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Improving the organizational scheme for conducting state examination of design documentation in order to obtain a reliable estimated cost using BIM

The organizational possibilities of resolving the problem of discrepancy between the estimated and actual costs of capital construction assets by dividing the process of state expertise into two organizational phases: checking the design solution of a capital construction project and assessing the reliability of the estimated cost were explored. The authors conducted an expert analysis of the current number of capital construction projects based on a survey of an expert group. The assessment revealed that on average 59.5 % of capital construction assets per year, financed from the state and municipal budgets, have more than 2 % discrepancy between the estimated cost at the stage of architectural and construction design and the actual cost of construction. The labour costs of specialists from the Ministry of Construction and Infrastructure Development of the Sverdlovsk Region were assessed if it was necessary to adjust budget programmes. The current scheme of interaction between participants in the construction process was formed, on the basis of which problem phases were identified. In problem phases, there is an information gap between the detail of the building information model necessary for the examination of design solutions and for assessing the reliability of the estimated cost of a capital construction asset. The authors of the paper have developed and proposed an interaction scheme using building information modelling technologies to obtain the estimated cost of capital construction assets eliminating the information gap by dividing the state examination process into two phases and calculated the difference in the time costs of processes in both schemes that is 51 days. It was proposed to make adjustments to the legislation with the approval of the examination process in two phases, as well as the approval of unified requirements for building information models for the implementation of the proposed scheme and the introduction of building information modelling technologies into the state examination process.

Keywords: *building information modelling (BIM) technologies, building information model, state examination, design documentation, reliable estimated cost, life cycle of capital construction objects*

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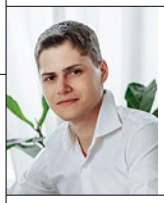

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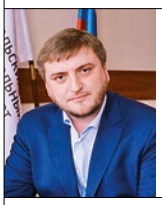

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INTRODUCTION

The introduction of building information modelling technologies into construction and investment design processes is becoming increasingly popular in our country. For various reasons, Russia is currently an objectively "catching up" country in the large-scale development of building information modelling technologies (BIM) implementing according to the "top-down" scheme [1]. Recently, this approach was adopted in the UK, where the British Standards Institute began to develop standards for building information modelling technologies in 2007 [2], and the government launched the process of implementing building information modelling in 2010, gradually adding the requirements until the release of requirements for all facilities financed by the state in 2016 [1, 3, 4]. The UK is now widely recognized as a world leader in the field of building information modelling technologies standards and guidelines.

In our country, the stagnation in the level of BIM development and the redistribution of resources was facilitated by a forced market shift towards domestic vendors, while the majority of the market was occupied by foreign software systems [5]. The more active BIM implementation is facilitated by the current editions of regulatory documents [6], [7], as well as past editions of the government regulations [8], the current version of which is currently at the development stage. The listed documents contain necessary requirements to develop a building information model, its composition and a description of the conditions when it is necessary to generate building information models. Thus, the large-scale application of building information models at all stages of the asset life cycle becomes almost inevitable in the future, despite the typical difficulties of BIM implementation [9].

At the same time, the necessity of developing building information models entails not only an increase in labour costs for their creating, but also the models can provide solutions to applied problem tasks of construction organizations, including the development of design solutions and their expertise. To achieve these goals, general requirements for building information models have been proposed in various documents already in force [10], [11] or emerging [12]. However, the process of conducting state examination at the stage of architectural and construction design is not fully adapted to the use of building information models when checking project documentation.

The current version of the Government Decree [13] provides for fundamental solutions for sections of the design documentation: standard structural units, lack of reinforcement, finishing sheets only in a tabular form, schematic diagrams of engineering systems. In this case, a specialist of an expert institution, in the process of examining design documentation, must obtain and analyze an array of necessary information to assess the reliability of the estimated documentation according to [14].

Thus, objectively, there is an information gap due to the different requirements for level of detail sections of design documentation according for [13] and the information necessary to assess the reliability of the estimated cost. It is obviously that it is impossible to prepare the specification necessary for drawing up an estimate based on a typical unit or schematic diagram. At the same time, on the one hand, a building information model is not able to contain a table with data, since it does not have a three-dimensional representation in a real object; on the other hand, it is not able to contain elements by which a specification can be formed, since then the composition of detail of the design documentation dictated [13] will be exceeded. This means that the requirements for the building information model in one situation will contain excessive information on [13], in another situation there will be insufficient information for the requirements [14].

Thus, specialists who carry out the examination of design documentation are faced with the problem of the lack of an unambiguously described scheme of interaction between participants in an investment and construction project at the stage of architectural and construction design using building information modelling technologies. As a result, an ordinary specialist, being a participant in the construction process in the field of determining the estimated cost at the stage of architectural and construction design, tries to avoid using of building information models due to the uncertainty of his responsibilities and specific tasks when working on a building information model.

Based on the main fundamental tasks of building information modelling technologies, accuracy, leading to a reduction in the risk of price increases, is the most crucial among them [15]. However, despite the use of building information modelling technologies, due to insufficient detail of the building information model at the time of the examination, there is an information gap between the level of the graphic part detail of the design documentation, which is necessary to assess the reliability of the estimated cost at the stage of architectural and construction design, and the graphic part detail of the design documentation in accordance with the requirements [13]. Therefore, at the stage of working documentation and clarification of the project, it may be necessary to recalculate the volumes of elements that were in the work volume statement of quantities or specifications, but were not present in the building information model. In case of an unfavourable outcome, having an underestimated project cost, the technical customer faces problems in the form of failed tenders, time costs associated with adjustments to the design documentation, and this also becomes one of the reasons for the emergence of unfinished construction projects.

METHODS

The authors formed an expert group consisting of the representatives of the Ministry of Construction and Infrastructure Development of the Sverdlovsk Region, municipal customers, such as the Capital Construction Department of Yekaterinburg, the Capital Construction Department of the Sverdlovsk Region. The group also included experts from the State Autonomous Institution of the Sverdlovsk Region "Department of State Expertise". The participants of the expert survey, based on professional experience, had to indicate the percentage of construction assets per year, for which the discrepancy between the estimated cost at the design stage and the actual construction costs was less than 2 %, from 2 to 5 % and from 5 to 10 %. According to the results, it was found that about 59.5 % of construction assets from the extensive combined experience of experts have a discrepancy in the estimated cost of more than 2 %. The graph of the survey results is shown in Fig. 1.

To assess the statistical significance of the results obtained, the Pearson test was applied. It was hypothesized that among experts' opinions, the average percentage value of projects with a cost difference exceeding 2 % is a statistically correct value.

According to Table 1, this value is 59.5 %. The measure of the dispersion was determined using the Pearson method using X_i-square statistics according to formula (1):

$$X_n^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}, \quad (1)$$

were O_i — the result according to experts (sum of columns 3 and 4 of Table 1);

E_i — expected result (in our case, 59.5 % was chosen).

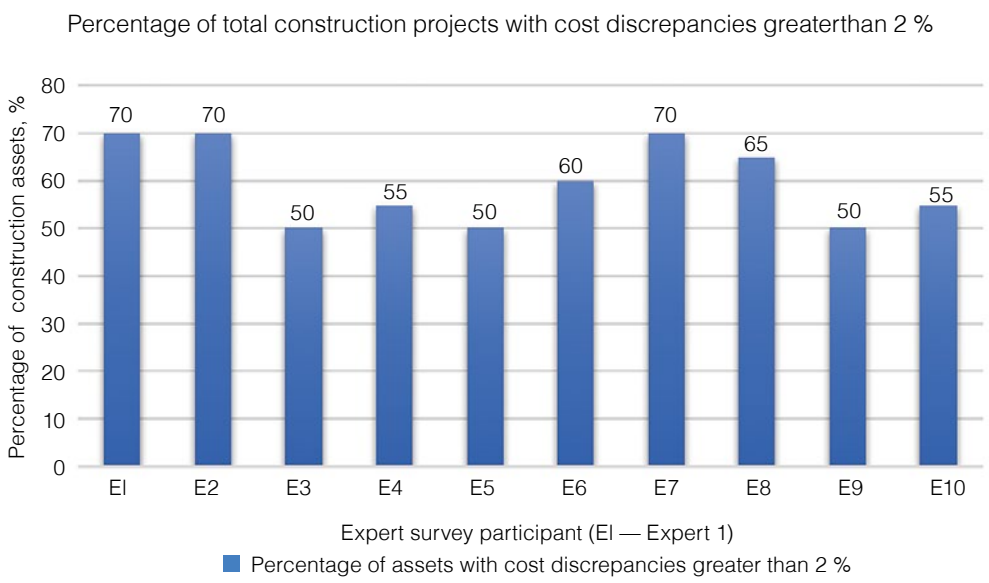

Fig. 1. Results of an expert study on the discrepancy between the estimated cost of construction assets and actual costs

Table 1. The percentage of construction assets per year depending on the discrepancy between the estimated cost at the design stage and the actual construction costs according to the expert group opinion

Expert's number	Less than 2 %	From 2 to 5 %	From 5 to 10 %
1	30	35	35
2	30	50	20
3	50	25	25
4	45	25	30
5	50	40	10
6	40	40	20
7	30	40	30
8	35	50	15
9	50	30	20
10	45	20	35
Average, %	40.5	35.5	24

$$X_n^2 = \frac{(70-59.5)^2}{61.5} + \frac{(70-59.5)^2}{61.5} + \frac{(50-59.5)^2}{61.5} + \frac{(55-59.5)^2}{61.5} + \\ + \frac{(65-59.5)^2}{61.5} + \frac{(55-59.5)^2}{61.5} + \frac{(50-59.5)^2}{61.5} = 14.5.$$

Further, the obtained statistics were compared with the critical value at 9 degrees of freedom k and a significance level of 0.05 (α) according to the table of critical values of the X_i-square distribution, that is, with 16.91898. Since 14.5 < 16.91898, the initially selected value of 59.5 % can be considered statistically significant.

The coefficient of concordance of expert opinions was also calculated to assess the consistency of opinions using formula (2):

$$W = \frac{12\sum_{i=1}^{n}(O_i - E_i)^2}{m^2(n^3 - n)}, \quad (2)$$

were m — a number of experts;

n — a number of selected objects (in our case 3).

$$\sum_{i=1}^{n}(O_i - E_i)^2 = (70-59.5)^2 + (70-59.5)^2 + (50-59.5)^2 + \\ + (55-59.5)^2 + (50-59.5)^2 + (60-59.5)^2 + (70-59.5)^2 + \\ + (65-59.5)^2 + (55-59.5)^2 + (50-59.5)^2 = 862.5;$$

$$W = \frac{12 \cdot 862.5}{10^2(3^3 - 3)} = 4.31.$$

So, the consistency was checked using the Pearson criterion by the formula (3):

$$W \cdot k \cdot n = 4.31 \cdot 9 \cdot 10 = 388.125 > 16.91898. \quad (3)$$

The experts' opinions are consistent. Thus, the hypothesis that the value of 59.5 % of construction assets that have a discrepancy in estimated cost of more than 2 % was found to be statistically significant and accepted for further research.

The discrepancy between the estimated and actual costs of two out of three capital construction assets reduces the accuracy of budget expenditure planning, which can lead to disruption of the planned implementation of large state and municipal programmes. To assess the consequences of the failure, the authors used an analysis of the labour costs of specialists from the Ministry of Construction and Infrastructure Development of the Sverdlovsk Region in case of necessity to increase the cost of the project. The results of the analysis are visible in the diagram presented in Fig. 2.

To adjust the budget programme, a total of 50 days of specialist work are required. It can be avoided with a correct assessment of the reliability of the estimated cost, which in turn is achieved by

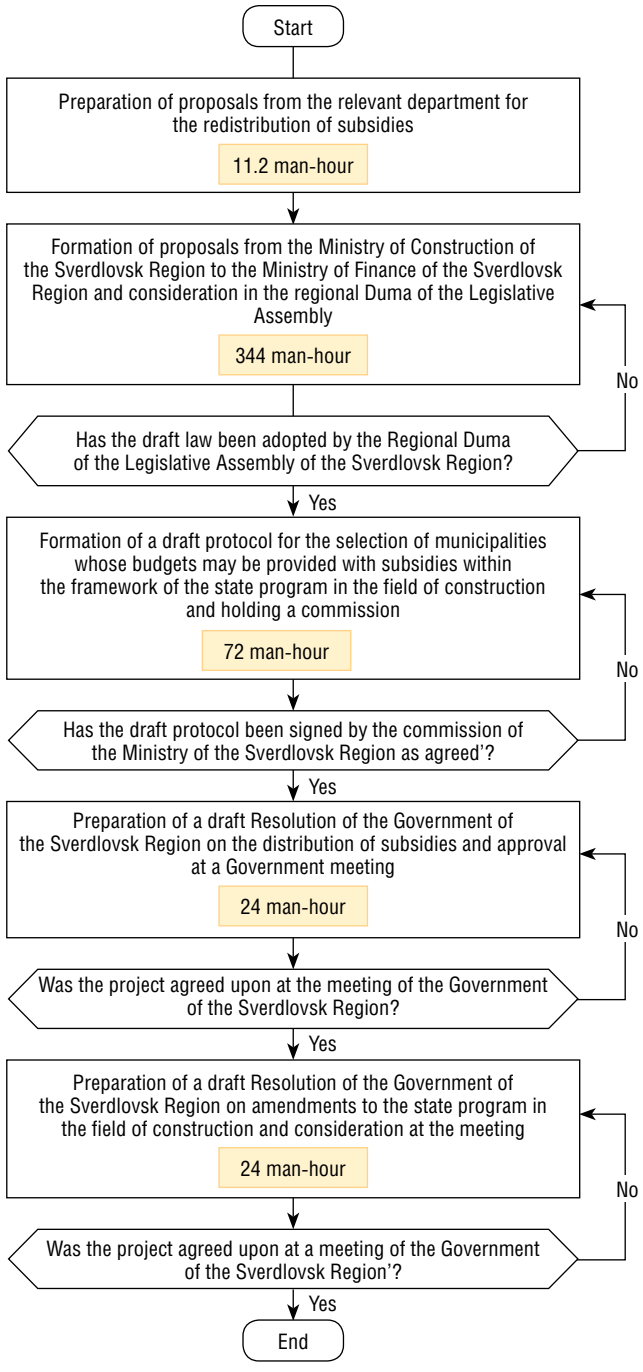

Fig. 2. Scheme for adjusting budget programmes taking into account the labour costs of specialists

a clearly described organizational scheme of interaction between participants in an investment and construction project using building information modelling technologies.

Thus, the authors of the paper formed the following goal of the study — to propose an organizational scheme for interaction between participants in an investment and construction project, which includes the use of building information modelling technologies and makes it possible to unambiguously describe the process of conducting an examination of design documentation, taking into account the assessment of the reliability of the estimated cost.

To achieve this goal, a couple of tasks were formed:

1. Describe the current organizational scheme of interaction between the participants of an investment and construction project and determine the deadlines for each stage using the example of an actually constructed facility in Yekaterinburg.
2. Identify the stages of the organizational scheme, at which there is an information gap between the attributive content of the sections of the design documentation and the possibility of generating on its basis lists of quantities and specifications to assess the reliability of the estimated cost.
3. Identify the stages the timing of which is increasing due to the identified problems.
4. Develop an organizational scheme for interaction between participants in an investment and construction project in order to eliminate the information gaps that arise today and, as a result, extended deadlines.

As a result of the analysis of the interaction of participants in the investment and construction project using on the example of preschool educational institution No. 1 with nursery groups in block No. 11 of the Akademichesky district in the city of Yekaterinburg, the diagram presented in Fig. 3 was formed.

In accordance with the current scheme design documentation is developed using building information modelling technologies and simplified detailing, then a state examination is carried out and a cost limit is determined. Next, a tender purchase is carried out for the development of working documentation and further construction of the asset. It often happens that the state customer has to re-execute the tender purchase, because they are not able to find a contractor. After that, taking into account the discrepancy in the volumes identified during the preparation, the working documentation is adjusted and sent for re-examination. Then construction is carried out and at this stage there are often time costs associated with procedural work to increase the cost of asset construction, such as acts of additional work and others, which leads to the necessity of implementing the diagram in Fig. 2.

After a thorough analysis of the current organizational interaction scheme, the following problematic stages were identified.

At the stage of the state examination, an information gap occurs between the information content of sections of the design documentation and the possibility of forming on its basis statements of quantities and specifications to assess the reliability of the estimated cost, since the use of a building information model is unreasonable either at the stage of fulfilling the conditions of technical regulations due to oversaturation of information, or at the stage of verifying the accuracy of the estimated cost due to the lack of information content. As a consequence, delays in terms of searching for a contractor occur at the stage of the tender procurement due to undervaluation and the need for repeated

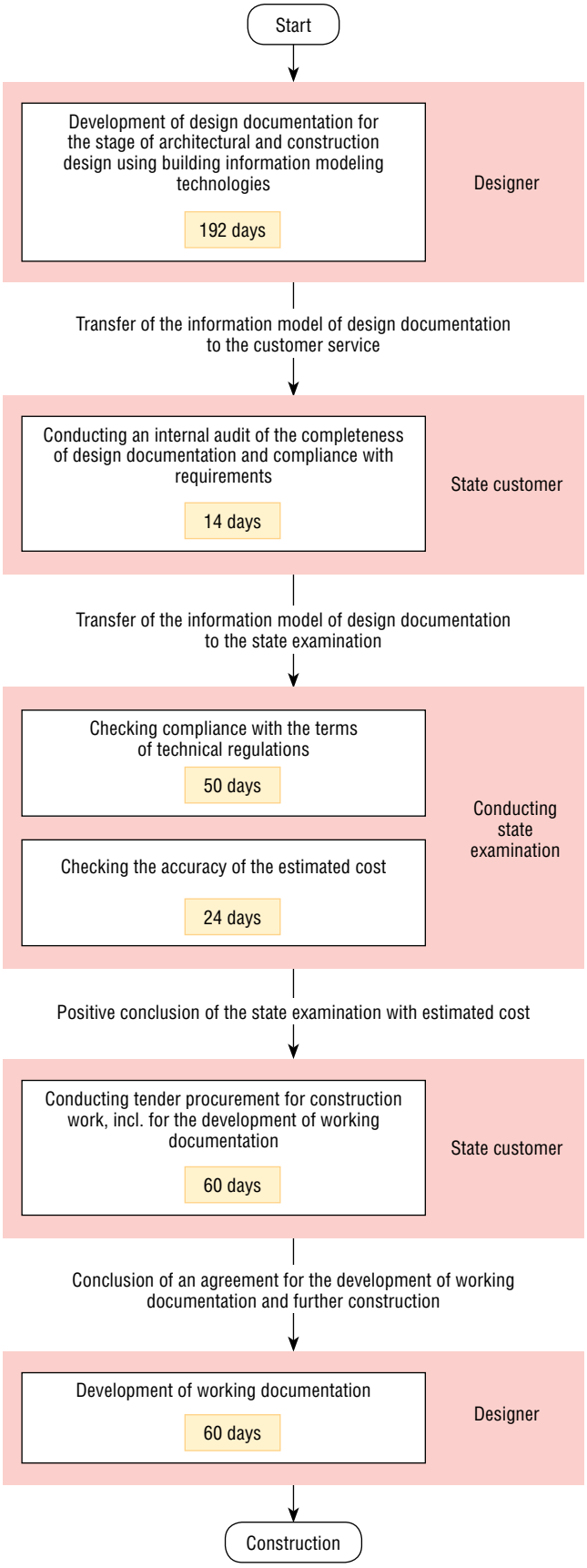

Fig. 3. The current scheme of interaction between participants in the investment and construction project

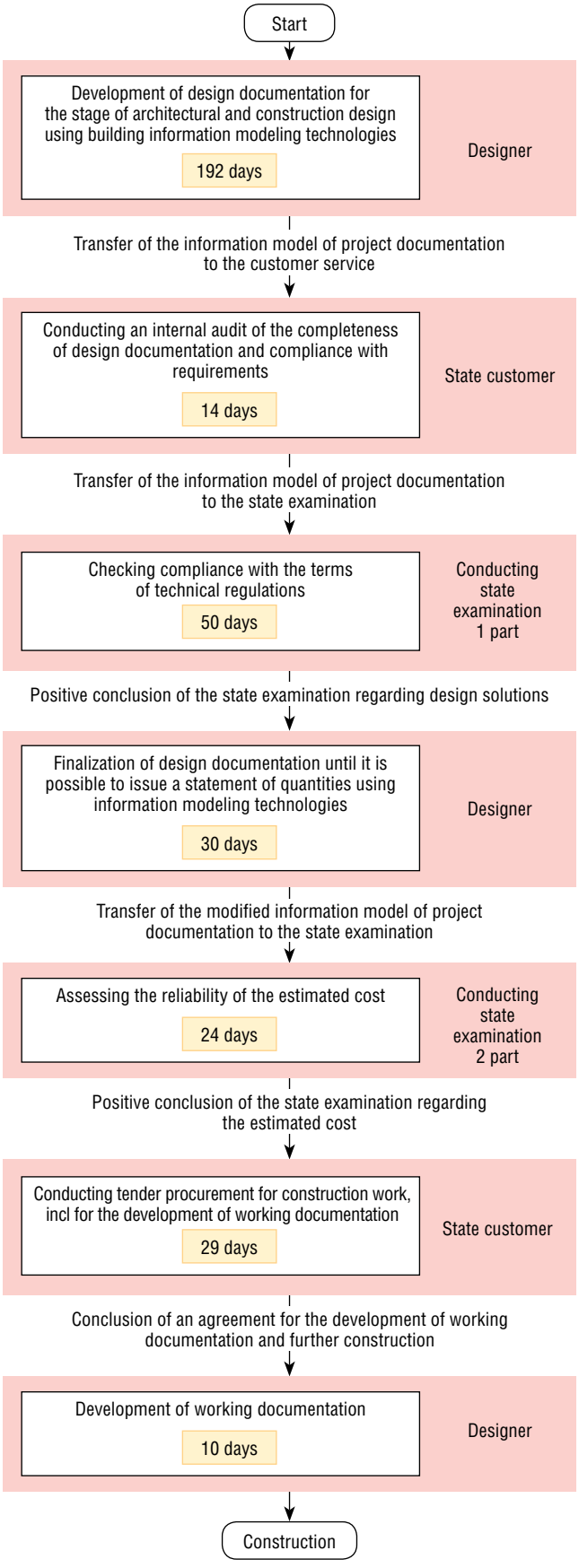

Fig. 4. Proposed scheme of interaction between participants in the investment and construction project

tenders, which also leads to additional labour costs described in Fig. 2 at the construction stage.

The information gap in the current interaction scheme occurs due to the fact that the design documentation is submitted once for state examination, and therefore for verification of design solutions and assessment of the estimated cost reliability. However, the detail required to accomplish these tasks varies. The information content of the building information model necessary to verify design solutions can be generated on the basis of the composition specified in the annex to the Government Decree [13], [16]. However, in order to assess the reliability of the estimated cost, it is necessary to be able to generate bills of quantities and specifications from a building information model, which requires additional detail from it and bringing the level of elaboration closer to the stage of working documentation due to elements such as utility networks instead of schematic diagrams, wall finishing elements instead of information about the belonging of the finishing to the premises and others. Thus, it is proposed to divide the state examination into two stages corresponding to the ongoing inspections. The scheme proposed by the authors is shown in Fig. 4.

RESULTS

To carry out an examination of design solutions for compliance with the requirements of technical regulations, it is proposed to perform a building information model for filling that meets the requirements specified in [13], without additional detail. Experts from technical departments express a positive opinion on the design documentation of the architectural and construction design stage in terms of technical regulations. This process can be implemented within the framework of expert support according to [14]. Next, the model is finalized by the designer, during which the building information model is filled with a list of parameters that is minimal and sufficient to assess the reliability of the values from the bills of quantities and specifications, thereby bringing the model detail to 80 % of the working documentation stage. After that, a re-examination of compliance with the requirements of technical regulations is carried out, and changes made to the approved version are monitored. Further, such a model is sent to the estimate department to assess the reliability of the estimated cost, which becomes possible thanks to its detail. Thus, the information gap identified in the current interaction scheme is closed. Due to the fact that the reliability of the statements of quantities of work is checked automatically, the accuracy of the calculation increases, therefore, the time costs associated with re-searching for a contractor are eliminated, which means the time for conducting a tender purchase is halved. Moreover, the costs associated with budget reallocation indicated in Fig. 2 are also excluded, since bills of quantities and specifications are controlled using automated 3D model checks.

Thanks to the division of the process of conducting state examination of design documentation into two stages (Fig. 5): verification of design solutions and assessment of the reliability of the estimated cost, the detail of the building information model is not a contradiction [13] and [14] at each stage.

When estimating the total duration of mandatory processes before the start of construction work, savings are also obtained. Under the current scheme of interaction between participants, the total duration of the processes is 400 days, while under the proposed scheme this duration is 349 days. As a result, the construction of an asset can be started 51 days earlier due to a reduction in the time required to verify the scope of work,

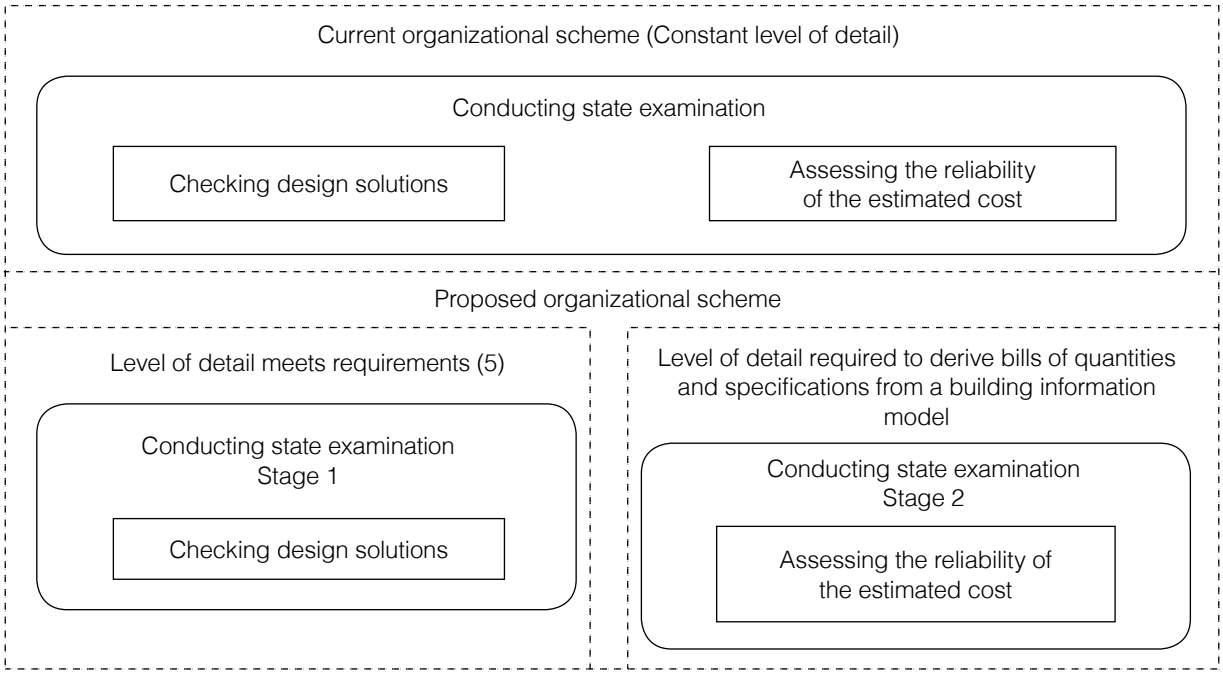

Fig. 5. Dividing the process of state examination into 2 stages

eliminating problems during tender procurement and eliminating the need for re-examination.

It is worth mentioning that nowadays, the implementation of the planned interaction scheme is possible only with legislative support, since despite the problems described in the paper when using building information modelling technologies, the requirements for the composition of design documentation [13] are mandatory and cannot be expanded without adjusting the legislation. Conducting a state examination in two stages is also not currently legally justified and can only be implemented as part of the expert support process. Therefore, for the further implementation of the research results, it is necessary to legitimize the requirements for building information models used in assessing the reliability of the estimated cost, as well as conducting a state examination in two stages, taking into account the increasing detail of the building information model.

CONCLUSION

The authors of the paper, during an expert survey, found out that on average 59.5 % of construction assets have a discrepancy in estimated cost of more than 2 %. The current scheme of interaction between participants in an investment and construction project was developed and the problematic stages of such a scheme were identified, related to the information gap between the detail of the graphic part of the design documentation necessary to assess the reliability of the estimated cost at the stage of architectural and construction design and the detail of the graphic part of the design documentation in accordance with the requirements [13]. The consequences of the presence of an information gap were analyzed, such as conducting a repeated tender purchase and the need for a repeated state examination. Based on the obtained results the duration of all stages was estimated.

The authors proposed an interaction scheme that divides the state examination process into two stages: verification of design solutions and assessment of the reliability of the estimated cost, allowing to avoid the emergence of an information gap. The application of the scheme helps to eliminate the consequences of the information gap identified in the current scheme, and makes it possible to reduce the duration of mandatory processes before construction work by 51 days. The need for legislative adjustments to implement the proposed organizational scheme was also described.

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Разработка схемы взаимодействия участников строительного процесса с целью получения достоверной сметной стоимости на этапе проведения государственной экспертизы проектной документации с помощью технологий информационного моделирования

В работе были исследованы организационные возможности разрешения проблемы несоответствия сметной и фактической стоимости объектов капитального строительства за счет разделения процесса проведения государственной экспертизы на два организационных этапа: проверки проектных решений объекта капитального строительства и оценки достоверности сметной стоимости. Авторами была проведена экспертная оценка текущего количества объектов капитального строительства на основании опроса экспертной группы, в ходе которой было выявлено, что в среднем 59,5 % объектов капитального строительства в год, финансируемых из государственного и муниципального бюджета, имеют более 2 % расхождения между сметной стоимостью на этапе архитектурно-строительного проектирования и фактической стоимостью строительства. Была проведена оценка трудозатрат специалистов Министерства строительства и развития инфраструктуры Свердловской области при необходимости корректировки бюджетных программ. Была сформирована действующая схема взаимодействия участников строительного процесса, на основании которой выявлены проблемные участки, на которых происходит информационный разрыв между детализацией цифровой информационной модели, необходимой для экспертизы проектных решений и для оценки достоверности сметной стоимости объекта капитального строительства. Авторами статьи была разработана и предложена схема взаимодействия с применением технологий информационного моделирования для получения сметной стоимости объектов капитального строительства, исключающая информационный разрыв за счет разделения процесса государственной экспертизы на два этапа, и рассчитана разница временных издержек процессов обеих схем, которая составляет 51 день. Было предложено внесение корректировок в законодательство с утверждением проведения процесса экспертизы в два этапа, а также утверждение единых требований к цифровым информационным моделям для реализации предложенной схемы и внедрению технологий информационного моделирования в процесс государственной экспертизы.

Ключевые слова: *технологии информационного моделирования, цифровая информационная модель, государственная экспертиза, проектная документация, достоверная сметная стоимость, жизненный цикл объектов капитального строительства*

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