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# Dynamic model of implementation efficiency of Building Information Modelling (BIM) in relation to the complexity of buildings and the level of their safety

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**Abstract.** The aim of the work is to present the efficiency of the establishment BIM into the building industry on the created dynamical model related to the extent to the complexity of buildings, in which Building Information Modeling (BIM) has been used as „a tool of the industry revolution 4.0 in the CZE“. The work shows the rank of the influence in establishment of new technologies 4.0 and Internet issues on increasing demands and complexity of buildings and their safety. A result of simulation in the dynamical model emerges the conclusion why we should be interested in the rise of the complexity extent of processes of the buildings in relation to corresponding cost of BIM. It shows that the establishment of BIM achieves the necessary extent of the efficiency, i.e. in what assumptions and parameters the significant reduction of the direct or indirect costs has been achieved in the construction, management of the buildings and the facilities in their life cycle.

## 1 Introduction to efficiency issues

Implementation of BIM is currently a worldwide trend and with its significance, it moves the current building industry towards the modern and system-intelligent "*Building 4.0*". BIM processes are implied by the increasingly expanding possibilities of information technologies (ICT). "BIM is a digital presentation of physical and functional building characteristics. BIM is a source of shared information about the building, creating a reliable foundation for decision-making in the course of its life cycle from the primary design to its demolition." [1,7]

There is a number of attributes that currently prevent wider BIM implementation. Apart from such as the traditional human reluctance to implement new things when they

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are not required, such as, for example, the missing need to create projects in the BIM environment for public contracts or unfamiliarity with the benefits of the BIM use or with the BIM in general (according to a survey, up to 70% of respondents in the UK aren't even aware of what BIM is exactly [1,7]). Therefore, only the "incomplete" fact whether the investment into BIM will pay off for them economically is essential for the companies.

After the introduction of BIM, the survey [2] states a growth of labour productivity by 30% and decrease in queries and information or other conflict misunderstandings in the course of the building and construction works up to 50%. In the survey with BIM users, the interviewees identically cite an increase in productivity. Up to 17% of interviewees talk about a 100% increase [2]. However, efficiency is dealt with only from a limited viewpoint of the primary design and projection. For example, it does not include the costs of further periods such as licences, library and database creation costs, in-service training, training of new workers and fluctuation of employees etc. In this concept, ROI (1. , Table 1.) in the BIM solution also does not comprehensively include parts of the whole building's process: subcontractors, contractors and other parts of the construction process and sustainability, that necessarily have to be transferred to the BIM system. Since the decisive element of the BIM efficiency are costs of the building operation in its entire life cycle, that makes up 65-80% of the total costs [3, 9] from which almost 1/3 consists of management and maintenance. Frequent reason for BIM application: "*The buildings owners want to decrease the direct running costs in the buildings because of the rise in the prices (for example) of energies during past years"* [12].

$$\frac{(B - (\frac{B}{1 + E})) \text{ x } (12 - C)}{A+(A \text{ x } C \text{ x } D)} = \text{ROI, first year} \qquad (1)$$

The formula variables are:

**Table 1.** Taken from - REVIT Building Information Modeling - (ROI).

| |
|---|
| A = cost of hardware and software |
| B = monthly labor cost |
| C = training time |
| D = productvivity lost during training |
| E = productivity gain after training |

### 1.1 Return rate of investment into BIM in the entire complex

Therefore, within the entire complex of the construction process and the life cycle of the buildings, the economic return rate and the profitability of the BIM implementation can be different. On the contrary, according to [4], it isn't possible to fully establish ROI in the BIM implementation along with its economic efficiency / return rate of the solution from the viewpoint of the existing unavailability of a sufficient number of demonstrable data (Table 2.). However, the implementation of BIM has unquestionably many advantages.

Contractors and subcontractors: the extent of transfer to BIM as an important element for the efficiency of savings in all the phases of LCC (Life cycle cost) [3, 9].

**Table 2**. The extent of transfer to BIM – CZE [9].

| | |
|---|---|
| Rather YES | 16% |
| YES | 21% |
| Rather NO | 42% |
| Strictly NO | 21% |

The National Institution of Building Sciences (NIBS) states, that the building industry can increase its performance by 4% in new buildings and by 1.5% in building reconstruction when using BIM [4]. Some other foreign studies and authors talk about a savings ratio of up to 20%. However, we are still talking about the economic profitability only, i.e. purely the financial aspect. But we also have to take other benefits into account that the BIM implementation brings and in which it is possible to estimate a positive benefit such as, for example, the limitation of risks and the safety of buildings. [5].

- reduction of the risk of a wrong analysis of the total price of the project (limiting extra costs)
- reduction of administrative burdens – print costs, user and operational documents etc.
- increase in cooperation of the involved parties in later stages
- significant increase in the quality of checks with a positive impact on the safety of the building during its use
- improvement of logistics planning and works in the BIM environment with an effect on error reduction in the construction part of the project – especially in complex projects
- reduction of the time necessary for project execution and reduction of risks that stem from technical-economical conflicts
- increase in safety (system warnings of current dates of regular repairs, revisions or checks in every building, including the placement of the technological system)

## 2 Dynamic models

The ability to understand very complex dynamic systems under uncertain conditions – that is, precisely in the situation when there isn't enough relevant information. The possibility of simulating both operational processes and complex aggregate strategic issues [10].

**Essential advantages:** explicitness, reliability of logical consequences, complexity
It is necessary to find the "weak" spots in which a small change brings about great consequences to the result of the behaviour of the entire system and to analyse them.

"The syndrome of 90%": 90% of the project are created in accordance with the project plan. The subsequent 10% will cause a delay or fundamental problems. For example, a delay in the schedule or financial plan in extensive investment projects by 100-200 and even more percent is not an exception. This issue exists also, for example, in strategic projects in the building industry. It is often caused by a wrong estimate of the expected size of the project. Another reason is a big delay in the detection project and process errors – before we're able to detect the weak spots, it's already too "late".

### 2.1 The places where errors in projects arise with which the system dynamics in relation to the BIM can help:

- wrong mental model (limited perception, errors in consequence)
- information and their sharing (we need: fast, comprehensible, adequate..)
- project processing (building on "unsuitable" paradigms..)
- analysis of feedback in the course of the project (test)
- underestimation of small changes with a subsequent extensive influence
- long duration of the project (effects of development cycles of the sector)
- necessity of cooperation and communication between the sectors

### 2.2 Determining the aim of the model

- Theoretical vs. practical model (ratio on the representation scale)
- Interpreting the situation (understanding it) vs. predicting its behaviour?

**Model assembly:**

Mental model → Conceptual model → Diagram, preliminary model → Model → Evaluation [11].

### 2.3 Basic Dynamic BIM implementation model (Without implementation of the subset employess)

The model Basic Dynamic BIM implementation (Figure 1.) is based on the system dynamics method [10]. The structure of the model is created by means of stock elements and flow elements [11].

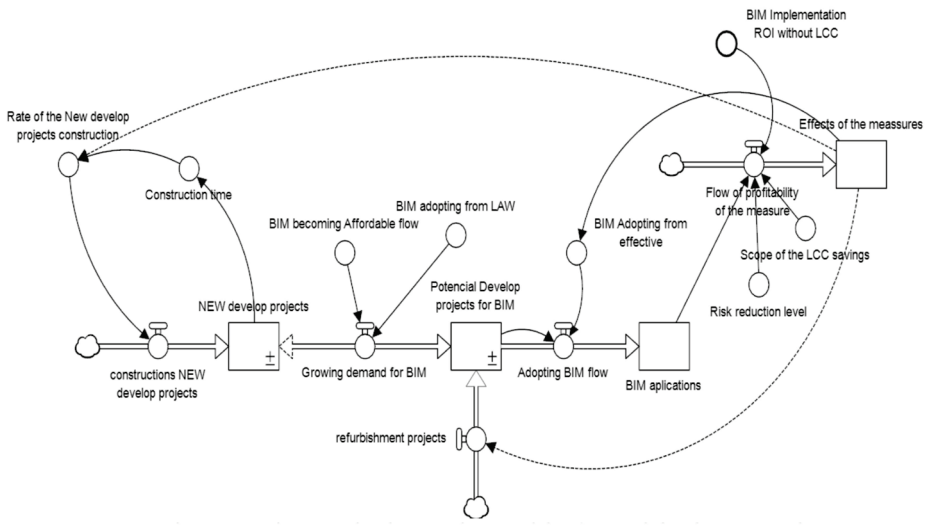


**Fig. 1.** Demonstration Dynamic BIM implementation model (Created in the SW Stela© Architect).

## 2.4 Mental description of considerations coming from the dynamic model

***Employment model, training*** (Figure 2.) shows the dynamic model as one of the key partial sub-models. The transfer to BIM concerns all the parts of this process in its coherence and complexity, and the process must respond to this. The extent of the effect from a BIM implementation is significantly influenced by two more attributes.

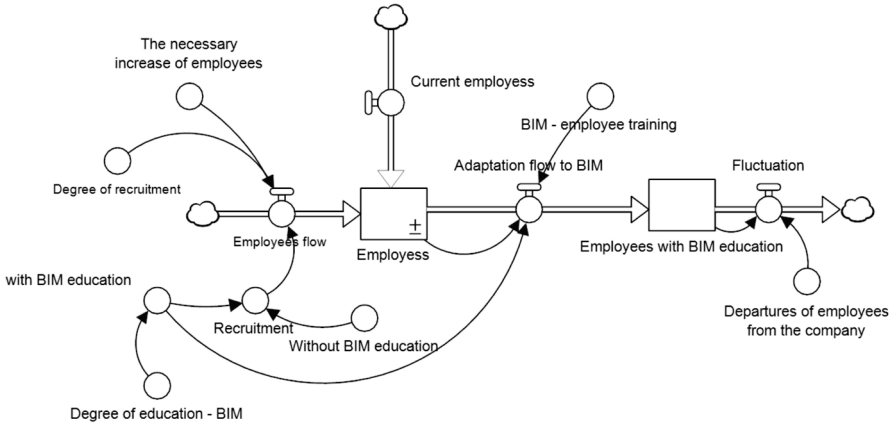


**Fig. 2**. Employment model, training (Created in the SW Stela© Architect).

-The extent of BIM implementation
-Costs / return rate for the period of the whole LCC, i.e also in the operational phase
-Human resources

The actual rate of return of the SW and HD purchase and employee training included in the ROI calculation for the efficiency calculation of BIM implementation isn't decisive and it is one of the elements of efficiency measurement. The model exhibits a strong feedback in case the conditions for positive BIM effects are met, i.e. the crossing of the BIM implementation extent in projects (that is, in case of a support from the state for these measures – the condition of a BIM use in public contracts that make up more than 50% of the volume in the building industry/year in investments [3,9]).

However, when a significant positive BIM effect on the building industry is achieved, the model shows a strong pressure on the sub-model ***Employment model, training*** (Figure 2.) again, since the need of an in-service training or recruitment of new employees who are capable of working with BIM significantly increases. Maintaining balance and positive effect is possible to achieve with a level of work education with BIM in the educational process at secondary schools and technical universities.

**BIM processes:** Planning → Execution → Management and operation → Demolition

This way, there are many benefits in the use of the BIM model from advanced visualisation methods including the simplification of the construction management to the reduction of costs for the operation of the building structure [6]. Therefore, BIM also demonstrates a visible effort to be the BI "M" (Building Information „*Management*") in its concept and application during the whole LC (Life cycle).

It is important for the people who work in the building industry across-sectors to also familiarise themselves with the BIM environment as users, along with people in the whole contractor and subcontractor chain. This is due to the complexity and long-term nature of the projects. Information that is provided by BIM must be understood by all the persons involved, so that they can efficiently use the information in connection to other elements and data of the processes. This requires a high degree of cooperation.

So all the more, the last word in the BIM abbreviation – modelling (M) – is being replaced by *"management – information management"* and that is the so-called knowledge management that has a unique place in such an advanced system integration such as BIM. Integration of processes and their source information coherence, which creates backward and mutually influencing dynamic bonds, shows that it is a developing dynamic process. Therefore, it is possible to apply ***System dynamics*** to describe it and to understand it. Especially in a situation of uncertainty, when data are not available in the necessary extent (since BIM is still a very young platform).

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