$$\delta = \frac{(n-1)(2Z_{max}-n)}{(n-2)Z_{max}} \tag{5}$$

$$Z_i = \frac{Q}{2 \sum_{i=1}^n d_{ij}} \tag{6}$$

$$Q = \sum_{i=1}^n \sum_{j=1}^n d_{ij}, i \neq j \tag{7}$$

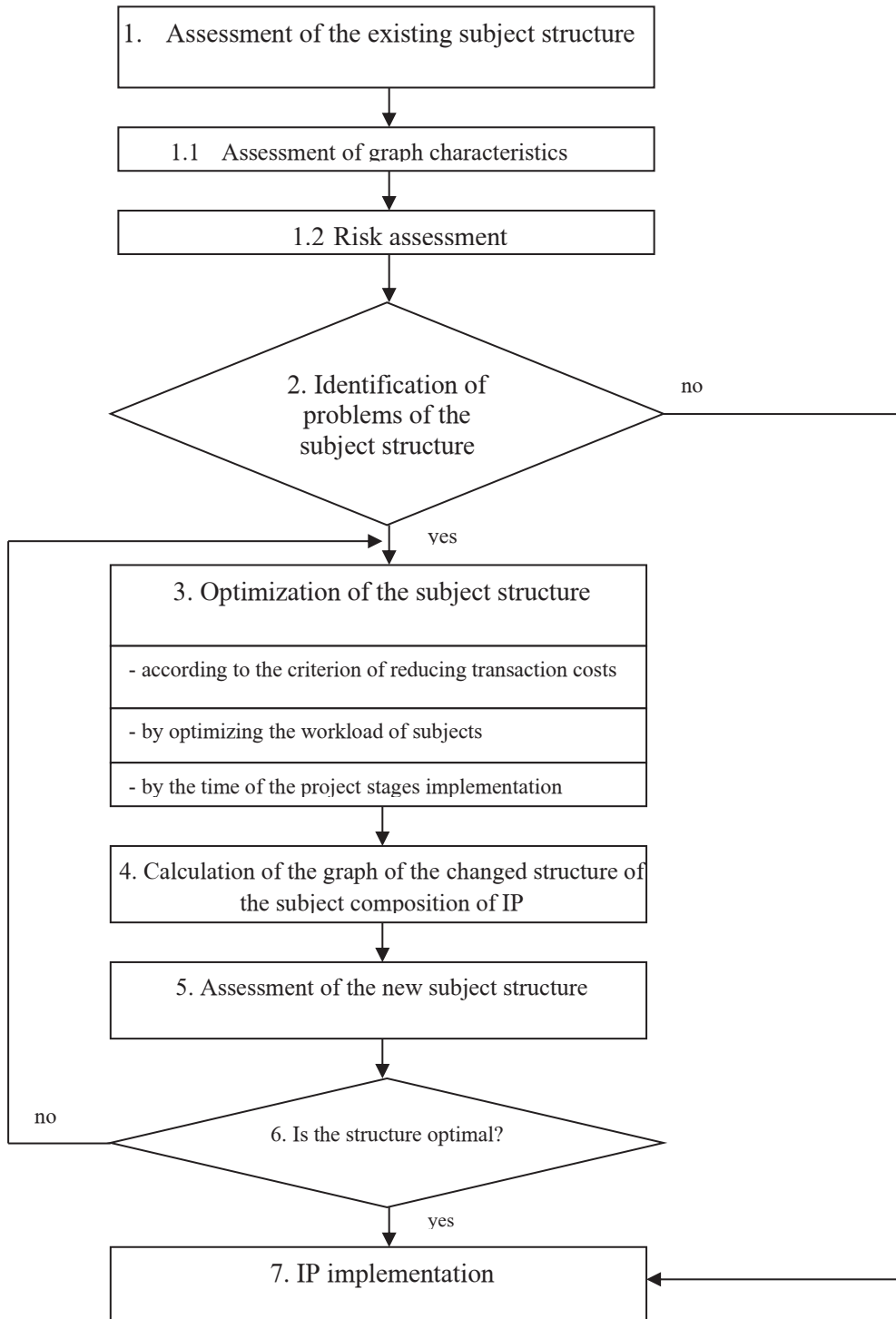
The higher the centralization coefficient, the more centralized the subject structure of the innovation process in the industry.

5. Graph density.

$$P = \frac{2 \times m}{n \times (n-1)} \tag{8}$$

In our case, an increase in the density of the structure indicates an increase in ties during decentralization (not a hierarchy, but a heterarchy of participants in an innovative project).

Based on the foregoing, we have proposed a methodology for structuring innovation in the HCS industry in the targeted focus of digital transformation.



**Fig. 4.** Block diagram of the algorithm for constructing the optimal subjective structure of innovation in the HCS industry in the context of digital transformation

## 4 Discussions

The above-mentioned features of the implementation of innovations in housing and communal services in the digital economy lead to the manifestation of a number of risks.

Consequently, it is required to highlight the specific risks of the innovation process in the industry with the involvement of subjects of the external environment, which can be characterized as interaction risks:

1. Default risks:
  - risks of opportunistic behavior - risks of default by an external entity as a result of pursuing its own goals;
  - risks of changing the state of an external entity - risks of default by an external entity as a result of unforeseen factors (risks of loss of solvency, eligibility, etc.)
2. Risks of conflicts of joint work - include both conflicts of internal systems of organizations, and inter-collective conflicts;
3. Information (communication) risk - possible non-receipt of information: incompleteness, delayed receipt, distortion, misinterpretation of information, the possibility of information leakage;
4. Risk of interference in the internal environment of the holding;
5. Risks of a pure transaction - the possibility of errors arising from the complexity of mechanisms for the intersubjective transfer of intellectual property (completed/uncompleted innovations), the possibility of errors in the implementation/execution of transactions, imperfection of valuation mechanisms, etc.

Since a complex system of relations in an innovation network requires an assessment of the risks of interaction for a specific subjective structure of the innovation process, it is advisable to assess the risks of interaction by the method of expert assessments using the probability and impact matrix.

## 5 Conclusion

The subject composition and the nature of the interaction of participants in the innovative activity of the HCS industry when introducing digital technologies, taking into account the above areas, should be determined taking into account various factors and conditions, among which the following are distinguished:

- conditions for the development and functioning of entities in the specific conditions of digitalization;
- innovative characteristics, the level of digitalization and the state of the industry;
- innovative potential of the participants, the presence or absence of a synergistic effect from interaction;
- stage of innovative development of subjects and their digital environment;
- content of the stages of the innovation process and the degree of their diversification, etc.

The choice of the optimal management structure allows not only reducing the costs of organizing and managing the innovative process of digital transformation of the industry, but also has a significant impact on the efficiency of innovation and the level of its digitalization in general.

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