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Development of Approaches and Organizational Models for the Mass Implementation of Information Modeling Technologies in the Investment and Construction Sphere

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Abstract: The rapidly increasing use of building information modeling (BIM) technologies in the world is highly relevant to the search for new approaches and managerial models for enterprises in the construction sphere. As shown in the study of several developing countries, there is a certain lag in this area compared with highly industrialized countries. A comparative analysis of countries in terms of the level of spread of BIM technologies was made using open data from job search Internet sites. In this regard, the urgency of the research is due to the need to develop appropriate approaches to intensify the implementation of BIM technologies in the construction and operation of buildings. The purpose of the study is the development of methodological foundations and applied models of functional interaction between participants of construction projects based on BIM. As a working hypothesis, the authors assume that the mass application of BIM technologies is possible in providing a set of measures of different nature: market, non-market, legal, economic, and organizational. The main results of the study provided a solution to the problem of a significant expansion of the scope of BIM technologies in the construction sector through the formation of an information eco-environment for interaction of participants in the project management system.

Keywords: building information modeling; BIM technologies; investments; construction; development; innovative process; software; risks

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1. Introduction

Use of BIM technologies is a global trend in engineering and construction (McGraw Hill Construction 2014; Dodge Data & Analytics 2021). BIM is generally considered to minimize project-related risks and uncertainty, and, therefore, improve the financial outcomes of the projects. To do so, the construction industry is gradually departing from traditional two-dimensional modeling and accelerates the shift towards digital three-dimensional modeling solutions. Some developed countries already use BIM in 80–85% of all design and construction projects (Ullah et al. 2019; Gorodnova and Lemeza 2022). As developing countries stay behind (Ariono et al. 2022), their construction companies, academia, and construction governance bodies face a challenge of fast-tracking development, implementation, and application of BIM. In order to change the status quo, it is necessary to improve the software development level (Boyko 2020), increase the amount of BIM-intensive construction projects, improve construction quality, and cut costs and construction time (Boyd et al. 2016). It is necessary to keep in mind that implementation of BIM is not a goal by itself but is a tool for efficient implementation of construction projects.

1.1. Literature Review

Use of BIM technologies allows a digital representation of objects' physical and functional properties and making models, where changes to parameters causes immediate recalculation of the others (Eastman et al. 2011; Sinenko et al. 2020). Thus, the building information model becomes a basis for what-if analysis and decision making while implementing project life cycle stages. BIM connects different project stakeholders such as owners, architects, designers, and construction contractors.

Generally, (Eastman et al. 2011) building information modeling covers three stages of the construction project life cycle, including design, construction, and operations, and brings positive results at every stage. During the design, BIM allows the optimizing of the project concept, limits the amount of rework and number of errors through three-dimensional visualization, and improves design productivity (Alekseev et al. 2019). During construction, optimized specifications allow decreasing logistics costs and simplify procurement. Tracking of construction activities can be improved by using various project metrics, devices, and solutions using digital models (Shalina and Larionova 2021). Digital copies provide transparency required for asset operation and maintenance. Altogether, BIM sets the foundation for a technological breakthrough in managing construction projects.

This approach covers neither development of BIM software by IT companies nor object commissioning and assets delivery to the markets. Taking these steps into consideration would create a more complex and objective system of measures to streamline and facilitate the complete life cycle of BIM—from software development through design, construction, and commissioning of the assets, to marketing these assets and operation and maintenance of the commissioned objects.

Construction project managers develop and customize an efficient digital environment for stakeholder collaboration covering the abovementioned stages, developing and implementing normative documents using support from regional BIM centers and specialized consulting companies (Kumar and Hayne 2017). Development project life cycle implementation based upon BIM technology allows solving complex problems of project proposals preparations, technical and financial expertise and surveillance, project management and audit, environmental assessment and consulting, and estimate and cost evaluation (Poljansek 2018). Mass use of BIM decreases chances for errors in project documentation by about 40%, and cuts design time by 20% to 50%. Time required for examination of design documents can be cut five to six times, the duration of project documents' examination and approval can be decreased to 90%, the duration of the project investment phase can be decreased by 50%, construction time can be decreased by 20% to 50%, while construction and operation costs can be decreased up to 30% (McGraw Hill Construction 2014; Ribeirinho et al. 2020).

Stakeholders of these processes include asset end users, authorities, developers, design companies, construction contractors and object operators, materials and equipment vendors, engineering companies, software development companies, banks, insurance companies, and other entities. All stakeholders are able to access BIM models and use the models to control their risks and costs. The benefits of using BIM also include accounting for stakeholder interests and resolving conflicts at every stage of the asset life cycle (Ullah et al. 2019; Ariono et al. 2022). In the course of developing building information models, it is necessary to track their correspondence with real processes and assess the way they support stakeholder interaction. Developers must also assess compliance with corresponding regulations in the field of BIM and related risks.

1.2. Research Goal

Research was aimed at substantiating a need to form and develop a joint ecosystem for managing projects that would consist of subsystems for stakeholder interaction. Another goal is to formalize measures for private–public support of BIM development and implementation processes. These goals differ from the initial goals of developing and using BIM for design and construction of single realty objects. Informational models were used to automate design, improve design quality, facilitate construction, minimize the number of design and construction errors, and reduce costs. It was achieved by using software from leading IT companies. As a result, it is now possible to design a project-level building information model, and derive related models for construction preparation, execution, and object operation. Today, digital transformation in the construction industry must occur on executive and economic levels. This requires stimulation of BIM implementation, mass usage of BIM, and minimization of BIM-related business costs in construction projects.

It is suggested that it is possible to formalize measures of public and private support of BIM implementation in the construction industry. These measures must reflect BIM utilization by project stakeholders at different project stages. Results include a system of organizational mechanisms for supporting BIM software development and BIM application in assets design, construction, commissioning, and operations. Practical results include unification and universalization of information and organizational approaches to modeling software development, object design, construction, and operation, increasing operations transparency, and improving interaction among the development project participants, which will in turn promote the implementation and use of BIM technologies by all project stakeholders.

2. Theory and Method

2.1. Foundation of Research

In 2021, the Russian market of BIM technologies constituted about 1.5% of the global market (PwC in Russia 2020). Despite active state involvement including approval of a roadmap for implementing BIM in construction, development of a national standard for residential buildings' digital copies, and organization of state-sponsored BIM competence centers (Ozhigin 2021), no leading Russian IT company with multi-billion-ruble operations is working in BIM (TADVISER 2022b). Therefore, fast BIM market growth including the involvement of approximately 100 national IT companies into the construction industry (TADVISER 2022c) is almost impossible (Boyko 2020), even though the global construction market has potential to grow up to 70% (Gorodnova and Lemeza 2022), at least partially due to the use of BIM.

Nevertheless, research demonstrates positive results of using BIM technologies. In 2017 and 2019, Concurator consulting company together with NRU MGSU ran surveys on the use of BIM (CONCURATOR 2017; CONCURATOR 2019). Surveys covered companies of different sizes, working in design, construction, asset maintenance, and other fields. Applications included nuclear power plants, roads and railroads, industrial buildings, social and sport objects, and administrative and residential buildings. Companies used BIM for a different number of projects (from 1 to over 30), and usually (over 66%) implemented BIM-related processes using their own resources and through inhouse development of required competences. Overall, BIM was implemented on a relatively low (22%) level compared with the global construction industry and leading countries, and almost all national construction companies were at the first level of BIM maturity on a Bew–Richards scale (Ginzburg et al. 2016; TADVISER 2022a). At the same time, it was found that for 81% of the surveyed companies, BIM implementation results exceeded initial expectations. Key factors blocking mass implementation of BIM technologies according to a 2019 survey (CONCURATOR 2019) included the high overall cost of obtaining and implementing technologies, limited availability of qualified professionals, and insufficient regulatory basis for using the technology. Other factors included limited owner and investor demand displayed during the construction tenders, and the contradictory system of national standards regarding the matter (Tereshko et al. 2021; Blinov and Belyaeva 2020). Key advantages of implementing and using BIM in Russia perceived by the survey participants (CONCURATOR 2019) included improved understanding of project goals and deliverables by stakeholders (70–72%), improvement of work quality and overall project implementation (72–74%), and data availability and accelerated data exchange (60–61%). Internal and external issues of BIM implementation and usage listed by respondents included lack of financing for technology implementation, complexity of management system reorganization, level of owner requirements towards quality, costs and time of construction projects, high software prices, and lack of professional support by private and public consultants.

Obtaining competencies in BIM is possible both in the process of professional activity and at the stage of studying at university (Mingaleva and Vukovic 2020). Recent research (Moskvina and Larionova 2022) demonstrated that it is possible to obtain higher education qualifications in BIM in 169 Russian universities, on 30 educational programs, of which 19 are bachelor and specialist -level programs, and 11 are master programs. The annual number of graduates in the field of informational modeling equals 20,483, and that totally covers the number of vacancies. However, the situation is different regarding regions. For example, there is no demand for specialists in 11 regions, and there are no training programs there, while in 22 regions there is no demand, but training is available. In 37 regions coverage of vacancies by local graduates does not exceed 5%, in 15 regions the coverage is within a 5-14% range. Leaders in coverage include the Tomsk region—27%, Voronezh with 23%, Saint-Petersburg—19%, and Moscow—18%. These facts demonstrate uneven coverage of vacancies by university graduates and create substantial differences in regional processes of BIM accelerated introduction, and mass usage in competitive environments.

Initial stages of BIM implementation in developed countries, such as Great Britain and Singapore, were also not without difficulties. For example, the four-part British national standard BS1192 "Collaborative production of architectural, engineering and construction information" was took ten years to develop (MagiCAD 2020), and at the initial stages of its implementation the level of collaboration and productivity of estimators, designers and construction specialists decreased in almost all project life cycle stages.

According to the BIM Handbook (Eastman et al. 2011), the international leaders in the field of BIM technologies include ArchiData Inc. (Canada), Asite Solutions Pvt. Ltd. (Great Britain), Autodesk Inc. (USA), Dassault Systems S.A. (France), Nemetschek AG (Germany), Solibri Inc. (New Zealand) etc.Developed countries implemented national-level support programs for BIM technology. Examples include the 3D-4D-BIM Program in USA (Wong et al. 2011), and the successfully executed road map for mass implementation of BIM technologies in Singapore (Kaneta et al. 2016). In 2014 the European Union formed an EU BIM Task Group with a purpose of sharing positive experience of implementing public projects using BIM technologies (MagiCAD 2020). The international experience demonstrates the interest of national authorities towards obtaining complete and actual digital data on the constructed object (Ilinova and Mitsevich 2021). Utilization of the lessons learned shall facilitate design documents approval acceleration and forming of a joint national database of objects (Ribeirinho et al. 2020).

The list of successful BIM-intensive projects include Magnifica comfort-class apartment complex in Saint-Petersburg, built by Swedish Bonava company, West Port apartment complex in Moscow by PIK Group, and Irina Viner-Usmanova Rhythmic Gymnastics Palace in Luzhniki, Moscow (PwC in Russia 2020).

State support of BIM development and implementation in Russia was concentrated mainly in developing Federal Law No 151 dated at 27 June 2019 (Government of RF 2019), which introduced terms of information modeling and a construction information classifier into a national Urban Development Code, and preparing a draft law on regulatory sandboxes in the area of digital innovations. Five codes of construction regulations and eight national standards were developed (BIM-Association of Russian Federation 2017; Blinov and Belyaeva 2020; Golovin et al. 2020; Chesnokova et al. 2020), some of which were later suspended for various reasons. Current plans for development include 15 standards and 10 codes.

The companies that successfully tried information modeling will most probably continue developments in this area; however, 50% of the respondents that did not use BIM by the time of the survey displayed no intent to use it in the future, while 42% did not give a definite answer. For 2022, this situation is troubling, but there are reasons for sticking to the existing 2D design systems, and there is a lack of intentions to switch to 3D systems. First of all, it is necessary to determine the goals of using BIM technologies in the complex sphere of organizing and managing development projects and creating and operating complex labor and material-intensive assets. It is evident that BIM technologies are not a cure-all, for example, development of unique engineering solutions for buildings and utilities will still require specialized CAD, GIS, and simulation software (NRU MGSU 2016). BIM technologies can be a supporting modeling tool used at higher levels of planning and design in order to improve the interaction of project participants and run a large number of routine activities (Mishlanova et al. 2022), such as making changes and correcting errors in design documents, formalizing design, and running what-if analysis of constructions and equipment combinations. Transition from 2D to 3D will allow for performing efficient and timely corrections of material requirements and amounts of time and effort required to perform different activities during the development projects. It is also necessary to consider that line managers of contractor and subcontractor companies still have no competences in BIM software, and still report performance using 2D data that are later converted to 3D by specialists. Usually, the use of BIM processes is controlled by the developer using available Russian or international software (Ginzburg et al. 2016), unified BIM standards for stakeholder interaction, and a pre-developed generalized building information model.

2.2. Methods of Research

The problem of high demand for BIM software developers, and designers, construction engineers, and maintenance professionals using BIM, in developing countries requires special attention. The authors performed comparative analysis of demand for BIM-proficient specialists on labor markets of different countries. Analysis was performed using data from the large international vacancy aggregator (https://www.indeed.com/ accessed on 19 November 2022) collected from job search portals and employers. The aggregator runs 62 country-specific job search sites with detailed vacancy descriptions and requirements for applicants in different languages. Selection was performed using the following search terms: BIM, Revit, CAD, Information modeling, etc., in the names and descriptions of the vacancies with the following manual validation. Information for Russia was collected using data from the HeadHunter (https://www.hh.ru/ accessed on 19 November 2022) aggregator site that contains information for 89 regions of the country. To assure data comparability, the relative number of vacancies per 1 million population was calculated, and a country rating was built.

To reach the research goal, the authors used the stage-based approach to project management and the sequence of steps for the innovations process to formulate a multistage approach to the implementation of BIM technologies in construction and described the required measures for public–private support of the said process. Research of complex and multistage socioeconomic processes allowed the design of process control mechanisms (Aastrup and Halldorsson 2008). While comparisons with research of BIM-concept development issues (Ariono et al. 2022) in developing countries were made that included extensive analysis of categories that stimulate BIM (including technologies, processes, and policies), and featured the list of BIM drivers, barriers, and development opportunities, the key accent in this research was the formation of project-stage-specific environments of stakeholder interaction within a development project management environment.

The roadmap for research in the field of accelerated implementation and mass use of BIM technologies in developing countries includes the following stages: definition of research goals, selecting a research basis (development project structure, known list of innovation process subprocesses, and stages of BIM technology development and implementation), forming environments for stakeholder interactions within a project implementation environment, and development of mechanisms for private–public support of BIM technologies.

Accelerated wide scale implementation of BIM technologies in development is considered from the point of developing and implementing complex development projects. This would require development of innovative software by IT companies and specialized providers of information models for design and construction processes, with further commercialization of the said software. It would also require acceptance and implementation of BIM-related technological innovations and three-dimensional parametric modeling in construction companies. Finally, as a result, owners will be able to provide end users with better objects in better time for less money. Another group of benefits can arise from use of "as-built" models while operating and maintaining created assets.

Substantial complexity of developing and implementing BIM solutions requires reviewing them using Robert Merton's middle-range theory by general statements that can be verified by data in order to integrate theory with empirical results. One can consider a chain of processes and subprocesses occurring within a sequence of four BIM technology application stages. The process of BIM software design by IT companies is followed by utilization of the software by development project stakeholders, creating assets that are then commissioned, sold on the market, and are operated for a long time, undertaking maintenance and various types of repairs. The four-stage model of BIM technologies' application at its first stage involves developers of information modeling technologies that perform internal subprocesses of the "novation to innovations" software design and commercialization process (Çıdık et al. 2017). At the second stage, software users implement these external novelties in the "innovations to novation" process for modeling asset design and construction algorithms. Delivery of project results to the owners or markets recreates diffuse and consumer-related subprocesses (Salaman and Storey 2002) of the "novation to innovations" process of delivering better and less expensive assets. Asset operators, in turn, learn and apply previously created "innovations to novation" BIM models as external novelties and use them for the purpose of asset preservation and improvement by means of operation and maintenance processes.

It is suggested to present the complete list of subprocesses for the above mentioned four-stage BIM implementation process as follows:

- Subprocesses on the "novation to innovations" process (Salaman and Storey 2002), implemented within the software development companies, including the novation subprocess (fundamental and applied research and novation formation); innovation subprocess (novation transformation into innovations, design, development, and production of innovative products); diffusion (selling innovative products on the consumer markets); consumption (of innovations); and replacement (innovations improvement) subprocess. The overall process occurring on the BIM software development company side can be described as a classic "novation to innovations" one.
- Subprocesses of the learning and application of 3D information modeling "innovations to novation" process that occurs at software user companies include the procurement of digital modeling innovative solutions on the market, initial learning of this novation, building it into existing production processes or replacing existing processes, support of the novation introduction processes, training personnel, developing BIM-related subsystems within the ecosystem of enterprise project portfolio management, improvement of the regulatory basis for implementing and using BIM; and improving efficiency of using information modeling.

The following process of presenting new products of construction to the market can be described as a "novation to innovations" process with classic subprocesses (Salaman and Storey 2002). Building information models designed for facilitating assets design and construction can be further improved and used to support asset operation, maintenance, and improvement. Terminal conditions for efficient BIM technologies' deployment include requirements concerning preservation of development project stage sequencing: the sequence of novation and innovative processes and subprocesses of creating new products—both software and construction—and the stages of marketing.

Issues associated with accelerated BIM introduction and utilization can be resolved using a thematic research methodology based on the nomological approach and middle-range theory concepts. This allows the study, generalization, and understanding of the essence for complex multistage socioeconomical processes, organizational mechanisms

(Popov et al. 2021; Mingaleva et al. 2020), and associated risks (Shalina and Larionova 2021).

The working thesis of research involved the possibility of achieving mass implementation and utilization of BIM technologies in development involving multiple stakeholders through various support measures including general market-level ones (forming conditions for equal and open competition and supporting a certain level of quality, price, and time-related expectations towards the construction products, supporting sales of specialized software and hardware, and staff training support); non-market support including monetary and non-monetary support of BIM implementation through private to public partnership mechanisms, industrial, regional, and social support of information modeling development; regulatory support (creating a favorable environment for obtaining and using said technologies, wide-scale discussion of BIM development problems in the professional community and by the general public); pinpoint financial support (financial stimulation of BIM development, implementation, and utilization, and supporting supply of construction products created using BIM); and organizational support (creating BIM development foundations, regional BIM consulting and support centers, and assistance in creating project life cycle support and stakeholder collaboration environments), etc.

3. Results

3.1. Demand for BIM Specialists in Different Countries

The authors performed comparative analysis of demand for BIM-proficient specialists on labor markets of different countries. Results are presented in Figure 1.

Figure 1. Ranks of countries by the quantity of vacancies in BIM dated 8 September 2022 (https://www.google.com/maps/d/edit?mid=1gd-U8SeJRDjzIaSpHx0_kqXLuefqZGw&usp=sharing/ accessed on 19 November 2022). The lighter the color is, the higher is the need for specialists in BIM.

Analysis of demand for BIM specialists demonstrated the highest demand in the developed countries. The leading country in the number of vacancies per million is the Netherlands (over 200 vacancies), followed by Ireland and Singapore (over 100 vacancies). Switzerland, Luxemburg, Japan, Belgium, Germany, and Hong Kong have more than 50 vacancies per million, while Norway is the last country among the top 10. It is necessary to note that these data correlate well with the country ratings in "Readiness for frontier technologies index" published by the United Nations Conference on Trade and Development (United Nations Conference on Trade and Development 2021). Spearman's rank correlation coefficient is 0.87, which is a positive high-level correlation. The latter supports the point that favorable economic conditions and supportive government policy promote implementation of new technologies (Jiang et al. 2022), with the following increase of demand for specialists with digital competencies.

Developing countries, including China, India, Brazil, and Argentina, display a small demand for BIM professionals (one or less vacancies per million); however, Russia with close to 10 vacancies per million holds the 24th position in the rating, which illustrates essential shifts in the field. At the same time, the authors note that BIM is not implemented with the same pace in different regions. For example, 35 Russian regions display no demand for BIM professionals, in 32 regions the number of vacancies is 1–4, in 12 regions it is 5–9, and in 5 regions there are 10–15 vacancies per million. Leaders include Moscow and Saint Petersburg with 44 vacancies per million, and the Novosibirsk, Sverdlovsk, and Tula regions having 20, 17, and 15 vacancies per million, correspondingly.

Analysis of BIM concept formation and development results in developed and developing countries demonstrating substantial differences in the maturity level of concept employment and application. Each developing country can select its specific problem zones and determine key maturity improvement directions, measures, and their timeframe. The key development direction for the Russian Federation at the moment is economic and organizational substantiation of measures for accelerated implementation and mass use of BIM.

3.2. Organizational Mechanisms for Facilitating BIM Implementation and Utilization

The existing definition of BIM (Sinenko et al. 2020; TADVISER 2022a) can be reformulated as an innovative approach to the design, construction, and equipment of buildings, their commissioning, introduction of construction products to markets, and providing maintenance and repairs of commissioned assets. The approach requires the collection and complex processing of complete architectural, technological, economical, and other data over the whole life cycle of an asset from the making of a conceptual decision to decommissioning. This would allow analysis of all key processes of BIM software development, object design, construction, commissioning, marketing, and operation in the ecosystem of managing projects and the BIM subsystem and forms a unified interaction environment (project ecosystem) for all project stakeholders, providing a means for simultaneous processing of a common dataset using common formats.

Based on the methodology that is used to implement BIM at different stages of the construction project cycle and middle-range theory, the authors developed five organizational mechanisms aimed at lowering risks of BIM implementation and utilization in construction.

Mechanism 1 is used to manage known subprocesses of a classic "novation to innovations" process implemented in software design companies and control public and private support measures for accelerating BIM development. The mechanism is described in Table 1 and presents mandatory measures to be initially undertaken through private–public partnerships. Measures include preferences for software development companies, providing them with methodological support, and development and improvement of information modeling standards. Overall, the mechanism allows public authorities and private entities to understand general issues related to the support of BIM software development and to determine depth and possible ways of involvement and support.

A similar method was applied to develop a mechanism for managing BIM software deployment in companies that participate in development projects. The mechanism also covers support measures for BIM implementation and utilization at different stages of project life cycles (Table 2).

Table 1. Managing subprocesses occurring at BIM software development companies and public–private support measures for accelerated development and implementation of BIM in development projects.

	BIM Software Design Subprocesses	Software Development Support Measures				
		General Market	**Non-Market**	**Regulatory**	**Focused Financial Support**	**Organizational**
1	Novation	1.1 Forming conditions for competition in the field of BIM development in the IT market	1.2 Stimulation of IT companies towards improvement of BIM technologies	1.3 Internal support of developments in the area of BIM technologies	1.4 Internal support of developing BIM software	1.5 Provision of methodological assistance in organizing associations of developers
2	Innovation	2.1 Developing preferences for companies applying BIM-related innovations	2.2 Tax support measures for activities related to developing BIM software	2.3 Making changes in legislation regulating BIM software development	2.4 Providing subsidies and preferential loans to developers	2.5 Organizing industry-level BIM forums for discussing issues with innovations
3	Diffusion	3.1 Assisting software developers in entering the IT markets	3.2 Preferences for introducing BIM software	3.3 Developing standards stimulating BIM software introduction to IT markets	3.4 Providing subsidies and preferential loans to developers	3.5 Creating entities for software introduction to IT markets
4	Consumption	4.1 Stimulating marketing in IT sphere aimed at developing and using BIM solutions	4.2 Preferences for companies using BIM software	4.3 Development of industry standards stimulating use of BIM	4.4 Financial preferences for users purchasing BIM solutions	4.5 Tax preferences for companies using BIM software
5	Replacement	5.1 Stimulating demand for improving BIM technologies	5.2 Stimulating growth of customer requirements towards BIM hardware and software	5.3 Developing perspective standards in BIM	5.4 Improving support methods for BIM software developers	5.5 Forming preferential environment for innovations in BIM technologies

Table 2. Managing subprocesses of BIM software implementation in development project participants and public–private support measures for accelerated BIM implementation and utilization.

	Implementation of BIM Technologies in Construction Process	Support Measures				
		General Market	Non-Market	Regulatory	Focused Financial Support	Organizational
1	Procuring (licensing) software	1.1 Forming critical demand for construction industry products on regional and national level	1.2 Stimulation of BIM implementation in construction	1.3 Developing federal, regional, and industrial BIM technology standards	1.4 Target public and private subsidies and loans for purchasing software	1.5 Organizing conferences and symposiums devoted to use of BIM technologies
2	Organization of software implementation by the users	2.1 Support of collaboration with software developers, consultants, and regional BIM centers	2.2 Assistance with training sessions on software implementation	2.3 Developing regulations concerning fast-track software implementation	2.4 Target public and private subsidies and loans for software implementation	2.5 Organizing mass BIM technology implementation training on federal, regional, and industry level
3	Software service support by developers	3.1 Stimulation of lowering the service support price	3.2 Organizational support of software developers aimed at lowering service prices	3.3 Developing standards and regulations on service support	3.4 Stimulating formation of a uniform digital environment for design and construction support	3.5 Integrating digital environments of the companies into construction industry environment
4	Training personnel to support BIM technologies	4.1 Stimulation of training involving consulting companies and regional BIM centers	4.2 Various forms of professional development in the field of BIM for the staff of technology users	4.3 Forming regulatory basis for professional assessment	4.4 Creation and support of national, regional, and industrial training centers	4.5 Organizing professional development system on national, regional, and industry levels
5	Forming stage-related BIM digital environments within the development projects' environment	5.1 Support of forming unified digital process model for project implementation	5.2 Support of incorporating digital project environments intro national urban development information system and other systems	5.3 Creating regulatory base for project digital environments and their components	5.4 Pinpoint support of the companies aimed at developing universal BIM solutions of national, regional and industry levels	5.5 Helping by involving consulting companies and regional BIM centers in the development of stage-related digital environments
6	Improving regulations concerning project life stages support	6.1 Supporting user initiatives in improving BIM standards	6.2 Improving BIM standards and regulations on national, regional, and industry levels	6.3 Public and professional discussion of improving BIM-related regulations	6.4 Development support for the most urgent regulations	6.5 Forming specialized BIM related structures in construction industry
7	Obtaining high level of BIM implementation maturity and efficiency	7.1 National, regional, and industry competitions in BIM utilization efficiency	7.2 Promoting BIM technologies among the end users of construction products	7.3 Developing algorithms and criteria for BIM efficiency stimulation	7.4 Developing national, regional, and industry guides for efficiency awards	7.5 Improving organizational mechanisms for performance stimulation

With this mechanism, users can select processes required to support implementation of BIM software, including professional training, competitions, and grant support improving BIM efficiency. To extend mechanisms 1 and 2, a third mechanism was developed covering management of general and production management subprocesses and functions of their participants at different stages of the development project life cycle (Table 3). The mechanism uses the stage-based approach to project implementation and determines stakeholder functions about the use of BIM technologies.

Table 3. Management processes and stakeholders in the course of implementing development projects.

	General Management Functions	**Production Management Processes for the Construction Stage of a Development Project Using BIM Technologies ***				
		Resource Management	**Time Management**	**Cost Management**	**Cost Management**	**Integration Management**
1	Planning project subprocesses	1.1 CTO/chief engineering officer of the construction company, department of BIM technologies	1.2 CTO/CEngO, department of BIM technologies	1.3 CFO	1.4 CTO/CEngO	1.5 Director/CEO
2	Organization	2.1 Construction superintendent, procurement dept.	2.2 Construction superintendent	2.3 Planning dept., financial dept., production dept., department of BIM technologies	2.4 Construction superintendent, production dept., department of BIM technologies	2.5 CTO/CEngO, contracts dept.
3	Control	3.1 Production dept., department of BIM technologies	3.2 Production dept., department of BIM technologies	3.3 CFO	3.4 Quality dept., department of BIM technologies	3.5 Director/CEO
4	Coordination	4.1 Construction superintendent, department of BIM technologies	4.2 CTO/CEngO, department of BIM technologies	4.3 Planning dept., financial dept., production dept., department of BIM technologies	4.4 CTO/CEngO, department of BIM technologies	4.5 CTO/CEngO, department of BIM technologies
5	Analysis and assessment	5.1 Production dept., department of BIM technologies, accounting dept.	5.2 Planning dept., financial dept., production dept., department of BIM technologies	5.3 Planning dept., financial dept., production dept., department of BIM technologies	5.4 Quality dept., department of BIM technologies	5.5 Contracts dept., department of BIM technologies

* Development project stages usually include concept stage, design and information modeling of object systems and subsystems, construction, delivery to the market (sale or lease of the object), operation of the object, modernization and reconstruction of the object, and object disposal with project closure.

Mechanism 4 for controlling subprocesses of asset operation using BIM software is described in Table 4. While mechanism 3 determines and covers all stakeholder functions, including functions of IT specialists, mechanism 4 allows the use of previously developed BIM software for servicing and maintaining assets, and performing turnovers of objects and utilities.

Table 4. Managing operation of the commissioned assets for a production company using previously developed BIM models.

	General Management Functions	**Subprocesses (Planned and Unplanned) of Operating Commissioned Capital Assets**		
		Maintenance	**Routine Overhaul**	**Total Overhaul/Full Repair**
1	Planning	1.1 Shop heads, IT group	1.2 Chief engineering officer, shop heads, IT group	1.3 Chief executive officer, shop heads, IT group
2	Organization	2.1 Maintenance team head, IT group	2.2 Maintenance team head, IT group	2.3 Chief engineering officer, maintenance service head, shop heads, IT group
3	Control	3.1 Shop heads, IT group	3.2 Chief engineering officer, shop heads, IT group	3.3 CEO, IT group
4	Coordination	4.1 Maintenance team head, IT group	4.2 Chief engineering officer, maintenance team head, IT group	4.3 Chief engineering officer, maintenance service head, shop heads, IT group
5	Analysis and assessment	5.1 Technical dept., quality dept., IT group, production, and financial departments	5.2 Technical dept., quality dept., IT group, production, and financial departments	5.3 Technical dept., quality dept., IT group, production, and financial departments

The resulting mechanism of promoting BIM technologies within the development project environment is used to manage processes of BIM implementation, utilization, and competitive use during the stages of BIM rollout (Table 5).

Table 5. Accelerating implementation and use of BIM technologies in the course of BIM rollout and corresponding measures of support.

	BIM Technology Promotion Stages	BIM Rollout Stages		
		Accelerated Implementation	Mass Use	Competitive Use
1	BIM software development by IT companies	1.1 Consulting support through regional BIM centers and commercial entities	1.2 Organizing interaction among the IT companies and end users through regional self-regulating organizations	1.3 Stimulation of competition on regional and national BIM technology markets
2	BIM-assisted design of assets by software user companies	2.1 Forming grounds for collaboration between IT companies and software users	2.2 Stimulation of mass BIM technologies' utilization in construction by regional and local authorities	2.3 Creating competitive environment for using BIM solutions by design companies
3	BIM-assisted construction of assets by the users	3.1 Financial, technical, and methodological user support from authorities and regional BIM centers	3.2 Forming national and regional requirements for complete coverage of investment and construction programs with BIM technologies	3.3 Organizing competition in BIM technologies' promotion by authorities and self-regulating organizations
4	Delivery of construction products to the market	4.1 Developing marketing concept for improving time to market values for construction products using BIM	4.2 Mass supply of modern construction products created using BIM	4.3 Forming competitive advantages of products created using BIM on construction market through self-regulating organizations
5	BIM-assisted operation of commissioned assets	5.1 Mastering BIM technologies by maintenance staff	5.4 Organizing training to facilitate usage of BIM technologies at all stages of production	5.5 Developing and implementing guidelines on BIM effects on market positioning of the products

4. Discussion

Developing digital environments is a stable trend developed in developing economies (Stonig et al. 2022; Rudnik et al. 2021). Use of BIM technologies in construction increased urgency of forming the stage-specific digital environments in the course of development project life cycles (Stepanova et al. 2019; Rudnik et al. 2022; Bank of Russia 2021; Marnewick and Marnewick 2022; Cabeças and Marques da Silva 2021; Ramenskaya 2020; Riaz et al. 2022) with consecutive transformation into the company environment for projects. A digital platform can facilitate interaction between construction industry stakeholders and enable design of an environment (internal and external) for managing investment and construction projects (Hein et al. 2020; Yasnitsky et al. 2022). Process-control mechanisms developed for the four stages of using BIM technologies can form the foundation for the project environment-based approach of information modeling development in construction (Paulus-Rohmer et al. 2016; Calabrese et al. 2021).

An environment that makes business flexible and stable (Harvard Business Review 2020; Cingöz and Akdoğan 2013; Enrique et al. 2022) can be interpreted as a complex project uniting multiple participants, interrelated business processes, and corresponding information services, applications, and platforms on a "win-win" principle (Ribeirinho et al. 2020; Miklos et al. 2019). To enable efficient project implementation, it is necessary to break its complex organizational and technological environment into project-stage-specific environments.

The abovementioned mechanisms 1–5 can become the base for developing an environment concept of resolving the complex problem for implementing BIM in the development and construction industry. BIM technologies become a "digital glue" that helps in merging and improving programs, platforms, and services belonging to various project stakeholders. Results include formation of a unified five-stage process of the BIM rollout in a project environment including development of innovative BIM software, digital transformation of design and construction processes, delivery of construction results to the markets, and operation and maintenance of commissioned assets. Other results will include decreased risks of BIM implementation. This effect will be achieved through stimulation of demand for innovative technologies and increasing stakeholders' interest in promotion of BIM. For example, it is possible to define an environment for implementing project control functions based on mechanism 3 that covers scope and integration management, managing time, costs, quality, resources, risks, communications and information, contracting and procurement, etc. Other examples include environments for managing project stakeholders and project life cycle stages. All these environments can be reintegrated into a project environment through the use of BIM technologies.

5. Conclusions

A profound economic transformation of any given country or region cannot take place immediately, and strategies can become fruitful only 10 to 15 years from when they are implemented (Darie et al. 2019). This underlines the need for urgent and ambitious actions to implement digital technologies in different economic spheres including construction and search for new approaches and managerial models to accelerate this process.

The authors used matrix methods to formulate the concept and recommendations for the support of accelerated BIM implementation, mass use of BIM technologies, and competition stimulation in the BIM market through administrative, market, and information-related activities at different stages of the development project and during the operation and maintenance of constructed assets. Results demonstrate a systematic approach to resolving the issue of introducing BIM technologies into all or most development projects. Resulting matrices contain mechanisms for solving problems at different levels. Further research can be aimed towards formulating environments for different stakeholders within a project environment.

The value of results with regard to mainstream research is obtained through developing a systematic approach to the acceleration of wide-scale BIM technologies' utilization within a development project's implementation framework. This allows closing the gap between developed and developing countries in the level of digital transformation in construction. The approach covered almost the whole range of actions aimed at implementation of BIM technologies and measures for public and private support of using BIM at all stages of development projects. Developed matrices included organizational mechanisms for solving related issues on national, regional, industrial, and private levels. It can be recommended to continue further research in the area of BIM technology promotion and improving environments for various stakeholders within the common environment of project implementation.

Forming digital environments in engineering and construction is considered an essential factor of success in competitive markets of construction products. This stresses the importance of the accelerated transition of construction and IT professionals, designers, planners, and maintenance specialists to the information modeling platform. The results of this transformation will cover the whole complex of processes including development of software for design, construction, and maintenance companies, implementation of the software, and generation of building information models, followed by efficient construction of the objects performing to satisfy user demand and cost-efficient operation of the resulting capital assets.

Fast and efficient implementation of BIM technologies for the processes of assets' design, construction, operation, and maintenance required a thorough environment-based approach that was proposed by the authors on the base of subprocess-based matrices, including all stages of implementing BIM technologies, project life stages, and project stakeholders. It is necessary to continue further research aimed at support and stimulation of developing information technologies and reaching a high level of maturity in the coordinated and efficient use of information modeling.

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