Computer-Aided Modelling, Evaluation and Management of Construction Projects According to PLM Concept

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Computer-aided modelling, evaluation and management of construction projects according to PLM concept

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Abstract. The major problem for investors in construction area is to choose the financially effective construction alternative, most often associated with underestimated actual demand for resources. The lack of information feedback among all participants of the project and the uncertainty treats at the design and construction stages are presented in this paper. Solution is the theoretical 3D building information model, combined with resource demand calculations, comparison of alternatives and determination the duration of all construction project life stages. The software based on this aggregate 4D PLM model can be the mean of effective management of the construction project, embracing planning, design, economic calculations, construction, management, usage and maintenance of the completed building. The paper also describes multiple criteria evaluation software used to identify the most effective construction alternative with presented suggestions of implementation in practice.

Keywords: Project life cycle management, 3D and 4D modelling, computer-aided evaluation and management in construction.

1 Introduction

Investors such as governmental organizations, financial-insurance companies, banks, industrial companies and active owners at the local and foreign real-estate markets face the same problem – the rapid grow of prices for real-estate and qualified human working power. The same big and more smaller problems influence the construction industry. The construction process is affected by many factors, influencing all the parameters (such as development, infrastructure, duration, resource demand, financial stability). At the beginning of the construction project implementation, efforts are made to predict the influence of these factors with the help of various calculation means and data bases, relying on both statistical and expert-provided data. It is assumed that parts of the project under consideration or even the entire project are similar to accomplished earlier construction projects. However, these assumptions are not always correct and their bias degree is quite high in comparison to actual obtained parameters after the construction project implementation.

In order to determine theoretical values of the parameters as precisely as possible [1] and to reduce errors in the field of construction, the use of Product Lifecycle

Management (PLM) [2], [3] or the so-called four-dimensional (4D) concept [4] is recommended. To achieve the effective management, fulfil the correct Enterprise Resource Planning (ERP) conditions with proper Supply Chain Management (SCM) and automated Material Requirements Planning (MRP), it is recommended first to create a 3D model of the construction project and to perform the simulation of its implementation. The fourth dimension – time, is employed for the analysis of simulation [5], [6], i.e. the project can be evaluated in terms of time (resistance to long-term effects, uniform durability of the project parts, saving power and other resources in implementing the project, analysis of the environmental pollution, etc.).

2 Objectives of the research

The works devoted to the analysis of various aspects of construction projects' management [7], scheduling-planning and safety [8], design-planning-estimating procedure integration [9] analyze both structure and models used to evaluate the available alternatives [10], as well as major principles of their implementation [9]. Researchers offered possibilities of cost and time reduction for project documentation [11], schedule information, visualisation, communication [12], construction projects management and analysis using 4D project both with IT power. Most of them identified advantages [8], [9], [12] such as the same design interpretation among project members, understanding of construction sequences, certified amounts of construction works, design quality analysis and possibility of alternative evaluation.

However, the researchers tend to underestimate the influence of suitability and precision of the evaluation data as well as the reliability of methods and means of their application [13]. The present paper analyses the indicators of project efficiency as well as the methods of determining their values and precision of the technique used which will help to avoid further comparative analysis of inefficient project alternatives. The application of 4D concept model for the construction project management will also can be considered as the computer-aided financial and organizational means for company management and resource planning.

A traditional construction project can be described as a model covering all stages of its implementation [4], [9]: development and planning, design and economic assessment, tender and negotiations, construction and handover, maintenance and utilization. In these stages certain participants (Customer, costomer's representative, department, designer, contractor, investor or owner) perform the appropriate actions. The information collected through earlier stages [6] is transferred to the next stages. However, the data collected in this way often are not suitable and should be changed in order to implement the most effective construction alternative.

The main problem is the lack of information exchange between the construction project developed-assessed by designers (architectural, technical and work design of the project, 3D models) [2] and the construction works performed by a contractor. For example, at the design stage, technical decisions are made without consulting with construction specialists, and, at the construction stage, the contractor often attempts to implement the vision of designers in the simplest way. The lack of information exchange among the project participants negatively affects its implementation of the

construction project: increasing the execution times, being the reason for the demand of non-scheduled resources, including ruined human resource management (HRM) and planned resource supply chain.

Therefore, to keep the schedule of the construction project implementation, based on the calculated resources, the effective management system of data distribution among the participants of project, control system throughout the whole construction project life [4], ensuring a full cycle of engineering support (The Building Continuum) [14] is needed.

3 Modeling and calculation analysis

Construction consulting and contracting company can fill the information lack ensuring coordination works and information feedback in development, design and construction stages. The feedback from the participants is ensured by using a 4D concept for the management of construction projects combined information flows inside enterprise. Therefore, a theoretical three-dimensional information model of the building (3D BIM) [14] consisting of intellectual volume elements [15] is developed, which is combined with resource demand calculations, comparison of the alternatives [16] and determination of the project lifetime at all stages of its implementation [17]. Expression of the 3D model in time embracing whole life of the project is 4D concept. Practically project manger can have whole information related with project before the construction process and can better prepare for project implementation.

A complete cycle of operations is being executed within the stages of the 4D concept model (Fig. 1) in order to make the best solution. A constant exchange of information between the stages [18] encouraging the selection of the most effective alternative is maintained. The structure of 4D concept model is divided into levels: at the first level (cells in bold), all stages and their interrelations are presented; at the second level (cells marked with dotted line), the initial data (and means) are presented; the third level (cells with arrows) is intended for the actions and processes to be carried out; the fourth level (big cells) presents the obtained result and benefits.

We can see that primary elements of the model structure have the greatest influence on the efficiency indicators, with the selection of the best solution mostly depending on precise determination of the demand for resources and Supply Chain Management (SCM). The errors made at this stage will prevent from determining the most effective alternative. Therefore, in order to establish the exact demand for project resources, a thorough calculation of the project-related quantities should be made. In most cases this manual work is time-consuming. To reduce the time needed for this the calculation of the required quantities and to avoid mistakes and inaccuracies caused by manual calculation, the 4D concept model can be used [4].

The main principle of the 4D model application is as follows: the quantities of modelled, described and parameterized elements are obtained automatically from the developed building information model (3D BIM) together with the determined demand for project resources. Basing ourselves on the specified technical capacities, we can obtain the timescale of the project operations and according their technological sequence the timescale of the entire construction project is derived.

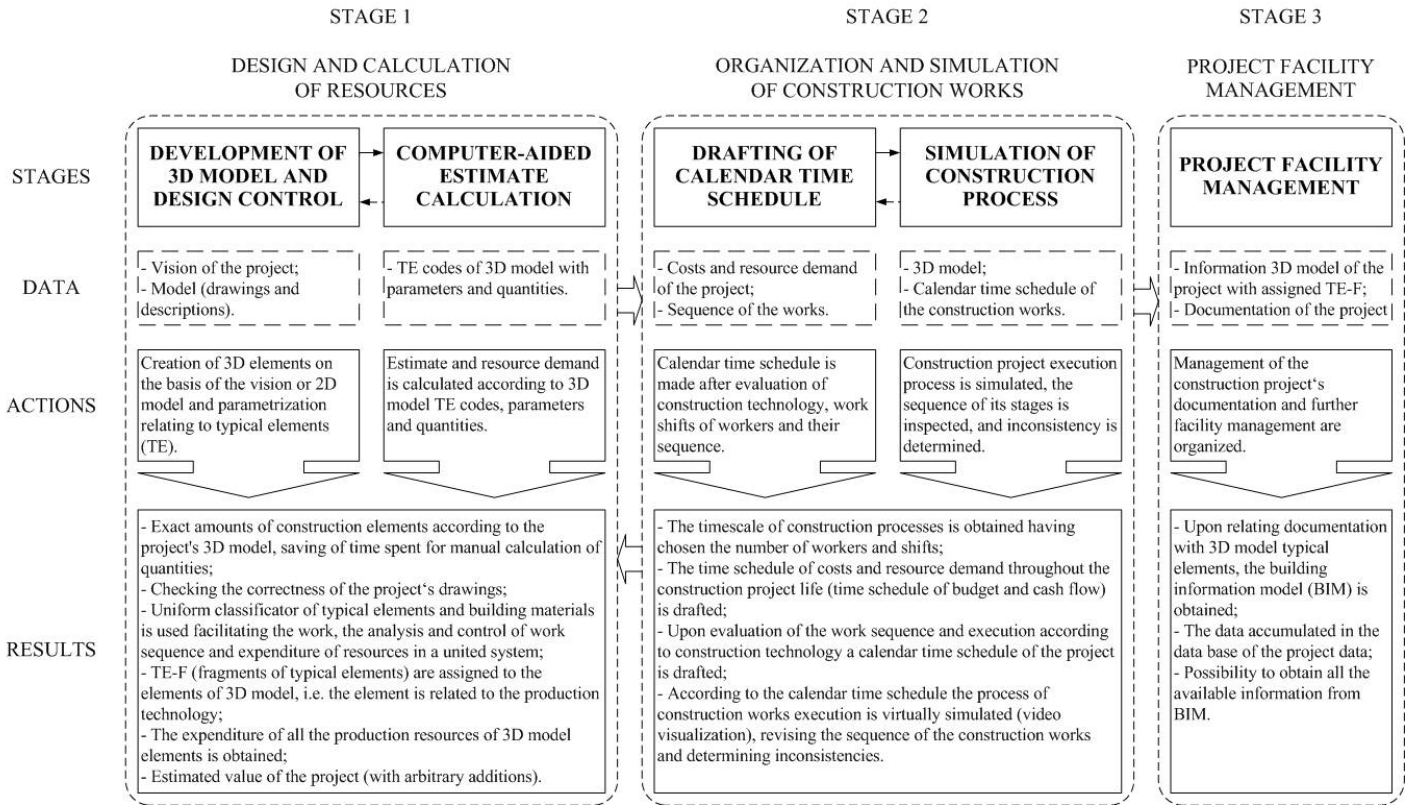

Fig. 1. The main stages of the 4D concept implementation and its elements

In the 4D concept model being used, the stages of every phase have inner cyclical relations needed for constant phase correction, while stages 1 and 2 share the data used for specifying the calculations and reducing the bias. Stage 3 receives the information from stage 2 saving it in the database (for further Facility Management).

To describe the 4D concept implementation (Fig. 1) a model of 4D concept implementation in the construction project management (Fig. 2) is made. This model has similar structure as his anterior but in addition it shows the management of calculated and collected data flow using special software packages such as SAS (System of the Automated eStimates – for composition estimates), Bentley Navigator and Microsoft Project. Included uniform classificators of typical elements (TE) and construction materials are used for control and analyze the course of construction and the expenditure of resources. Particular programs are connected with interrelationships and also the relations between stages are presented.

The effectiveness indicators of the stages are obtained, which are later used for multiple criteria comparative assessment of the construction project alternatives. When the whole cycle of the 4D concept is completed, the precise data of the analysis of the alternatives are obtained and used for choosing the final alternative of the construction project. If some major adjustments for 3D BIM must be made to ensure smooth Enterprise Resource Planning (ERP) with adequate Supply Chain Management (SCM) for several construction projects [19], its advisable to use full 4D concept implementation cycle.

The research made by scientists [4] has already compared duration of construction stages to determine the demand for resources, to calculate the estimates and to compare the construction alternatives. Main conclusion of this research is – the time saved to complete tendering procedures using 4D concept, compared to tendering procedures made in ordinary way, can be used for managing a larger amount of construction project tenders with a possibility to perform a more thorough analysis and a comparison of more alternative solutions for each construction project.

4 Determining the effective construction project alternative

When 3D BIM model is completed, the main characteristics of the construction project are analyzed and the 4D concept is applied, a model suitable for determining the most effective alternative in each project implementation stage is developed (Fig. 3). The generalized model of computer-aided construction project management throughout its life consists of initial stage and four project life cycle stages (lower row) individually combined with comparison of alternatives (upper row).

Initial stage. Every construction element from developed 3D BIM model must be assigned to typical element (TE) by describing and parameterizing according construction technology and exceptional implementation conditions. Assignment gives possibility to ensure the storage of all information related to the certain element of 3D model in single data base and can be used for any assessment.

3D model and TE stage. The estimate of the construction project is generated automatically according to quantities of each TE and general quantities of the project. Collected data can be used to establish tendering procedures for contractor selection.

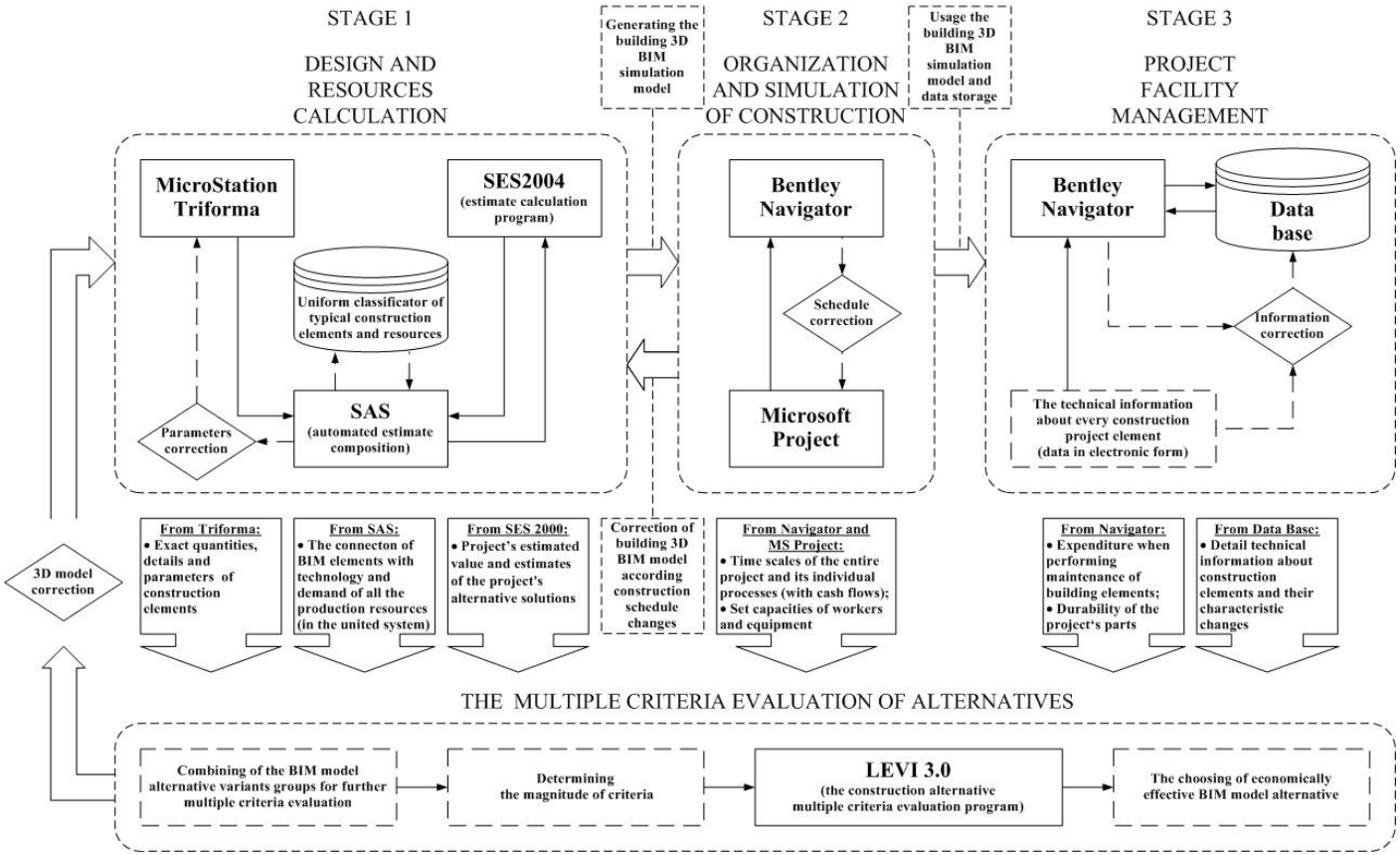

Fig. 2. A model of 4D concept implementation in the construction project management

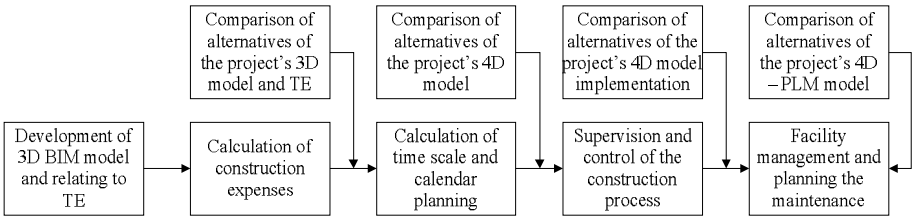

Fig. 3. A model of computer-aided management of the construction project throughout its life

4D model stage. Using the data from the 3D model and TE stage (resource demand) and having entered the technological sequence it is obtained working time schedule of the construction project, project implementation timescale, duration of processes and the demand of resource. In this stage it is available the simulation of the construction project implementation (visualising the future construction process) and analysis of possible alternative scenarios to foresee-reduce risk and uncertainty.

4D model's implementation stage. A virtual model of the project expressed in time (4D) is used for the supervision, control and management of the construction process with effective correction of the inconsistencies, i.e. there is a possibility to determine the difference between the actual and theoretical demand for resources and to follow the scope and course of the construction process in the visualisation. Information about actual demand of resources helps to control costs and dynamically react to volatile situation in construction site.

4D PLM model stage. All the available information related to facility management and maintenance is accumulated in the virtual model of the project (database), i.e. the data on the producer of the element, element's characteristics, peculiarities of maintenance, warranty servicing period, etc. are accumulated there.

Practical benefits of presented models can be described as: better management, communication and visualization of implemented projects with more consistent project documentation. Therefore project team was supported with: early information about missed design solutions and possible arising problems before production-installation, generated quantities for tendering procedures and analysis comparing to actual amount of the works. The 3D model connected with construction and supply schedule were used as a tool for operative planning and management of construction process. That is why detailed solutions enable manager to stay a step ahead, anticipate and solve everyday problems even before the client is confronted with them.

The best solution for construction company must be based on effective management of construction projects with analysis of the resource demand change. The possibility of comparison the alternatives in each stage (Fig. 3) can be applied using multiple criteria evaluation methods. In construction, the indicators of the implemented designs often differ from those calculated according to the design and drafts. The lack of information results in uncertainties or unreliable or incomplete data. When these uncertainties are caused by random effects defined by evaluations according to the distribution laws set by various statistical methods, then we have the problems of stochastic indefiniteness [10]. In decision-making under these uncertainty conditions, the game theory methods may be applied [20].

5 Multiple criteria evaluation of alternatives

In this paper, the research is focused on the integration of multiple criteria decisions into computer-aided modelling-management-evaluation systems as well as using the algorithm of the synthesis methods [21], for combining several construction projects or a few phases of design stages into a joint system [6]. The researchers Peldschus, Zavadskas, Ustinovichius developed decision support software LEVI 3.0 [10]. Using this software, it is possible to find solutions to problems by different methods, to compare the construction projects and to select the most economically effective project implementation alternative in construction industry [22].

LEVI 3.0 can evaluate the effects of the application of different methods of transformation on the numerical results and improve the quality of transformation as well as ensuring precise solving of technological and organizational problems (tasks). This application with usage of the appropriate transformation methods allows to avoid inaccuracies in assessing the alternatives of construction projects.

6 Conclusions

The interconnection of the construction process participants and exchange of information are ensured by introducing the 4D concept for managing the construction projects. The main advantage of the 4D concept as a whole is a feasibility to simulate the management of the project, to calculate precisely the demand of financial and corporeal resources on the basis of 3D model, to determine the timescale of the project implementation and to assess the alternatives effectively.

Therefore, all the information should be accumulated in the building databases for further construction and facility management. It is advisable to use the multiple criteria decision support software LEVI 3.0 as a powerful tool for choosing the effective construction project alternatives.

The software based on the 4D PLM model should be in further developed as a powerful means for analyzing and effective management of the construction projects with analysis of the resource demand change and Supply Chain Management (SCM) throughout the construction project implementation and service life.

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