COMPARISON OF DIFFERENT COST ESTIMATION METHODS WITH USE OF BUILDING INFORMATION MODELLING (BIM)

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Abstract. The paper deals with the topic of cost estimation methods with the use of Building Information Modelling (BIM) in construction projects. As BIM is trending in construction industry, and many countries make decisions to require BIM in public contracts, the demand for various utilization of digitized construction related data increases. One of utilization options is the use of BIM for quantification of construction projects production and for following cost estimation. The paper presents results of a research on possible methodologies for such BIM utilization. The methodology has not been established yet, as there are many various estimation systems with different requirements – e.g., cost estimation systems require a different structure, information models have different standards, country specific legislation requires different information, calculation formulas vary etc. The paper shows and explains different solutions for different cases in general, so the results are applicable for most of the different cost estimation systems throughout the world. The presented solutions are then compared to show their advantages and disadvantages for the purpose of possible implementation of new systems. Based on general methodologies, country or company specific steps may be taken to properly develop the working system for BIM data utilization in cost estimation processes. The paper ends with conclusions and discussions on further research and further harmonization of the mentioned cost estimation methods.

Keywords: BIM, Building Information Modelling, comparison, cost estimation, quantity takeoff.

1. Introduction

Construction industry resonates with possibilities of digitalization nowadays in the whole world. The commercial sector introduced the term Building Information Modelling (BIM) many years ago to mean simple digitalization of the design documentation [1]. However, this idea has roots in even older theory established by the recently retired [2] Professor Eastman [3] and other authors. Today, after more than 20 years of further development, BIM is much more important. It is a buzzword and a marketing tool, but also a set of tools and processes (methods), and even a methodology in itself [4]. Unfortunately, the market is still struggling with its implementation into practice, which is not surprising, because the construction industry is rather complex and resistant to innovation, especially when compared to other industry branches.

There are many various possibilities of BIM utilization, some of which are so important for the traditional construction process that they are referred to as the so called nD (i.e. 4D for time-related modelling, 5D for cost-related modelling etc.). In spite of their importance, these utilizations are also the most complicated ones, when compared to other so-called BIM uses [5] like clash detection, visualization, spatial coordination, iterative design, model collaboration etc. This paper focuses on the topic of 5D, more specifically on utilization of BIM in the field of cost estimation and quantity takeoff. This particular utilization is relevant for any kind of construction projects, from small houses to large complexes, from transport infrastructure projects to building construction, from reconstructions to new constructions, from city construction to rural development etc. It is also one with a relatively long tradition. When compared to, for example, virtual and augmented reality visualizations, which are quite new, there have always been cost estimation done in old fashioned ways. Now, when we have information models at our disposal, extreme possibilities like one-click takeoffs are at our hands. Yet, it has not been utilized up to its potential, and one of the culprits is tradition. Methodologies for quantity takeoffs and cost estimation used to be carried out manually. Such methodologies are usually hard to do digitally, because of heavy reliance on the human factor. With the introduction of BIM, it is necessary to modernize these methodologies, so that they allow the construction industry to utilize digitized data to its full potential. As a matter of fact, many countries are currently developing or already developed their national standards, of which the cost estimation is a crucial part [6]. This worldwide BIM adoption creates great opportunities (possibly even the only opportunities) to modernize methodologies of cost estimation and to shape them according to current (and also future) data-related possibilities. This means especially innovating old data structures or even inventing new ones and creating new methods of using these data structures. The present paper

deals with one of the steps in preliminary analysis for creating such methodology, specifically it focuses on different data interoperability methods and their simple comparison.

2. Methodology

The research is explorative, mainly positivistic and descriptive. The overall character of the research is driven by the defined goals, which are:

1. What are the possible methods of cost estimation in construction projects with the use of information models from a system perspective?
2. What are the key differences between the identified methods?

The research methodology is mostly inductive. Based on the examined sources, conducted discussions and especially practical experience of the authors, the basic conclusions were formulated and then generalized. The results were tested and corrections were made with respect to possible practical application.

3. Research

Cost estimation methods for construction projects with the use of BIM depend on many factors. From the system point of view, these factors are often connected with data characteristics and handling. Cost estimation covers the production cost, which is only a part of whole Life-cycle Cost (LCC) [7-9]. Nevertheless, it is an important part. The calculation and following estimation are based mainly on production quantities and relevant cost indicators, according to the defined calculation formula (see Fig. 1). Unfortunately, the calculation formula often takes into account many more variables besides production quantities. That is why the use of BIM for cost estimating sometimes struggles with its implementation.

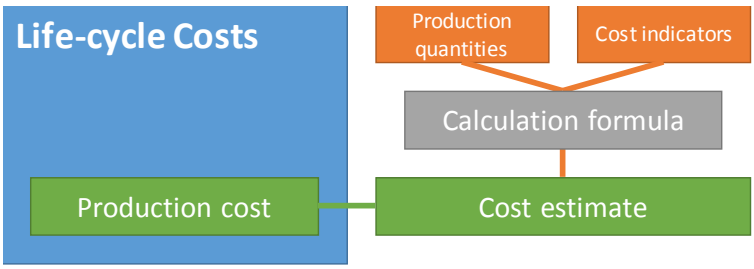

Fig. 1. **Cost estimate scheme**

The research presented in the paper focuses on the orange part of Fig. 1., i.e. how to consolidate production quantities and cost indicators in with the use of BIM. In this perspective, an information model is perceived as a database with structured data about the construction project, while cost indicators are external data, usually in the form of a database. These external data may cover not only prices, but also other externalities. For the purpose of the research, they were considered only as data related to production cost estimates. Interoperability of both databases can be defined and maintained in various ways, which are mainly based on:

- dependency;
  - independent (i);
  - one dependent on another (d);
  - integrated (x);
- data flow;
  - one database is feeding data to another (f);
  - one database is getting data from another (g);
  - manual export is necessary;
  - automatic (integrated);
- data structure;
  - standardized;
  - compatible;
  - different.

Dependency describes how two databases interact which each other. Usually, databases are so different that they are independent. They are object classification systems (like OmniClass, Uniclass etc.) or software defined structures (families, libraries etc.) for the information model. Similar classification is usual for cost databases, which normally include more items, when compared to information models, because of the necessity of evaluating not only physical objects, but also tasks and special items. Data flow describes how two databases interact with each other. The most common system is manual, when the user has to export data from one database and then import them to another. Even worse scenario is, when one of the databases does not allow import or export and the user has to input data manually. On the other hand, fully integrated database covers both structured data. The way in which integrated databases work technically is beyond the scope of this paper, but it is important to state that there are various ways of approaching full integration, each of them with its own obstacles. Data structure addresses another factor of interoperability. Every database has its own structure and the lack of standardization results in the necessity to find a way in which those databases can be connected. This is also very important and it will be further dealt with in the discussion section of this paper.

4. Results

During the research the following methods of cost estimation were identified:

- iMC methods;
  - iMC method;
  - iMCg method;
  - iMCf method;
- iCM methods;
  - iCM method;
  - iCMf method;
  - iCMg method;
- Dependent methods;
  - dMC method;
  - dCM method;
- Integrated methods;
  - xMC method;

The methods mentioned above will be briefly described in the next chapter. For the purpose of explanation, they were divided into thematically similar categories. Identified categories are then compared in Chapter 5, and simple adopting strategies are presented in Chapter 5.1 to support their implementation into practice.

4.1. iMC methods

iMC methods are independent database methods using data from information models to populate cost databases. This process is usually realized manually, based on the used tools. This is represented in Fig. 2 by the first part, where manual transfer is symbolized by grey the process (basic iMC method).

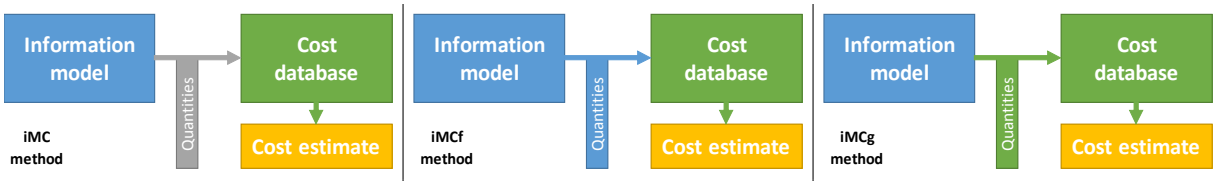

Fig. 2. **MC methods schematics**

iMC methods may also be realized in semi-automatic or fully-automatic way. Data from the information model are either automatically fed into cost database (iMCf method), or the cost estimating tool is able to extract data from the information model itself (iMCg method). This way, cost database is automatically populated with at least some quantification data, based on the level of standardization. These methods are the most common cost estimation methods during early BIM

adoption stages, because it is very source demanding (both money and people wise) to change the cost database, so it fits new digitalization requirements. The specific estimation process is driven by the used estimation tool.

4.2. iCM methods

iCM methods are similar to iMC methods by the independent nature of both databases. The schematics are explained in Fig. 3.

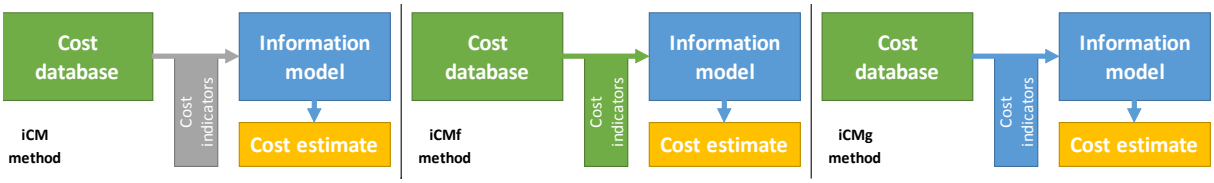

Fig. 3. **CM methods schematics**

The difference is in the way how data are handled. While in iMC methods, cost estimate is the result of work in the cost database with the appropriate tool, the idea behind iCM methods is that cost estimation can be derived from the information model itself. Software developers often prepare their data structures this way – some of BIM tools have predefined property for object-related costs, supported by platform proprietary formats. Even open frameworks like IFC enable addition of cost data to their data structure. Although the information model allows to incorporate cost information into the database, such databases are usually not complete, as model is defined by its objects, while cost calculation often requires further assessment of items, which are not given in the model. This might result in unnecessary creation of placeholder objects or attached information, which are then hard to organize. Data can be transferred manually (basic iCM method), fed by the cost database (iCMf method) or extracted directly from the cost database (iCMg method).

4.3. Dependent methods

Dependent methods are methods, where one of the databases (slave) is dependent on another (master), as explained in Fig. 4.

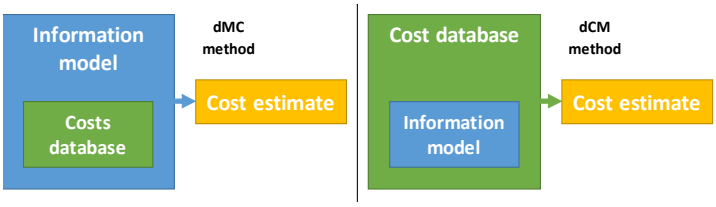

Fig. 4. **Dependent methods schematics**

dMC method considers the information model as the master database, which has integrated cost database. This method is very similar to iCMg method. The difference is in tools used. While iCMg method often uses more varied tools for cost estimation as a part of one BIM environment, in dMC method, only one such tool is necessary. Analogically dCM method is very similar to dMCg method. The advantage of any given dependent method is in its tighter integration and therefore more efficient workflow. The problem is with available tools. This is valid especially for dMC method, because BIM tools are constantly evolving and have not gone through years of testing, as cost estimating tools have.

4.4. Integrated methods

Integrated methods are the most sophisticated methods, dealing with BIM more as with a methodology [4] than just as with a tool. The methods schematics are explained in Fig. 5 for both dependent and independent databases.

These methods (xMC methods) are based on fully integrated environment for cost estimation, which is connected to the information model and cost database. It is possible that these databases are dependent or independent, but this fact has only marginal impact. Fully integrated environment allows the user to work with current databases (which is especially important for cost databases) and utilize

all possible advantages of digitalization. The requirement for integrated environment is at least partly working standardization, considering the working tools are provided.

Fig. 5. **Integrated methods schematics**

5. Comparison

Based on the research, the identified methods were compared on general level. The results are presented in Table 1. Even such simple comparison may be used as a base for decision making when developing the BIM implementation strategy.

Table 1

Cost estimation methods comparison

Category	iMC methods	iCM methods	Dependent methods	Integrated methods
Regularity	Common	Common	Uncommon	Uncommon
Tool dependency	Independent	Partly dependent	Dependent	Dependent
Standardization reliance	Standardization welcome	Standardization important	Standardization important	Standardization required
Traditional data structures	Yes	Yes	Partly	No
Data cloud utilization	Objects	Cost databases	Cost databases or Objects	Cost databases and Objects
Workflow efficiency	Worst	Worse	Better	Best
Implementation costs	Lowest	Lower	Higher	Highest

The methods were compared in the manner of regularity – more regular methods are more likely to be adopted successfully. They were also assessed on the basis of their tool dependency and standardization reliance, which is important in case of irregular database structures in examined market or company, and in case of implementation into practice. Possible data cloud utilization was also assessed, together with workflow efficiency and implementation costs.

All the mentioned methods have their place all over the world. Their implementation into current practice is mostly dependent on the current state of BIM implementation in the relevant market and long-term strategy.

5.1. Method adoption

Simple adoption guide for all of the compared methods is presented in Table 2. More comprehensive adoption strategy is needed for proper implementation of the mentioned methods into cost estimation systems, but such deeper analysis was not part of the presented research. The presented adoption steps are merely informative and based only on conducted comparison.

6. Discussion

While the research identified key aspects of cost estimation methods with the use of BIM from system perspective, there are many factors which were not discussed. Project phase utilization of BIM tools may be carried out similarly in some paper in the future, as cost estimation methods vary greatly based on available data [10; 11; 12]. Further research in this field should lead to better employer's information requirements during any given stage of construction projects.

Table 2

Simple adoption guide

Method	Adoption steps
iMC methods	Create workflow for utilization of data from information models. Find tools that cover defined requirements. Use traditional cost estimation database, but be prepared for necessary adjustments of its structure to extend possible automatization.
iCM methods	Create workflow for connecting cost database to information modelling tool and define workflow. Test results and push implementation of defined workflows into tools functionalities. Test in practice.
Dependent methods	Define required standardization and workflow. Find or create tool that covers defined requirements. Optimize cost database (preferably) or model structure and test in practice.
Integrated methods	Define required standardization (do not dwell on traditional systems). Choose or create appropriate BIM classification system and adjust cost estimation database to match this system. Develop working tool which allows the use of both databases and define environment, in which databases can be regularly updated. Test.

Another possible extension of the research is the technical aspect of interoperability arrangement. Specific standards have to be taken into account in this field and various software tools have to be considered.

Many interesting questions arise from the cost estimator and model author/user requirements. To mention a few, there is the topic of accuracy and missing items when comparing two databases. Also an approach to the items, which are not modelled or where the calculation formula is more complicated (i.e. not based only on quantity). Further harmonization of the defined terminology and taxonomy is crucial.

The topic of cost estimation using BIM is contemporary, although not new. Both practice and governmental institutions are still struggling with its full implementation [13], along with other necessary steps, which might have been already done [14]. The biggest problem seems to be the standardisation and legislation support. This is especially painful in the field of cost estimation, as there is no proper standard across practice and national markets. This is the most important part, as standardization is crucial for automated cost estimation and utilization of the information model in the cost estimating discipline. Still, the world is not perfect and even without business competition there is a very long way ahead of us to achieve the required level of normalization. The solutions in this case are open access distributed databases and standards, and tools with open API, which allows creation of decentralized blockchain-like [15] environment.

7. Conclusions

In total, 10 different and most common cost estimation methods with the use of BIM were identified. After their identification, they were categorized into 4 different categories. Each category was explained and characterized. For every category, a short comparison chart was created and filled. Based on the comparison chart, a simple adoption guide was presented to show, how even marginal comparison can be utilized into practical information. Both defined goals were achieved.

Acknowledgements

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