Proposed Interconnecting Database for BIM Models and Construction-Economic Systems in The Czech Republic

Vojtech Biolek 1, Tomas Hanak 1, Michal Hanak 1

1 Brno University of Technology, Faculty of Civil Engineering, Veveri 95, 602 00 Brno, Czech Republic

biolek.v@fceu.vutbr.cz

Abstract. With global emergence of Building Information Modelling (BIM), the Czech Republic needs to adapt the systems currently used for accessing projects to the new way of designing. Unfortunately, the main emphasis in the Czech Republic is still put on the first stage of the project, i.e. the creation of a 3D model. Converting a 3D model into a BIM model also requires information needed by other civil engineering fields. Consequently, it is necessary to determine which kinds of information must be supplied to BIM models and also how to input or import data from other software tools or systems. This article focuses on construction-economic systems, which comprise the cost estimation of buildings, modelling life-cycle costs, and administration in the operation phase of a building. The main problem encountered in the Czech Republic is the disparate nature of BIM databases, price databases, LCC databases and building administration databases. This article aims to propose a database of functional parts that could serve to connect the individual databases, or at least provide means to aggregate the individual databases in a proposed structure of functional units.

1. Introduction

A new approach to Building Information Modelling (BIM) projects has already come to the attention of the Czech expert community, which is documented by the plan to introduce mandatory BIM documentation for above-the-threshold contracts (over 5 million Euro) by 2022 [1, 2]. In many European countries, BIM documentation in public contracts is or will become mandatory – since 2010 in Norway and Denmark, since 2011 in the Netherlands, since 2016 in the UK, since 2018 in Spain, since 2020 in Germany, etc. [1].

The communication between individual systems used in a construction project poses one of the challenges that need to be resolved for BIM to be successfully introduced. The ČSN EN ISO 16739 standard prescribes the Industry Foundation Classes (IFC) format for data sharing in the construction industry; the format describes a neutral mechanism of the information structure within a BIM model [3]. It is questionable, however, how the information is distributed and used in other than drawing software tools. This article primarily deals with construction-economic systems, which comprise the cost estimation of buildings, facility management and indicators of building life-cycle costs. The main objective of the article is to contribute to creating a connecting database to integrate data from the individual systems into functional parts to ensure that information produced by one system are correctly classified in other systems.
2. Overview of the present situation
Currently, the Czech Republic lacks an instrument to integrate the individual systems used in construction for the purposes of BIM. The current practice with BIM involves mostly drawing software, where the data entered into the BIM model are hardly usable in other software tools. The main reason lies in the disparate databases and unsuitable displaying of constructions in the BIM model.

The following subchapters specify the databases of the individual construction-economic systems and the BIM model structure. Given the comprehensive nature of the subject matter, especially the number of individual structures in a building, not all options are included. Only the structures related to the construction stage are specified for the purposes of the article, excluding all internal installations such as electrical, sanitary, heating, air-conditioning etc.

2.1. BIM model
As mentioned in the introduction, the ČSN EN ISO 16739 standard [3] specifies the structure of minimum recommended IFC parameters of the BIM model. To simplify, the BIM model structure can be described in two parts – product and system. The product means the individual elements of the BIM model, either geometric (wall, column, ceiling etc.) or spatial (room, storey, building etc.). The system means a group of related BIM model parts created for a common purpose or for common function. To illustrate, a building may comprise residential and commercial parts. The BIM model structure is illustrated in ‘Figure 1’ [3, 4].

![Figure 1. Basic BIM model structure, based on [3] and [4]](image)

One of the issues with using BIM models in other systems lies in the different approach of different design engineers to creating the model. The floor is an example of that – it can be modelled as a whole, including the load-bearing structure, or split into two structures – the load-bearing structure and the flooring, the suitable variant of which should be selected in an appropriate manner [5].

2.2. Building cost estimation
The estimation of costs of buildings in the Czech Republic is conducted using a price database based on the Classification of Structural Components and Construction Works (Třídník stavebních konstrukcí a prací, TSKP) [6]. Works are divided to main construction works (hlavní stavební výroba, HSV) and associated construction works (přídržená stavební výroba, PSV) [7]. ‘Table 1’ includes a list of construction parts associated with the construction stage (excluding internal installations such as electrical, sanitary, heating, air-conditioning fittings etc.).
Table 1. Basic division of the construction stage based on TSKP (excluding internal installations) [6, 7]

| No. | Description                                      |
|-----|--------------------------------------------------|
| HSV | **Main construction works**                     |
| 1   | ground works                                    |
| 2   | foundations                                     |
| 3   | vertical structures                              |
| 4   | horizontal structures                            |
| 5   | Roads                                           |
| 6   | surface treatment, floors, and mounting of doors/windows |
| 9   | other constructions and works, demolition       |
| PSV | **Associated construction works**               |
| 71  | Insulation – damp-proofing, moisture-proofing, gas-proofing; membrane roofing; heat; acoustic and seismic treatment; chemical-proofing |
| 76  | structures – translucent; carpentry; tilt-up; sheet metal; tile roofing; joinery; ironwork; steel structures |
| 77  | floors – tiled; stone; cast terrazzo; block; coated; cast |
| 78  | finishing works – ceramic facings; stone facings; coatings; paintings and wallpapers; upholstery; glazing; surface treatment of technical equipment |
| 79  | other construction and PSV works                |

The TSKP classification is based on matching constructions of similar contents, which means it does not observe the system of functional classification of constructions. The waterproofing section is an example of the approach, as it includes structures associated with waterproofing of the foundations as well as waterproofing membranes under ceramic tile facings.

2.3. Facility management

The Czech Republic has no unified system of structuring buildings for the purposes of facility management. This means that each company creates its own system of structuring buildings based either on its own practice or the software tools it uses. Examples of facility management software used in the Czech Republic were specified in articles [8] and [9]. They include e.g. Buildpass, which uses TSKP classification, and Archibus. Structuring of a building in the area is dependent on the what the company wishes to monitor, to what extent and detail, etc. An example of a basic structuring of a building given by Kmochová in [10] is indicated in ‘Table 2’.

Table 2. Basic structuring of a building for the purposes of facility management [10]

| No. | Description          |
|-----|----------------------|
| 1   | roof covering        |
| 2   | sheet metal elements |
| 3   | chimneys             |
| 4   | façade               |
| 5   | floors               |
| 6   | basements            |
| 7   | windows              |
| 8   | doors, gates         |
| 9   | ceilings             |
2.4. Life cycle costs indicator
Life cycle costs (LCC) are among the tools used to assess investment projects (including, but not limited to, construction projects) that take into account the overall costs during the whole life cycle of a project. The LCC indicator can help find the most suitable construction design that will help keep the costs as low as possible during the given period. In her publication, Marková [11] divides buildings, for the purposes of calculating LCC, into functional parts, which represent the given structure as it is incorporated in the building, in contrast to TSKP (Table 3).

| No. | Description |
|-----|-------------|
| 01  | lower structures – foundations including excavations; waterproofing vertical structures – vertical load-bearing structures and the outer structures; partition and dividing structures; chimneys |
| 02  | horizontal structures – ceiling structures, staircases |
| 03  | roof – roof structure; roof covering |
| 04  | interior and exterior wall surfaces |
| 05  | openings – interior and exterior doors; gates; windows |
| 06  | floors |
| 07  | installations |
| 08  | miscellaneous |

As part of a previous research, we proposed a system for adopting up-to-date data for calculating LCC [12]. The principle is based on evaluating data from current buildings included in facility management software tools and the subsequent transfer of information on the costs and frequency of individual tasks in the operation phase of the life cycle of a building (repairs, replacements, cleaning) into the calculation of the indicator of the building’s life cycle costs. For this reason, and also because there is no single facility management system, it is suitable in terms of further usage to unify the building structuring system of facility management and the indicator of life cycle costs, which should also correspond to the proposed connecting database.

3. Proposed connecting database
Following on the issues described above, it is necessary to divide a building into individual structures which can be paired with the individual systems. It is also important to know who will use the BIM model and how, since certain professions are interested only in a part of the building while other structures are of marginal importance to them.

A building can be divided into four main functional parts – load-bearing structures, roof structures, façade and surface treatment of internal spaces. This division can be used not only in construction-economic systems. For example, this is relevant during the construction of the building, where the first stage consists in the construction of the load-bearing structures which give the building its bulk. Afterwards, the roof structures and façade are built to protect the building from the elements. Treatment of interior spaces takes place in the final stage.

One of the most expensive parts of the building in terms of acquisition costs are the load-bearing structures – foundations, walls, columns, ceilings, girders and staircases. At the same time, these structures do not require significant attention in the operation phase of the building since their service life is identical to the lifetime of the entire building [10]. Elements of load bearing structures correspond to the elements of the families used in the BIM model (see Table 4). Only in some cases is it necessary to adjust the manner in which they are drawn. This involves especially the walls (columns) and ceilings. It is a common practice that load-bearing parts are drawn including surface treatment, which does not correspond to the proposed system. Another example
consists in the manner in which beams are drawn. They can be modelled as one component or may form a part of the ceiling. Similarly, a chimney may be drawn and included in the model as a wall or as a single component. These drawing possibilities pose no obstacle to connection with other system, provided there is an agreement on a uniform practice.

**Roof structures** and the **façade** constitute other groups of functional parts. These are functional parts which must be monitored in terms of facility management on account of their shorter lifespan and the need for more frequent repairs because of their exposure to the external environment. They also comprise sets of structures which are treated as one whole during construction and in the operation phase. In terms of BIM, the structures of these functional parts correspond to the elements used in the model, similarly as the load-bearing structures.

**Surface treatment of interior spaces** is more important in terms of life cycle costs management, given the need for cleaning and repairs of wall and ceiling surfaces arising from their shorter service life, adjustment of the interior to the owner’s requirements, etc. From a practical point of view, surface treatment of interior spaces is specified for each room separately as each room in a building serves a different purpose and has different requirements for the treatment of walls, ceiling and the floor. This is reflected in the two possibilities for its incorporation into the BIM model. One possibility is to model the given structure using BIM model elements; the other option is to include information on surface treatment with respect to the individual room (see Table 4).

**Table 4.** Comparison of the proposed connecting database with the BIM model and TSKP classification [authors’ own work]

| BIM model               | Connecting database (LCC, facility management) | Building cost estimation (TSKP)       |
|-------------------------|-----------------------------------------------|---------------------------------------|
| **LOAD-BEARING STRUCTURES** |                                               |                                       |
| wall foundations        | foundations                                    | foundations                           |
| wall walls              | vertical structures                            |                                       |
| column columns          | vertical structures                            |                                       |
| floor ceilings          | horizontal structures                          |                                       |
| floor / component girders, (main) beams | horizontal structures                  |                                       |
| stairs staircase        | horizontal structures                          |                                       |
| wall / component load-bearing part of chimney | vertical structures |                                       |
| **ROOF STRUCTURES**     |                                               |                                       |
| roof wooden roof frame  | carpentry structures                           |                                       |
| roof roof covering      | tile roofing; membrane roofing                 |                                       |
| component metal sheeting of roof elements | sheet metal structures                    |                                       |
| component other roof elements – roof windows, skylights, antennas etc. | sheet metal structures; joinery structures, ironwork structures |                                       |
| **FAÇADE**              |                                               |                                       |
| window windows          | joinery structures                             |                                       |
| door entrance door, gate | joinery structures                           |                                       |
| wall façade composition | exterior surfaces treatment                    |                                       |
| component exterior window sills | sheet metal structures               |                                       |
| component other façade elements – covers, railing, blinds, etc. | joinery structures; ironwork structures |                                       |
| **SURFACE TREATMENT OF INTERIOR SPACES** |                                               |                                       |
| wall / room wall plastering | interior surfaces treatment                  |                                       |
| wall / room facings     | ceramic tile facings                          |                                       |
| floor / room ceiling plastering | interior surfaces treatment; |                                       |
| ceiling suspended ceilings | dry building structures                    |                                       |
| floor / room floor      | floor structures                               |                                       |
heat insulation; coated, tiled etc.

floors

The second possibility faces the problem that the particular surface will not form a part of the 3D model; there will be only a text information on the room.

The connecting database serves to correctly classify BIM model elements in the TSKP system during building cost estimation; this is necessary because some elements, e.g. walls, have functions in multiple functional parts. It is therefore necessary for the BIM model creator to assign to the particular element an exact specification in the connecting database. Conversely, the connecting database will accurately specify the data or information that must be entered by the design engineer with respect to the given element. Accuracy and sufficient information is needed because in terms of cost estimation, one structure in the BIM model is spread over multiple items in one or more construction parts (TSKP). For instance, a reinforced concrete wall in the BIM model is displayed as a single element, but for the purposes of building costs estimation, it is divided into five items – concrete filling; supply and assembly of the rebar; assembling and removing the formwork. The example of the reinforced concrete wall demonstrates that the BIM model must include information on the volume of concrete, concrete class, rebar class, the mass of the rebar and the area of the formwork, i.e. information unnecessary in the case of a standard brick wall.

4. Conclusions
Division of a building into functional parts brings multiple benefits over its life cycle, both in terms of managing the construction of the building and managing the costs in the operation phase. This is accomplished by reflecting functional parts as the actual parts incorporated in the building, which are supplied as a whole. In terms of construction-economic systems, the main use consists in the integration of information and data which are to be included in the BIM model and subsequently correctly classified in the relevant systems. For correct use of the connecting database, the approach of design engineers to modelling certain structures in the BIM model needs to change. Such a change, however, can be motivated by better usability in multiple phases of the life cycle of buildings.

Acknowledgment
This research paper was written with the support of Brno University of Technology, grant project no. FAST-J-18-5584 “Utilization of building lifecycle costs in the BIM”.

References
[1] Ministry of Industry and Trade, “Concept of implementation of the BIM in the Czech Republic,” September 2017 (in Czech)
[2] Government Regulation No. 172/2016 Coll., on determination of thresholds and amounts for the purposes of the Public Procurement Act (No. 134/2016 Coll.) (in Czech)
[3] ČSN EN ISO 16739, “Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries,” Czech Office for Standards, Metrology and Testing, 2017
[4] IFC4 Documentation. BuildingSMART: International Home of BIM [online]. International, 2013 [retrieved on: 2018-03-26], available at: http://www.buildingsmart-tech.org/ifc/IFC4/final/html/index.htm
[5] E. Radziszewska-Zielina, M. Glén, “The application of the electre I method for the selection of the floor solution variant”, Advances and Trends in Engineering Sciences and Technologies – Proceedings of the International Conference on Engineering Sciences and Technologies, ESaT 2015, pp. 359-365, 2016.
[6] H. Kalivodová, L. Krejčí, “Třídímk TSKP” (TSKP Classification), Stavební klub, 2006
[7] Číselníky TSKP (TSKP Numbering Lists), ÚRS Praha, [retrieved on: 2018-03-26], available at: https://www.cs-urs.cz/ceseliniky-online/tskp/ (in Czech)
[8] D. Macek, J. Dobiáš, “Buildings renovation and maintenance in the public sector,” Procedia
Engineering, vol. 85, pp. 368-376, 2014

[9] J. J. McArthur, “A building information management (BIM) framework and supporting case study for existing building operations, maintenance and sustainability,” Procedia Engineering, vol. 118, pp. 1104-1111, 2015, ISBN: 8085967391

[10] A. Kmochová, “Pasporty domů, bytů a nebytových prostor” (Technical records of buildings, flats and non-residential premises), Polygon, pp. 167, 1996 (in Czech)

[11] L. Marková, “Náklady životního cyklu stavby: náklady investora, celospolečenské dopady” (Building Life Cycle Costs: Investor Costs and Implications for Society), Akademické nakladatelství CERM, 2011, pp. 125. ISBN: 9788072047628 (in Czech)

[12] V. Biolek, T. Hanák, I. Marović, “Data Flow in Relation to Life-Cycle Costing of Construction Projects in the Czech Republic”, IOP Conf. Series: Materials Science and Engineering, Vol. 245, pp. 9, 2017.