The budget development processes’ formalization for a construction project based on digital technologies

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Abstract. the article discusses the budgeting processes in the project estimates development (PSD) based on an intelligent control system (IMS). At the same time, at the pre-project stage, the project budget is formed according to the “top-down” scheme and at the stage of its implementation - according to the “bottom-up” scheme. The processes of linking project budgets with the budget of the project organization itself are carried out in the process of “exploding” the project into individual elements, and the management of the project development processes in the methodology under consideration is represented as a hierarchy of organizational and technological models (OTM) in the developed at DSTU IMS “Design”.

Introduction

DSTU is developing the ISU “Design”, in which the processes of the linking project budgets with the project organization budget itself are carried out in the process of “exploding” the project into structural elements (Figure 1).

A number of subordination levels are distinguished in the system of exploration, according to which the information grouping that occurs during the project life cycle is carried out:
- a project for a building or a complex of buildings and structures;
- a subproject (object) for a separate building or structure within the complex;
- a structural element (SE) is a building element, for example, a column, plate, beam, etc. according to which the development of working drawings and specifications is carried out at the design stage;
- the design solution (DS) is the result of designing a part of a building consisting of one or more structural elements: drawings, specifications, calculations, descriptions, etc.;
- technology - a technological map developed at the DS and including: the composition of the design work, their complexity and sequence of implementation, qualification requirements for the specialists, the requirements for the documentation quality, hardware and software.

With the project management in construction, two types of budgets for the project and for the business as a whole are developed. For the business purposes, project budgets, regardless of their implementation timing, should be divided into monthly, quarterly and annual, taking into account the frequency of the planned and actual data comparison required for management purposes. At the same time, at the pre-design stage, the project budget is formed according to the “top-down” scheme, in the process of disaggregating the contract price in accordance with the adopted system of project exploration into the structural elements and building an information model for design process management on this basis. As a result, a project budget, which in the future becomes the law for a design or construction organization, is developed.
Figure 1. The structure of the information model for the design processes management

The operational budget necessary to control the project implementation is drawn up depending on the conditions of specific contracts concluded with the structural divisions of the general project organization and subprojects, according to the “bottom-up” scheme. At this stage, the process should be organized so that budgets approved according to the top-down scheme do not contradict those that will be formed according to the bottom-up scheme.

To ensure the adaptability of the organizational and technological models used in the design management process in the IMS “Design”, the special algorithms and models are used to disaggregate the planned and aggregate actual information on the project. Based on the developed system for collecting and processing information in almost real time mode, the deviations of the actual characteristics of the model’s work from the planned values are calculated, and then the development and adoption of the solutions to bring the control model to a given organizational and technological normal are made. The project development processes management in the methodology under consideration is represented in the form of the organizational and technological models’ hierarchy (OTM):

- OTM-1 is the network model of the project as a whole, where a section or subsection of the project is considered as work;
- OTM-2 is a network model of the project section, where DS is considered as work;
- OTM-3 is a network model or a Gantt line graph, where the work is the technological processes for the development of drawings, structural calculations, etc. design solutions, issued in the form of relevant documents. In fact, OTM-3 is the attached model of OTM-2.

The results of the OTM-1 calculation - the timing of the project sections are the limitations in the development and calculation of the OTM-2, and the time limits for the calculation of the OTM-3 are the deadlines for the implementation of the DS obtained as a result of the OTM-3 calculation.

Let us consider the description of the OTM-1 project $\bar{P}$, which includes a subset of the project sections $g_i \in \bar{G}_{p}$, $i = 1, n$, where $n$ is the number of partitions. The relationship between them can be represented as an $n$-ary relation: $f \in \bar{G}^n \times \bar{P}$, $g_i \in G, i = 1, n$ and the technological communications
graph $A(\overline{T}, \overline{G})$.

OTM-2. Many design solutions included in the section $g_p$ project p can be represented as $L_g$. The relationship between the sections and the design solutions can be represented as an n-ary relationship: $f \in L^n \times \overline{G}$, $l_i \in L$, $i = \overline{1, n}$. The network model OTM-2 can be represented by a graph of the design solutions’ technological connections $V(\overline{T}, \overline{L})$.

OTM-3. DS development involves the implementation of a subset of the work, the result of which are the relevant documents (drawings, specifications, calculation results, etc.). Such a relationship can be represented as an n-ary relation: $f \in \Xi^n \times \overline{L}$, $\xi_i \in \Xi$, $i = \overline{1, n}$, where each n work in the set of the work corresponds to one design solution. The network model OTM-3 can be represented by a graph $L(\overline{X}, \Xi_1)$, where $\overline{X}$ – defines many network graph events; $\Xi_1$ denotes the work performed by the design solution $l$, characterized by laboriousness ($Q_i$): $i = \overline{1, n}$.

The algorithm for developing the project budget is an iterative process of disaggregation - aggregation of information in accordance with the adopted scheme of project decomposition into the elements (Figure 2).

The initial version of the project budget is developed at the preparation stage for design using the information from the previously implemented projects and expert assessments.

1. Determination of the main project’s parameters, taking into account the investment income (margin) receipt and ensuring the reliability of the project on time. The source data are the two main parameters fixed in the contract: $C_p^e$ the cost (price) and $T_p^k$ the project development deadline $p$. Budget development starts with the project investment component definition, the so-called investment profit. The investment profit amount $\vartheta$ is set in % of the contract price

$$\Delta G_p = C_p^e \times \vartheta / 100;$$

(1)

where, $\Delta G_p$ – is the investment profit in value terms.

The planned indicators are: the cost and completion date of the project used by the project organization in the project management should be less than the contractual values. The project development cost $C_p^p$ taking into account $\Delta G_p$ will make:

$$C_p^p = C_p^e - \Delta G_p.$$  

(2)

In this case, the condition must be met $C_p^p < C_p^e$, which determines the investment effectiveness of the project. In order to ensure the reliability of the project on time specified in the contract, it is advisable to reduce it by the amount of the temporary reserve $\Delta T_r$ to compensate for the possible temporary deviations that may arise due to the unforeseen circumstances. The temporary reserve $\Delta T_r$ determined by the experts, and the planned deadline for the project in this case will be:

$$T_p^p = T_p^k - \Delta T_p$$

(3)

where, $T_p^k$ and $T_p^p$ as the project completion dates are contract and planned respectively.

2. Determination of the planned characteristics of the project sections. For the project $p$ sections, the expert budget sets the planned budgets and the duration of their implementation. In this case, the information is used on the previously implemented analogue projects. First, the budget structure of the sections is determined in % of the planned project cost, which is taken as 100%. After agreeing on the project budget structure in % terms, the sections’ budget is calculated in value terms. The formula for calculating the budget in % and the value terms is $P \in G_i$, $i = \overline{1, n}$. Based on the calculation results and the OTM-1 integrated network schedule optimization, in which each work corresponds to a specific project section, the time parameters of the work sections are determined (Figure 3).
Figure 2. Schematic diagram of the disaggregation–aggregation process of the information when calculating the project budget

The planned characteristics of the work-sections can be described by the following variables: \( T_g^n, T_g^o, t_g, C_{pg} \) where, respectively \( T_g^n, T_g^o, t_g \) denote the start, completion and duration dates \( g \) section in accordance with the schedule, and \( C_{pg} \) – of the \( g \) section planned budget. In the process of calculating and optimizing the OTM-1 network schedule, two main limitations are taken into account:

The sum of the planned budgets of the project sections should not exceed the planned budget of the project

\[
\sum_{g=1}^{n} C_{pg} \leq C_p^p, \quad (4)
\]

where \( n \) – is the number of sections, and the planned budget of the project \( p \in P \).

The estimated project completion date \( T_p^P \) must not exceed the planned value \( T_p^k \).

If any of the restrictions is not met, the parameters of the project’s particular section are changed and OTM-1 is re-calculated. The calculations are repeated until the conditions of restrictions are met (1,2), or a solution to change the project restrictions values: the planned budget or (and) the planned deadline is made.

For the management accounting organization, the planned project cost is converted into the planned complexity based on the average cost of 1 person that has been developed in the design organization – the designer’s working days \( B_{w}^d \). A correction factor may be introduced depending on the project complexity \( \gamma \).

\[
Q_p^P = \left( \frac{C_p^P}{B_w^d} \right) \gamma, \quad (5)
\]

Thus, the planned labor input essentially becomes the project budget.

In a similar way, the planned complexity of the project section is also determined.

\[
Q_{pg}^P = \left( \frac{C_{pg}^P}{B_{wg}^d} \right) \gamma, \quad (6)
\]

where \( Q_{pg}^P \) – is the planned budget of the project section in the labor dimension.
Figure 3. A block diagram of the project planned budget development
The process of developing the project sections’ budgets is iterative in nature with the participation of all interested parties of the structural subdivisions - the general contracting and subcontracting (if it is planned to involve them in the design) organizations, in which the constraint can be observed, in which the sum of the planned budgets of the project sections in the labor dimension should not exceed the planned budget of the project: \( \sum_{g=1}^{n} Q_{pg}^P \leq Q_p^P \).

The estimated completion date of the \( g \) section \( T_g^o \) should not exceed the planned determiner as a result of the OTM-1 \( T_g^o \leq T_p^n \) calculation. Moreover, the local criterion of the project documentation development optimality for the section may be its planned complexity \( Q_{gp}^P \rightarrow \text{min} \).

Similar to the considered algorithm, the planned characteristics of the design solutions are determined, and then the planned characteristics of the work as part of the DS are determined.

The work on determining the characteristics of the work is greatly facilitated if the design organization maintains a database of similar projects and has already completed a project similar in characteristics to the project under consideration.

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