

Innovation Technology Implementation in Facility Services in Russia

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Abstract: The main function of building envelope is to protect people who live in the building from climatic effects by providing a comfortable microclimate and lighting in the house. Most residential multi-apartment buildings in the Russian Federation were built before mid-1990s with low energy efficiency and, often, low quality. The situation is aggravated by the lack of timely repair, which adversely affects the performance of these buildings. The sphere of individual housing construction also lacks of quality control at all stages of the life cycle of a building. Builders ignore important features of the building design, or the construction works are carried out by unqualified workers, without sufficient quality control. This results in increased energy consumption during the operation of the building, compromised microclimate in the house, violation of environmental requirements, and, in the absence of timely repairs, loss of the bearing capacity of the structural elements of the building. Important areas of development in the field of housing construction are to energy efficiency, improvement of the system of operation and maintenance of buildings, transparency in the operational performance of buildings for owners and investors. To obtain such benefits, it is necessary to develop a strategy for implementation of intelligent technologies and smart engineering systems to improve energy efficiency, automate operational processes and create an 'intelligent' profile of a building. The article presents a study of energy efficiency of buildings and justifies smart management of real estate objects, in order to save resources and timely respond to the decline in their operational qualities. In the modern conditions of market economy, when most of the housing stock is privately owned, it is necessary to create a modern economic and organizational mechanism for overhauls, reconstruction and modernization of building with the use of BIM technologies. The result of the overhaul and reconstruction works is the restoration and improvement of the operational characteristics of buildings. An overhaul or a reconstruction is advisable if the technical condition of the building has been compromised and effective operation and maintenance are impossible. The proposed methodological and practical recommendations aim at implementing the organizational and economic mechanism for managing the quality of overhauls, reconstruction and modernization of real estate objects, meet the emerging need for developing practical measures to revitalize the activities in the housing market and to improve the quality life of the population. **Keywords:** facility services, innovation, infrastructure, quality, energy saving, energy efficiency, smart meter.

1. Introduction

Today operation and maintenance of residential buildings are impossible without innovative intelligent technology. Gault (2018) defined and measured innovation in all sectors of economy. Appio, Lima and Parutis (2019) wrote about technological forecasting and social changes in reference to Smart Cities. Arundel, Bloch and Ferguson (2019) and Marconi and

others (2016) highlighted such priorities as promoting innovation in the public sector and aligning the measurement of innovation with political objectives.

Rauter and others (2018) and Pavlatos and Kostakis (2018) reviewed open innovation and its impact on economic efficiency and innovation activity. According to Caragliu and Del Bo (2019) innovative Smart Cities directly influence the Smart City policies and urban innovations.

In Russia, a number of large cities positioning themselves as Smart, such as Moscow, St. Petersburg and Kazan, have developed a property management system at the local level, however, there is no uniform national standard for this process.

In order to improve the efficiency of residential real estate management in modern economy, it is necessary to categorize buildings according to legal criteria and functional purpose at the overhaul stage and also to be able to plan the operational performance of a building at the construction stage by creating a Building Information Model and using intelligent technologies in design, construction and operation. Recent work in this field focused on dynamic characteristics of smart grid technology acceptance (Park, Kim and Yong 2017) and introduction of the Internet of Things for development of smart buildings (Jia and others 2019).

The life cycle of a building has, tentatively speaking, three stages, namely, design, construction, and operation. There is also a fourth stage, that is reconstruction or demolition (including the change of functional purpose), closely interconnected with the operation.

At the first and second stages, the terms of reference are developed; the design and estimate documentation is drawn; BIM modeling is performed; investment analysis of the construction project is carried out if necessary; the investor, the general contractor and the other participants in the investment and construction processes are determined; and a physical object, having a certain functional purpose and a set of consumer qualities and properties, is created.

At the third stage, the good condition of all structural elements and systems of the building are maintained and the adjacent territory is improved or developed. Any building, regardless of the form of ownership and location, must be under constant maintenance to ensure normal functioning during the entire life cycle, which can reach one hundred and more years (Jiang 2012; Xie 2011; Romanova and others 2015). Bakhareva and others (2016) and Romanova (2013, 2015, 2016) promote the idea of intellectualization of buildings and the entire housebuilding industry based on information technology.

The operation stage includes 'consumption' of the building; that is, in other words, the use of its engineering systems, equipment, adjacent territory, etc., for specific purposes. The main task in this case is to ensure trouble-free operation of all structural elements of the building with strict observance of sanitary and hygienic standards, proper use of engineering equipment, maintenance of optimum temperature and humidity conditions, compliance with maintenance and repair plans, servicing and improvement of adjacent territories, etc.

Li and others (2018) showed the implementation of architecture, technologies and systems into a Smart Home. Gao and others (2017) addressed the theory and practice of intelligent collection of data on the operation of residential buildings by the example of modern technologies in smart district heating system.

Wetzel and Thabet (2015) addressed the use of a BIM-based framework to support safe facility management processes. Sepasgozar and others (2019) confirmed the relevance of implementing citizen-centric technology in developing smart cities and created a model for predicting the acceptance of urban technologies. As early as five years ago Fazli and others (2014) stated the effectiveness of building information management (BIM) in project management.

The duration of trouble-free operation of the building and its systems can differ. The standard service life of the foundation, the walls and the main bearing elements is regarded as the standard service life of the building. The service life of some individual elements can be 2–3 times less than the useful life of the building. It is necessary to replace its elements or their parts to continue using the building comfortably and safely for its intended purpose in the course of the entire service life. Also, the engineering systems and the structural elements require setup, restoration and failure prevention over the entire service life of the building. Operation of buildings to full wear is often impossible, therefore, works are needed to compensate for normal wear. If planned maintenance is not performed on time, premature failure of the structure can occur.

It should be noted that buildings and constructions are the main consumers of heat. Government regulation in the field of thermal performance of building is prioritized in most countries of the world. Such requirements root in rational use of non-renewable natural resources, environmental protection, reduction of greenhouse effect and minimization of emissions of carbon dioxide and other harmful substances into the atmosphere. For example, thermal imaging allows localizing the places of heat loss and assessing the condition of exterior wall envelope in order to timely protect it from the adverse effects of the external environment.

In the Russian Federation, energy audit of buildings is voluntary. The proportion of buildings surveyed is about 5%, most of which have been surveyed in preparation for the overhaul of the property.

Today, available are various structural elements, engineering systems and building materials, of foreign and domestic manufacture, with different performance indicators, service intervals and cost of maintenance. When estimating the construction costs and making the investment project analysis, the cost of operation is often calculated incorrectly, and the owner of the building often lacks additional funds for operating expenses, which leads to a considerable loss in performance of the building in the first five years. The regulatory technical documentation that sets forth the rules of design, construction and operation of buildings is continuously amended. However, such amendments are mainly aimed at reducing energy losses and energy consumption of buildings by changing the layout of the building, adding facade insulation, introducing energy-saving technologies (most often by reducing the overall energy consumption of electrical installations, lighting devices, etc.) and they pertain to construction and operation of smart buildings.

Despite the fact that information and digital technologies, including voice recognition systems, artificial intelligence and robotics, are on the rise in Russia, the overwhelming majority of the country's population still take utility meter readings manually and report them monthly to the utility companies. This creates inconveniences for residents who have to keep track of utility meter readings (utility meters are often installed in hard-to-reach places), and, obviously, taking meter readings by hand does not help store and systemize such important data. Since in Russia there is still no generally accepted system of intelligent metering that would collect, store and use meter readings, valuable data gets lost, while they can be used not only for basic statistical purposes but also for energy saving studies, decision-making, design of real estate, improvement of existing housing, development of BIM technologies and in other areas.

This paper discusses how to use BIM-modeling not only at the stage of design but also the stage of operation, taking into account all engineering systems and structural elements with given service intervals, strength properties, stress-strain behavior and other characteristics and providing for automation of operational processes by installing various fire-detection systems, security systems, gas and vapor sensors, anti-icing systems for roofing, etc., to minimize human factor and ensure maintainability. During BIM modeling, it is recommended to use energy-efficient design and construction technologies, to minimize operating expenses by automating

the maintenance of systems, installed in the building, to reduce the heat and power consumption whenever possible, and to evaluate the possibility of introducing models of using renewable energy sources.

The purpose of the study is to scientifically substantiate the improvement of building operation quality, to conduct a practical survey of buildings in order to determine their operational characteristics, and to define the conditions for the development of smart innovations in the operation of real estate.

2. Methods

Regardless of the functional purpose and the form of ownership, buildings and structures are the main energy consumers due to the availability of systems and equipment that converts this energy into comfortable and safe living conditions for owners or temporary tenants.

At the same time, the requirements to the utility services are often unobserved, for example, the air temperature in living rooms, the temperature and pressure of the hot water, the illumination and the heat supply in common areas and utility services rooms, etc. fail to meet the requirements of regulatory documents. In addition, if the scheduled maintenance and repairs are not performed in due time, utility networks, technological equipment and structural elements of the building wear out faster. Construction errors and violations, made during the erection phase, lead to deterioration in the performance of the building. An example of such violation is incompliance with the requirements to external insulation of the facade. This violation is often found both in apartment buildings and single-family houses. Blow-through slits and cracks appear, forming cold bridges. Sometimes, poor-quality materials are used or insulating techniques are ignored. When using modern eco-friendly materials for individual housing construction, for example, laminated veneer lumber (LVL), the construction technology is often violated. The consequences are significant heat losses during the operation, mold and fungi on the walls and comfortable microclimate in the house. In some cases, in the absence of proper quality control, such violations result in the loss of bearing capacity of the structural elements of the house.

At the design stage, simultaneously with designing in effective thermal protection, the use of energy resources should be rationalized by increasing the efficiency of engineering systems and equipment and reducing the consumption of heat and power with the help of automated equipment management systems.

Unfortunately, in individual housing construction, future home owners apply simplified procedures for development and approval of the house design, technical supervision of the quality of construction and installation works, acceptance and commissioning of the house because the current procedures, established by law of the Russian Federation in the field of construction, allow it.

Some people build their houses relying on their own resources, without any design or quality control at all stages of the construction works, or contract incompetent construction organizations. This can result in decreased strength characteristics of the building, poor environmental performance and energy efficiency, deteriorated microclimate in the house and even danger to life and health of the residents if the requirements of regulatory and technical documentation in the field of construction are seriously violated.

The main task of the building envelope is to provide comfortable living conditions and protection from adverse climatic conditions; what is also important is to ensure the natural illumination indoors.

Generally, Russian experience in construction can be characterized by low interest in the construction of individual houses. In the Soviet and post-Soviet period, standard projects for individual housing construction had been issued in mass circulation, and there had been also

recommendations for developers. The government had set the task of using secondary resources for production of building materials, such as production wastes. It has been planned that the construction of individual houses would reach 30% of housing development in the country. However, priorities changed and it became necessary to build apartment buildings on a massive scale. Today, in the Russian Federation, apartment buildings make up over 75% of the new housing development (the figure may vary depending on the source).

Every year, the number of housing grows due to the support from the federal target programs. Increasing the availability of land plots and providing them with the necessary infrastructure made it possible to actively develop individual housing construction using modern durable, environmentally friendly and energy efficient materials.

For example, the current housing construction program in the Republic of Tatarstan envisaged commissioning of 2.403 million square meters of housing in 2018. Also, in 2018, 87 houses with 9,711 thousand apartments (527 thousand square meters) were to be built under the program of government housing stock under the President of the Republic of Tatarstan.

The ratio of the number of apartment buildings to individual real estate in the Russian Federation is 86% to 14%, respectively.

Today, the share of cast-in-situ, brick-built and stone houses is growing, while the number prefabricated concrete panel houses and wooden houses, built during the Soviet times, is decreasing, thanks to housing renovation programs. Such old buildings are demolished due to their low energy efficiency and high cost of reconstruction of the main structural elements in order to maintain them in good condition. Most residential buildings erected in the Soviet and post-Soviet times, including individual houses, were built with poor thermal insulation of the envelope.

Since thermal imaging inspection is an integral part of smart operation of a building, the thermal imaging survey was performed and included the following activities:

- visual inspection;
- instrumental examination of external envelope of the building and its engineering systems (thermal imaging survey);
- collection, systematization and analysis of the obtained data;
- development of measures to improve energy efficiency and energy saving, assessment of resource savings;
- assessment of the economic efficiency of implemented and proposed activities.

Thermal imaging of the studies buildings was made with the FLIR E4 thermal imaging camera (refer to manufacturer's web-site for specifications and certificates: <https://www.flir.eu/support/products/e4#Overview>).

The following devices can also be used for such thermal imaging surveys: heat flux density meter, hygrometer, anemometer, data logger with temperature sensors, or thermometers, pyrometer, manometers, power quality analyzer, light meter, etc., depending on the purpose and objectives of the survey.

Obviously, the intellectualization of a building becomes possible only with regular monitoring of the utility systems.

The transition to smart buildings by creating a BIM model of the existing buildings and its engineering systems can be carried out not only in new construction projects, but also in periodic maintenance, overhauls, reconstruction of buildings and structures, taking into account the structural features of buildings, their historical and cultural value, etc.

The introduction of intelligent technologies and systems should be carried out in several stages, depending on the depreciation of the building and its engineering systems, the form of ownership, the location, the level of accessibility for all categories of citizens, and other indicators. However, a complete BIM model must be created during the next repair works, with

brake down to sections requiring repair. Thus, the building owner can have a real understanding of the condition of the property, the amount of funds needed to maintain and repair the utility systems in the coming years, taking into account the existing performance indicators and the target indicators to be obtained with the intellectualization.

In Russia, low-rise construction is currently attracting increasing attention from both consumers and government agencies, developers, investors, architects and design studios. A privately-owned single-family house is a dynamically developing type of private property and a commodity in market operations. A private house is not only a residential building, it also incorporates ancillary buildings, a land plot, etc. The quality of a low-rise building includes many properties (individual indicators) characterized by the particular complexity of their interrelations and a multi-level structure. There are the following system problems and shortcomings in the field of quality management of low-rise construction:

- construction activities are not adequately controlled, since they do not ensure full compliance with the established requirements of regulatory and technical documentation in force in the territory of the Russian Federation;
- use of materials that do not meet the requirements of regulatory and technical documentation in force in the territory of the Russian Federation, violation of the requirements of transportation and storage of building materials;
- violation of construction techniques and errors in installation of structures of buildings;
- violation of the requirements for the maintenance of buildings and structures.

In the context of tough market competition in the construction industry, many construction companies choose low-quality building materials, with reduced durability and environmental performance, in order to reduce the cost of construction.

To ensure a comfortable microclimate in the residential buildings, it is necessary that the temperature of the external envelope would be about the same as the air temperature in the room, otherwise discomfort is possible due to heat dissipation by the external envelope and formation of condensate on the internal wall, which can lead to mold and fungi growth. In this case, it is necessary to take into account that the temperature of the internal walls depends not only on the selected material and thermal insulation, but also on the quality of construction and installation works. In the presence of construction joints, improperly mounted structural elements and improperly installed facade insulation, windows and doors, etc., there appear cold bridges that let the heat escape.

Often, violations of the requirements for installation of building structures are hidden, and visual inspection cannot identify them. In this case, special equipment, such as a thermal imager, is recommended.

The Federal Law No. 261-FZ On Energy Saving and Improving Energy Efficiency sets forth the main objectives of an energy survey of a building:

- obtaining objective information on the volume of used energy resources;
- determination of the figures for energy efficiency;
- determination of the potential of energy saving and improvement of energy efficiency;
- development of measures of energy saving and improvement of energy efficiency and their cost assessment.

3. Results and discussion

The obtained thermal images show the defects of external envelopes of the studied buildings of various types, forms of ownership and functional purpose (Figs. 1, 2).

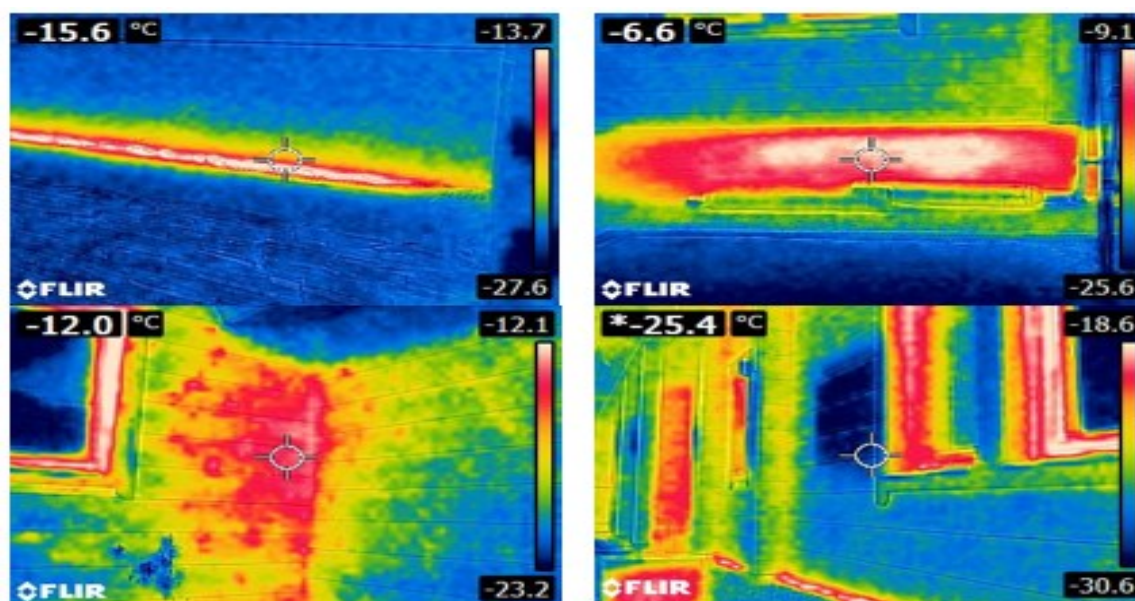


Fig.1. Thermal images of the facade of an LVL house (Object 1).

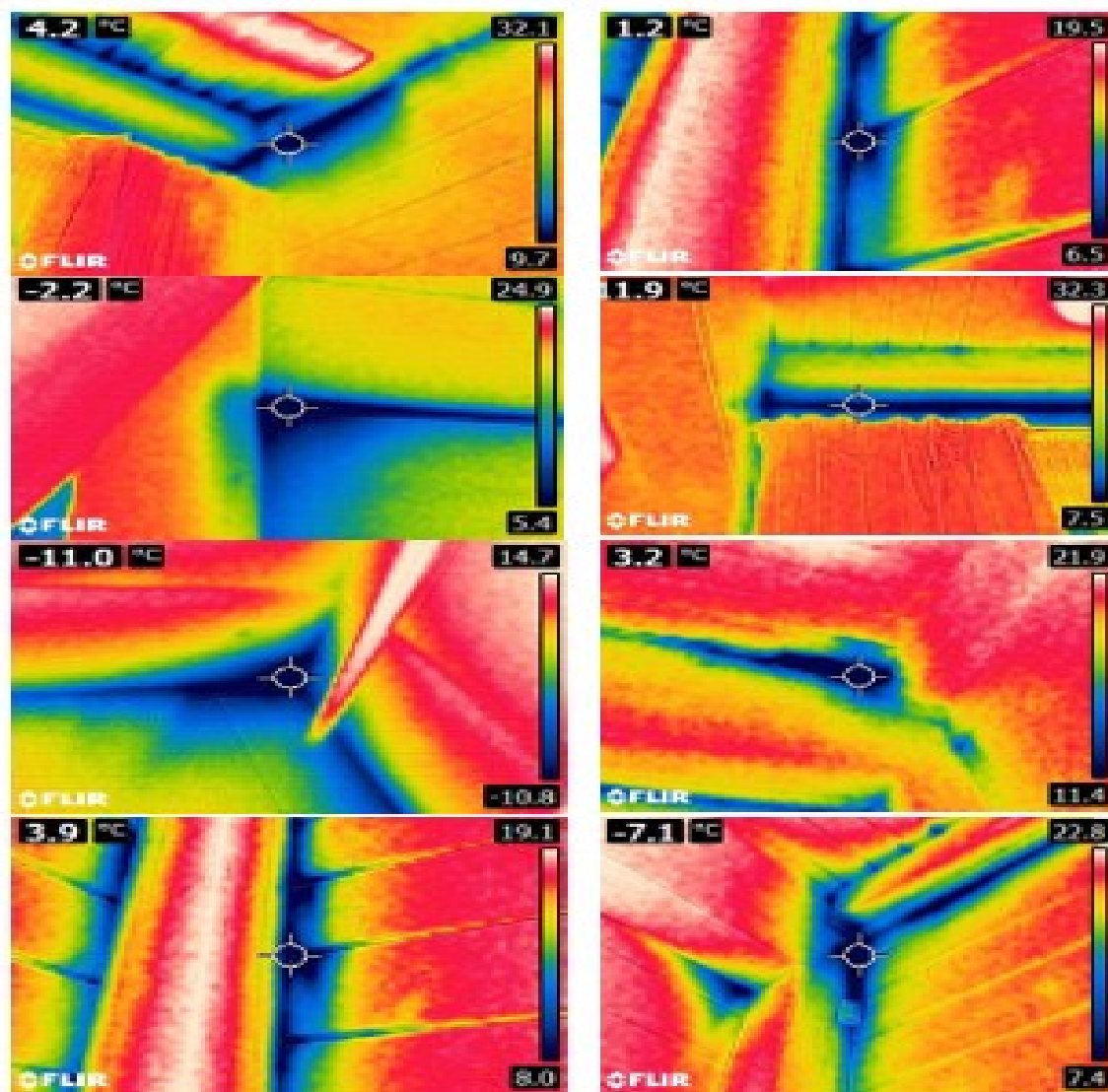


Fig.2. Thermal images of the envelope made inside an LVL house (Object 2).

It was found that during the construction and installation works at Object 1, the installation technology of windows and doors structures was compromised; the construction joint between the foundation of the house and the first row of logs was not insulated; and the construction technology of the LVL house was compromised, namely, laying of sealant in-between the logs.

At Object 2, gross violations of the construction technology of assembling an LVL house were found, namely:

- the sealant in-between the logs had low quality and has become useless over time;
- due to repeated violations of the construction technology, the house has subsided unevenly; some beam structures got 'suspended' on the 'portals', which were decorated with substandard stone, without any subsidence elements. Now the beam structures rest on the columns also without any possibility to compensate the subsidence of the house. Due to this, the beams are suspended and, as a result, some rows of logs lack proper support. The joints between the logs along the entire perimeter of the house have opened up;
- there are no jacks to compensate the subsidence of the house;
- in the frame of the house on the second floor and in the double-height part of the ground floor, the insulation is compromised; poor-quality materials are used, namely, the insulant and the tape; the insulation was mounted with gross violations of the construction technology.

Due to the numerous violations of the construction technology, mold and fungi has appeared in the freeze-and-thaw action areas; the windows also thaw and freeze inside. A 1.2-2 m thick ice built-up was found on the roof.

Another object surveyed was an apartment building with a bearing frame made of cast in-situ reinforced concrete, having 182 apartments. The energy efficiency class of the building has not been defined yet. The material of the exterior wall envelope was lime brick masonry with insulation.

The conducted survey revealed gross violations of the construction technology in brickwork:

- brickwork joints were not sealed during masonry works;
- low quality insulation was used;
- brickwork of the internal walls was done with violations and the insulation does not fit tightly to the walls;
- windows and doors were installed with crude errors;
- heating lines were not installed in the staircases;
- doors on the staircase landing are wooden, without insulation; gaps and joints were not sealed.

The thermal imaging survey of five objects (four wooden low-rise LVL houses from 400 to 1800 m² assembled by different construction teams and one high-rise apartment building) showed that the quality of the work performed on the construction site was not controlled properly. Gross violations were made in the construction and installation works, the materials used did not meet the requirements of the regulatory technical documentation, and the operation of these building has been conducted with gross violations as well, all summing up to the following consequences:

- mold and fungi appeared on the walls and the comfortable microclimate in the building was compromised;
- increased heat loss through the exterior wall envelope resulted in excessive energy consumption;

- in the absence of due attention to the violations, the carrying capacity of some structural elements, or of the building as a whole, may have been compromised.

As a rule, in case of poor-quality construction and installation works, or in case of violations of the requirements of the regulatory and technical documentation, the areas of excessive moistening and freeze-and-thaw action should be detected by means of visual inspection during the operation phase. Also, in case of violations described above, the dew point may be shifted inside the building, leading to the condensation on the walls, destruction of insulation or walls, and growth of mold and fungi, which has a negative effect on the health of the residents. If the carrying capacity of the outer walling during the operation is compromised due to the above factors, overhaul, reconstruction, or demolition of the building becomes necessary.

To ensure the standard quality and energy efficiency at all stages of the life cycle of real estate objects, a construction organization must increase the labor productivity of workers, improve the quality of construction and installation works performed by them, and ensure saving of construction materials based on the improved labor productivity of workers, efficient use of working time, mechanical aids and material resources, and availability of modern equipment and means of non-destructive control. All of these are examples of effective property management.

At the same time, the demand for electricity, water and natural gas is rapidly growing in the 21st century. Since their cost is high, closer attention must be paid to how we use natural resources and whether we are doing anything to use them more effectively to reduce consumer costs and, of course, to protect the environment.

Unlike the United States of America and other Western countries, Russia began thinking about energy saving measures only recently. The law on energy saving projects was passed only at the end of 2009, and it served as a starting point for the development of improved accounting infrastructure (AMI, also known as the ‘smart metering system’).

However, this good first step aggravated the situation at first: homeowners associations (HOA), property management companies (PMC), and real estate owners found themselves absolutely unprepared for the amount of data they suddenly had to deal with. Utility consumers were fined if they were late in providing utility meter reading to their HOA or PMC.

Such amount of work both for utility consumers (who had to take meter readings manually), and HOAs or PMCs (who has to process and store this data somehow) is extremely difficult, if not impossible, without suitable technology. Unfortunately, today there is still little progress in this matter.

We interviewed employees of HOAs and PMCs in the city of Kazan. The majority of respondents feel that they really struggle with processing of the collected data but they do not fully support the idea of switching to smart metering systems. However, it should be noted that:

- utility consumers would like to simplify the collection of utility meter readings, find a way to control electricity, water and heat consumption and, therefore, save money.
- engineering companies that are seeking new markets would like to introduce new technologies as early as the construction stage, because it can help not only save resources and reduce construction costs, but also attract more technically savvy customers, i.e. homeowners and tenants who want to save on their utilities by using smart technologies.

Smart metering technology automates the process of taking meter readings and makes it easy to regularly provide data to utility companies and to accurately invoice consumers. Such systems also benefit consumers since the readings are taken every 15 minutes to 1 hour (depending on how the setup) and it allows consumers to monitor the consumption of electricity, water and heat during the day and night. It can change the rules of the game when it comes to maintenance problems. For example, if a consumer monitors water consumption and

sees that water is used from 2 to 4 am, while the household is usually asleep, this indicates a leak. In general, smart metering systems allow households to use energy and water more responsibly and help consumers make a positive contribution to the environmental protection. Smart meters can be used with home power management systems, such as web-based tools, that can be installed in the building. Smart meters can display power consumption, help find ways to save energy and money, and allow users to remotely adjust thermostats or turn off appliances.

To achieve the ambitious goals set in the innovative concept of energy saving in Russia, it is necessary:

1. to conduct expert review of building design projects in terms of energy efficiency;
2. control the quality of construction works.

The second factor is especially important in construction of low-rise individual houses that do not fall under the control of state supervisory authorities.

Fig. 3 presents the algorithm of modernization of housing management according to BIM model.

This approach seems especially useful in planning and performing maintenance and repair of buildings. It provides for using proven, modern, high-quality materials, which guarantee of long service life of a building and significantly increases the transparency of operation of a building. The proposed automation of operation processes can decrease the number of failures of elements and systems.

The intellectualization of operation processes based on the utility automation with smart metering technology can improve the efficiency of the above mechanism.

At the moment there are three main reasons that prevent the implementation of AMI:

1. only the owner (owners) of the building can decide which meter to install on their property. If this basic yet crucial step is not taken, all benefits associated with the use of the smart metering system will be delayed;
2. the second reason is of psychological nature; although it takes a lot of time to take meter readings manually and then report this data to HOA or PMC, many consumers are used to doing it, and they may be reluctant to learn how to use new meters and understand the advantages of transition to AMI;
3. the third reason explains why HOAs do not the initiate the transition to smart metering systems. Housing managers understand that, while AMI brings tremendous benefits to consumers, it will replace employees who don't want to lose their jobs with devices. However, rightsizing (using fewer people but more devices) can obviously help HOAs and PMCs to reduce their operating costs.

4. Conclusions

The introduction of smart metering technology forms a much-needed basis for digitizing housing infrastructure and metering the natural resources that people consume daily. Thus, AMI helps reduce operating expenses, and the financial factor is crucial in any decision-making process. However, there are several other benefits that are convenient for consumers who monitor the consumption of utilities:

1. the automated process prevents human errors in talking the readings;
2. synchronized databases immediately transmit data to utility providers and utility bills are generated electronically, instead of using paper, which is another environmental benefit;
3. smart metering systems are extremely helpful in obtaining more accurate readings for statistical purposes and help prevent power outages;

4. since in Russia starting from 1 January 2017 PMCs are responsible for paying to utility providers for the provided electricity, heat and water, smart accounting technologies can help employees of PMCs and HOAs to monitor readings, analyze utility consumption, compare billing periods for a particular consumer, track payments, prevent non-payments, etc.;

5. as any modern technology, AMI makes data processing less time consuming. Building operation and maintenance costs can be significantly reduced.

Finally, considering all the years of development and implementation of AMI in the USA and following their experience, consumers in Russia can be confident that the transfer to digital means of collecting and storing data on the use of utilities will bring obvious benefits, not to mention the fact that it completely correlates with Federal Law No. 261 “On energy saving and improvement of energy efficiency” and with the national concept of digitalization of Russia.

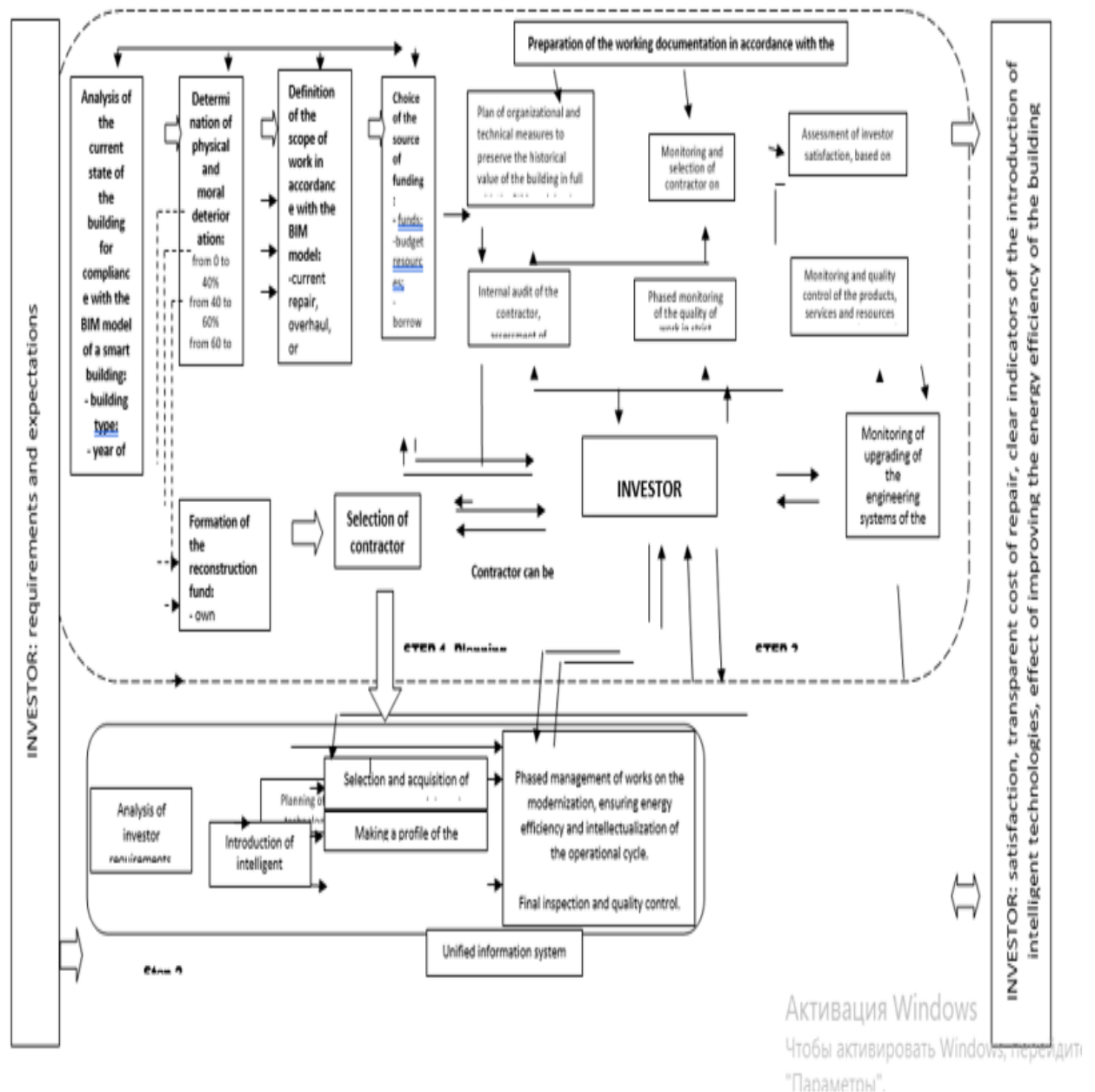


Fig. 3. Organizational and economic algorithm for managing the modernization of housing according to the smart building model

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