Cost Estimation in BIM for Transportation Constructions in Czech Republic

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Abstract. Detailed and precise drafts of competition are key to successful BIM implementation in Czech localization, as they are used for creating BIM model and they are further worked with. This can only be ensured by specifications in contract – as far as information model and Cost management (CM) are concerned, the specifications required are data appointment and Execution plan of building information modeling which both should be included in contract. The data defined in these documents carry great potential for further use within building information modeling, realization and operation, and they have not yet been used to full extent of their potential. This paper explores what should be included in the above suggested key documents from CM point of view and also what is the current level of construction documentation in transportation engineering in the Czech Republic.

1. Introduction
Building Information Modeling (BIM) as comprehensive process of data creation and management throughout the asset life cycle where it has major impact in sustainable development. Managed data links preparation, execution and operation of the building in one information model, which allows more economical and efficient project preparation, construction execution and building maintenance, rehabilitation and demolition. Supporting every decision-making need with rich information. Therefore, the development of BIM is currently underway in the Czech construction industry. Government decree from 2nd November 2016, no. 958, on Building information modeling and its importance for construction practice with concept for institution of BIM in Czech construction appoints Ministry of Industry and Commerce as the warrantor of instituting BIM methodology in Czech construction practice. Ministry of Industry and Commerce, jointly with other ministries as they were stated in the decree, including Ministry of Transportation, have been appointed to create such conditions – financial and other – that BIM may be implemented fully in the Czech Republic.

Therefore, government decree no. 958 activated both public and private sector to create necessary documentation for implementing BIM in Czech construction businesses. To implement BIM in transportation constructions, Ministries need to establish specific guidelines which define the process of BIM implementation with regard to specifics of transportation constructions. Information model of a road or railway construction is in effect its digital representation with all its functional characteristics. Information model (IM) serves as an open database for construction project, building,
operation and maintenance. [1, 2] Information model as such is therefore a digital representation of physical and functional characteristics of an entire infrastructure construction.

Detailed and precisely drafted documents of competition are key for successful implementation of BIM in Czech construction environment, as these documents are used as input data for information modeling. Success of a BIM model can be only ensured when all necessary data are specified in contracting documents – this is of special concern for Cost management (CM) and BIM Execution Plan (BEP) which should be included in contract. [3, 4] These documents define graphical and non-graphical information on individual construction elements. For graphical specifications, we refer to national decrees stating content and volume of project documentation, as well as Level of Development (LOD) guidelines, because to this day, there are no other, more detailed nationwide standards.

Non-graphical information comprises mainly of localization and characteristics of individual elements. [5] This information carries great, yet unused potential for information modeling in projecting phase, realization, and operation. There are three major development areas for information modeling for the purposes of CM: from Quantity Takeoff (QTO), to Bill of Quantities (BOQ), Cost control during construction phase, communication about elements creating the information model (life cycle, maintenance costs, etc.), even as far as Facility Management (FM). This paper deals with the first area in project timeline – creating QTO and BOQ from an information model.

2. Cost estimate

Cost estimate development connected with information modeling is currently the most valued issue in CM as seen by construction companies. The full potential of information modeling has not been used in the initial phase of a project. This is often caused by insufficiently defined parameters for graphical and non-graphical part of information model. Elements are not designed in sufficient detail, their sizes or quantities are not realistic or there is insufficient amount of non-graphical data for the purposes of QTO and BOQ. These problems ought to be solved by BEP, and it is often discussed who is responsible for establishing BEP and other IM demands. Should the contractor define BEP (i.e. a construction company which should be able to define what data they need and how they want to use them)? Or should the designing company already have a default BEP and make such changes as are needed for specifics of individual projects? While the first option seems rather logical – the contractor should know the "what and why" of their project, especially if the contractor is a construction company which uses similar data and information models on a daily basis – there are issues concerning the necessity of keeping a highly qualified team for the purposes of information modeling within the company. That means additional financial expenses. Oftentimes there are such expert groups within construction companies, labeled as Virtual design and construction (VDC) department. Figure 1 depicts the processes for this option.

![Figure 1. IM creation processes within a construction company / carried out by the contractor](image-url)
Such practice is new and utilized mostly in innovative construction companies and with contractors. The goal is to create QTO/BOQ with as much automation as possible. Therefore, maintaining graphical standard as required by LOD is paramount, so that quantities are realistic. Second, equally important requirement is a non-graphical descriptor which defines each element for purposes of automation, i.e. element ID clearly stating its description and characteristics, placed in element parameters. In construction business, these parameters are stated in Classification System (CS). Classification system is thus key to automated creation of QTO/BOQ from IM.

![Diagram](image)

**Figure 2.** Principles of data transformation from IM to QTO/BOQ

Every country has its local classification system for constructions. In the Czech Republic, Classification of Structures and Works (CSW) is used. CSW was established in the last century and, unfortunately, is not tied closely enough to modern construction work which heavily relies on data and BIM. It takes great amount of designing time to draw information model in such way that CSW and BIM can be used jointly, and therefore such designs are costly. Similar situation in many countries leads to replacing old classification systems by current ones, such as Uniclass 2015 in Great Britain or CoClass in Sweden. Czech CSW is lacking coherence with modern foreign systems. This is key factor, though, as software solutions for construction projects are developed by corporate multinational companies (such solutions are utilized by 90% of designer companies nowadays). Software solutions attempt at making use of all new structures of local classification systems. And vice versa – newly created classification systems are designed to cooperate with software solutions used by design companies so that the smoothest possible data flow is attained.

### 2.1. New CS requirements linked with information modeling

In order to make CS useful, certain requirements have to be met. Firstly, the goal of CS with respect to information modeling is unequivocal localization of element in given space (building, room, etc.) and classification of element according to functional, constructional and material characteristics (signs of object-oriented classification). Sorting elements within CS must be useful for further work with model. Apart from making groups of elements (filters) according to position or characteristics within a model, it may also be needed for making cost estimates of construction, simplifying work at construction site, assessing the full life cycle of construction, etc. Classification needs to respect characteristics of design software at all its levels.
Relation to "outside world" is a key parameter to any new CS. It is necessary for a new national CS to maintain compatibility with international standards (e.g. ISO-12006-2) both in design, with designers oriented towards western market, and with respect to consequent solutions which need to be implemented in national environment. The code of each element has to be complex and comprehensible at the same time. CS also needs to make amends for elements outside its database (methodically, or by means of special category). There also needs to be an option of inserting identification signs of a project without making the whole code illegible or asystematic. The last requirement there is – CS needs to cover the whole construction market. Currently, there are different classification systems for each subdivision of construction market which makes the situation confusing.

3. Data standards
Contractors and innovative construction companies use project documentation with specification of BIM requirements. Data structure of graphical and non-graphical elements is defined together with definitions of milestones, responsible people, and copyright. Projects which have been realized and are described in the form of case studies in this paper contained 20-page drafts of competition and an additional chart with specifications for more than 600 element types. As mentioned above, these documents were specified by construction company. Ideally, such situation would be the result of common national data standards, with its content, structure and terminology guaranteed by national guidelines, with respect to valid construction laws. Full functionality of such kind of standard including database of construction element characteristics is expected by 2022 in the Czech Republic. [6]

3.1. Substeps of preparing National Data Standard for Construction
National Data Standard for Construction (NDSC) is being prepared in the Czech Republic by Czech Standardization Agency. The topic is broadly consulted with expert public, representants of public administration, universities, construction companies, design companies and contractors.

NDSC specifies requirements for format, measurements, scale, level of detail, file names, designations of project viewpoints, metadata, colour standards, and other. Data standard makes data sharing possible for all participants of construction project. NDSC is to be used by data authors to prepare information models of buildings and for sharing characteristics (attributes) of construction elements. It can also be used as a tool to define required usage for all those who access information models of buildings. NDSC specifies requirements so that they can be used by investor as well as manufacturers of construction elements, designers, BIM library providers, contractors and subcontractors. The document is expected to be used in all phases of a project – design, realization, operation and maintenance, to the end of construction life cycle. NDSC defines requirements for information models with regard to project blueprints generated from IM.
Definitions of characteristics required by NDSC make use of IFC data structures [7], as this allows information exchange between different software platforms.

The primary users of NDSC are expected to be public investors, therefore the first version of standards aims at this target group. Such clusters of parameters will be preferred which allow public investors to gain maximal advantage in realistic time. The primary goal is information exchange between public investor and participants of construction process who need to be directly addressed by the investor.

We also perceive as necessary to define NDSC for co-operation among all other subjects working with construction information. Further work on NDSC in the following phases will thus continue to offer support for further use of NDSC in construction businesses. The final goal is complete information exchange support concerning full life cycle of a construction project.

Currently, Ministry of Industry and Commerce is running internal review of NDSC suggestions which specify its architecture, terminology and other requirements. [8]

4. Case study

In co-operation with a multinational corporate construction company, a measure has been made of current level of data utilization from IM to create QTO/BOQ. Leading construction company in IM usage both in the Czech Republic and in Europe offered two recently realized information models of transportation constructions to be used in research at Czech technical university in Prague (CTU). The level of detail is specified in guideline LOD 350. The models represent finishing of a motorway construction and a reconstruction of railway station including the railway line.

| Table 1. Basic information on finishing of a motorway construction and a reconstruction of railway station |
|-------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Motorway         | Start           | Finish          | Winning bid     | Winning bid     |
|                   | 04/2014         | 09/2017         | 16 057 126 €    | 38 708 333 €    |
| Legth of road    | 4 788 m         |                 |                 |                 |
| Railway station  | Start           | Finish          |                 |                 |
|                   | 03/2015         | 11/2017         |                 |                 |
| Reconstructed line total | 33 000 m       |                 |                 |                 |
The goal of case study is to ascertain current options of utilizing IM data to create QTO/BOQ with regard to current projects representing level of BIM usage in the Czech Republic. Linking of data is tested by comparing cost estimates acquired by manually created QTO with cost estimates automated from IM. As long as an element is graphically correctly drawn, its quantity fits real requirements, the value is taken into cost estimate (possible deviation of ± 5%). An element is taken into cost estimate when it is matched to a BOQ element and therefore can be matched with a cost.

### Table 2. Method of calculating percentage value from total costs for a building project

| Building activity (item) | Quantity takeoff – manual | Quantity takeoff – IM | Total price [€] | Percentage value from total costs |
|--------------------------|---------------------------|-----------------------|----------------|----------------------------------|
| Concrete column C 20/25 | 18 m$^3$                  | 18 m$^3$              | 2 196          | 0.014                            |
| Asphalt concrete ACP 20 thickness 50 mm | 980 m$^2$ | 50 m$^3$ | 1 842 000     | 11.48               |
| Compacted gravel fraction of 16/32 mm | 15.2 t | - (in IM connected with another element) | -             | -                                |
| ... (next items)         | ...                       | ...                  | ...            | ...                             |
| Sum for a building project |                           |                      | 13 648 557,3  | 85                               |

This transformation is depicted in Figure 3, unfortunately without the elements of automation. Non-graphical descriptors of classification code were not included in IM, thus, unfortunately, all data had to be manually matched with QTO/BOQ elements.

### Figure 5. Information models of constructions (motorway, railway station)

Results of case study are shown in Figure 6 where the difference between manually calculated total costs and automatically generated cost calculation is shown in budget figures. Financial differences between IM model data and real values are primarily caused by level of detail of IM. Some constructions have been faulty drawn (or joint) and could not be taken into calculation. Further, LOD 350 does not require drawing of certain details and/or elements. Often, these are locks, plumbing, carpentry which are then missing in IM. On the other hand, concrete constructions and other road layers were estimated rather correctly. These constructions are predominantly defined by volume (tar, concrete) which is easily acquired from IM.
5. Conclusion
Innovative construction companies and contractors have begun to specify BIM requirements as early as drafts of competition to simplify BIM implementation. Ideally, this process is based on standards and guidelines defined by national data standard, guaranteed by national institution and defining content, structure and terminology, with respect to law on construction products which specifies statement of characteristics.

To further develop classification methods linked to information modeling, precise drafts of competition and designs need to be made, with BEP as the leading document. BEP states not only graphical and non-graphical expression of IM, but also possibilities for further use of data. For automation of QTO and BOQ, compatible classification system is of key importance. There is need to develop a new classification system in the Czech Republic which would meet the needs of IM – this is already happening in countries where BIM is applied. The use of a classification system to identify elements in the information model must be linked to a price system that forms the basis of the valuation process in the construction industry. The proposed ideal workflow in terms of linking the element (product, object, structure in the building information model) and budgeting item (price system) based on the price system is shown in Figure 2. Although even with optimal classification system and workflow, cost estimates will not be 100 % correct, they will come substantially closer to real values.

Case study showed the current level of IM use for estimate of costs and it was compared with a traditional solution. In two construction projects designed at the same level of detail (while LOD 350 itself has reached its limits and standards should be raised higher) there have been markedly different outcomes in estimate. In motorway construction, estimate generated from IM reached 85 % of total cost, in reconstruction of a railway station, the automated estimate remained at 78 % of total cost. These values show a worthy level of automation potential. Yet, due to the absent connection of e.g. classification codes with IM, data transfer was a demanding process.

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