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POSSIBILITIES OF DIGITIZATION IN CONSTRUCTION DURING THE BUILDING LIFE CYCLE

Abstract:

The object of this paper is to figure out the possibilities of digitization in the construction industry and whether the digitization is beneficial. Construction industry has a share 6% of world GDP and is therefore the cornerstone of the world economy. However, compared with other industries, almost all of them are investing more into digitization than the construction sector. Fewer investments in digitization are just in the agriculture and hunting sectors. The author of this paper would like to point out what digitization possibilities can be used in construction industry to reduce construction costs, more accurately control construction and reduce operate costs.

Keywords:

BIM (Building Information Modeling), innovation, life cycle cost

JEL Classification: O32

Introduction

Civil engineering is ready for a change. Labor productivity has stagnated, and innovation has been far too slow. The entire life process of the construction does not take place within a single enterprise, which leads to mistakes, economic losses and delays due to complicated coordination between stakeholders and loss of information. However, digital transformation has now begun. The core of the transformation is Building Information Modeling (BIM). The purpose is to reduce the cost of the whole life cycle of the project and improve information sharing. For all participants in the building process, a new era is taking place. They need to develop new skills, acquire additional knowledge, and work on existing processes, particularly in data sharing.

Civil engineering has a share of world GDP of 6%, which is roughly $ 10 trillion. It is therefore the cornerstone of the world economy and serves almost all other industrial area. These are primarily overland structures, traffic structures, industrial buildings and economical buildings. However, compared with other industries, almost all of them are investing more in digitalization than civil engineering does. Only agriculture and hunting are still behind civil engineering [2]. The crisis in the civil engineering sector can also be perceived by the fact that while in other branches of the economy labor productivity has increased significantly, it is stagnant in the civil engineering sector (Figure 1).

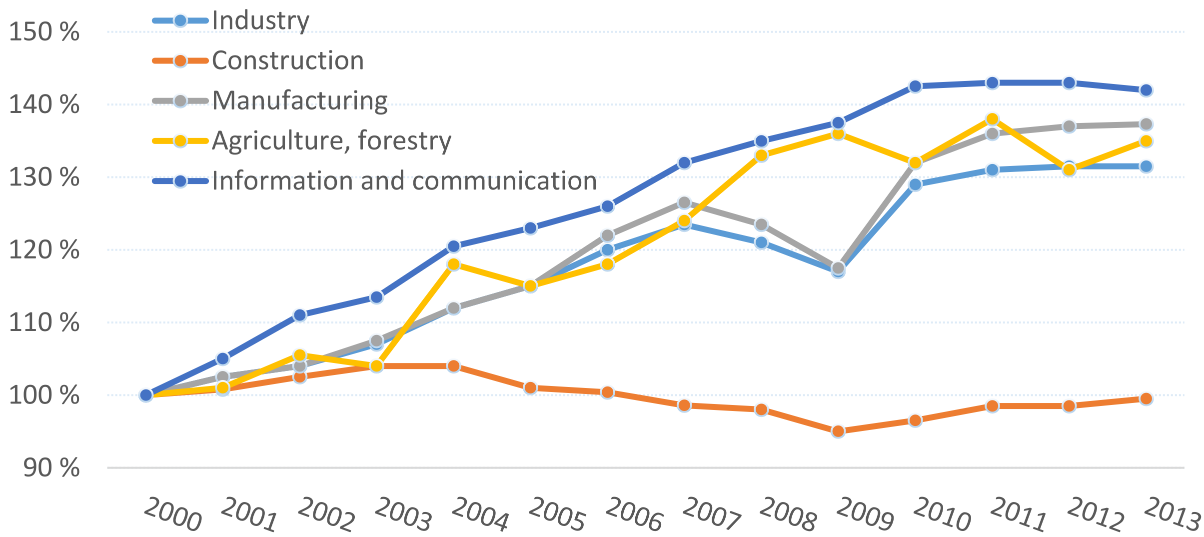

Figure 1 - The progress of productivity in the EU [3]

A key factor in technological transformation is software change. As a successor to the traditional Computer-aided design (CAD) environment, there is BIM, which serves all the stakeholders of investment construction throughout the building's life cycle. The key difference is that each object is depicted in a digital 3D model and relates to a variety of information and guarantees the interconnection of all this information (drawings, reports, tables, datasheets, etc.). Everything is in a common data environment, accessible to all participants in the construction process, so that they can see the real progress of the construction at the design, implementation and operation stage.

Another key factor is 3D print technology. It is also becoming applicable for large building components and concrete or steel structures. The main advantages are the speed and the price, and the ability to print structural elements or entire building components, walls or even houses and bridges. Companies also use 3D scanners to create digital models of complex buildings using a cloud of dots, making it very easy for designers to work on refurbishments, but also checking quality and deterioration of materials.

Digital technology, in some cases, shows huge added value from the initial conceptual design of the construction to the final phase - the demolition. By using these technologies correctly, companies can reduce the cost of the whole life cycle of a building and the construction time. How this digital technology can be used is outlined in the examples below.

Digitalization options during the design phase

1. Parallel cooperation on the project
   BIM facilitates the collaboration between architect, designer and other project partners. Everything is based using only one construction model, which can detect interdependencies and collisions and quickly assess the collision problem.
2. Mapping and scanning
   Aerial mapping and laser scanning technology can be used to transform existing buildings and infrastructures into virtual 3D models. This is important for renovations and repairs. It delivers great time savings in comparison to physical manual measurement.
3. Big Data suggestions
   Big data can serve us, for example, in infrastructure designs where we can monitor the use of individual routes by collecting data from security cameras, sensors or mobile phones. This information combined with the BIM model gives us the opportunity to create an endless variety of possibilities in a relatively short time.
4. Simulation
   BIM tools allow us to carry out various types of simulations, saving the cost of building operations up to 30%. We can create many different simulations by easily changing the materials in the models.

Digitalization options during the construction phase

1. Shared real-time data
   One of the main tasks at the construction stage is to provide all stakeholders with enough information directly from the construction site. This concerns the investor, designer and contractor. BIM allows information to be collected in real-time on a CDE (Common Data Environment) platform so that all project participants can coordinate their activities and can also detect collisions even before the construction starts. That helps in saving both financial and time resources.
2. Used data for construction planning
   Using data from previous projects, the resources can be optimally allocated and activity on the construction site can be planned. It is also possible to reduce the costs of staff and the transport of materials and equipment. From the model, we also have the ability to generate element specifications, including area and volume characteristics, which we can use directly to when making orders for material.
3. Methods of production
   The BIM concept contains detailed building information that can make it easier to manufacture, prefabricate, and possibly work with 3D printing.
4. Autonomous and automated constructing
   Intelligent machines and robots increase site security, productivity and accuracy. Remote control systems can be used for excavators, mobile and static cranes, dozers or loaders. This helps to reduce the error rate of the construction work.
5. Real time site monitoring
   Modern technology such as laser scanning can be used to monitor construction, where we can follow the process of construction. Thanks to this technology, we can compare the model with the actual realization of the building in great detail.

Digitalization options during the operational phase

1. Maintenance of the building
   The BIM concept facilitates the operation and maintenance of the building by providing a virtual building model. The model can be used as a repository of information that is generated during the preparation of the building and is enriched with the necessary information from the construction phase as well as from the previous use of the construction.
2. Delivery of construction and commissioning
   The digital building model simplifies the commissioning process. For example, the contractor can collect information from tests and test runs and transfer them directly to the 3D model. He then provides this data to the investor or building operator in an internationally recognized open format IFC (Industry Foundation Classes) format. There we can find additional information about the technologies and manuals for each device.
3. Predictive maintenance and real-condition monitoring
   It is possible to reduce the number of manual inspections, unexpected failures and the amount of preventive maintenance thanks to using data sensors, 3D laser sensors or cameras. This also reduces the construction's operational costs.
4. Reconstruction and disposal
   Based on a well-maintained building model, the impact of major repairs or the demolition of the building can be assessed. By accessing detailed information on used materials, for example, the possibility of using waste from demolition for subsequent recycling can be evaluated.

Reasons for using BIM systems

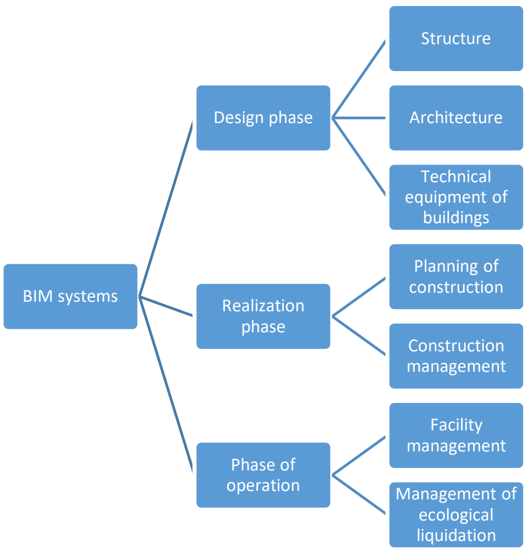

Figure 2: Areas of BIM systems application during the construction's life cycle [author]

Most projects are struggling with the problem of operating within the set budgets. According to Professor Stephen Lockley, it is up to 30% of the projects. Lockley also states that up to 37% of materials end up on the construction site as waste due to imperfect preparation and coordination. It is possible to save up to 25% of additional works on construction projects if designed using BIM systems. The greatest savings occur in detecting collisions. If these collisions are revealed in the framework of design preparations, the problem can be solved way more economically and quicker than in the framework of the construction.

By using digitalization, transparency and better access to information in decision-making at different stages of the life cycle of a building is enhanced, as well as easier analyzes in the early stages of design.

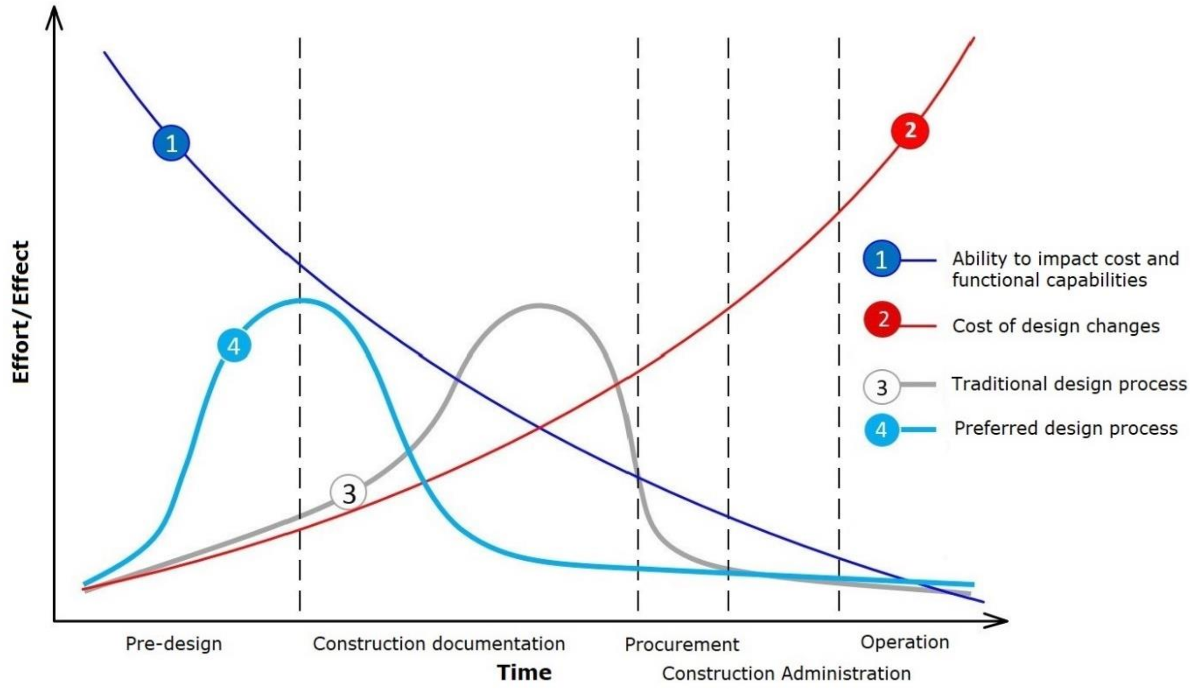

Figure 3: Economical representation of change during the project life cycle [10]

The state is the largest owner and asset manager and it would be beneficial for the state administration to require information on owned buildings in an open, uniform format. That way it could more easily make independent opinions and have better data available for the use of government-owned assets.

To compare the impact of digital transformation, an analysis of three studies is presented here [8]. There is an administrative building, a building for infrastructure and an industrial construction. The aim of the analysis was to compare the costs of Life Cycle constructions using classic, existing solutions and Life Cycle through digital transformation.

1. **Administrative building**
    - 5 floors
    - 10 000 m2
    - Study period – 30 years
    - Construction time – 14 months

   Digital transformation
    - BIM across Life Cycle
    - Data-driven construction planning
    - Strict construction monitoring

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Table 1 - Life Cycle Cost impact [in $ million]

Phase	Original price	Price after digital transformation	Difference
Design	1,8	1,8	0 %
Construction	25,2	21,6	12 %
Maintenance	22,0	17,6	18 %
In total	49,0	41,0	15 %

2. Infrastructure construction (highway)

- Length – 100 km
- 4 bridges
- Study period – 35 years
- Construction time – 42 months

Digital transformation

- BIM across Life Cycle
- Automated and autonomous construction
- Status monitoring and predictive maintenance

Table 2 - Life Cycle Cost impact [in $ million]

Phase	Original price	Price after digital transformation	Difference
Design	10,8	10,8	0 %
Construction	189,4	152,2	19 %
Maintenance	84,8	77,0	10 %
In total	285,0	240,0	16 %

3. Industrial construction

- Combined-cycle gas turbine plant
- Study period– 25 years
- Construction time – 20 months

Digital transformation

- BIM across Life Cycle
- Data-drive construction planning
- Intelligent and effective operation and maintenance

Table 3 - Life Cycle Cost impact [in $ million]

Phase	Original price	Price after digital transformation	Difference
Design	41,0	37,7	5 %
Construction	338,4	291,1	14 %
Maintenance	160,6	147,2	10 %
In total	540,0	479,0	12 %

The study shows the possibility of costs reduction throughout the building's life cycle. There is no (or only minimal) proposal to reduce costs because of better and more accurate planning and optimization of the design already in the early stages of the project. In the construction phase, the cost reduction is a significant consequence of detailed planning and real-estate tracking during construction. At this stage, the added value is the faster construction process due to the elimination of collision cases or automated construction using modern excavators and bulldozers (fleet management systems). At the maintenance stage, the cost reduction is also significant as a result of the energy simulations already carried out in the design, as well as the cooperation between BIM and FM.

What lies ahead?

The foreign construction markets (Scandinavia, Great Britain, USA, Singapore, ...) have been preparing for digitalization in construction and the adoption of the BIM concept for years. It is not just about technical and technological mastery of the BIM concept in modeling, but also the preparation of legislation and standards. In the international sphere, BIM is a synonym for BuildingSMART. It is a nonprofit organization that supports and promotes BIM. This organization was established in 1994. At that time, it was called the Alliance for Interoperability (AIA).

Digital transformation in most countries is fueled by associations which help to promote and develop BIM. It is the same in the Czech Republic. In the past years, BIM has moved forward mainly through the activities of private companies. In 2011, the BIM Expert Board (czBIM) was established to cover the issue of BIM in our country.
Now, czBIM has 5 working groups dedicated to the development and support of BIM in the Czech Republic.
They focus on:

1. BIM & Standards and legislation
2. BIM & Education
3. BIM & Implementation
4. BIM & Infrastructure constructions

Nevertheless, the role of the BIM guarantor in the Czech Republic has already been taken over by the state administration. The Ministry of Industry and Trade prepared a document on the Implementation of the BIM Method in the Czech Republic on 1.9.2017, recommending imposing the obligation to use the BIM method for over-limit public works contracts funded from public budgets from 1.1.2022. On 1.1.2018, the Czech Agency for Standardization (ČAS) was established by the Office for Technical Standardization, Metrology and State Testing (ÚNMZ) and it is intended to cover the concept of the introduction of BIM in the Czech Republic. This agency works closely with the czBIM association, which started the civil engineering transformation in the first place.

With these steps, the government has made a clear signal that it supports the implementation of BIM in construction process practice and wants to support this change.

The plan for the necessary steps to implement the BIM concept is given in Chapter 6.1 The concept of introducing BIM in the Czech Republic [13].

As can be seen from the concept [13], several milestones should be achieved by 2022. One of the most important parts is the pilot projects and their evaluation, then also the projection of changes in the related legislation in the implementation of the BIM method and also the creation of a BIM education system for Czech education and state administration.

Complications in implementing the BIM methodology concept

We encounter various issues in the implementation of the BIM concept. One of the key issues is the inconsistent standardization of formats. Each entity (states, software tool suppliers, designers, contractors) has different BIM requirements and its implementation.

One could say that an international standard will be created to be used everywhere in the world. But that is not the case. A big problem is the diversity of national markets and their legislation.
In the long run, we often face the unwillingness to educate participants in the construction process and the reluctance to apply new approaches in practice.

Other complications are the high investment costs of new software and common data environments. Also, the lack of information on the development and future of the BIM design direction. However, digitization is growing based on government regulations, large pioneering companies are already focusing on this issue, and many new companies with digitalization technologies are just entering the market.

Conclusion

The paper focused on digitalization in the construction industry and tried to cover the concept of BIM methodology, and the benefits or pitfalls it could bring. However, digitalization in construction seems inevitable. Businesses that are already engaged in transformation can deliver a great competitive advantage.
The study illustrates the Life Cycle Cost of buildings and illustrated the possible cost savings due to using digital technology.

Future steps are is clear. Construction is in the frame of digitalization at the very start, and if we compare the development of Construction 4.0 and Industry 4.0, big changes are ahead of us. It is necessary to move these changes forward and promote their growth. The crucial step will be the speed of national standards and their implementation in practice.

Acknowledgements

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