Application of BIM for resource management in small enterprises: saving and environmental friendliness

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Abstract. This article is aimed at finding ways to accelerate the implementation of BIM by actively involving small businesses in the implementation process. A differentiated approach to the implementation of BIM has made it possible to determine that the scale of costs and changes in large and small organizations in the investment and construction sector differ significantly. Many of the factors hindering the implementation of BIM in small organizations are not insurmountable or are absent in a small organization due to the limited functions performed by it. Accordingly, the scale of costs and organizational transformations required by a small organization when implementing BIM is many times different from those needed by a large organization. Based on the differences in interaction models in a large and small organization when implementing a project using BIM, the main aspects of BIM implementation in small organizations are formulated, a methodology for implementing BIM in small organizations is proposed, taking into account their specifics and orientation to the requirements of the external environment. Active involvement in the BIM implementation process will significantly contribute to the spread of the technology. This will help reduce the amount of resources consumed (material, labor, energy, financial), reduce construction debris and emissions, and increase the economic efficiency of projects. The massive implementation of BIM in construction based on the involvement of small organizations will allow for an economic effect at the meso- and macro–level – the level of the region and the country due to the scale of the construction industry in the economy.

1 Introduction

Construction is the most important branch of the economy, creating the basis for the functioning of other industries and spheres of life, providing the population with housing, various objects of social, transport and engineering infrastructure. Construction traditionally plays a significant role in the economy, providing a high share of GDP.

Currently, one of the main trends in the development of the global economy is digitalization, automation and robotization of production processes [1, 2, 3]. Digitalization and automation can significantly increase labor productivity, reduce the volume of routine

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work, reduce the time and costs associated with manual collection and processing of information and manual labor. However, the use of digital technologies and tools increases the requirements for the quality of equipment, the level of education of employees and often leads to adjustments (from minor to almost revolutionary) of business processes [4, 5], which leads to expenses for organizations during the implementation of innovations, but ultimately increases the economic efficiency and competitiveness of organizations [6, 7].

The construction industry is also in the trend of digitalization, however, according to research data, it is one of the laggards in this issue [8, 9]. A key aspect of the digitalization of the construction industry is the introduction of building information modeling (BIM). BIM is understood as a new concept of investment and construction project management based on the creation of an information model of a building containing many mutually related parameters about an object under construction that have a geometric reference. The application of this construction management concept allows you to obtain a number of advantages: a common understanding of the project by all its participants, the formation of high-quality project documentation with the possibility of checking for collisions, which, accordingly, affects the quality of construction, higher planning accuracy [10, 11, 12]. All this together provides opportunities for significant resource savings:

- material resources: by reducing and even eliminating the need for alterations at the facility, which may arise in a situation of poor quality of project documentation, inconsistency of project sections, as well as by reducing waste;
- labor resources. Losses associated with downtime due to clarification of project information, alterations, inefficient organization of work and inaccurate planning are usually eliminated when implementing BIM. In addition, the use of BIM leads to a shorter construction period, which also saves labor costs on the site;
- energy resources both at the construction stage (by reducing the construction period and improving the quality of work organization) and at the operation stage, which is even more important due to the duration of operation of the real estate object [13];
- financial resources, which is a logical consequence of saving all other types of resources and provides an increase in the economic efficiency of investment and construction projects [14, 15].

Many researchers note that construction using BIM is becoming safer [16, 17] and environmentally friendly [18], which indicates the importance of using BIM not only to increase the economic efficiency of projects and construction organizations, but also to ensure the sustainability of construction and social and environmental effects.

Despite the obvious advantages of using BIM, some researchers note the slow pace of implementation of this technology [19, 20], due to the presence of a number of barriers, such as high cost and complexity of implementation, causing adjustments to business processes and even organizational structure [21, 22, 23].

This article is aimed at finding ways to accelerate the implementation of BIM by actively involving small businesses in the implementation process. The author assumes that active involvement in the BIM implementation process will significantly contribute to the spread of technology, which will have the effect of reducing resources and increasing the economic efficiency of projects, which, ultimately, due to the significant scale of the construction industry in the economy of any country, will allow to obtain an economic effect at the meso- and macro-level – the level of the region and the country.

The object of the study was the enterprises of the investment and construction sector involved in the implementation of construction projects, while performing a limited amount of work (usually 1-2 types of work within the framework of performing the functions of a contractor or subcontractor) and are in the process of deciding on the possibility of implementing BIM. The subject of the study is the processes of organizing the implementation of BIM in small organizations of the investment and construction sector.

Small organizations have become a center of research interest due to the fact that their number is usually very large, they are essentially the foundation of the economy. As in many industries, organizations of various scales operate in construction – from micro-organizations consisting of several people to large enterprises with significant financial turnover and thousands of employees. At the same time, the share of small and medium-sized enterprises in the total number is usually high for the economy as a whole. For example, in Russia, the share of such enterprises is 94% [24]. According to the data presented in the sources, the share of small and medium-sized enterprises in the European Union is about 90%, and they employ more than 67% of the working-age population [25, 26]. A similar situation, characterizing the overwhelming share of small and medium-sized enterprises in the construction industry, is noted according to the results of the analysis of publications in many other countries [27, 28, 29, 30].

Small organizations traditionally perform contract and subcontract work in investment and construction projects of various scales, including large ones. One of the barriers to BIM implementation identified during the research is the difficulty of finding contracting parties (customers, contractors) who are ready to work with BIM. The spread of BIM in small organizations would reduce the level of this barrier and would contribute to the expansion of the use of BIM.

2 Materials and methods

Literature analysis was used as the main method of conducting the study, which was carried out in several stages:

1. Research of information sources on methods, ways and procedures for the implementation of BIM in construction organizations. The study of these sources allowed us to conclude that they are concentrated, as a rule, on the use of certain software to solve the problems of forming an information model [31], the features of forming an information model when working with various projects – industrial [32], transport infrastructure facilities [33], etc. A lot of attention in various sources is paid to the benefits of using BIM. There are also descriptions (case studies) and comparative studies of examples of BIM application at various facilities [34, 35];

2. Research of the features of BIM implementation in small construction organizations. The study of these sources shows that the authors focus on describing the advantages of implementing BIM [36, 37]

There are also studies suggesting dividing the process of BIM implementation in small organizations into several stages, involving: 1) directly the stage of initiation of implementation (independently or with the help of external experts and consultants), the formation of their own BIM experts; 2) stabilization of BIM application processes and retention of experts; 3) the stage of formation and implementation of competitive advantages of the application BIM [38].

The studied sources contain very little information about the features of BIM implementation in small organizations that could be applied in practice during the implementation process. As a rule, information about the implementation processes is generalizing in nature, they do not take into account the specifics of the activity and the scale of the organization. This leads to the conclusion about the complexity of implementation for all organizations, regardless of its scale and functionality, significant changes in work technology, restructuring of business processes and organizational structure, etc.

Nevertheless, as a hypothesis of the study, it is accepted that the processes of BIM implementation can be scaled taking into account the size of the organization and organized based on its capabilities – both in terms of staffing and financial capabilities. This approach

will allow a wider range of small organizations to be involved in the BIM application process and, ultimately, will contribute to its dissemination.

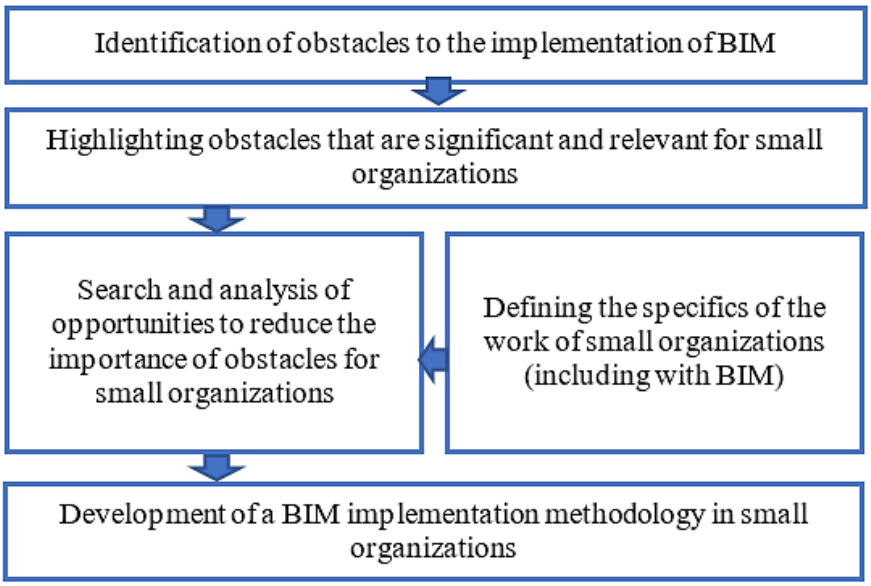

Fig. 1. The main stages of the research aimed at forming a methodology for implementing BIM in small organizations.

Accordingly, in order to determine recommendations for the implementation of BIM in the practice of small organizations, the following steps were performed within the framework of this study (Fig. 1):

- the main obstacles to the implementation of BIM have been identified. Of these, the most sensitive ones for small organizations are highlighted;
- an analysis of the possibilities of reducing the importance of these factors in small organizations, taking into account the specifics of the organization of their activities;
- a methodology has been developed for the implementation of BIM in small organizations in the investment and construction sector, taking into account their characteristics.

When performing these research steps, both the method of literature analysis and the modeling method were used, which allows us to visualize the number and complexity of relationships and information exchange during the execution of project work within the organization and with its external environment (contractors). This made it possible to identify differences in the number and complexity of relationships in large and small construction organizations. Based on such differences, a differentiated approach was applied to determining the conditions for the implementation of BIM projects in large and small organizations, the main aspects of the implementation of BIM in small organizations were identified and a BIM implementation methodology aimed directly at such organizations was developed.

3 Results

At the moment, there are many different studies available to identify both the advantages and obstacles to the implementation of BIM in construction organizations in different countries. In general, they can be generalized into the following groups:

- shortage of qualified personnel both directly in organizations and in the labor market. Often, specialists do not want to learn new technologies and, having significant work experience and a high level of qualification in their specialty, cannot be involved in projects using BIM. As a rule, organizations face either the need to bear significant costs for training their employees, or they are forced to look for specialists in the labor market (which are not enough), providing them with a high level of remuneration;

- large financial expenses for the purchase of hardware and software. The implementation of BIM requires that the computer equipment used when working with the information model has high performance, so it is almost always necessary to update the working computers of employees, as well as the purchase of servers. As for the software, this is also a significant cost item. Moreover, there is a wide variety of software products on the market that can be used for various purposes at certain stages of working with an investment and construction project, therefore, as a rule, it is necessary to purchase several programs. This is accompanied by the corresponding costs of training employees to work with these programs;

- the complexity of self-implementation and the high cost of implementation consultants. The complexity of implementation, the need for a serious restructuring of all processes, up to a change in organizational culture, is noted in many literature sources. The same is noted in the results of many studies conducted by interviewing representatives of construction organizations. On the one hand, this certainly reflects the actual state of affairs – the introduction of BIM does involve changing many processes of working on a project, on the other hand – awareness of this complexity is in many cases the determining factor in refusing to implement. In cases where the external environment (contractors and especially customers) does not require the use of BIM as a prerequisite for the performance of work under the contract, organizations refuse to have difficulties with the implementation of BIM, since this is not necessary;

- lack of requirements from investors and customers (when participating in tenders), unwillingness of contractors to work with the information model. The implementation of BIM is uneven, both organizations that can be called BIM experts and those who work using traditional methods of managing investment and construction projects are present on the market. The proportion of organizations using BIM varies from country to country, but it is always possible to select contractors (including customers) who do not use BIM;

- resistance from employees, owners and management of organizations. The implementation of BIM requires serious training, abandoning the usual methods of work, is associated with an increase in workload in the workplace, therefore it often meets resistance to changes from employees and management of organizations. Such resistance may also come from owners who are unmotivated to explore new organizational conditions and new project management methods, as well as invest heavily in the implementation of BIM;

- the duration of implementation and adaptation, accompanied by a temporary decrease in the effectiveness of activities. The implementation of BIM, as a rule, assumes that after the direct purchase of equipment and software, as well as training of employees, it is necessary to implement several pilot projects. This means that employees will need to do double work – perform it using traditional methods and duplicate it using BIM. This increases the complexity of the work and reduces the efficiency of labor. After the pilot projects are implemented, you can proceed to work only in BIM. However, it will take some time for employees to gain experience, so the work will initially be characterized by a slower pace, the presence of errors, etc., which also temporarily reduces the effectiveness of activities. And only after gaining sufficient experience can one get all the advantages of working with BIM, which are described in the literature and found in the research results. This usually takes 2-3 years.

Of the listed obstacles to the implementation of BIM for small organizations, we can single out those that are especially significant for them and can be perceived as

insurmountable. These include high financial costs for the purchase of hardware and software, the complexity of self-implementation and the high cost of implementation consultants, lack of customer requirements.

Other obstacles discussed above for small organizations should not be considered insurmountable. Small organizations tend to be quite dynamic in terms of recruiting and/or training staff and in terms of overcoming resistance to change on the part of employees. Adaptation processes can be concentrated on small projects, while reducing labor costs and complexity of customization.

Based on the above, it can be concluded that for many small organizations, the most serious practically insurmountable obstacles to implementation are the high cost (which a small organization cannot afford) and the complexity of implementation. Therefore, the search and analysis of opportunities to reduce the importance of obstacles for small organizations will focus on these obstacles to implementation. To do this, it is necessary to take into account the specifics of the work of small organizations.

Small organizations are characterized by a small number of employees and small financial turnover. This assumes that within the framework of investment and construction projects, they perform, as a rule, 1-3 functions / types of work (for example, for design organizations, this may be the execution of work on the design of 1, 2 or 3 sections of project documentation), that is, the functionality of a small organization within the scope of work and the scale of work is limited. For such an organization, the priority is always the requirements of the customer (general contractor, general designer), which determine the specifics of the work and the result that must be transferred to the customer. This result of the work of a small organization is part of a large volume of work performed by its customers (general contractor or general designer), and the need to integrate the results of the work of a small organization into the overall result lies directly in the field of responsibility of the customer. To do this, the customer determines the requirements for the performance of work and accepts work in accordance with the requirements specified in the contract – this is what ensures the integration of the results of the contractors' work into the overall progress of the project. Thus, the complexity of the organization of work and the interaction of performers for a large and small organization are seriously different. A large organization must coordinate the work of various teams within the organization, as well as coordinate work with contractors and integrate their results into the overall result. The interaction model of a large organization performing many functions at the same time (or performing many sections of project documentation) is schematically presented in Figure 2.

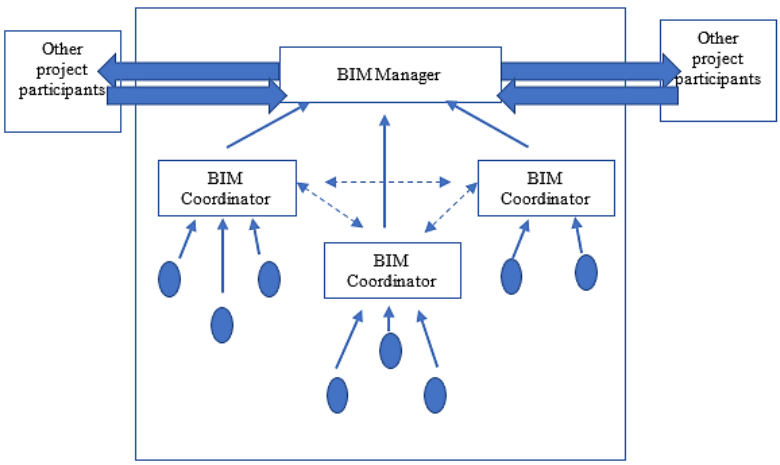

Fig. 2. A model of interaction in a large organization when executing a project using BIM.

The interaction model of a small organization performing a certain limited amount of work, as a rule, 1 (sometimes 2 or 3) function or type of work within a BIM project has a much less complex interaction scheme (Fig.3):

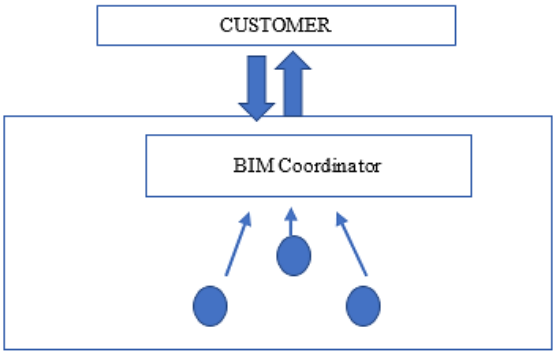

Fig. 3. A model of interaction in a small organization when executing a project using BIM.

So, within an organization, as a rule, it is not necessary to correlate and coordinate the work of several groups on a project, while focusing on both the customer's requirements and their own BIM standard. As a rule, one team works on a project, performing one type of work (less often 2 or 3). The main task is to coordinate directly with the customer, who makes specific requirements for the result of the work. This determines, accordingly, the limited responsibility of a small organization within the framework of the project, the limited competencies. The set of competencies needed directly to work in BIM is also limited, as the functions performed are limited.

Such a difference in the scale of project activities that exists between large organizations performing the functions of a general contractor, general designer or performing a large set of functions and works within the project and small organizations performing the role of a contractor/subcontractor and performing a limited amount of work within a narrow set of functions leads to the need for a differentiated approach in the organization of BIM implementation.

Large organizations have to bear significant costs associated with the scale of their activities:

- purchase of equipment, which includes both the purchase of high-performance computers for a large number of employees involved in the work, and servers that allow processing information model data (for example, checking the model for collisions);
- purchase of software, which is not limited to the purchase of 1 or 2 programs. As a rule, to perform various types of work, you need to purchase various programs, each of which is designed to perform a particular job;
- for each of the purchased programs, it is necessary to conduct employee training;
- it is necessary to adjust the processes, including the organization of work in groups with the emergence of new positions related to work in BIM – BIM coordinators, BIM managers. They interact by organizing work, each in his own group, with each other, ensuring coordination of the work of the groups, with the BIM manager, ensuring the formation of the overall result of the work and the project manager;
- these changes in processes and the emergence of new functions and positions for working with BIM technologies lead to an adjustment of the organizational structure;
- the organization of interaction becomes more complicated in the process of transition to work with BIM, since the pace of technology development among employees will vary. In addition, employees working with traditional methods will remain during the transition

period, which is a necessary temporary measure to maintain labor productivity during the transition period;

- the large scale of work also determines the fact that during the transition there will be a significant drop in labor productivity associated with the need to work out pilot projects by all employees involved in the implementation of BIM;
- the need to coordinate the work of various groups on the project determines the need to develop your own BIM standard. The BIM standard is developed, as a rule, in several stages, at each of which the requirements are clarified and specified;
- the scale of activities and the number of employees involved in BIM, changes in business processes and organizational structure, the need to adopt new principles and methods of work will also lead to the need to adjust the organizational culture to increase motivation and work efficiency.

Thus, we see that the volumes of costs and changes in large organizations when implementing BIM are really large in scale and complexity, which could become insurmountable for a small organization. However, the scale of change in small organizations has serious differences:

- as a rule, the purchase of equipment is limited to the purchase of the necessary number of high-performance computers (according to the number of employees involved in the process). As a rule, the purchase of servers necessary for storing and processing information model data is not provided, since this is done on the customer's equipment;
- the purchase of software is also limited in nature – software is purchased in accordance with the work performed. These are usually only a few positions;
- for each of the purchased programs, it is necessary to conduct employee training;
- the processes of work are being adjusted, but the organizational structure, relationships and the process of interaction in the organization during the performance of work do not undergo significant changes;
- there is no need to develop your own BIM standard - the orientation in the rules of work and its results is determined by the customer's requirements (it can be developed over time based on accumulated experience and stable relationships with customers). This makes it necessary to adjust to external requirements every time, but significantly reduces the complexity of setting up processes within the organization at the time of BIM implementation;
- the small scale of the organization, as a rule, implies a convergence of the pace of development of new technologies by employees, since in a small team communication and interaction, exchange of information and experience are more informal;
- in addition, small organizations tend to be less bureaucratic and more dynamic, which facilitates the gradual transformation of organizational culture;
- a drop in productivity during the BIM implementation process is inevitable, as well as the number of errors at the initial stage. However, the scale differs significantly from what we can observe in large organizations.

From the specifics of the implementation of BIM in small organizations, it follows that the scale of costs and organizational changes are seriously different from what we can observe in large organizations – there is no need to carry out a number of works (changes in the organizational structure, the development of a BIM standard and the introduction of a new organizational culture), which makes the implementation of BIM in small organizations more accessible than it might seem without applying a differentiated approach to the implementation of BIM.

An important feature of the introduction and implementation of BIM projects in small organizations will be orientation to the requirements of the external environment, primarily the customer. At the same time, the requirements of different customers will differ. Therefore, the implementation of BIM in a small organization should begin with the search

for a potential customer (new) or identifying a customer interested in switching to BIM and working in BIM among the existing pool of customers with whom there are stable business relationships. Identification of the customer's requirements in terms of working with BIM is necessary to determine the direction of BIM implementation for a small organization: what kind of software it uses, etc.

This orientation towards the customer and his requirements determines the order of work that can be recommended to a small organization when implementing BIM (Fig.4):

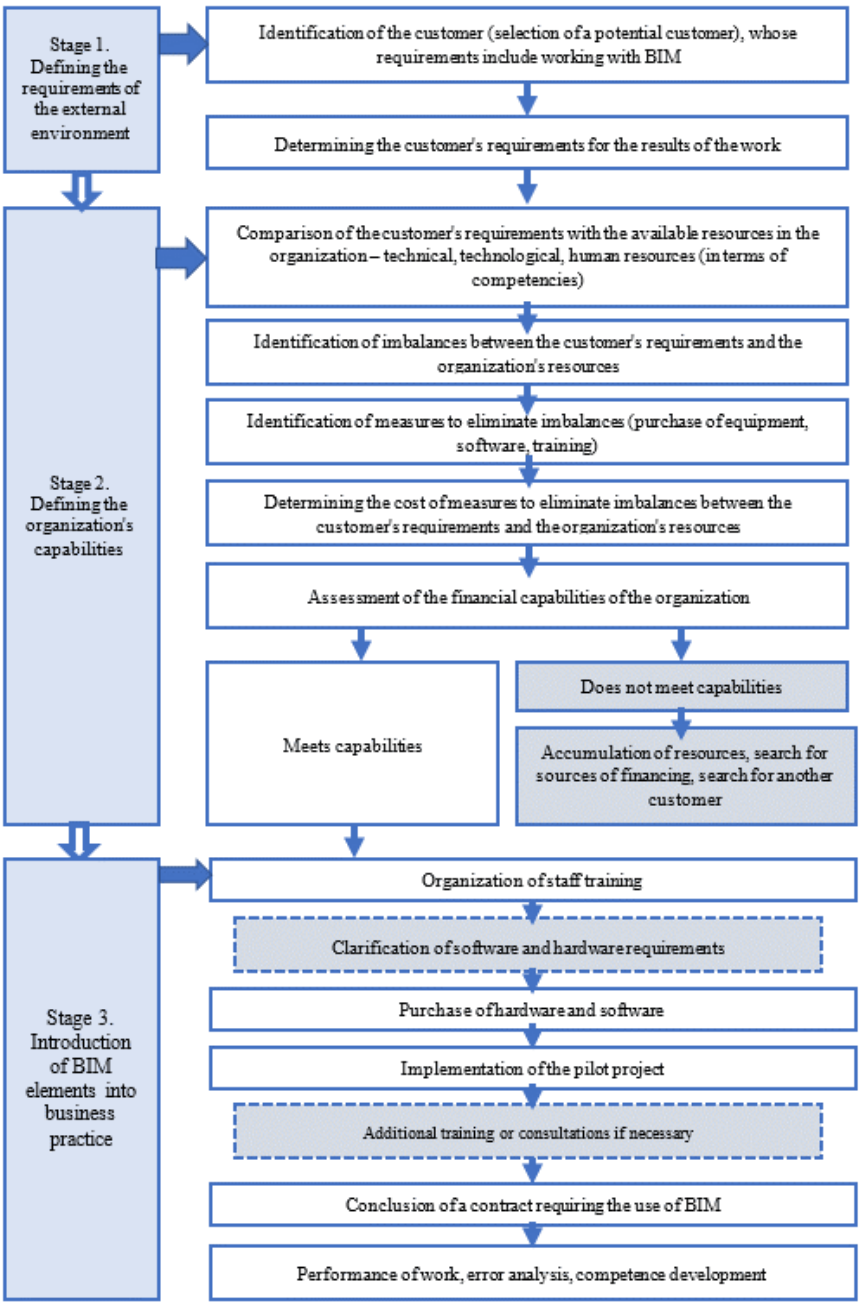

Fig. 4. BIM implementation methodology in small organizations.

Within the framework of the methodology presented in Figure 4, there are 3 main stages of BIM implementation for a small organization in the investment and construction sector:

1) defining the requirements of the external environment. As already noted, due to the limited capabilities of a small organization, the implementation should be carried out in such a way that there is a potential customer for the results of the work, therefore it is necessary to knowingly determine both the customer himself and his requirements for the process of forming an information model in terms of the work performed by the organization;

2) based on the identified requirements of the customer, it is necessary to determine the organization's ability to fulfill them. So, it is required:

- to compare the customer's requirements with the available resources in the organization – technical, technological (in terms of using a certain set of tools – software), personnel (in terms of competencies both directly in the field of work performed and in relation to the use of the required software in the formation of an information model);

- to identify imbalances between the customer's requirements and the organization's resources and determine measures to eliminate them, in particular, the volume and technical characteristics for the purchase of equipment, software and personnel training;

- to determine the cost of events and financial capabilities of the organization. When identifying inconsistencies with the capabilities of the organization, it is necessary to provide measures to gradually overcome the identified financial imbalance – to accumulate resources, find sources of financing or, possibly, to search for another customer with other requirements for the work on the formation of an information model;

3) in case of identification of the compliance of the organization's capabilities with the customer's requirements, the stage of implementation of the introduction of BIM elements into the practice of activity begins, within which personnel training is carried out (within the framework of training, requirements for equipment and / or software necessary for work can be clarified), purchase of equipment and software. Next, it is mandatory to implement several pilot projects, in which, simultaneously with the performance of work in the traditional way, employees duplicate work in the new software, taking into account the requirements for the formation of an information model. In most cases, one pilot project is not enough. Despite the fact that the implementation of pilot projects will significantly reduce the efficiency of the employees involved in the BIM implementation process, this will ensure the development of practical skills and reduce the risks of implementing the first contracts for work using BIM. During the implementation of pilot projects, the need for additional training may be identified. Only after completing all the above steps, it becomes possible to conclude the first contract with the requirement of using BIM. Based on its implementation, an error analysis is carried out, identifying areas of competence development.

4 Discussion

One of the controversial issues of BIM implementation in small organizations is the cost-effectiveness of such implementation. Of course, the scale of the economic effect and benefits that a small organization receives is incomparable with what we can see in a large organization. In this case, there is a certain kind of proportionality – large-scale costs and changes in a large organization lead to a large-scale effect, and in a small organization the effect will be much lower and generally correspond to the scale of its changes and costs. However, this does not mean that the effect will be absent. The gradual (as with a large organization) accumulation of experience in BIM will lead to important results:

- improving the quality of work;

- increasing the productivity of work by automating some functions, accumulating experience, and forming their own developments;

- improving the efficiency of information exchange with project participants and customers;
- saving resources, both for the organization itself in the process of performing work, and ensuring significant savings in the whole project of all types of resources (material, energy, labor, financial), reducing the volume of construction debris and emissions during construction;
- increasing competitiveness in a market that will inevitably strive for a gradual and complete transition to BIM.

5 Conclusion

As a result of the application of a differentiated approach to the organization of BIM implementation processes, significant differences in the scale of costs and changes between large and small organizations in the investment and construction sector were revealed. It is determined that not only the scale of costs differs, but also for a small organization, in principle, some transformations that are necessary for a large organization when implementing BIM (development of its own BIM standard, serious adjustment of the organizational structure, introduction of a new organizational culture) are irrelevant. However, there are also specifics related to the orientation to the customer's requirements. This orientation determines the need to build the entire implementation process around the customer's requirements, which is reflected in the author's methodology for implementing BIM in small organizations.

As a result of the conducted research and on the basis of a differentiated approach to the implementation of BIM based on the scale of the organization, the following aspects of the implementation of BIM in small organizations are formulated:

- limitation (limited functions performed within the project) leads to a limited number of competencies necessary for mastering, a limited amount of software and equipment purchases, and, accordingly, limited costs required for the implementation of BIM;
- orientation to the requirements of the external environment (first of all, to the requirements of the customer);
- stage-by-stage approach, which involves performing a number of steps in accordance with the proposed methodology.

A differentiated approach to the implementation of BIM and an understanding of the limited scope of changes in small organizations will make it clear that the barriers to implementation are not insurmountable for them. This will allow them to be involved in the BIM implementation process, ensuring an increase in the pace of implementation as a whole.

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