Transform Approach for Formation of Construction Project Management Teams Based on Building Information Modeling

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Abstract

The study is devoted to transform approaches to the formation of construction project management teams in the context of digitalization of the construction industry. It is necessary to more widely use Building Information Modeling (BIM) technologies in the implementation of construction projects. The methods and approaches used in the information technology can be the key to the success of a project in construction, while moving from traditional management methods to innovative approaches with the maximum use of BIM at all stages of the project lifecycle. A model of the transition of enterprise business processes to BIM-management is proposed, depending on the stage of the construction project and the volume of investments in the development of the company. The study considers models of organizational transformations of the project management system and the project management team, which are both the "brain" and the main resource that determines the quality of management, interaction, support and the success of projects. The object of this article is BIM-management as a technology for increasing the competitiveness of enterprises in the construction industry. Study of issues related to the use of BIM in construction, elucidate ion and clarification of the essence of BIM technology with the determination of the positive and negative aspects of its implementation. The study shows the dynamics of BIM efficiency growth for start-up companies and companies already entrenched in the construction market.

Keywords 1

Digitalization of the construction industry, BIM-management, project management team, BIM specialists

1. Introduction

The construction industry is one of the areas of economic activity that is most fundamentally subject to transformation due to the general global processes of "digitalization". There is a need to transform the way the customer works with project information and with the project management team in connection with the increasing penetration of Building Information Modeling (BIM) technologies into the implementation of construction projects. Therefore, for the effective use of BIM, there is a need for coordination and unity of methodological support for the activities of not only the manager, but also the entire project management team. The dominant role of information technology in the digital transformation of construction activities prompts the feasibility and need to adapt IT to solving problems and tasks in the construction industry. To improve the efficiency of all stages of the object's lifecycle, it is necessary to rechange the theoretical and practical aspects of engineering

Proceedings of the 2nd International Workshop IT Project Management (ITPM 2021), February 16-18, 2021, Slavsko, Lviv region, Ukraine
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activities for lifecycle contracts based on the theory of simulation and the functional method using artificial intelligence and BIM technologies [1]. Based on the results obtained from research, it can be said that when using BIM technologies, investors have increased confidence in construction projects. A study by Autodesk [2] provides the following results:

- technical faults are detected on time, due to this, the cost is reduced by 10%;
- project implementation time is reduced by 7-15%;
- the accuracy of estimated calculations increases by 3%;
- the development of construction estimates can be reduced by almost 80%;
- reduced defects and construction waste by 30%;
- it becomes possible to more accurately assess the effectiveness and targeted spending of budget funds.

Table 1 shows the results of studies of the BIM implementation, which indicate an improvement in a number of performance indicators.

Table 1

Information model of the territory planning project at the stage of urban design

№	Advantages	Companies:	
		"Beginners"	"Experienced"
1	Increase in profits	10%	45%
2	Support for the duration of specific work chains	12%	50%
3	Reducing the number of changes in the project	25%	75%
4	Repeated agreements with former clients	20%	60%
5	New service offer	28%	72%
6	New business marketing to new customers	27%	73%
7	Increase in staff productivity	36%	65%

The authors of [3-7] note such a need for the formation of competitiveness in a strategic perspective due to increased global competition in the construction services market, acceleration of innovation and technological development and reindustrialization of the world economy. Construction engineering is a progressive organizational scheme aimed at increasing the productivity of the construction industry through project-oriented and scientifically based on methods of organizing construction production, as well as improving the technology of construction of objects through the introduction of scientific developments [8]. Having analyzed the domestic and foreign experience of enterprises in investment and construction activities [9-11], it can be argued that in the Ukrainian economy there is a tendency to borrow foreign experience in the implementation of long-term construction projects by concluding an agreement with one company for the entire range of services: from project development, construction, operation and subsequent disposal, i.e. throughout the entire life cycle of an object [12-16]. BIM technology is a modern approach to design, construction and operation. It allows combining various software products and tools, which allows modeling much cheaper, simplifies the visualization of the future object [17, 18]. The transition of the industrial and civil construction industry to a higher level of competitiveness [19] in many countries of the world is associated with the creation of full-fledged BIM models.

The consulting company "McGraw Hill Construction" [20] conducted a survey among companies in the construction industry and found out what benefits they received with the introduction of BIM. Thus, the study showed the following results: 41% of the surveyed companies noted a reduction in the number of errors after the introduction of the technology. In turn, 35% and 32% drew attention to improving communication between managers and designers and improving the company's image, respectively. A complete list of research findings is shown in Fig. 1.

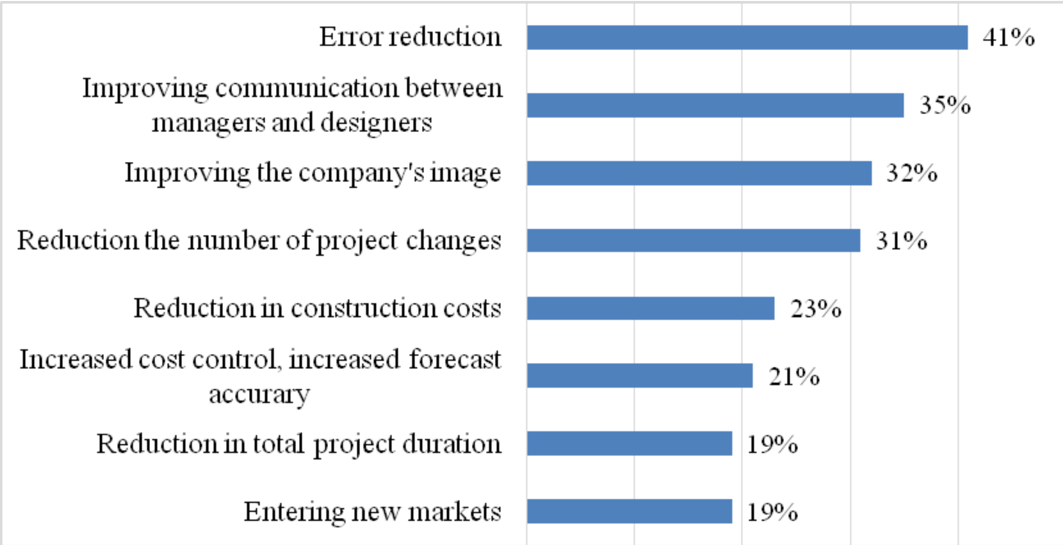

Figure 1: Results of BIM implementation. Source: [20]

Nevertheless, despite all of the above, BIM technology, in addition to all the advantages, has certain disadvantage. Experts identify the following difficulties in implementation:

- retraining from Computer Aided Design (CAD) to BIM software product;
- the interaction of departments when working in BIM technologies takes a long enough time to get used to;
- high price category for the purchase of the corresponding software products;
- limited BIM managers who are ready to train entire staff and organize the transition to BIM technologies.

All these problems put the introduction of BIM technologies in Ukraine into a difficult position. A key indicator of a company's maturity in using BIM technologies is the level of technological, organizational and management changes as part of the transition to BIM.

The purpose of the article is to develop models of organizational transformations of the project management system and the project management team, which are both the "brain" and the main resource that determines the quality of management, interaction, support and the success of projects.

2. Theoretical Studies

The role of the project manager, the coherence of the project management team and the ability to generate synergy is further enhanced in the context of digital transformation in construction. Strategic management of role communication and the interaction of its members play an important role for team management.

BIM technologies are constantly evolving. This led to the creation of technologies 4D modeling, 5D modeling, 6D modeling, Product Lifecycle Management, Multi-D modeling – PLM and other similar technologies. They help to intensify innovation processes and act as a basic condition for the development of enterprises in the construction industry. BIM is not perfect, it doesn't work automatically, and it doesn't replace humans. Moreover, BIM technology requires a lot of professionalism and a comprehensive understanding of the process from the participant in the construction process. But at the same time, BIM brings a creative component to work, makes human work more efficient.

Obtaining a reliable cost estimate for the implementation of the project implementation of BIM-technologies is possible through a systematic analysis[21–30] of the three areas of investment. Only after such an analysis is the feasibility of determining the effectiveness of the company's transition to information modeling technology.

A complex computer model that describes object and construction process is the result of BIM modeling. This simulation brings together all information into a single database. This allows getting up-to-date project documentation and visualization.

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1. reengineering of business processes and management system;
2. transformation of the organizational structure in terms of staff composition and qualifications;
3. formation of supporting infrastructure.

The transition to information modeling technologies is a set of interconnected processes, and investments in the project of implementation of BIM-technologies are formed from a set of investments in all three areas, presented in Fig. 2.

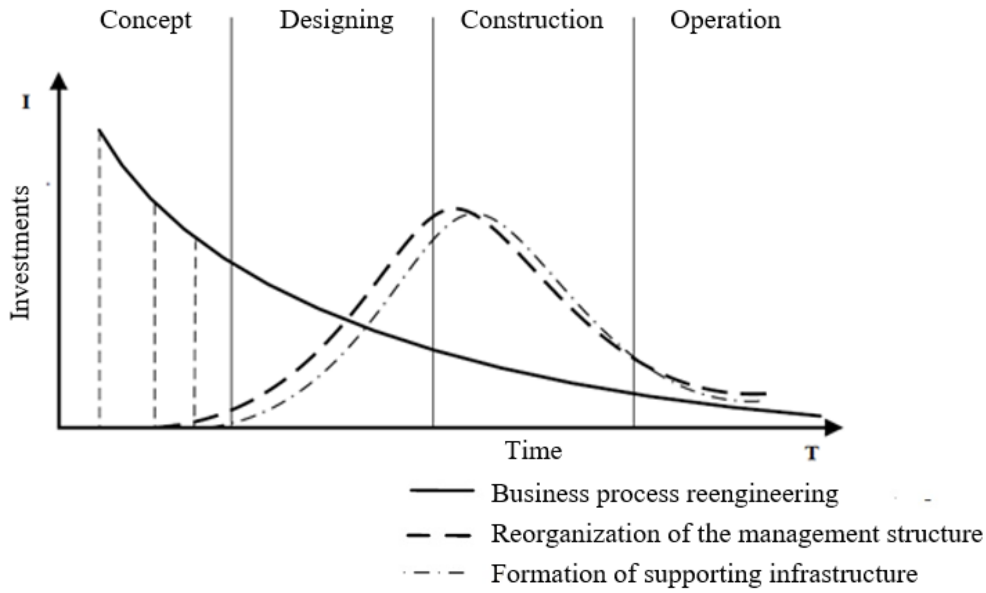

Figure 2: The cost structure of the enterprise at different levels of BIM-processes

The model of transitional business processes of the enterprise to BIM management depending on a stage of development of the company is offered to be de-scribed by the following functional equation:

$$\int_0^T (C(t) - C^{BIM}(t))\, x(t) dt = I_{BIM} \tag{1}$$

where x is total income, C is current costs without using BIM-management, C^{BIM} is current costs when using BIM-management, I_i is investment costs incurred for the implementation of BIM-technology, T is period of time during which it is expected to recoup investment costs in BIM-technologies.

The decision on the feasibility of transition to BIM-technologies at each stage of the construction project (see Fig. 2) must be made by comparing current costs with the investment costs of implementing new technologies. If the left part of equation (1) is over than the right part, then the investment in the introduction of BIM-technologies is justified and the company can make the transition to a new level of management:

$$\int_0^T (C(t) - C^{BIM}(t))\, x(t) dt > I_{BIM} \tag{2}$$

If the costs of implementing BIM-technologies exceed the current costs at this stage of the construction project, the company refuses to switch to BIM management:

$$\int_0^T (C(t) - C^{BIM}(t))\, x(t) dt < I_{BIM} \tag{3}$$

Each level of maturity of BIM-processes represents potential goals of the company. Thus, there are n levels of maturity. Fig. 3 visualizes the performance of the transition to the next levels of maturity BIM. In this case, CAD-technologies occupy the level i (i ∈ [A; B]). The transition from one technological level to another is an economic-technological leap (step) is *m*.

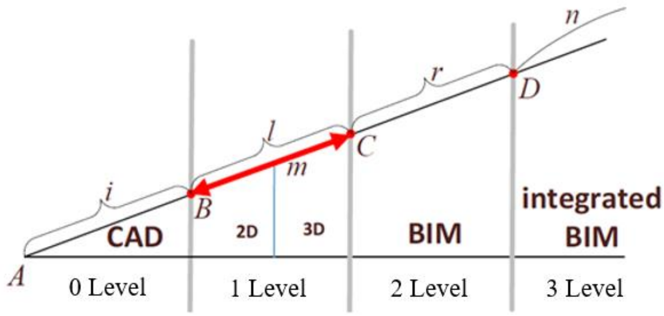

Figure 3: Visualization of the transition of the administration system by activity at the BIM level
Source: author's development based on [1]

The efficiency of BIM-technologies gradually increases with the transition from i to n level, which is equivalent to reducing the specific production costs of each subsequent level of maturity of BIM-processes. At transition from one level of maturity of BIM-processes to the subsequent there is an increase in price of IT therefore we will enter coefficient of increase in price k > 0 and we will receive expenses for transition from one level of maturity of BIM-processes:

$$I_l = I_i + kl, \qquad I_r = I_l + kr, \qquad I_n = I_r + kn \tag{4}$$

In this case, the economic and technological equilibrium for each transition has the form:

$$(c_i - c_l) * K_l = I_l, \qquad (c_i - c_r) * K_r = I_r, \qquad (c_r - c_n) * K_n = I_n \tag{5}$$

Estimation of economic and technological step at m = l-i = r-l = n-r has the form:

$$K_l = \frac{I_l + k(i+m)}{k_{BIM} m},\ K_r = \frac{I_r + k(l+m)}{k_{BIM} m}, K_n = \frac{I_n + k(r+m)}{k_{BIM} m}, \tag{6}$$

where is the company's revenue at 1 level of maturity of BIM-processes; is income of the company on 2 levels of maturity of BIM-processes; is the company's revenue at 3 levels of maturity of BIM-processes; is investment to move to level 1 maturity of BIM-processes; is investments for transition to level 2 maturity of BIM-processes; is investment to move to level 3 maturity of BIM-processes; *m* is economic and technological step; k_i= $(c_i - c_l) = (c_l - c_r) = (c_r -$ is the coefficient of increase;

In the left part of each of the obtained equations (6) are the values of the potential for the development of BIM-processes, in the right part of the investment for the transition from one level of BIM-processes to another. With insufficient potential for the development of BIM-processes, the spread of new technologies stops, which indicates the impossibility of transition to a new level of BIM-processes.

Thus, the logical condition of transition from one BIM-level to another is established, which is presented in Fig. 4. and is described by the following inequalities:

$$\begin{aligned} k_{BIM} m K_l &> I_l + k(i+m), \\ k_{BIM} m K_r &> I_r + k(l+m), \\ k_{BIM} m K_n &> I_n + k(r+m), \end{aligned} \tag{7}$$

where $k_{BIM} r$, $k_{BIM} n$, $k_{BIM} n$ are development potentials of BIM-processes, respectively, at *l*, *r*, *n* levels; $I_l + k(i +$, $I_r + k(l +$, $I_n + k(r +$ are appropriate investments for the transition from one level of maturity of BIM-processes to another; *k*-cost reduction factor at each subsequent level of development of BIM-technologies (k > 0).

There are two strategies of economic and technological transformation: sequential transition and abrupt transition. Analysis of functional dependence in Fig. 4 shows that as the BIM development potential increases, the line $k_{BIM} 1$ approaches the vertical axis of Investment (I), therefore, the critical value m 'decreases.

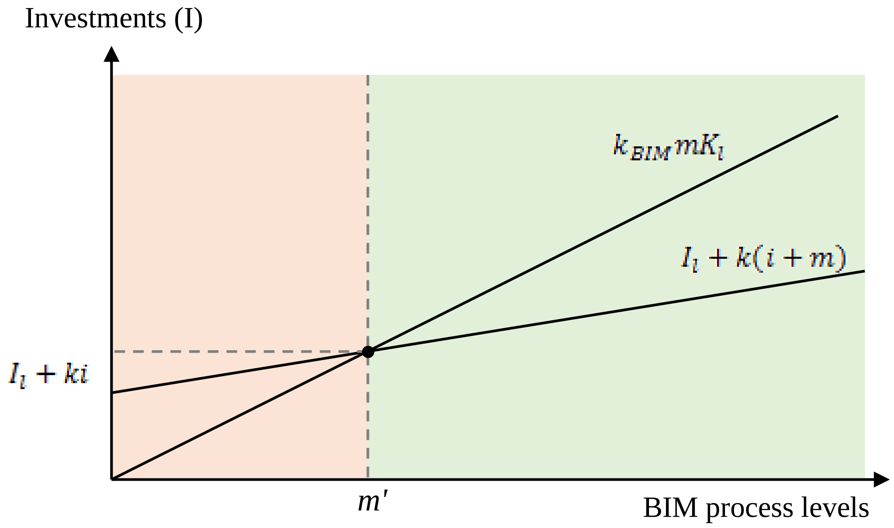

Figure 4: Functional dependence of BIM-investment development potential on the level of maturity of BIM-processes

Thus, the high potential of information modeling technologies contributes to a more smooth transition from one level of maturity to another, which indicates a high rate of economic growth and a large scale of production, which contributes to a more even transition to a new economic and technological level. Therefore, the first strategy of consistent transition of economic and technological transformations is more acceptable.

The minimum economic and technological step *m'*, which will be economically feasible, is determined by the ratio:

$$m' = \frac{I + ik}{k_{BIM} K - k} \tag{8}$$

The proposed model of choosing the strategy of transition to BIM and further technological development is an evidence base for choosing the best way of technological transformation in the company based on the analysis of planned costs, production volumes in the implementation of innovative and technological potential of the company. This model makes it possible to estimate the minimum economically justified technological step that the company must withstand to move to the next level of maturity of BIM-processes.

Fig. 5 presents a scheme of the formation of a team of BIM specialists to manage construction projects at different stages of the lifecycle.

The BIM-manager should appear at the beginning of the process of implementing information modeling technologies. At the initial levels of maturity of BIM-processes in the company, the manager is actively involved in the development of work processes, standards and templates of the company. In the future, supports the information model, maintains it up to date, as well as forms training programs and training of employees.

It is recommended to connect BIM-masters during the design process using information modeling technologies. The key task of the BIM-master is the technical support of the information model from the creation of means of entering information into the general data environment to the implementation of expert support for users of BIM-content.

The BIM-coordinator is responsible for ensuring the integrity of the information model by integrating the results of the work of specialists in related specialties according to the approved rules and standards of the company.

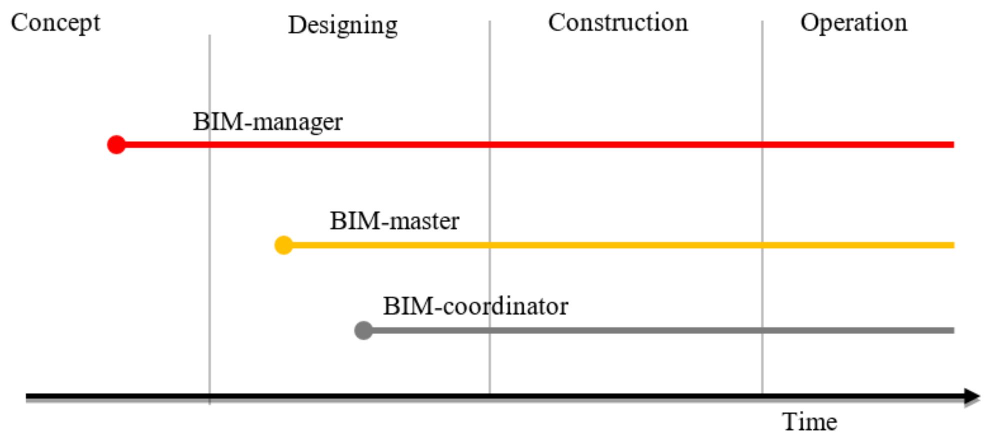

Figure 5: Formation of a team of BIM specialists to manage construction projects at different stages of the lifecycle

It is necessary to transfer all specialists of the organization to the new technology to achieve the maximum effect from the transition to information modeling technology of the company. Modernization and improvement of existing tools in the company must already be performed. At this stage, it is necessary to replace the existing approach to solving the company's problems to innovative through training. It is important to keep in mind that the reduction of labour productivity in the early stages is an inevitable phenomenon (see Fig. 6), which with effective management of learning processes will be replaced by growth. Thus, the choice of educational technologies is one of the determining factors influencing the effectiveness of the transition to BIM-management.

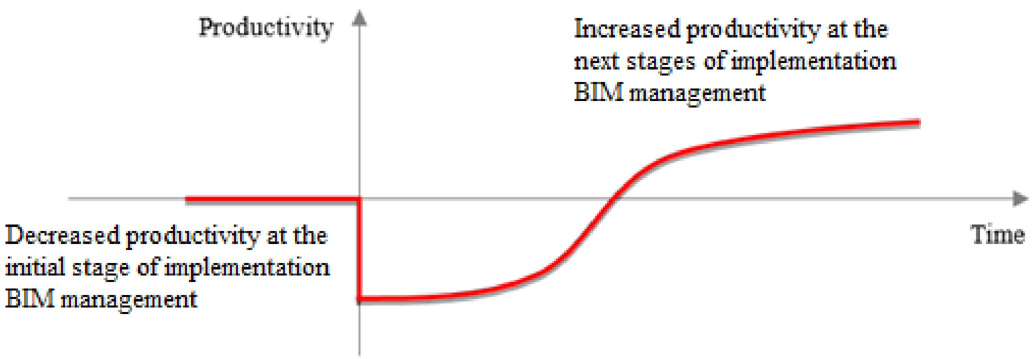

Figure 6: Changes in productivity during the transition to BIM-management

In fact, it is necessary to rethink the usual stages of project implementation in connection with the massive digitalization of activities in the construction industry. In particular, the "design" stage, usually ending with the receipt of project documentation in different countries of different composition and depth of detail in changing conditions, will most likely end with the creation of a "digital twin" of the future real estate object, which has been checked for collisions and other inconsistencies, supported by the appropriate library digital elements necessary for the implementation of the project, containing complete information about all kinds of building materials, structures and engineering equipment. It is this prototype of the construction site that is the digital information BIM model. At the same time, a digital model of a construction object can really include all the comprehensive information necessary not only for construction, but also for operation, modernization, reconstruction and subsequent liquidation of the object.

3. Organizational transformations in the project management system based on Building Information Modeling

The emergence of new and the transformation of old responsibilities is inevitable when a construction company switches to BIM-management.

Fig. 7 presents a model of organizational transformations in the project management system, when BIM technologies are introduced in construction projects. Recommendations for project managers on monitoring the implementation of the project are developed using BIM logic in connection with the active development of the use of information technologies and information about an object throughout the entire life cycle through the use of BIM models.

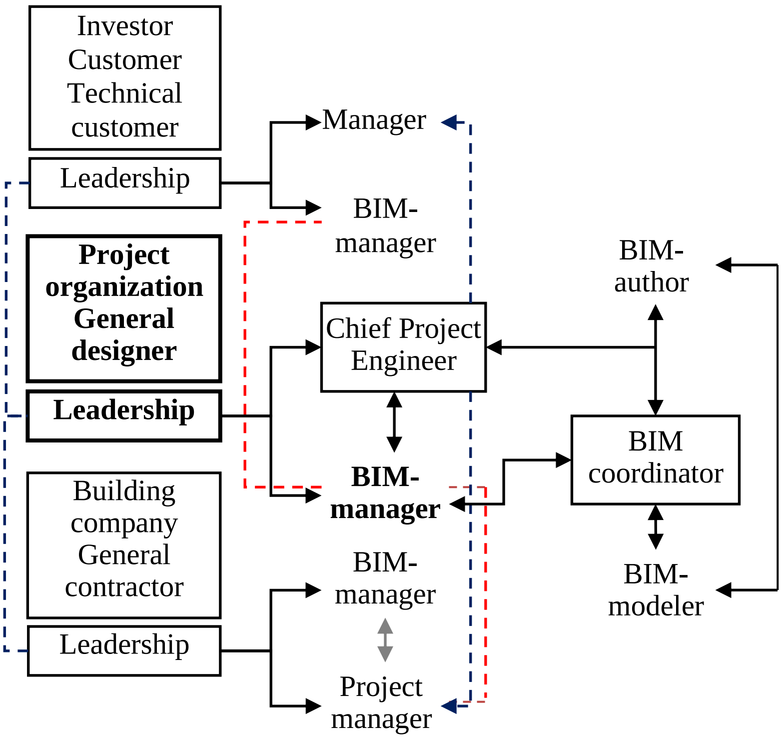

Figure 7: Model of organizational transformations in the project management system, when BIM technologies are introduced in construction projects

Fig. 8 presents a model of project BIM management team. Before starting the project, the team of performers determines the general strategy for developing the model, after which the BIM manager prepares a project file for joint work based on the created template. It is the BIM manager that "launches" the project. Then the other participants are already connected to it, creating their local copies, linked by synchronization with a common central file.

BIM-modeler.

This specialist creates libraries of components and reproduces CAD data from 2D drawings into 3D model. It is the responsibility of this specialist to create the components that make up the information model. This specialist does not solve any engineering problems. It should be noted that these functions can be performed by both the BIM-author and the BIM-coordinator in parallel with the main responsibilities.

BIM- author.

This specialist develops the project, maintains the model, and provides technical coordination. This specialist carries out design duties with BIM-software and supports the BIM-concept. The qualifications of a BIM-author in working with software have to correspond to his engineering position and the complexity of the design work entrusted to him. The minimum qualification threshold for a BIM author is basic knowledge of the software in which he will work an understanding of the principles of collaboration and knowledge of the BIM standard.

BIM-coordinator.

This specialist develops the BIM Execution Plan, conducts regular audits of the information model and checks it for collisions. This is the person responsible for the information modeling process in the BIM project. BIM coordinator in its pure form does not accept or agree on design decisions.

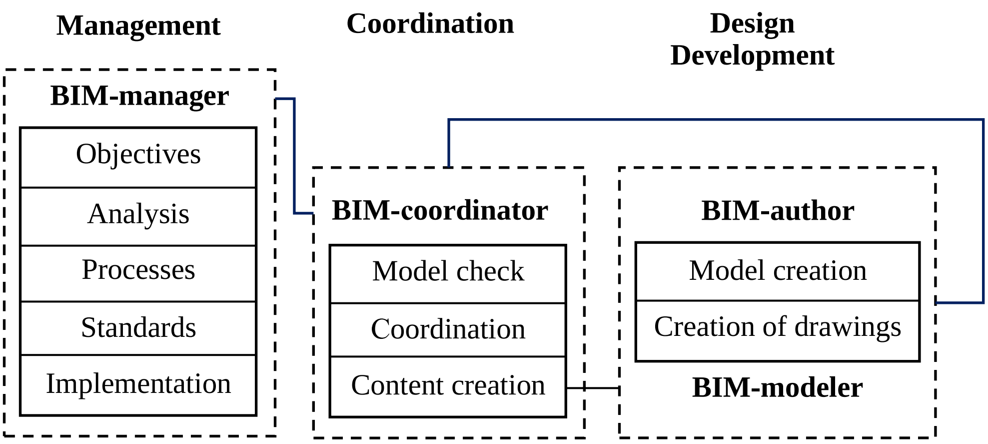

Figure 8: Model of project BIM management team

BIM-manager.

This specialist is engaged in the development of a BIM-process management strategy, internal regulations, training methods, BIM Execution Plan and audit the information model. If the BIM-author and BIM-coordinator are inherent only in design organizations, then the BIM-manager should also be in the service of the technical customer and in the construction general contractor. The duties of a BIM-manager in a design organization differ from those of a BIM-manager in the customer service and a BIM-manager in a construction general contractor. BIM-manager in a design organization performs the following main duties and functions:

- development of a strategy for creating a BIM-model and internal rules for working with a BIM-model, preparing a file for collaboration;
- development of modeling and design standards, unification of various elements for working with the model;
- organization of storage of related files and source data files;
- managing the creation of required library items model management, administration and verification of information in the model;
- coordination of the work of specialists;
- training employees to work with the program, consulting at all stages of work;
- distribution of tasks and changing roles between project participants exchange of experience with other specialists in the organization;
- study and implementation of new BIM-programs and BIM-applications that help in the work on the project.

The main task of the BIM-manager in the project team is the information technology management of the creation of the BIM-model and the coordination of the actions of all participants in the project BIM-process.

4. Conclusion

The article discusses the need to transform approaches to the formation of construction project management teams in the context of digitalization of the construction industry based on the use of BIM technologies.

The results of work present two models of organizational transformations of the project BIM-management system and the project BIM- management team, which are both the "brain" and the main resource that determines the quality of management, interaction, support and the success of projects.

It is necessary to revise the existing approaches to the formation of management teams for such projects for the effective implementation of modern mixed, hybrid projects at the intersection of information technologies, technologies for organizing construction production and the production of building materials and structures. Implementation of BIM technology in construction projects is impossible without BIM-manager.

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