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Interconnection of Construction-Economic Systems with BIM in the Czech Environment

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Abstract. The need to use Building Information Modelling (BIM), which brings multiple benefits, including sustainable construction, in the Czech Republic is also reflected in the area of construction-economic systems. Construction-economic systems include building cost estimation, LCC calculation and facility management. The Czech construction sector is hampered by the diversity of these systems, despite the need for them to be interconnected and share data amongst themselves. For this reason, previous research has proposed a general connecting database to integrate data from the individual systems and effectively share them also within the framework of BIM designing. This paper generally describes further possibilities of expanding the connecting database to include another level. Specifically, this is demonstrated on one of the functional parts, i.e. the wall. A more detailed classification with attributes necessary for conclusive listing in the price database is proposed for the selected functional part.

1. Introduction

The accelerating technological development brings integration of information technologies into all industries. In the construction industry, Building Information Modelling (BIM) is especially relevant. BIM design aims to change the approach to construction projects by incorporating the entire building life cycle of a building into the overall thinking. It brings to the table several modern possibilities and involves all stakeholders in the construction process, thus revolutionising co-operation within the project.

The Czech Republic has agreed to mandatorily incorporate BIM in above-the-threshold public contracts (above EUR 5 million) by 2022 [1–2]. BIM documentation in public contracts is or will become mandatory in many European countries – 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. [2].

The effectiveness of applying BIM-based design in the Czech Republic is conditional on multiple factors. It must be considered that there are deeply rooted processes in the individual parts of the construction process which must relate to the BIM design system. This paper is based on previous research, which defined the connecting database to integrate data from the individual construction-economic systems [3]. The aim of this paper is to elaborate on the proposed connecting database by moving to the next level of division, specifically in terms of a single construction element, specifically a wall.

2. Literature Review

Building Information Modelling is a digital representation of the physical and functional characteristics of a building. BIM thus includes more elements than just the 3D model as such, i.e. modelling of all associated processes, project simulation tools and information management [4–5].

The main purpose of a construction process should be to design a sustainable structure with a small economic and ecological footprint [6]. One of the main indicators of sustainable construction are the building's life cycle costs and its carbon footprint. BIM design provides a good tool to track economic and ecological impacts. BIM-based design can help reduce the costs of construction works [7], manage life cycle costs and environmental information [8] and simulate the building's performance and energy efficiency [9].

In order for BIM information to be usable in the Czech environment, the existing systems need to be plugged in. This article deals specifically with construction-economic systems, which comprise the cost estimation of buildings, facility management and indicators of building life-cycle costs. As noted in the introduction, this paper builds on previous research [3] which defined the connecting database developed to address the problem of the incongruity of the individual systems. The distinctive features of the individual systems are listed below.

The recommended structure of the **BIM** model is based on IFC parameters; in its simplified form, the model's structure can be divided into two parts: the product and the 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 a common function [10].

Building cost estimation is carried out using the Czech Classification of Structural Components and Construction Works (abbreviated as TSKP), relies on matching structures of similar nature; this means it does not observe the system of functional classification of structures. TSKP is a very detailed database which includes over 100,000 items of structures and materials [11].

In terms of **facility management**, there is no unified system of classification of building parts in the Czech Republic, which means that each building owner creates its own system, often by adopting systems from international software solutions [12]. Generally speaking, a building is usually divided and classified based on the needs of repair, maintenance and cleaning.

The **building life cycle costs** (LCC) indicator quantifies all costs arising over the structure's life cycle. Aside from acquisition costs, it predicts the frequency and costs of repairs, maintenance and cleaning of the individual building's structures. LCC is one of the recommended indicators for assessment of public contracts in the Czech Republic [13], but there is no legislatively-defined structure for a database serving as a basis for LCC calculation.

The proposed connecting database from previous research divides a building into four main functional units – load-bearing structures, roof structures, façade and surface treatment of internal spaces. This division is based on multiple factors. The first is 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 weather and the elements. Treatment of interior spaces takes place in the final stage. Functional units also perform other functions, e.g. in the case of a façade described in [14]. This classification is also useful in the operational stage of the building, i.e. in facility management. The proposed classification divides structures based on their maintenance needs. The internal spaces are structures which require daily maintenance and cleaning. Conversely, load-bearing structures usually require little intervention over the building's life cycle. The roof covering and façade may require occasional care due to their exposure to weathering effects which reduce the lifetime of these structures and necessitate more frequent repairs or replacement [3], where the quality of the materials used is an important factor [15]. The proposed connecting database is shown in Table 1.

Table 1. Proposed connecting database [3].

Functional unit	LOAD-BEARING STRUCTURES	roof	FAÇADE	SURFACE TREATMENT OF INTERIOR SPACES
Functional part	• foundations • walls • columns • ceilings • girders, (main) beams • staircase • load-bearing part of chimney	• wooden roof frame • roof covering • metal sheeting of roof elements • other roof elements – roof windows, skylights, antennas etc.	• windows • entrance door, gate • façade composition • exterior window sills • other façade elements – covers, railing, blinds, etc.	• wall plastering • facings • ceiling plastering • suspended ceilings • floor

The main purpose of the connecting database is to integrate the individual systems. Data should be shared in both directions. The first direction is from the BIM model to the cost estimation system and subsequently from the cost estimation system to the LCC calculation and the facility management system. The other direction leads from construction-economic systems to the BIM model, including not only specific data resulting from a cost analysis or LCC calculation, but also the attributes that need to be added to the BIM model to enable work with them in other systems.

3. Proposed integration of construction-economic systems with BIM

Firstly, it is necessary to describe the way in which data exchange will take place. The process starts with the creation of a BIM model in a drawing software, which then has to be compressed via the connecting database (1) and transferred to cost estimation software for cost-evaluation (2) and its LCC need to be determined in order for the investor to get an idea about the economic cost of the building. The BIM model must include all information necessary to make an estimation of the building's cost; this, after exporting the data to a cost estimation software, enables to create the building project's budget. The building's budget serves as a basis for calculation of LCC. Since the budget's structure differs from the one needed for LCC calculation, the budget must be compressed via the connecting database (3). At this point, facility management functions only to calculate LCC by supplying data on cycles and costs of repairs, maintenance, cleaning and service life of the individual structures in complete buildings in order to make the calculation of LCC as accurate and reliable as possible [16]. Data from facility management software are transferred via the connecting database to LCC calculation (4-5). After evaluating LCC, which also include the acquisition costs from the cost-estimation software, the data are transferred via the connecting database (6-7) into the BIM model. After the building is completed, the BIM model becomes a part of facility management and data from the BIM model are used as input information for the planning of repairs, maintenance and cleaning of the structures incorporated in the building. The entire process of data sharing is shown in Figure 1.

As follows from the facts described above, it is necessary for the BIM model to include information necessary for building cost estimation. The whole system of cost estimation plays a key role determining the amount of input data, because the database is extensive. The variant solutions of the classification of structures with regard to the required information are listed below.

3.1. Variant 1

Classification of structures closely corresponds to the price system classification. This would result in a large number of types of structures specified by their parameters. It would also entail the need for an extensive and complex database of parameters of which many would be fairly similar.

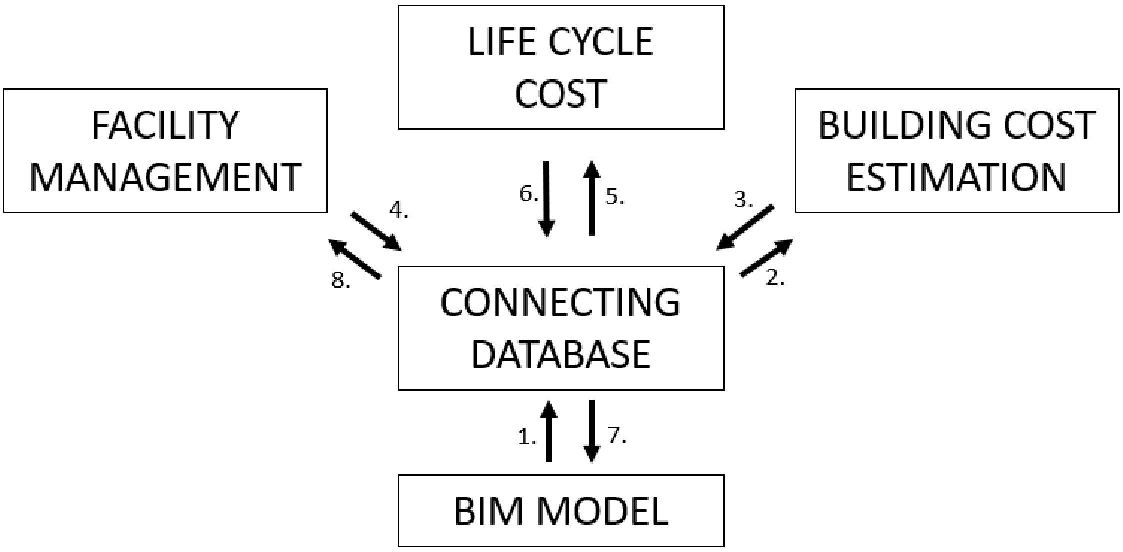

Figure 1. Data sharing between construction-economic systems and the BIM model (prepared by the authors).

3.2. Variant 2

The second way and the opposite to the first variant is to create a classification that is as universal as possible. This would entail a concise database of the structure types with their basic distinctive features, such as “brickwork – single layer”, which would be further specified by parameters, whose database would also be concise and more universal. A disadvantage of this variant would consist in the parameters of the LIST data type with multiple items to satisfy all relevant structure types. In all parameters, the items of the list would have to be filtered by the needs of the given type of structure, e.g. only three items would need to be selected from a ten-item parameter of the LIST data type. However, the most significant disadvantage lies in the presumed high degree of mutual exclusion of parameters within a family (i.e. a group of elements with common or similar attributes or parameters). For example, determining one parameter of a structure would exclude some other options in another parameter, or this parameter would be excluded completely.

3.3. Optimised variant

The proposal for integration of data reflects the effort to achieve an optimal solution featuring both relative conciseness and clarity of the classification of structures and universality of parameters but also make sure that the solution is adjusted to the price system classification. Filtering parameter contents depending on the given structure cannot be avoided under these circumstances, but the emphasis is to avoid excluding entire parameters when selecting some options from a different parameter; only certain possibilities of their selection are potentially excluded. The optimised variant is chosen as the best approach for the further case study.

4. Proposed classification of structures and parameters for the “wall” functional part

In this part, the paper proposes classification of the “wall” functional part, specifically brick and concrete walls. The “optimised variant” was selected because of the aforementioned advantages. Wooden and steel structures have been excluded because they are drawn differently; in BIM, the individual elements of the wall (panels, beams, etc.) are modelled separately. The proposal includes a selection of structures from the price database comprehensive enough to include all possible kinds of brick and concrete walls available on the construction market. The proposed classification is included in Table 2.

Table 2. Proposed classification of structures of the “wall” functional part [prepared by the authors]

STRUCTURE	PARAMETERS
Sacrificial formwork blockwork	X1; X3; 1; 8; 4; 28
Quarrystone masonry	X2; 9; 10; 11; 24
Firebrick wall	X2; 12; 14; 20; 22; 27
Single-layer brickwork – perforated bricks, non-flat, classic P+D	X1; X3; 27; 22; 20
Single-layer brickwork – perforated bricks, flat	X1; X3; 20; 22; 27
Single-layer brickwork – soundproofed	X1; X3; 13; 20; 23; 27
Single-layer brickwork – thermally insulated	X1; X3; 15; 16; 20; 23
Concrete masonry blocks	X2; 22
Dry masonry brickwork	X2
Vibrating press cast concrete blockwork	X2; 20; 26
AAC blocks	X1; X3; 13; 20; 21
Lightweight ceramic aggregate concrete blockwork	X2; X3; 19; 20
Concrete blockwork with thermal insulation inserted	X1; 20; 27
Lightweight concrete blockwork with ceramic aggregate and thermal insulation	X1; 20; 27
Lime-sand brickwork	X1; X3; 17; 18; 20; 22
Fair-face brickwork with fireclay bricks	X2; 7; 22
Mass concrete walls	X1; X2; 1; 3; 5; 6; 25
Reinforced concrete walls	X1; X2; 1; 3; 4; 5; 6; 25; 28
Lightweight ceramic aggregate concrete walls	X1; X2; 2; 6

The specifications of the walls are given by their parameters (see Table 3). The parameters are chosen to enable unambiguous designation of the structure in the price database, but parameters not significantly affecting the price of the structure are not included. Each parameter has its unique code that serves to identify and connect it. It also carries its name and data type. Data type is a manner of determining the parameter by the user. The parameter is either of the LIST data type, where the user chooses from a list of items, or YES/NO choice determining whether or not the given parameter applies. Another possibility is to enter the values manually – the VALUE data type. In parameters marked by X, the data type is designated as DATA BIM SW. These are the data that can be automatically retrieved from the BIM model.

Table 3. Database of parameters [prepared by the authors].

CODE	PARAMETER NAME	DATA TYPE	EXAMPLE
1	Concrete class	LIST	C8/10; C12/15; C16/20; C20/25; C25/30; …
2	Lightweight concrete class	LIST	LC8/9; LC12/13; LC16/18; LC20/22; …
3	Environmental factor requirements	LIST	No special requirements; Environmental factors resistant
4	Bearing wall reinforcement	LIST	10 216 (E); 11 373 (EZ); 10 505 (R); …
5	Concrete wall type	LIST	Standard; Suspended ceiling; Sacrificial formwork; ...
6	Formwork type	LIST	Single-sided flat; Double-sided flat; ...
7	Fireclay brick format	LIST	290x140x65 mm; 250x123x65 mm
8	Sacrificial formwork block type	LIST	Smooth face; Natural face; Coloured face; ...
9	Stone shape	LIST	Irregular; Regular (for bonding); ...
10	Volume of 1 item of stone	LIST	Under 0.02 m3; Over 0.02 m3
11	Joint width	LIST	Under 4 mm; Over 4 to 10 mm; ...

12	Brick length	LIST	290 mm; 250 mm; 240 mm
13	Block design	LIST	Smooth; Tongue and groove; Flat
14	Firebrick type	LIST	Solid core; Solid core for unplastered facework; ...
15	Types of integrated thermal insulation	LIST	No insulation; Hydrophobic rockwool; ...
16	Heat-transfer coefficient	LIST	Over 0.26 to 0.30; over 0.22 to 0.26; ...
17	Lime-sand brick format	LIST	NF 240x115x71 mm; 8DF 248x240x238 mm; …
18	Brick structure	LIST	Solid core, Perforated
19	Lightweight ceramic aggregate concrete block type	LIST	Thermally insulating; Soundproofed; ...
20	Manufacturer	LIST	Heluz; KM Beta; Wienerberger; …
21	AAC block strength	LIST	Under P2; over P2 to P4
22	Mortar type	LIST	M1; M2,5; M5; M10; M15; …
23	Type of binding material	LIST	Full-area thin-layer mortar; foam; ...
24	Type of construction	LIST	Wet; Dry
25	Ceiling concrete formwork	YES/NO	
26	Round blocks	YES/NO	
27	Masonry strength	LIST	
28	Reinforcement weight	VALUE	
X1	Area	DATA BIM SW	
X2	Volume	DATA BIM SW	
X3	Thickness	DATA BIM SW	

The proposed integration should serve to facilitate quick transfer of information and data between construction-economic systems and the BIM model. The database of structures is based on an established system of building cost estimation. The building cost estimation system's strength lies in its large database of structures, which can, however, also constitute a weakness as it creates the need to process large amounts of information in order to reach the most accurate price. This price is then crucial for calculation of life cycle costs of the building, taking into account that the acquisition costs form a large part of the overall life cycle costs and can also serve for the calculation of the costs of repairs, maintenance and cleaning (if calculated as a percentage of the acquisition price).

5. Conclusion

The objective of this article is to demonstrate a possible procedure in connecting construction-economic systems with the BIM model. The proposed solution is introduced in chapter 4 on an example of a wall as a functional part. The third level of division of a building (its structures) is created based on the price database, which should contain all types of structures which could potentially be used to construct a building. This means that there is a one-sided view of the types of parameters, which often do not suit the authors of the BIM model. In order for the proposed connecting database to be functionally incorporated in the construction process of BIM design, the main participants of the construction process must engage in a discussion. On the one hand, adjustment of the price database based on the BIM model will certainly be necessary; on the other hand, it will be necessary to change the approach to creating the BIM model so that all systems can co-operate productively. Given the fact that the system of facility management is not established in the Czech Republic and neither is it established in the system of calculating LCC, the connecting database could be the facilitator of their approach to and incorporation into the ordinary construction practice in the Czech Republic.

The introduction of the connecting database should make building design more effective. Its main advantage lies in a faster building cost estimation and the resulting calculation of total life cycle costs, which is crucial for finding the optimum price with regard to the acquisition costs and costs of operating the building. Therefore, a further development of this methodology promises to greatly contribute to sustainable construction and development of environmentally friendly projects.

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