Value Engineering in Construction as Synthesis of Methodology of Investment Flows Management and Price Formation

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Abstract. Due to modern worldwide practice and investment construction and price formation analysis the necessity of application of value engineering methods is becoming as never justified at all the hierarchy levels of construction. The purpose of the work is to get a theoretical base of value engineering, which means to work out some quality model of running an investment-construction project cost-effectively, corresponding to the internal and external influences on the investment-construction activity and ensuring the ideals of the sustainability through the balance of the investment flows in the investment-construction field. Literature sources analysis are carried out to implement the goal. Methods of the system analysis and management, comparison, expert evaluation are used. Sufficient methodical base is presented in the article. The investment-construction structure is described with modern scientists’ works, the connections and correlations between the planning, financing and pricing subsystems are presented, the influence of these subsystems on the building construction subsystem is set out in the article. The investment flows are described through the structure and developed balance of the investment flows in the investment-construction field with a mathematical model. In the conclusion the necessity of application of the value engineering methods in the investment-construction field is justified and a mathematical model of synthesis of price formation and investment flows management, which is considered a theoretical base of value engineering, is formed.

1. Introduction
Modern trends in the development of science and construction point at the possibility of regulation of the events and processes, occurring in the space of investment-construction practice, to implement the objectives of sustainability with economic methods. In this connection the planning, financing and pricing subsystems implement the tasks of supporting the construction field at all levels of the hierarchy, maintaining the homeostatic equilibrium of the system and measuring efficiency and profitability of the production and supporting processes. These subsystems together with the data subsystem shows the move of the investment flows and identify the finance-economical results of the investment-construction activity at the hierarchy levels. Thereby, the planning, financing and pricing subsystems, with the help of the coordinated cooperation of their elements, maintain optimal intensity of all investment flows in the investment-construction activity, and this is an important condition for the effective operation of construction as a technical and economic system.
2. Literature review

Native scientists Sborshchikov S.B. and Yermolaev Ye.Ye. described in their works [1,2,3,4] more than once, that close relations are formed between the in- and out- investment-construction activity flows, and besides, costs may be allowed only to the extent, that the sources of income allow them to be, i.e. the homeostatic equilibrium state must be observed. Wherein the inflow and outflow of the investment resources balance characterizes the relationship between distribution and consumption in the extended reproduction process and the final application of construction products.

Homeostatic equilibrium reflects the essence of the technical and economic systems development at the hierarchy levels in the space of national economy, the rapidly changing nature of the system development is also appearing in it. In modern conditions the concept of homeostatic equilibrium generally expresses spatiotemporal consistent and synchronization state of all the interdependent processes.

The defining property of homeostatic equilibrium is its dynamic, rapidly changing nature. For its part, the coordinates, determining the equilibrium state at the moment, are influenced by permanent and rapid changes, characterizing general investment-construction activity development. Therefore, the homeostatic equilibrium state is developing through the common tendency to the constant adaptation to the diversity of appearing impacts, through constant overcoming states, that became undesirable due to science and technology development. The ratio «equilibrium – disequilibrium – equilibrium» expresses the dynamic nature of development and its source in the investment-construction activity.

At the same time in this state the balance of inflows and outflows of the investment resources characterizes the links between the distribution and consumption in the expanded reproduction process, final construction production use.

As a continuation of this statement it was mentioned by other scientists and paraprofessionals [5,6,7,8,9,10,11,12], that pricing subsystem has a great meaning for an accurate representation of all construction components activity results. The economic category “price” is the basic methodological maintenance category of this system.  This category is at the same time an important managing system control lever, ensuring the proper use of financial, material and technical resources and the improvement of construction efficiency in general and at the hierarchy levels.

Likewise, first Sborshchikov S.B. [1,2], then Zhuravlev P.A. [7] reveal mutual influence of the pricing and building construction subsystems. According to this influence the elaboration and application of construction products in fact arise out of prices, which are the main instrument for measuring labor expenditure, material and technical resources.

The price of construction consists of a considerable list of value indicators, characterizing products, services, energy suppliers, independent condition and variable functions, such as market conditions of supply and demand or sales opportunities, the whole investment-construction situation, or availability of the required material resources, abilities to attract financial support, or credit availability, availability of an effective technological support of the construction process with the required equipment and qualitative labour resources, availability of development land, provided with connections to engineering services, possibility of providing design and survey data, etc. [7]

The general thesis of dependence of the price of construction on market conditions shows the inseparable connection between the investment-construction field and the whole economic situation in general. It is the construction industry, that suffers the very first in the financial crisis, bringing down the facilities, coming into commission, and its output to the pre-crisis level is measured in years or even decades. Nowadays, the construction field is not such a reliable investment instrument, as, for example, currency investments, precious metals, obligations are, it is these assets, where money run in crisis situations. Another important market indicator is a level of investment from the budget sources, the private capital is more willing to co-finance, with an active investment by budget of the specific facilities. The forecasting the economic growth or recession with a reasonable degree of probability is an unreachable task, so this condition may be attributed to the degree of uncertainty. [7]
At the same time the most significant and with that laborious for the rationing and forecasting process factor, affecting the price, is the cost component of the investment-construction process. [7]

With the help of prices, the management subsystem stimulates the increase of labor efficiency, introduction of the results of science and technology development, rational use of worktime, main funds, material and technical resources, as well as the interest of contractor organizations, their functioning in a single direction.

Prices, profit, credit and other economical levers of the planning, financing and pricing subsystems are used to implement the strategic and tactic objectives for stimulating the sustainability activity of the investment-construction elements and facility development.

One of the important functions of the planning, financing and pricing subsystems and their cooperation is an objective and adequate representation of the emergence and application of the investment flows in the construction.

3. Materials and methods
There are various and complicated flows of the labour, material, technical, energetic, informational and financial resources between the elements of the investment-construction system, they are characterized by a large number of direct and reverse links and make the investment-construction industry a complex and unified system (figure 1).

The flows of labour, material and technical resources are determined by the interaction of four subsystems: human resources subsystem, building construction subsystem, construction products implementation subsystem and material and technical support subsystem.

The flows of material and technical resources go from the effect accumulating to subsystem to the building construction subsystem and research and development subsystem. Their intensity, direction and coherence with labour flows are regulated by control actions, that go from the management subsystem.

The flows of material and technical resources are also heading to the building construction subsystem, as well as research and development support subsystem from ones' kind of support subsystem.

The most significant macro flow, feeding all the subsystems and providing sustainability in the system of investment-construction activity, is expressed in the implemented construction products, created by the subsystem of the same name.

There is a central feedback in the structure of the investment-construction activity due to the flows of labour and material and technical resources, this feedback may be enlarged in the following way: human resources subsystem – labour resources – building construction subsystem – construction products – construction products implementation subsystem – effect accumulation subsystem – potential for sustainability – modernization and renovation subsystem – efficiency level of the investment-construction activity – human resources subsystem.

The above links characterizes the labour force as a departure point and main element for the increase of efficiency of the investment-construction activity and implementation of a complex of interrelated construction modernization and renovation measures. Labour productivity growth increases the intensity of the flows at the output of the building construction subsystem, thus the volumes of construction products increase, the efficiency of the investment-construction activity increase in general. Construction products, that are the input value for the subsystem of its implementation, provide this system with the output values increase, i.e. revenue. It in turn affects the modernization and renovation subsystem, i.e. potential, determining the increase of efficiency of the investment-construction activity and labour. Therefore, the feedback in the structure of the investment-construction activity closes.

In this regard the investment-construction activity, as the techno-economic system and its subsystems, where main investment flows appear, may be balanced (table 1).
Resulting subsystems

Basic executive and auxiliary subsystems

Analysis and synthesis subsystems

Management subsystem

Informational support subsystem

Planned financial provision subsystem

Pricing subsystem

Control - solution

Material and incentive subsystem

Human resources subsystem

Labour force

Task - solution

Building construction subsystem

Construction products implementation subsystem

Effect accumulation subsystem

Material and technical support subsystem

Material and technical resources

Material and incentive subsystem

Labour force

Task - solution

Research and development support subsystem

Modernization and renovation subsystem

Research and development deliverables

Research and development support subsystem

Modernization and renovation subsystem

Figure 1. Structure of the investment-construction field
### Table 1. The balance of the investment flows in the investment-construction field

| Costs                                      | Income                  | Construction engineering subsystem | Planned financial provision subsystem | Human resources subsystem | Material and technical resources provision subsystem |
|--------------------------------------------|-------------------------|-----------------------------------|---------------------------------------|--------------------------|-----------------------------------------------------|
| Building construction costs                | \( A_{11} \)            |                                   | \( A_{12} \)                          | \( A_{13} \)             | \( A_{14} \)                                        |
| Taxes, fees, encumbrances                  | \( A_{21} \)            |                                   | \( A_{22} \)                          | \( A_{23} \)             | \( A_{24} \)                                        |
| Labour expenses                            | \( A_{31} \)            |                                   | \( A_{32} \)                          | \( A_{33} \)             | \( A_{34} \)                                        |
| Costs for the material and technical resources provision (the value of the material and technical resources at a price of free) | \( A_{41} \) | \( A_{42} \) | \( A_{43} \) | \( A_{44} \) |
| Balance                                    | \( \Delta_1 \)          | \( \Delta_2 \)                    | \( \Delta_3 \)                        | \( \Delta_4 \)           |                                                     |
| Total                                      | \( X_1 \)               | \( X_2 \)                         | \( X_3 \)                            | \( X_4 \)                |                                                     |

Cell A11 of the previous table characterizes the flows, that are formed between the building construction subsystem components, so-called direct costs.

Cell A12 represents the investment flows between the building construction and planned financial provision subsystems. They include tax cover, various deductions, fees, encumbrances, etc.

Cell A13 contains the investment flows from the building construction subsystem to the human resources subsystem. They include labour expenses and costs, connected with the organization of construction (so-called overhead costs).

Cell A14 is the investment flows, that represent costs for the material and technical resources provision (the value of the material and technical resources at a price of free).

The balance may be expended, it allows to give a similar characteristic to other investment flows, appearing in the construction field. The processes, occurring in the sales, modernization and renovation subsystems, may be also included in the balance.

The following identifiers may be applied to describe the investment flows, with a mathematical model:

- \( \phi_{ij} \) – an intension of the investment flow from the element i to element j (i, j = 1, 2, ..., n);
- \( x_j \) – an amount of inflows(incomes) to element j (j = 1, 2, ..., n);
- \( y_i \) – an amount of outflows(costs) from element i (i = 1, 2, ..., n).

The system of equations, that characterize homeostatic equilibrium, may be obtained with the given indicators: \( \sum_{i=1}^{n} \phi_{ij} = x_j \) and \( \sum_{j=1}^{n} \phi_{ij} = y_i \).

We assume, that the ratio of incomes from the element i to the overall investment flow, coming to the element j, is the quantity \( \lambda_{ij} \), i.e.

\[
\frac{\phi_{ij}}{x_j} = \lambda_{ij} \tag{1}
\]

With this provision the following system of equations, representing the investment flows, may be obtained:

\[
\sum_{j=1}^{n} \lambda_{ij} x_j = y_i \tag{2}
\]

In matrix notation it is \( \Lambda X = Y \).

If \( x_i = y_i \), i.e. the amount of income is equal to the amount of costs, then it can be written like this: \( \Lambda X = X \) and by this \( \Lambda X - X = (\Lambda - E)X = 0 \), where E – identity matrix, X – results of the building construction; Y – costs for erection.
With the help of this equation the consequences of changes in the intension of individual flows, for example raise in wage under certain construction conditions, changes in companies’ profit etc., may be modelled.

4. Results

If we take into account, that construction operation at the hierarchy levels depends on the concentration of certain amount of labour force and the volume of material resources at every instant, then their optimal distribution between the objects and fields of activity, cost saving and permanent development of labor productivity may be considered not only as an objective necessity, but also as decisive prerequisites of sustainability. Application of these factors leads to the fact, that reduction in expenses for erecting an object due to the development of labor productivity influences on the price level.

Therefore, there is a necessity for economic methods, through which operative measures, corresponding to the internal and external influences on the investment-construction activity, may be taken, and for further formation of the system of cost engineering. In this regard the following designations may be applied to describe price formation: \( P \) – price vector; \( A \) – matrix of the direct costs, including essential wage; \( R \) – overhead costs vector; \( V \) – profit vector. Thereby, price formation is expressed by the ratio:

\[
P = P \cdot A + R + V
\]

This implies:

\[
P = (R + V) \cdot (E - A)^{-1}.
\]

5. Conclusions

With the help of this equation and special procedures the effect of price changes on certain types of material and technical resources and reduction of costs per unit may be determined. Thereby this model may be used to manage value (costs and profits) of the investment-construction project, i.e. is a theoretical base of value engineering.

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