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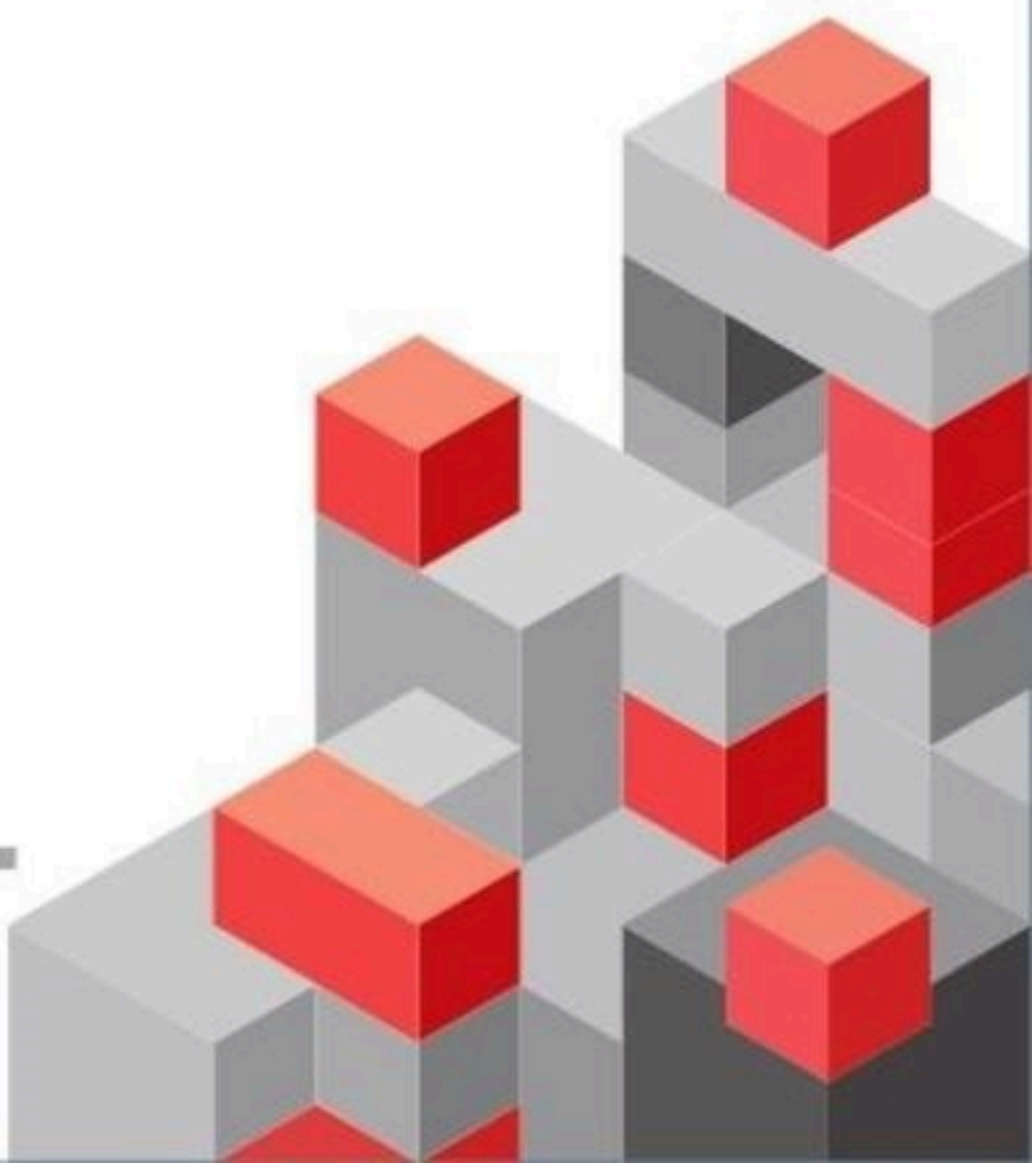

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Technical paper **Open Access**

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Knowledge management by construction management template for sustainable entrepreneurship

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Abstract: The article is devoted to the development of a new information and communication concept – "construction management template (CMT)". This concept changes the way knowledge management in construction is due to: taking into account the most effective modern and traditional methods of management; use of information technologies; end-to-end integration of different solutions into one information and communication tool.

CMT is an information and communication model in the form of a three-dimensional parametric part of a building or structure and the associated resource schedule of works used to plan and control management, architectural, technological, operational, and economic decisions throughout the construction project.

Combining different construction solutions and including management innovations, the developed information and communication concept is the latest way to manage knowledge in construction. Development of the information and communication concept CMT takes into account the use of modern software, innovative and most effective traditional methods of managing enterprises of the full investment construction cycle. The practical significance of the results lies in the development of recommendations for: finding and using efficiency reserves in construction management with the help of modern information technologies; development and use of construction management templates for knowledge management.

The obtained results allowed establishing the new method of management in construction increases the accuracy and speed of management influences, while reducing the cost of management. Thus, more sustainable development of construction entrepreneurship is possible.

Keywords: construction management template, knowledge management, construction information modeling, full investment construction cycle enterprise, scientific organization of labor and management

1 Introduction

A set of information technologies has been developed, which have the general name 'building information modeling (BIM)'. A distinctive feature of publications on this topic is the emphasis on software tools, rather than ways to manage the investment construction process with these programs. On the other hand, there is a number of management practices that increase production efficiency. One of them is knowledge management. There are many approaches to this discipline of management, but fewer publications have been found that cover this topic in relation to construction. The Soviet system of labor management in construction was based on the development of labor cost estimates and the scientific organization of labor and management. The foreign management approach is based on the prior role of leadership, organization, and production administration in particular system and process approaches and project management. The disadvantage of using these practices is that each of them is considered separately. In addition, the level of management culture in the construction industry as a whole is critically lacking. All this leads to irrational use of possible reserves of increasing construction efficiency,

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unreasonable costs of the introduction and further use of innovations, poor quality of management, and low sustainability of construction.

Thus, the urgent task is to develop an information and communication concept that would combine knowledge management practices, the most effective management methods, and the possibilities of modern software products. Given the high amount of commercial, managerial, and production information processed in the management of the investment construction process, 'construction management template (CMT)' can be such a concept.

2 Literature review

Analysis of information sources showed that a number of reserves can be identified to increase the efficiency of construction production.

- Scientific organization of labor and management in construction (Eremin 1970) in combination with modern information technology can be implemented as follows. The rational forms of labor organization are modeled detailing processes in accordance with the organizational structure of the enterprise. The introduction of new methods and techniques is modeled by technological maps and regulating documents. Rationing and stimulation of work are modeled by labor estimates and work schedules.
- Quality management system allows to increase the efficiency of corporate governance (International Organization for Standardization 2009, 2012b; UK BIM Alliance 2019). The use of information technologies makes it possible to implement a number of principles of these concepts. Orientation on a customer is implemented by such production models that are consistent with the customer evaluating the final product. The process approach is implemented in the development of models by determining the rights, duties, and responsibilities for managing the components of the models. A system approach is the most effective way to create production models. Continuous improvement is achieved through archiving versions of production models and comparing them by numerical criteria. Decision-making based on facts is possible in the presence of a reliable decision-making compact model that allows to quickly and objectively assess the state of the object of management.
- Project management is the core technology of management in construction, because any construction project aims to create a unique product (by architectural, planning, territorial, technological, financial, and other characteristics) and is limited in time. Therefore, the use of project management practices increases the efficiency of construction and determines the use of information management tools (International Organization for Standardization 2012a; Project Management Institute 2017).
- Engineering includes a number of different works and services (including exploration, consulting, architectural design, management, research, calculation, and analysis), the combination of which gives their customer additional value and competitiveness (Chau et al. 2005; Anees et al. 2013; Hu and Liu 2018).
- BIM, production, and financial modeling aim to implement better and less labor-intensive organization and control of construction in terms of product (construction object), processes, and cash flows of construction (Sacks et al. 2008; Park and Cai 2017). The BIM technology research works have shown (He et al. 2017) that the most interesting for scientists are the following topics: work environment, approaches to implementation, BIM stakeholders and implementers, BIM process, and BIM product. The most modern ideas about the technology of BIM are embodied in a series of standards ISO 19650 (International Organization for Standardization 2018b).

Knowledge management is the management of information resources owned by a person or organization, which allows making the right decisions and taking effective action in certain conditions (International Organization for Standardization 2018a). Such a discipline of management as 'knowledge management' dates back to 1993, in post-Soviet management practices – in 2003 (Milner 2003). Knowledge management aims at two main tasks: efficiency – the use of knowledge to increase production by increasing speed or reducing costs; innovation – the creation of new products, services, enterprises, and business processes. It is important to distinguish the concepts of 'information' and 'knowledge', the two main differences of which are the ability to comprehend and use knowledge in comparison with information. Review (Ahmed and Walewski 2017) went further and developed a basic model consisting of four levels of knowledge management maturity:

1. Data – unstructured information that has no use.
2. Information – information that answers the question 'who, what, when, where?' during production.
3. Knowledge – information that answers the question 'how?' during production.

4. Wisdom – information that answers the question 'why?' during production.

Accordingly, the knowledge management processes are described in the most detail: at the project level – in the construction standard ISO 19650-1: 2018 (International Organization for Standardization 2018b) and at the enterprise level – in ISO 30401: 2018 (E) (International Organization for Standardization 2018a). The most balanced approach to the resources and results of 'knowledge management' contains the specialized standard ISO 30401: 2018 (E) (International Organization for Standardization 2018a).

Studies show that knowledge management promotes sustainable development (Martins et al. 2019), especially at the enterprise level (Abbas 2020). The tool for this can be BIM (Liu et al. 2021). There are studies that express the sustainable development of the construction industry through project management indicators (Stanitsas et al. 2021). However, the review of the literature indicates that quantifying the effectiveness of sustainable development in construction requires further research (Lima et al. 2021).

The analysis of information sources showed that the allocated reserves of management efficiency do not only exclude but also do not complement each other. Thus, there is the unresolved problem of introducing effective management methods in the conditions of their mutual inconsistency in order to achieve sustainable development. Since any management methods are based on information tools, it is critical to implement them taking into account the capabilities of modern software products and the principles of knowledge management, in particular, the model of knowledge maturity. All this outlines the need to create an information and communication concept that would solve these combined problems – 'CMT'.

3 Research objective and methodology

The objective is to develop the concept of 'CMT' for knowledge management aiming at sustainable development in construction. To achieve this objective, the following tasks were solved:

- analysis of information sources on the research topic was carried out;
- information and communication concept 'CMT' was defined;
- ways of sustainable development of construction enterprise by the use of 'CMT' were proposed;
- recommendations for the implementation of the concept of 'CMT' were developed;
- the effect was determined that stakeholders can get when using the concept of 'CMT'.

The following methods were used in the study:

- while the development of basic schemes for the use of information tools in construction and of the concept of 'CMT' – methods of generalization and classification; system approach, combinatorial-morphological analysis, abstraction, formalization, methods of management theory; methods of qualitative and comparative analysis;
- while the development of recommendations for the implementation of 'CMT' and determination of its effectiveness – method of system-structural analysis and synthesis, methods of expert-heuristic evaluation and process-operational approach; methods of management theory; and methods of comparison and specification.

4 Results

4.1 Definition of information and communication concept 'CMT'

Investment construction projects are characterized by a high degree of detail of processes and are bound to the construction site. This specificity involves constant quality assurance of the product and processes of the project in terms of their increased complexity. Construction has signs of project orientation. It is possible to organize management in accordance with the processes of the 'Project Management Guide' (Project Management Institute 2017) by applying one of the basic principles of the quality management system (International Organization for Standardization 2012a, 2012b) (documentary recording of managerial influences) jointly with the traditional solution of scientific organization of labor and management in construction – process map. To do this, it is necessary to:

- expand the concept of 'process map' to the concept of 'CMT';
- form the knowledge base of the enterprise of the full investment construction cycle consisting of the CMTs;
- form models of operational activity of the organization (interdependent models of product and project processes) on the basis of these templates;
- carry out a documentary issue of tasks and acceptance of the final result by means of models (Figure 1).

The presented scheme (Figure 1) allows using information models to reorganize management. The current level of development of information tools allows:

- forming and working with models of any level of detail. This makes it possible to increase the accuracy and efficiency of managerial influences and save managers' time on planning and control.
- creating comprehensive interconnected product and process models of construction. This leads to a new interpretation of the concept of scientific organization of labor and management through the formation and use of templates for effective design and technological solutions.

Figure 2 shows the main ways of the document management of a construction company. It is based on the schematic diagram of Figure 1. The document in this scheme is an information storage unit (paper or electronic), which clearly states the responsibility for the data.

The developed scheme (Figure 2) shows that the main elements of the system 'Management in construction with the help of information technology' are the database of CMTs (based on the principles of knowledge management and scientific organization of labor and management) and product and project processes (containing product versions and project processes) 'target plan', 'operational plan' and 'fact'. The project process model includes financial processes and results. The efficiency of the implementation of the presented scheme (Figure 2) depends on the following: degree of development of the knowledge base of CMTs; sequence in fixing and realization of workers' responsibility for the information in the specified documents.

The CMT is an information and communication model in the form of a three-dimensional parametric part of a building or structure and the associated resource schedule of works used to plan and control management, architectural, technological, operational, and economic decisions throughout the construction project.

CMT:

- contains information on architectural planning and organizational, technological, and operational decisions;
- is an integral template in the design and is the element of the structure of the construction information model;
- includes other templates of greater detail;
- is the object of constant optimization in terms of architectural, technological, managerial, commercial, and other indicators;
- serves as a basis for industry databases of construction products, resources, and materials;
- has different details depending on the stage and characteristics of the construction under consideration;
- structures communications during the investment construction process.

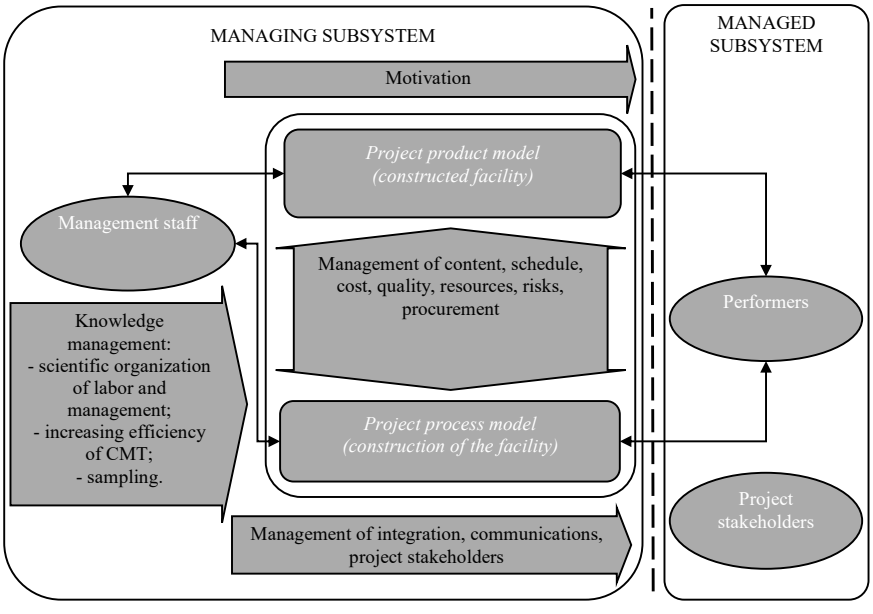

Fig. 1: Diagram of the knowledge fields of project management when using CMT and product and project processes models. CMT, construction management template.

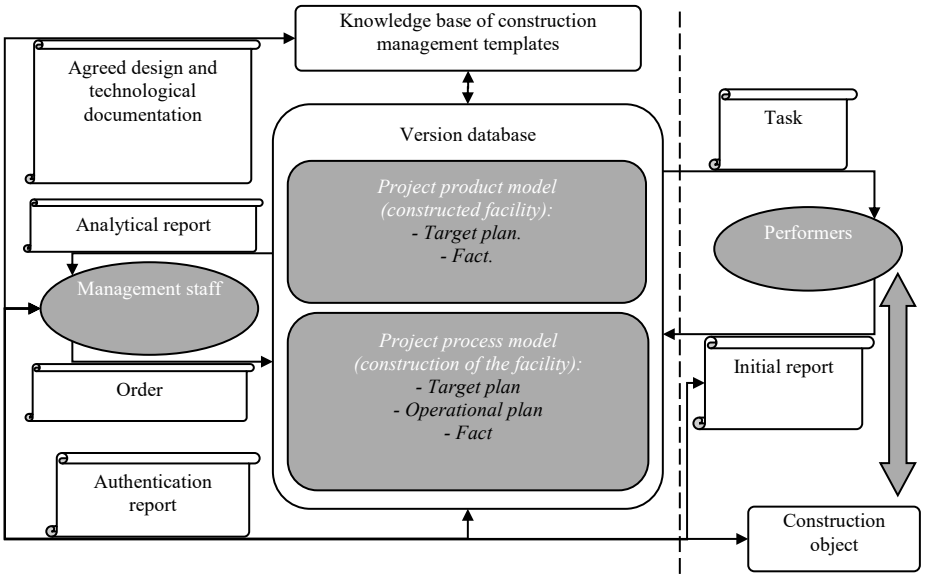

Fig. 2: Diagram of the managerial documents movement when using CMT and product and project processes models. CMT, construction management template.

It should be noted that the solutions included in CMT are the result of the design and product processes model of investment construction activities. At the same time, CMT is the task for the organization and a method of construction control. According to Table 1, we can identify a number of use areas of the concept 'CMT': commercial, communication, management, architectural, technological and operational. All of these areas increase the degree of sustainable development of the construction organization by organizing knowledge management of specified directions.

As it can be seen from the definition, the CMT consists of two databases: the project product model database (construction object) and the project process model database (construction schedule). These databases are mutually integrated by:

- structures of these models: spatial and technological;
- the classifier of CMTs;
- the classifier of parametric objects/works on construction of the facility with the formula of work volumes calculation.

In addition to the above, there should be used classifier of resources involved in the work and the classifiers of the outcoming documents of the models: the classifier of plans, sections, specifications, and drawing templates; and classifier of tasks and reports. When using CMT, the main principle is the database (as a source of information) and outcoming documents (as reflections of information).

The basis of the relationship between the elements of the database of the project product model (parametric objects) and the elements of the database of the project process model (processes) is the classifier code and the formula for calculating work volumes, which are integral parts of the CMT and are developed as its part.

Since a characteristic feature of CMT is its focus on the business model of investment construction activity, the degree of its differentiation is determined by organizational factors of the construction environment. That means the definition of the object of control (Figure 3). The maturity of the managing system is described in Figure 3 on the basis of Annex A of the document of International Organization for Standardization (2012a, 2012b), where 'intuitive management' corresponds to level 1, 'quantitative management' corresponds to levels 2–3, and 'optimization management' – levels 4–5. This consolidation was adopted in order to adapt the standard to the conditions of investment construction projects.

The types of CMT can be described by the degree of differentiation:

- Operating CMT – corresponds to the highest level of differentiation (intermediate construction products and individual operations). It is characteristic of a developed management system, because it implements the most detailed organization and control.
- Consolidated CMT – corresponds to the average level of differentiation (finished construction product (product model element) and work (several operations combined with one result)) and combines several operating templates. It corresponds to the standard organizational scheme of construction and is the most common for everyday use in production.

Tab. 1: Using the concept of 'CMT'

Direction of use	How the CMT is used
Commercial use	The CMT is a model of construction product.
	The use of CMT allows to assess its investment attractiveness at any stage of the project.
Communication use	The CMT is a formalized unit that regulates the procedure for issuing, processing, and receiving production information.
	The CMT increases the speed of data logistics, the accuracy of its provision, thereby reducing the cost of communications.
Management use	The CMT is formed under the influence of the organizational structure of construction.
	The CMT is an element of the business model of construction.
	The CMT is used for the delivery of tasks and control of production.
Architectural use	The CMT allows to evaluate and increase technical, economic, and ecological efficiency of architectural decisions.
	The CMT reduces labor costs for changes and coordination of design decisions and increases their visibility.
Technological use	The CMT formalizes the method of production, the resources needed to create products, requirements for the beginning, result, and culture of production.
	The CMT allows to estimate and increase technical, economic, and ecological efficiency of the used technologies.
Operational use	The CMT shows the main operational indicators of the product of investment construction activity.
	The CMT serves as a basis for the operational model of the constructed facility.
	The CMT allows to estimate and increase the energy efficiency of construction.

CMT, construction management template.

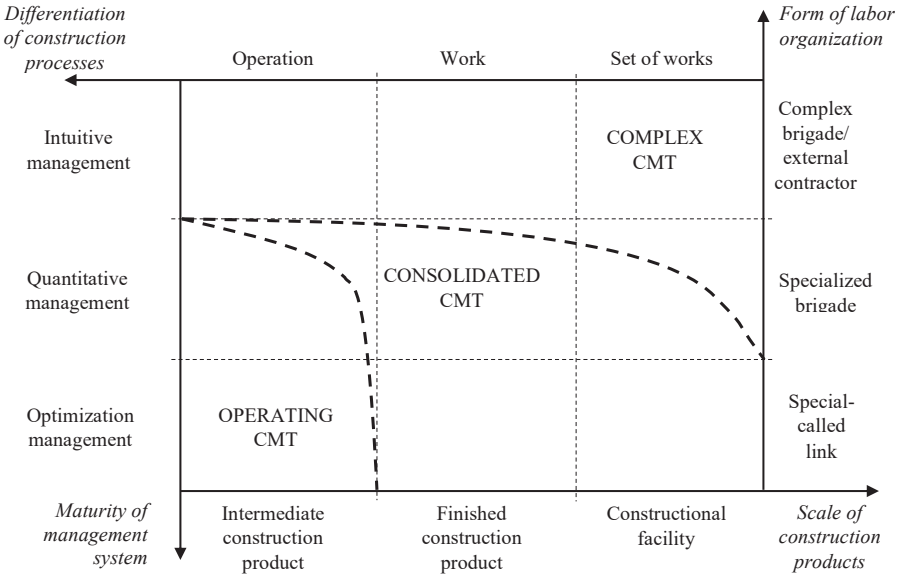

Fig. 3: Differentiation of CMTs for different organizational factors of the enterprise environment. CMT, construction management template.

- Complex CMT – corresponds to the lowest level of differentiation (a significant isolated part or finished construction facility and several sets of operations (works)). It combines several consolidated templates. It is used for investor settlements, sales, and customer service as part of development.

Figure 4 contains the approach to differentiation and structuring of CMTs at different phases of the investment construction project. According to Figure 4, the complex CMT can be used in all phases of the investment construction project: consolidated CMT – on the phases of approval and working design, as well as construction;

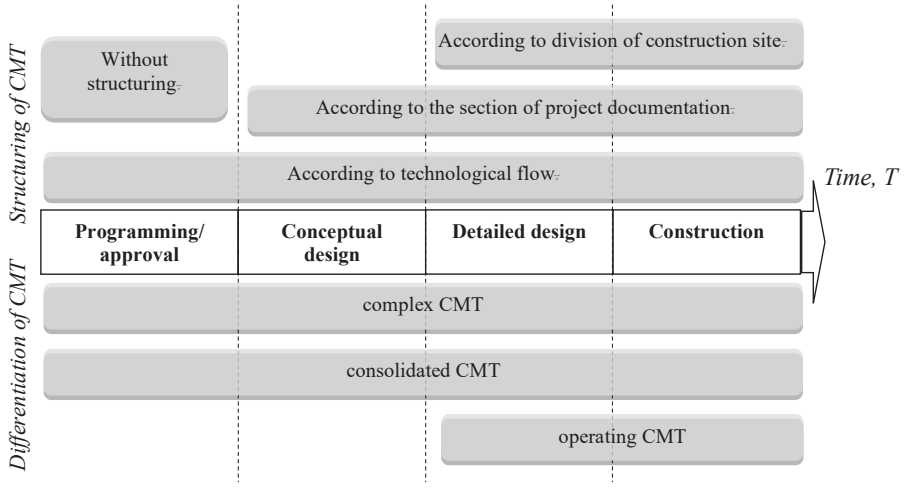

Fig. 4: Differentiation and structuring of CMTs at different phases of the investment construction project. CMT, construction management template.

operating CMT – during working design and construction. It confirms the tendency to increase the detail of construction information models during the development of the investment construction process, identified during the analysis of information sources.

Figure 3 shows that the structuring of the CMT is based on technological, spatial principles, and design documentation brands. The analysis of the design documentation brands showed that they combine the technological and spatial principles of structuring and, therefore, need refinement. It seems rational to refine in the direction of the technological principle and technological flows, as the design documentation is the task for the production of works. The analysis of the figure shows the tendency revealed in the analysis of information sources to more complex structuring during the development of the investment construction process.

Figure 5 contains the scheme of the interaction of software using the concept of 'CMT'. Analyzing the scheme, we can note the following:

- The 'core' of the CMT is the product and project process models, but the CMT may include some results of supporting calculations and documents.
- The set of CMT, interconnected by organizational and technological links, forms a model of enterprise resource planning (ERP). This model is dynamic in space (formed on the basis of the project product model) and time (includes management of available resources).
- The basis of the operational plan of CMT is laid in the product model of the project, so it is critical to control the implementation of the principles of the concept in its development.
- The interaction of the CMT with the environment is realized through the means of extended resource planning (XRP) and resource planning, synchronized with the consumer (CSRP). At the same time, it is important to document the entrances and exits, which are provided by using the information carrier, and the responsibility of the person providing the information.
- There should be an approved enterprise regulation document for the effective interaction of software within the concept of CMT. This document should describe responsible executors for work in software products and terms, periodicity, and formats of data transfer. This document may differ depending on the degree of maturity of management in the enterprise, the degree of maturity of knowledge management, the software involved, other factors, and, in any case, is interconnected with the BIM regulation document.

Since CMT is the main center of commercial, managerial, and production knowledge in the organization, it is important to explore its life cycle within the project (Figure 6).

5 Discussion

5.1 Sustainable development of the enterprise with the help of CMT

As indicated in the introduction, the main problem of modern construction in developing countries, to which Ukraine belongs, is low management culture. Namely, the lack of use of such management practices as the scientific

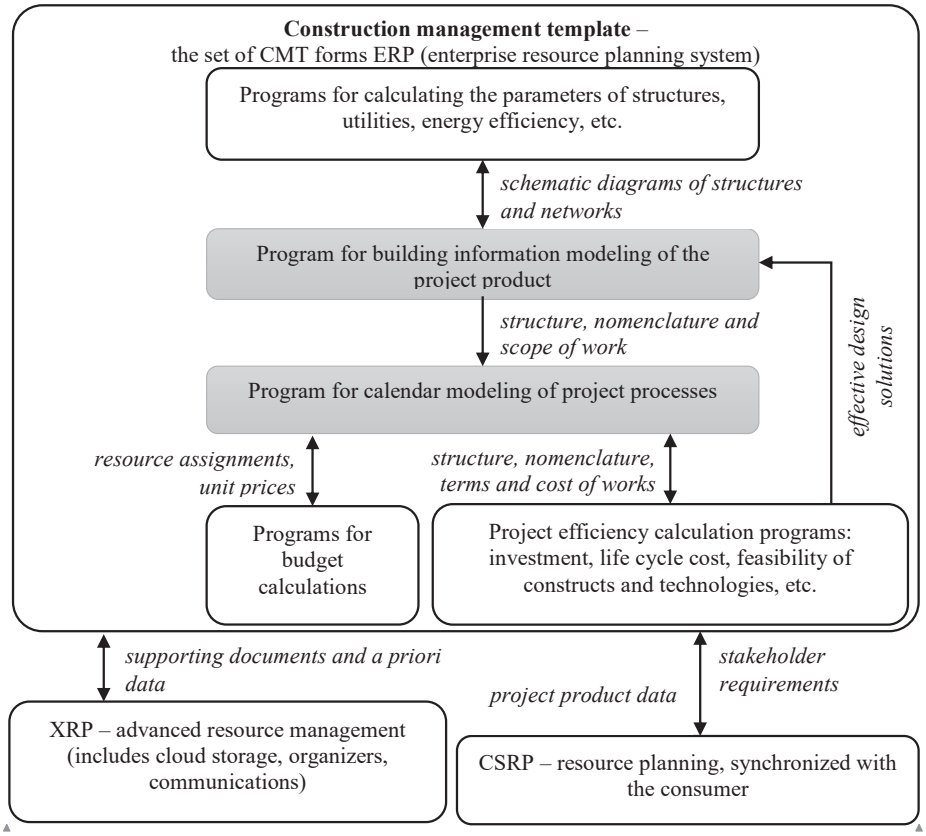

Fig. 5: Interaction of software within the concept of 'CMT' (programs containing CMT are highlighted by dark gray (product models and project processes); transmitted information – by italics; arrows show the direction of information transfer). CMT, construction management template; CSRP, customer synchronized relationship planning; ERP, enterprise resource planning; XRP, extended resource planning.

organization of labor and management in construction, quality management system, project management, engineering, and knowledge management. This happens in the presence of powerful BIM tools. However, the principles of using these tools in management have not been sufficiently studied. All this leads to a low level of sustainability of the full investment construction cycle enterprise.

To solve this problem, it is proposed to use the information and communication concept 'CMT'. It is an information and communication model in the form of a three-dimensional parametric part of a building or structure and the associated resource schedule of works used to plan and control management, architectural, technological, operational, and economic decisions throughout the construction project. As shown by the conducted studies, the use of CMT, in comparison with existing practices, allows to achieve the following:

- Always have an up-to-date version of production information about the investment construction process in the form of interconnected models of project product and processes located in a publicly accessible database.
- Adapt BIM tools to the accepted practices of managing the conditions of the investment construction process, the existing infrastructure of software tools.
- Implement mutually agreed management practices through the development of CMT, their integration into the organizational environment of the enterprise, and the investment construction process through an assignment of rights, duties, and responsibilities within this concept.
- Implement the practice of preserving, analyzing, and optimizing production information in various directions, thereby controlling the maturity of enterprise knowledge.

The implementation of the concept of 'CMT' by individual construction companies (general designers, general contractors, and consulting engineers) requires the development of such a discipline as 'knowledge management.' This broadly means the processes of creating, classifying, processing, analyzing information on production, management, and business. Researchers introduce the concept of knowledge maturity as generalizing characteristic, for which knowledge management takes place.

Increasing the degree of knowledge maturity contributes to increasing the degree of sustainable development of the construction company. The algorithm of management of knowledge maturity by means of CMTs is shown in Figure 7.

Figure 7 contains a number of blocks: gray highlights the levels of knowledge maturity achieved by established practices, which are described in white blocks. Zero level of maturity means unstructured, non-digitized knowledge ('data'). The sustainable development of the enterprise/project usually depends at this level on the professionalism of the team, because all knowledge is stored by specialists. It is necessary to transfer knowledge from specialists to information blocks to grow up from this level – create CMT. Databases become 'smarter' than specialists after full control over production, which occurs by filling the CMT with actual data. There is a transition to the first level of maturity 'information (who, what, when, where?)' at this point. It is possible after the transition to start using knowledge for organizing the production. It is important to provide production tasks exclusively with the use of CMT and monitor their meticulous implementation. It is critical to establish the diligence of specialists in terms of tasks – then the value of the corporate knowledge base becomes higher than the value of knowledge of specialists. This is the transition to the second level of knowledge maturity – 'competence (how?)'. This allows to implement management, architectural, organizational, and technological innovations by adjusting the tasks on the basis of more effective CMT. The diligence of specialists to perform changing tasks gives the opportunity to analyze the impact of certain innovations on the efficiency of the enterprise/project. The possibility of such analysis means the transition to the third level of knowledge maturity – 'wisdom (why?)'.

As shown above, an increase of the enterprise's knowledge maturity implies a change in the purpose of using production information and its optimization in accordance with the rationalization of the enterprise in the following directions: commercial, communication, management, architectural, technological, and operational. By increasing the maturity of enterprise knowledge management, it is possible to increase the maturity of management practices, that is, the degree of sustainability of the full investment construction cycle enterprise.

1. Creation and updating of CMT to fill the corporate knowledge base. Association of CMT of different differentiation.
2. The use of complex CMT in the urban programming/ approval and economic feasibility study.
3. Approval of models consisting of CMT as a target plan. Approval of the electronic task for designing on the basis of CMT.
4. Finalization of CMT as a part of product models and project processes and their examination within the conciliatory design stage.
5. Approval of CMT as a part of product models and project processes according to commercial, administrative, production criteria as working models (depending on a methodology of management of the construction project, can occur in stages).
6. Issuance of tasks and production control using CMT.
7. Commissioning of the CMT as a part of product models and project processes with the completed construction object.
8. Use of CMT as a part of operational models.
9. Elimination of CMT as part of the model when dismantling or changing the purpose of the construction object.

Fig. 6: Life cycle of CMTs within the investment construction project. CMT, construction management template.

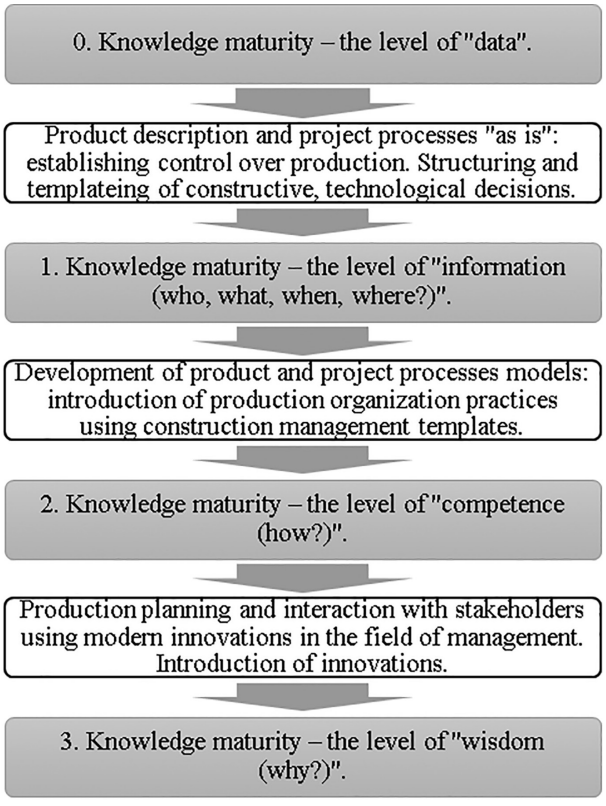

Fig. 7: Management of knowledge maturity with the help of CMTs (gray highlights the levels of knowledge maturity; white – practices, the establishment of which moves to the appropriate level of maturity). CMT, construction management template.

5.2 Recommendations for the implementation of the concept of 'CMT'

As mentioned above, stakeholders can be divided into three groups using the concept of 'CMT': external participants (government regulators, investors, consumers), managing party (consulting engineer), and managed parties (developers of CMT, contractors, and suppliers). Analysis of Figure 8 justifies the selection of these parties.

Analysis of Figure 8 shows that the role of the consulting engineer in the use of CMT is threefold:

- First, the consulting engineer must manage the knowledge of the investment construction process. For simplicity, this role is indicated in the figure as 'BIM manager'.
- Second, the consulting engineer should work on encouraging stakeholders during the project – by ongoing sales and customer service. For simplicity, this role is indicated in the figure as 'merchant'.
- Third, the consulting engineer must manage the investment and construction process – to carry out leadership, organization, and administration of the project. For simplicity, this role is indicated in the figure as 'construction project manager'.

The implementation of construction management models (Figures 1 and 2) using information technology can be performed in accordance with Figure 9.

The peculiarities of this algorithm (Figure 9) are the following: the need to audit the management and information systems of the enterprise before implementation and the close relationship of management methods and information technologies that are implemented.

The algorithm of CMT use at stakeholders' requirements satisfaction of investment construction process is shown in Figure 10. The main idea of the developed algorithm is a transparent comparison of stakeholders' requirements and the advantages of CMTs in the plan-actual dimension during all stages of the investment

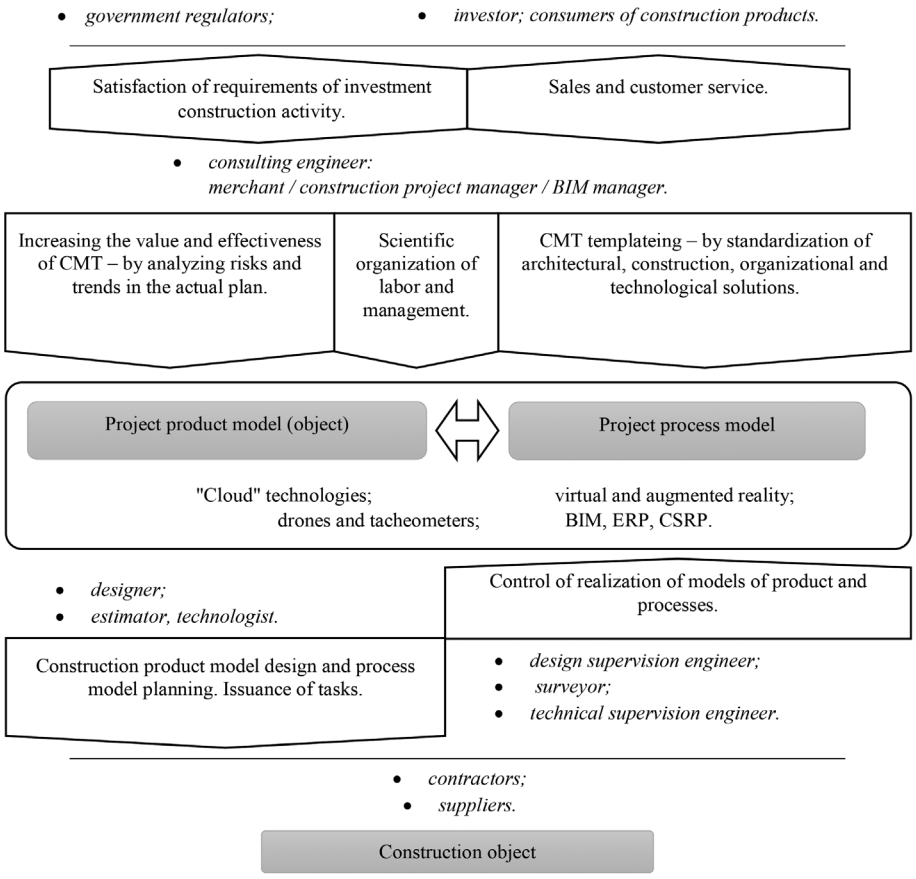

Fig. 8: Schematic diagram of stakeholder communication using the project management approach and the concept of 'CMT' (*Notes:* [1] BIM – construction building information modeling; [2] ERP – enterprise resource planning; [3] CSRP – customer synchronized relationship planning). CMT, construction management template.

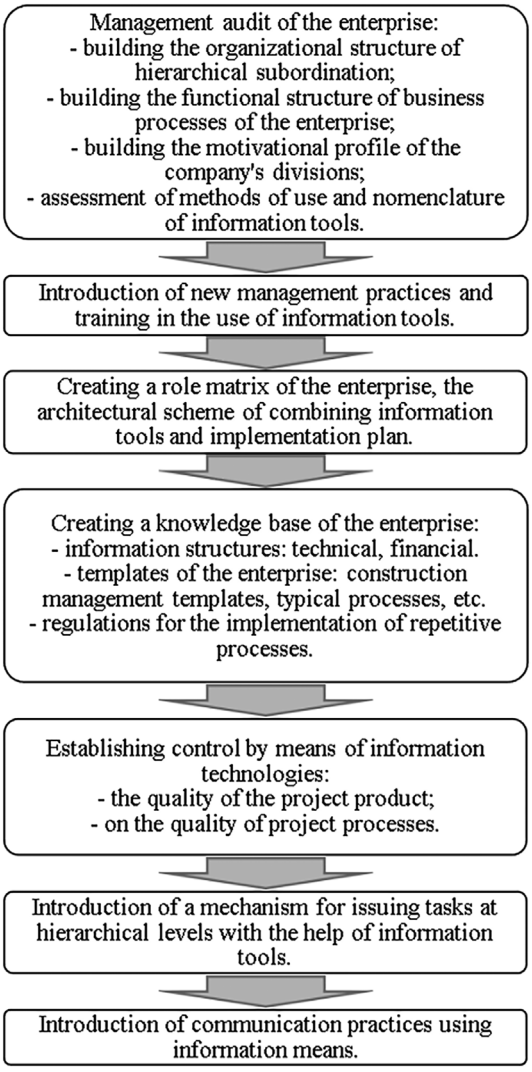

Fig. 9. Algorithm for implementing construction management models using information technology.

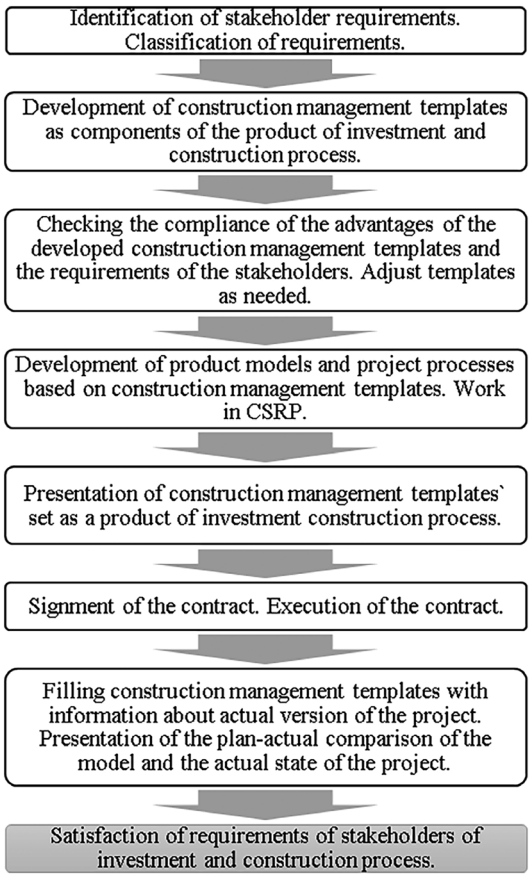

Fig. 10. Use of CMTs in commercial activity ([1]CSRP – Customer Synchronized Relationship Planning). CMT, construction management template.

and construction process. The stakeholders are understood as government regulators (compliance of versions of CMT with regulatory requirements, urban planning requirements, rules of construction works, approved project examination, etc.), investors, and final consumers of construction products (compliance of versions of CMT with preferences important for the parties, contractual obligations, etc.) as shown in Figure 10.

Figure 11 contains the algorithm for using the concept of 'CMT' in business modeling to improve management efficiency. The main advantage of CMT in this direction is to increase the speed of information logistics in the investment construction process:

- use of prefabricated information blocks and modern software products allows to prepare optimized solutions for the organization of production, as well as to reduce the cycle of control and decision-making in management;
- this, in turn, allows making more efficient decisions when the investment construction process deviates from the plan or when external conditions change;
- making operational decisions prevents inefficient spending of resources and directs them in the priority direction.

At present, the state of standardization of architectural, structural, organizational, and technological solutions in Ukraine leaves much to be desired. The government does not have the processes of creating, updating, and using national databases of construction materials, resources, and technologies in digital form. Resource element estimates cannot always be used in the investment construction process, as they may not correspond to the actual construction production in full. Therefore, it is important to use CMT as a tool for government

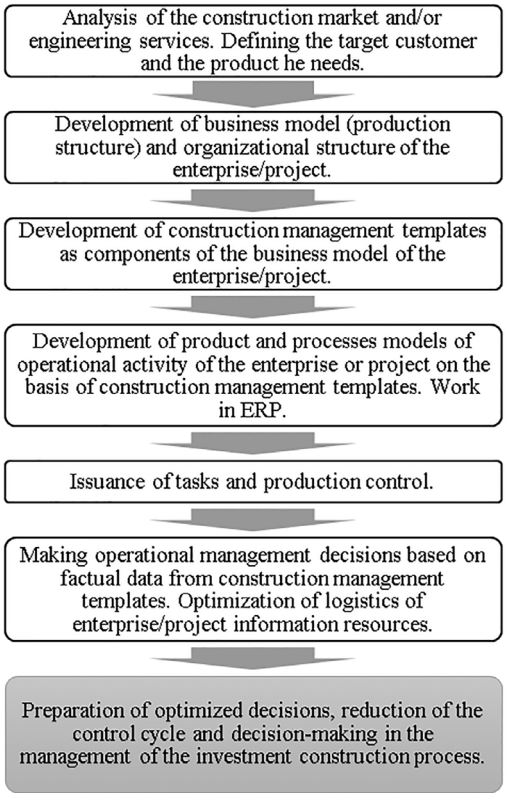

Fig. 11: Use of CMTs in management ([1]ERP – Enterprise Resource Planning). CMT, construction management template.

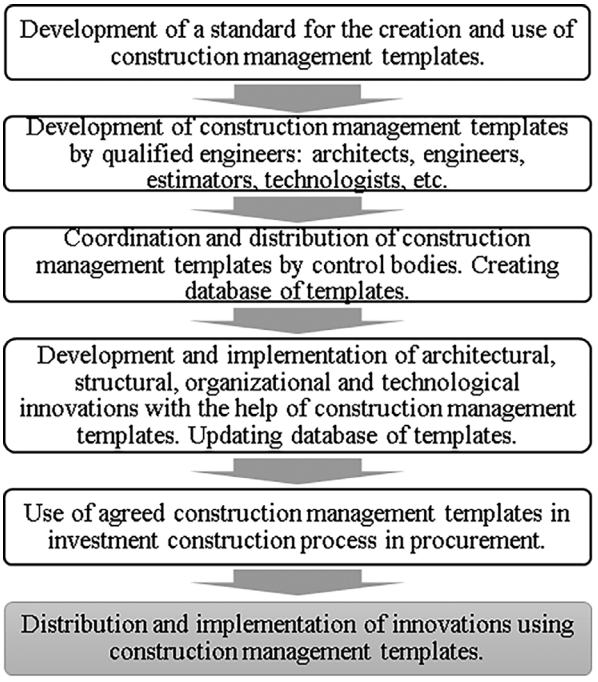

Fig. 12: The use of CMTs in the introduction of architectural, structural, organizational, and technological innovations. CMT, Construction management template.

standardization in construction, as well as a tool for innovation. The corresponding algorithm is shown in Figure 12.

5.3 The effectiveness of the concept of 'CMT'

CMT is a management tool that allows stakeholders to get the potential economic and technical effects of the investment construction process (Table 2).

The investor can delegate to consulting engineer broad powers to improve the quality, reduce the cost of construction, and the cost of the building life cycle. This is because consulting engineer is the provider of comprehensive service for the organization and control of construction. Thus, there is a need to develop special performance indicators of the consulting engineer in order to calculate his reward. It is necessary to develop a management concept for the use of information technology in construction to measure such indicators, which will record the planned and actual course of the investment construction process and will measure the effectiveness of the consulting engineer.

Preliminary analysis showed (Figure 8) the triple role of the consulting engineer in the organization and control of the investment construction process, as well as his subordination over the developers of CMT, contractors, and suppliers. It is appropriate to determine the degree of consulting engineer's responsibility for each of the three roles to measure his effectiveness and to record the relevant indicators, and the main of which are construction quality, construction cost, and building life cycle cost. There is offered for the enterprise of full investment construction cycle with private financing:

- to create an information infrastructure for templating of architectural, structural, organizational, and technological solutions – a database of CMT;
- to oblige the consulting engineer to develop versions of the 'target plan' for product models and construction processes based on these CMT;
- to oblige the consulting engineer to record the actual course of construction for product models and construction processes with a separate agreement on the frequency of this control between the customer and the consulting engineer;
- to measure the efficiency of the use of CMT, comparing the planned and actual indicators;
- to calculate performance indicators (Table 3) based on data from product models and construction processes in accordance with the responsibility of the consulting

Tab. 2: Economic and technical effect for stakeholders of the investment construction process when using CMTs

Stakeholder	Due to which the effect is achieved	Efficiency indicator
State control bodies	Accurate and reliable control of investment construction process – through the control of versions of the CMT at the stages: certification of materials, technologies, and equipment for inclusion in the databases of CMT; issuance of urban-planning conditions and restrictions and technical conditions; electronic examination (including the use of automated tools for determining conflicts: spatial, technological, financial, etc.); commissioning of the building (by comparing the CMT and the actually erected building).	Percentage of mutual conformity of versions of CMT, acceleration of capital turnover (direct). Reducing the cost of construction, operating costs, building life cycle cost; increasing the profitability of the construction industry, energy efficiency, indicators of requirements for buildings, CSI (indirect).
Investor (consolidated and distributed)	Quality control of investment construction project management through control of conformity of versions of CMT at stages of the technical and economic substantiation, designing, construction on technological packages of works:	
Consumer of construction products	comparative analysis of CMT versions for compliance of architectural decisions, cost, and terms of construction; transparent communication with the consulting engineer, as a result – high quality of construction service.	
Consulting engineer	Improving the quality of management through: acceleration of logistics of project resources (initially informational, as a result – communication, financial, labor, material). reducing routine, increasing the role of leadership in management.	The interval between control points for decision-making, the accuracy of production information (direct).
CMT developers (architects and designers, estimators, and technologists)	Use of modern software products. Use of agreed pre-prepared information blocks from databases of CMT. Regulation of business processes.	Reducing the complexity of modeling, increasing labor efficiency (direct). Increase in wages (indirect).
Contractors and suppliers	Reduction of non-production costs due to well-established logistics of resources. Implementation of innovative design and technological solutions. Regulation of business processes.	Reducing the complexity of work, increasing profits, reducing the duration of work, accelerating capital turnover (direct).

CMT, construction management template.

engineer and the degree of subordination of designers, contractors, and suppliers;
- to calculate the reward of a consulting engineer on the basis of efficiency indicators and agreed on formula.

6 Conclusions

The analysis of information sources showed several reserves for improvement of the efficiency of management and sustainability in construction. These reserves can be used through an information and communication concept that combines the capabilities of modern software products for modeling of construction products and processes, as well as the most effective management methods: scientific organization of labor and management; system and process approach; project management and engineering; and knowledge management.

The developed information and communication concept 'CMT' has the following elements of scientific novelty:

- allows to increase the efficiency of construction – commercial, managerial, communicational, architectural, technological, and operational;
- is a tool for knowledge management in construction, which provides further development of modern approaches to management;
- makes it possible to introduce innovations in management and production to determine their planned and actual efficiency with increased accuracy;
- allows to increase the degree of sustainable development of the construction company by managing the knowledge maturity.

Sustainable development of the enterprise with the help of CMT can be achieved by changing the purpose of using production information and increasing the maturity of management practices.

A set of interconnected algorithms, which have been developed, allows to implement and use the concept of 'CMT' in the commercial, management, technical regulation, and implementation of innovations. The use of CMTs allows to manage the knowledge maturity through

Tab. 3: The choice of performance indicators of the consulting engineer depending on his role and the degree of subordination of participants in the investment construction process

Participant in the investment construction process	The role of a consulting engineer		
	Merchant	**Construction project manager**	**BIM manager**
Developers and controllers of the project product model (designers; engineers of author's supervision; surveyors)		The cost of the construction object, the total cost of construction and operation of the building during the life cycle; the coefficient of usable area of the house, the speed of the technological process, and labor costs of service personnel; dynamics of labor costs of designers; indicators of mechanical resistance and stability, fire safety, the safety of life and environmental protection, operational safety, noise protection, energy saving	The total cost of construction and operation of the building during its life cycle; building energy efficiency class; the percentage of mutual compliance of the versions of the CMT, the accuracy of production information; the percentage of executive documentation on the quality of work
Developers and controllers of the project process model (estimators, technologists, technical supervision engineers); suppliers		Economic efficiency of production; accelerating capital turnover	The percentage of mutual compliance of the versions of the CMT, the accuracy of production information; the percentage of presence of executive documentation on the quality of work
Contractors		Dynamics of labor costs, mechanical production; the speed of construction of a building or individual structural elements	Accuracy of production information
Regardless of the subordination of the participants	Sales dynamics; economic efficiency of marketing; CSI	The interval between control points for decision-making; the degree of entropy of management, the level of risk of resource use.	

BIM, building information modeling; CMT, construction management template; CSI, consumer satisfaction index.

structuring, templating of production information, and relationship with the processes of the full investment construction cycle enterprise.

The developed schemes allowed to determine the performance indicators using the concept 'CMT':

- for various stakeholders of the investment construction process: state control bodies, the investor, consumers of construction products, the consulting engineer and his team, contractors, and suppliers;
- performance indicators of the consulting engineer depending on his role and subordination over the participants of the investment construction process.

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