AUTOMATED MANAGEMENT, MODELLING AND CHOOSING OF ECONOMICALLY EFFECTIVE VARIANT IN CONSTRUCTION

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INTRODUCTION

A construction process is affected by many factors, which in one or another way influence all the parameters (development, infrastructure, duration, resource demand) of the investment project of construction being implemented. Efforts are made to foresee the influence of these factors with the help of various calculation means and databases, based on both statistical and expert (high experience) data. When calculating, it is assumed that parts of the project under examination or even the entire project is similar to those construction projects that were accomplished earlier, but these are only assumptions and their bias degree is quite high in comparison to actual parameters, obtained after implementation of the project.

In order to determine as precisely as possible theoretical values of the parameters [1] and to reduce errors, in the field of construction it is offered to apply PLM (Project Life Management) [2] or so called 4D concept. In the mechanical engineering industry the project life management has been used already for more than ten years enabling in static and dynamic environment simulating not only 3D nodes [3], but also the whole construction project consisting of elements [4], to which their specific characteristics (and other relevant information) as well as permanent interconnections have been assigned [5]. The fourth dimension – time – is employed for the analysis of simulation, i.e. the project can be evaluated in respect to time (resistance to long-term effects, uniform durability of the project parts, economy and of resources and energy related to implementation of the project, analysis of ecological pollution, etc.).

OBJECT OF STUDY

There are many studies examining aspects of investment construction projects [6], analysing specifics of their structure, application and suitability of the alternatives evaluation models being in use [7] and principles of implementation. However, scientists tend to underestimate the suitability and precision of the evaluation data as well as the reliability of methods and means of their usage [8]. Therefore, this paper analyses the prevention of efficiency indicators, determination of values and precision of their determining. The application of 4D concept model for the investment project management will be assessed as well.

We can define a traditional investment construction project being analysed from the beginning of its implementation through the end as a model (Fig. 1). The model is comprised of stages, in which the mentioned participants perform corresponding actions (the structure is divided in columns). The information collected through stages is transferred to the next stage, but the data collected in this way often are not suitable and are to be changed in order to put into life the most effective variant. The cells marked in the model by dashed line represent two blocks: the upper block is a model of construction project developed and assessed by architects and designers (architectural and technical drawings of the project, 3D models) [2]; the lower block represents the construction works performed by a contractor. The main problem becomes evident - there is no constant reciprocal link when sharing information between these two blocks during design and construction stages, i.e. in designing technical solutions are adopted without consultation of construction works specialists, and during construction the contractor often attempts to implement the vision of architects and designers in the most simple way. Such a lack of reciprocal sharing of information among the participants of the project has effect on smooth implementation of the investment construction project (increasing the timescale of the project implementation and being the reason for the demand of non-scheduled resources).

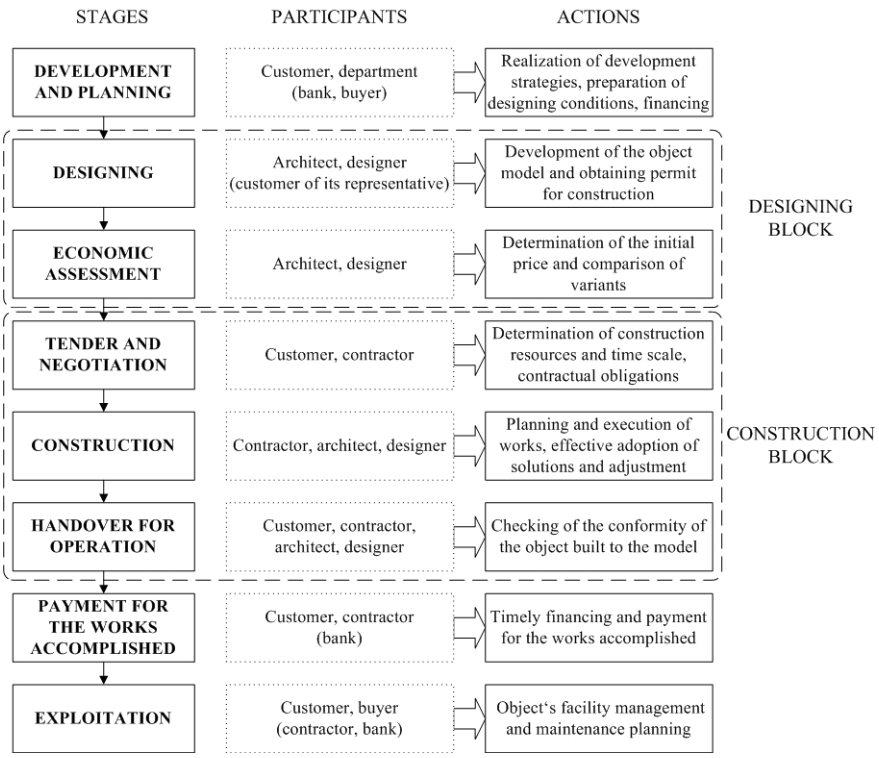

Fig. 1. *Traditional model of investment construction project implementation*

Therefore, in order to implement an investment construction project within the estimated time period using the calculated resources it is necessary to manage the flow of information among the participants of the project in the most effective way during all the investment construction project life, ensuring a full cycle of engineering support (The Building Continuum) [9].

MODELING AND CALCULATION ANALYSIS

Introducing 4D concept for the management of investment construction project fulfills obligatory ensuring of the constant reciprocal relation between the participants. However, in order to manage the project, first of all it is recommended to create a 3D model of the project and to perform simulation of the project implementation. This is a developed theoretical three-dimensional information model of the building (3D BIM – building information modelling) consisting of intellectual volume elements [10], which is combined with resource demand calculations, comparison of alternatives and determination of duration of all the stages of investment project life [6]. Such expression of 3D model in time within all its life is the project's 4D conception. A constant cycle is being executed within the stages of this 4D concept model (Fig. 2) in order to adopt the best solution, and there is a constant exchange of cycle information flow between the stages encouraging selection of the most effective variant. The structure of 4D concept model is divided into levels: on the first level (cells in bold) stages and their interrelations are presented; on the second level (cells with dotted line) primary data (and means) are presented; the third level (cells with arrows) is devoted for the actions and processes being carried out; the fourth level (big cells) presents the obtained result, benefit and advantages; in the fifth level the indicators of stages effectiveness are obtained, afterwards used for further multiple criteria comparison of the construction variants.

We see, that primary elements of the model's structure make the biggest influence on the efficiency indicators, and selection of the best solution mostly depends upon a determination of demand for precise resources, because in case of a mistake, the determined most effective variant will not be the most effective. Therefore, in order to establish the demand for the project resources, a thorough calculation of the project related quantities is to be made, and this work is time-consuming, as most often the calculation of quantities is performed in a manual way. To reduce the time period necessary for the calculation of the quantities in relation to the construction project and to avoid mistakes and inaccuracies that occur due to manual calculation, a 4D concept model can be used.

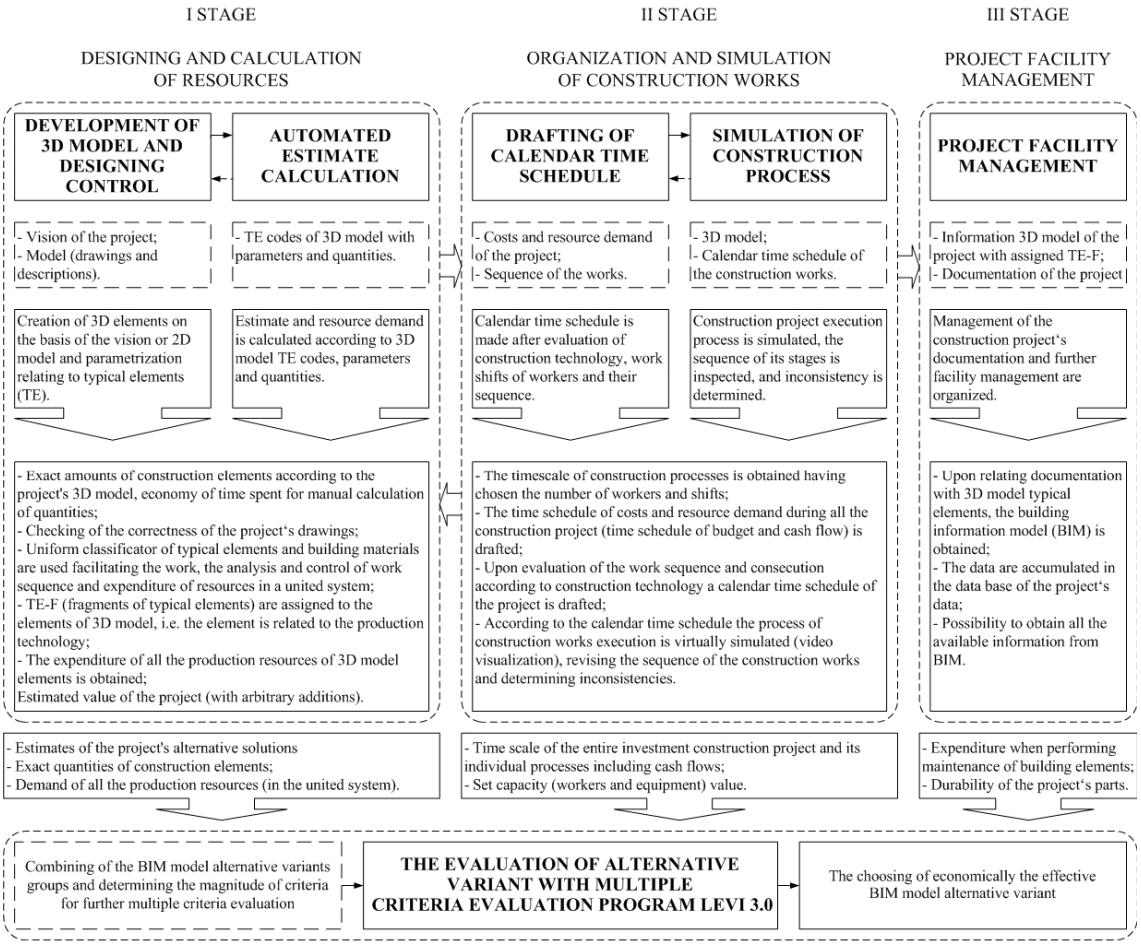

Fig. 2. *Stages of 4D concept and its elements*

The principle of 4D model application is as follows: the quantities of modelled, described and parameterised elements are obtained automatically from the developed building information model (3D BIM), and the demand for project resources is generated. According to set technical capacities, from the resources demand we obtain the timescale of the project's processes, from technological sequence of which the time scale of the entire investment construction project is derived.

The research that was made and comparison of calculation work timescales are necessary in order to determine quantities and demand for resources, to make estimates and to compare alternatives. The results of this research as well as advantages and disadvantages of each method are presented in Table 1 and Table 2.

Table 1. The calculation of work timescales for usual execution of tender works

Usual execution of tender works (medium size construction project – in total 88-140 man-hours)
1) Review of project documentation (descriptions, drawings and correction of ambiguities) – 8-16 man-hours; 2) Manual calculation of workload – 48-80 man-hours; 3) Entering of quantities and making of estimates – 16 man-hours; 4) Inquiry about prices and adjustment of the estimate – 4-8 man-hours; 5) Finalizing and revision of the commercial offer – 4 man-hours; 6) Analysis and presentation of every alternative variant – 8-16 man-hours.
ADVANTAGES: estimate program is enough to make an estimate. DISADVANTAGES: a lot of time is wasted for calculation of quantities and recalculation when there are changes in relation to the project data; the influence of human factor is big; the information obtained contains unknown level of error (is not precise); there is no time for analysis and presentation of alternative variants.

Table 2. The calculation of work timescales for usual execution of tender works

Execution of tender works using 4D concept (medium size construction project – in total 60-140 man-hours):
1) Review of project documentation (descriptions, drawings and correction of ambiguities) – 8-16 man-hours; 2) Development (preliminary) of 3D model and generation of work load report – 32-48 man-hours; 3) Parameterising of typical elements and generation of reports – 8 man-hours; 4) Inquiry about prices and adjustment of the estimate – 4-8 man-hours; 5) Finalizing and revision of the commercial offer – 4 man-hours; 6) Analysis and presentation of every alternative variant – 4 man-hours.
ADVANTAGES: time is economized (especially when analysing and regenerating alternative and erroneous estimates), quantities and estimates are regenerated effectively according to the modified project data, the level of bias of the obtained information is known (the bias is quite accurate), alternative variants are obtained quickly (a multicriteria comparison is possible), performance of calculation works in relation to the tender requires 46% less of man-hours. DISADVANTAGES: a skilled specialist knowing how to use special software (for development of 3D model and elements parameterising) is necessary.

The data of analysis shows that the saved time can be used for the management of more construction project tenders with a possibility to perform a deeper analysis and comparison of more alternative solutions for each project.

Therefore, in the 4D concept model being used stages inside every phase have inner cyclical relations that are necessary for constant phase correction, when I and II stages constantly share data that are used for specifying calculations and reducing bias, and III stage accepts information from II stage and saves it in the data base (for further Facility Management). After all the cycle of 4D concept is finished precise data of the analysis of alternatives are quickly obtained, on the basis of which the final variant of the project is accepted (optimal group of variants of the project's BIM model elements is selected) or primary data and 3D model are adjusted.

DETERMINATION OF EFFECTIVE VARIANT

Having analysed the characteristics of the investment construction project and applied the 4D concept, a model suitable for determining a precise most effective variant is developed. The generalized model of the investment construction project automated management within its entire life (Fig. 3) consists of 4 individually used blocks. Data of each block after the accomplishment of every stage can be analysed comparing the selected alternative variants, and the collected information can be transferred to the next block. In this way a flexible simulation and real time analysis are obtained, with the help of which in case there are any changes in the situation (at any stage of the project implementation cycle) alternative solutions can be assessed and the most effective variant at that time chosen using 4D concept and virtual 3D BIM model data.

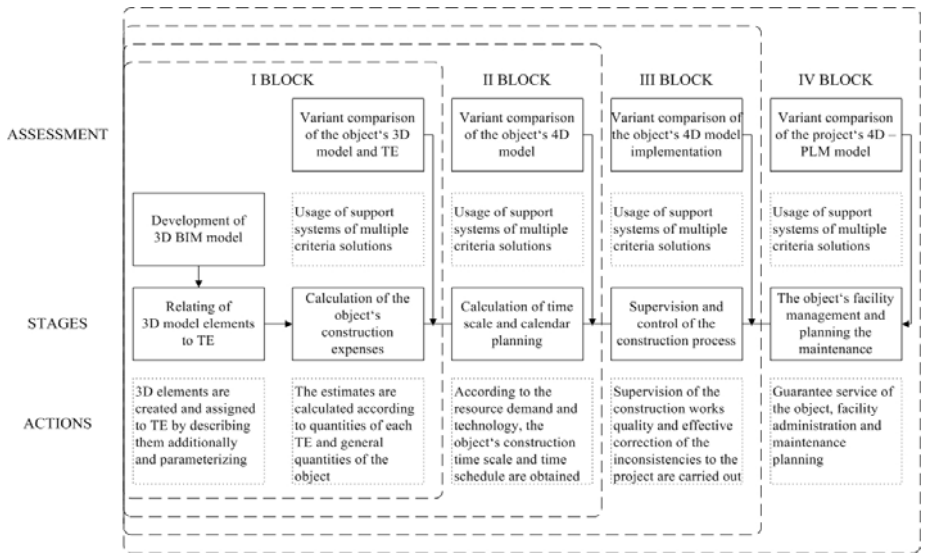

Fig. 3. *Model of the investment construction project automated management within its entire life*

The detail description of the blocks, model stages, actions, evaluation process and results is given in list below:

1) **I BLOCK (3D and TE)** This block consists of 3 stages: on the basis of the available drawings and the construction project model, 3D BIM (Building Information Model) is developed; the elements of the created 3D model are related to typical elements from the uniform classificatory of construction elements and resources, and additionally described and parameterised; the estimate of the construction project expenses is generated automatically. When all the data of the block are collected, a comparison (assessment) of alternative solutions can be performed;

2) **II BLOCK (4D):** This block is made of the previous I block and one additional stage, which is calculation of the project implementation time scale and calendar planning. Having data from the first block (resource demand) and having entered technological sequence, calendar time schedule of the construction project is obtained with accurate time scales of the processes and resource demand within the time scale. In this block the simulation of the construction project implementation is also obtained (visualising the future construction process). When all the data of the block are collected, a comparison (assessment) of alternative solutions can be performed using indicators of time scale;

3) **III BLOCK (4D LIVE):** This block consists of the previous I and II blocks and one additional stage – supervision and management of the construction process. A virtual model of the project expressed in time (4D) is used for the control and comparison of the theoretical model and actual construction works, i.e. there is a possibility to compare what is the difference between the actual resource demand and theoretical one, and to see what works and on which day are to be accomplished (to follow the scope and course of the construction process in the visualisation). When all the data of the block are collected, a comparison (assessment) of alternative solutions and analysis of possible inconsistency of resources can be performed;

4) **IV BLOCK (4D PLM):** This block consists of the previous I, II and III blocks and one additional stage - the object's facility management and maintenance planning. All the available information about the elements is accumulated in the virtual model of the project (data base), i.e. the data on the producer of the element, element's characteristics, peculiarities of maintenance, guarantee period, etc. are accumulated. When all the data of the block are collected, a comparison (assessment) of alternative solutions and calculations of the possible resource demand for regular maintenance procedures can be performed.

As it is shown in Figure 3, it is available to compare (assess) the alternative solutions or evaluate the alternative variants in each block of the model. In this stage it is advisable to use multiple criteria evaluation methods. Some scientists in this case suggest – "the construction project implementation alternatives under consideration by selecting effective constructional-technological-organizational variants (a construction system) may be performed applying the methods for synthesis of multi-criteria solutions" [12].

In construction indicators of the implemented designs are different from those calculated according the design and drafts. The existence of information lack does determine the unreliable or incomplete information. When random effects defined by evaluations according to the distribution laws cause these uncertainties set by various statistical methods, then we have the problems of stochastic indefiniteness [7]. Usually the problems of this type may be solved by the methods of game theory solely.

In case then weight ratios of efficiency indicators are unknown the pending task or problem shall be considered as a decision to be made under the conditions of uncertainty (indefiniteness). And for decision making under the conditions of uncertainty the game theory methods may be applied [11].

In this paper as one of the measures intended for improving research focused on the integration of multiple criteria decisions into decision support systems an algorithm of the synthesis methods [12] for combining several construction project or a few phases of design stages into a joint systems is used [6]. The professors of Vilnius and Leipzig high schools have been performing a research into the problem of multiple criteria evaluation and uncertainty for several years. They were analysing the usage of mathematical-statistical methods for multiple criteria evaluation and have applied game theory to solve uncertainty problem. All these calculations are fulfilled by LEVI 3.0 software (Peldschus, Zavadskas, Ustinovichius *et al.*) [7]. Using this new software (Fig. 4) it is possible to find solutions for a task by means of different methods, to compare the investment construction project variants by choosing the solutions (Fig. 5) and choose the economically effective variant in construction.

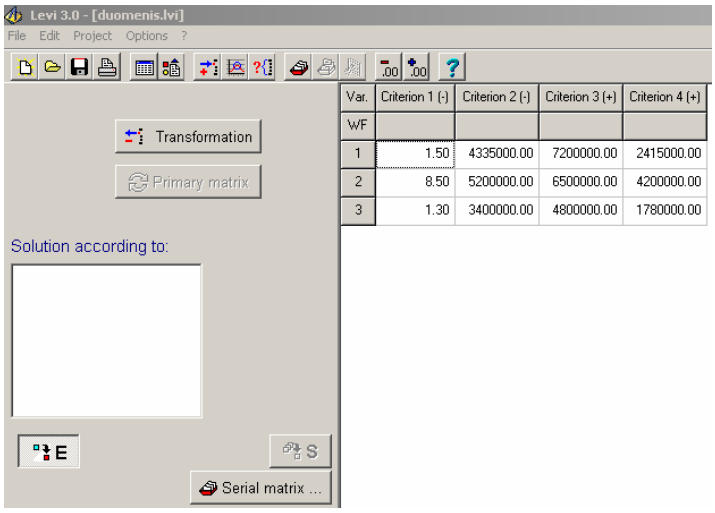

Fig. 4. *Levi 3.0 example – structure of data input*

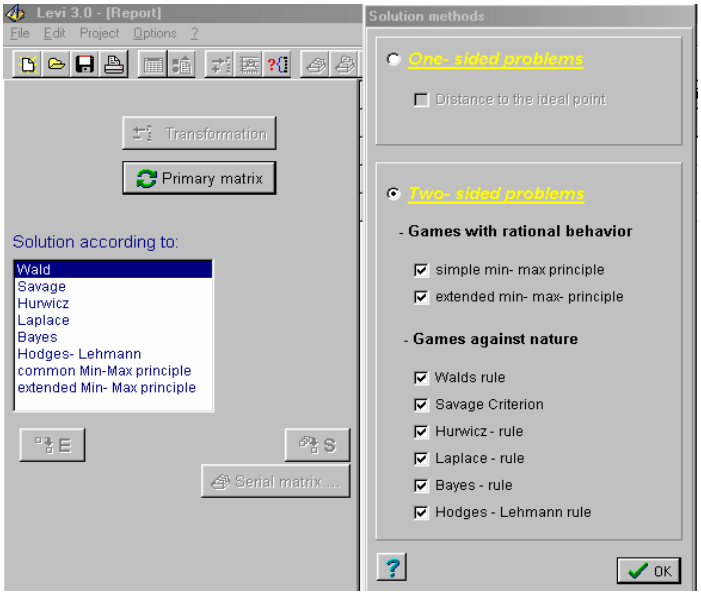

Fig. 5. *Levi 3.0 example – input of solution methods*

Following the static equilibrium, the equilibrium in the game theory has a particular significance. Compared calculations with other methods of solution are necessary because the application of the equilibrium in the game theory to the building process is not always possible [7]. These problems are to be solved through the application of the software LEVI 3.0. It were evaluated the effects of the different methods of transformation on the numerical result and to improve the quality of transformation and precise solving technological and organizational problems (tasks). This accurate use of needed transformation methods allows avoiding inaccuracy problem [8] in investment construction project variants evaluation with the software LEVI 3.0.

CONCLUSIONS

1. Obligatory ensuring of the constant reciprocal relation and constant mutual information flows between the construction process participants is fulfilled by introducing 4D concept for the management of the investment construction project;
2. The advantages and benefits of I-st stage (Design and calculation of resources): precise quantities of construction elements are obtained; the time wasted for manual calculation is economized; the correctness of the drawings is checked; uniform classificatory of typical elements (TEC) and construction materials (CMC) are used allowing to control and analyse the course of works

and expenditure of resources in the unified system; the estimated value of the project is obtained along with all the estimate documentation.

3. The advantages and benefits of II-nd stage (Organization and simulation of construction works): the time scales of construction processes are obtained; the schedule of the expenses and resource demand during the entire construction project and calendar time schedule are drafted; the succession of the construction works is checked and inconsistencies are established.

4. The advantages and benefits of III-rd stage (Designing and calculation of resources): the building information model (3D BIM) is obtained; the data are constantly accumulated in the data base of the project; there is a possibility to obtain all the available information from BIM (data in electronic form); the expenditure in relation to facility management during maintenance and reconstruction of the building elements is planned; durability control and accounting of guarantee works.

5. The advantage of whole 4D concept is a possibility to simulate the management of the project, on the basis of 3D model to calculate the precise resource demand, to determine the time scale of the project implementation and to assess effectively alternatives. Therefore all information must be accumulated in building information data bases for further construction and facility management.

6. It is suggestible to use the multiple criteria decision support software LEVI 3.0 as evaluation tool to choose effective construction investment project alternative group.

7. The software based on this combined 4D PLM model must be in further developmental stage as a means to analyse and manage effectively the investment construction project through its implementation and entire life.

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