Implication of BIM on selected aspects of sustainability

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Abstract. Sustainability in civil engineering industry represents space for the subject of discussions and extensive research opportunities. On the other hand, this represents worldwide pressure to explore this area. Sustainability in the context of Building Information Modelling technology is also often a controversial topic. BIM technology brings many benefits. Exploring these technologies from the field of sustainability and environmental aspects is more than desirable in the light of global developments in this field. The aim of the research was to point out and propose a structure of environmental parameters based on the acquired knowledge, which will be incorporated into the emerging database of elements - information models. The paper presents a proposal for the structure of the database of structural elements taking into account cost parameters, time parameters, environmental parameters and life parameters, points out the main advantages of the proposed database and defines the aims of further research. The aim of the paper was to analyse the current state and possibilities of implication of certification systems for sustainable construction and describe the current state and impact of BIM implication on selected aspects by survey.

1. Introduction

Architecture, engineering and construction (AEC) industry is the last period associated with changes in this area. These changes relate in particular to new opportunities for the use of information technology, new technologies supporting process automation and, last but not least, a series of activities promoting better results for the environment. All these changes and challenges are aimed at sustainability in this industry [1]. The basis for these sustainability changes and challenges is to know the current situation. Especially when using new technologies, as well as BIM, it is important to know and analyze the consequences of this use [2] [3]. Environmental issues and the area of environmental sustainability are often defined by certificates and recommendations when it is possible to ensure that specific environmental policy objectives are met [4]. The use of BIM technologies can also be helpful in this area. AEC industry has a lot of opportunities use 3D BIM technology in each stage of construction project [5] [6].

Building information modelling is the process of creating and managing digital representations of physical and functional characteristics. Building information models are files that can be extracted,
swapped, or networked. The aim is to link and support decision-making. BIM is a source of knowledge and information that forms the basis for life-cycle decision making [7].

BIM is a process for creating and managing building project information throughout the project lifecycle. Outputs of this process is the building information model. The model is based on information collected and updated at key stages of the project. BIM collects all the information about each part of the building in one place. The technology helps to integrate different aspects of the design effectively, reducing the risk of errors or irregularities and minimizing costs. The BIM object accurately defines the product, its properties, geometry (physical properties of the product), and contains visualization data that gives the object a recognizable appearance and functional information [8].

Building information modelling extends the 3D model (spatial dimensions-width, height and depth) with non-graphical information - time parameters (4D), cost parameters (5D), parameters taking into account the analysis of the environment and sustainability of buildings (6D) and information about facility management. The future of construction is in digitization. BIM represents the future of building design and long-term management [9] [10] [11] [12].

Based on the above facts, a basic research problem arises in the field of implication BIM technology on selected aspects of sustainability. Based on this facts was set the research aim like to analyse the current state and possibilities of implication of certification systems for sustainable construction and describe the current state and impact of BIM implication on selected aspects.

The problem statement is also to analyse and describe the BIM implication on selected aspects. For these purposes, a survey was carried out in construction project management in Slovakia. This part and methodology are further specified in the results part dealing with the issue (Chapter 3).

2. Certification systems for evaluation of building and materials
Towards the end of the 20th century, selected systems or methods of environmental assessment of buildings began to be used as a legitimate means of assessing the performance of buildings in many countries. The aim of certification systems is to assess the sustainability of buildings. The Sustainability Assessment of Buildings promotes the sustainable design, construction and operation of buildings and allows better integration and promotion of environmental aspects with costs and other criteria that influence decision making. The assessment of the environmental performance of buildings covers a wide range of problems and may involve a number of environmental, economic and social factors [13].

Environmental sustainability deal with the impact of a building on the environment. The dimension is concerned with optimizing resources through reuse and recycling as well as reducing environmental impacts and optimizing resources across the building's life cycle (building material construction, construction, recycling and disposal) and reducing the use of toxic substances and mitigating negative land use impacts and biodiversity [14].

Environmental aspects include:
- environmental impact – LCA – Life Cycle Analysis,
- resources - reducing the use of resources (energy, materials, fuels and water) to eliminate the use of limited or non-renewable resources,
- biodiversity – increasing biodiversity and remediation of areas - remediation of green areas, promoting the use of brownfield areas,
- recycling - consider reusing or recycling material [14].

Economic sustainability provides for a balance between total costs and building quality. The aim of this type of sustainability is to ensure a balance between total construction costs, including operating costs and the quality and life-cycle value of the building, including the possibility of changing the use of the building [14].

Social sustainability deals with the impact of the building on the health and welfare of the occupants and users of the building. In the context of social sustainability, it is important to ensure the safety of people and buildings, such as fire safety. Internal conditions. It is important to design buildings in accordance with the requirements of the internal comfort of the environment and to ensure thermal and visual comfort, quality acoustics, air, water and light [14].
2.1. Certification systems

For this purpose, various methods and systems for the environmental assessment of buildings and materials are being developed. Among the most important methods are the following globally used systems:

- LEED certification sustainable - it is used for environmental assessment of new buildings and existing buildings, commercial buildings, residential and other types of buildings. System evaluates: Sustainable sites, Energy Efficiency, Water Efficiency, Materials and Resource Use, Indoor Environmental Quality, Emissions, Operations and Maintenance [15] [16],
- BREEAM and BEAM Plus- used for environmental assessment of new and existing buildings. The system evaluates buildings in the areas of management, energy, health, well-being and comfort, pollution, transport, landscape and ecology of materials, waste and water [17] [18],
- CASBEE- evaluation consists of the principle of evaluation of the internal environment, environmental technology, external state of the environment, energy, natural resources and materials. The system evaluates 2 main factors Q (quality) - environmental quality of buildings and operation, and L (loadings) - environmental burden of the building [19] [20],
- GREEN Star – it assesses buildings in terms of site selection, energy and resource consumption, environmental impact, indoor environment quality, functionality, long-term functionality, social and economic aspects [21],
- Living Building Challenge –system is evaluating Sustainable Sites, Energy Efficiency, Water Efficiency, Materials and Resource Use, Indoor Environmental Quality, Equity, Aesthetics [22],
- NABERS- designed to evaluate different types of buildings. The system enables annual evaluation without independent evaluation experts. It allows to minimize environmental impacts while saving costs, improving comfort and health benefits. The system assesses energy efficiency, water use, waste management and indoor environment quality [23],
- WELL Building Standard – system is exploring indoor lighting, health, fitness, comfort, mind, indoor quality and water [24].

![Environmental aspect](image)

**Figure 1.** Certification systems and their impact on environmental aspects of sustainability [14]

Individual certification systems are characterized by high quality processing. The individual systems have been developed with the specific aim of assessing environmental or social sustainability aspects. To a minimum, these systems assess the economic aspects of sustainability. The individual systems focus on the environmental aspect (52% of the total weight) and the social aspect (43% of the total
weight). These aspects also greatly affect the economy and value of the building and thus directly affect the economic aspect of sustainability [14].

Consideration of the environmental, economic and social aspects of sustainability in individual certification systems are shown in Figures 1 to Figure 3.

![Figure 2. Certification systems and their impact on social aspects of sustainability [14]](image)

![Figure 3. Certification systems and their impact on economic aspects of sustainability [14]](image)

3. Current state of BIM implication on selected aspects

Last decades, civil engineering industry has changing continuously. Progressive technology is more intent than before. Use of information and communication technology is increasing in whole industry. Based on these facts a problem has been identified. A partial task is to analyse and describe the BIM implication on selected aspects. Therefore, in this part of the research, we did not use secondary data but conducted our survey, based on which you can see these results in the tables below. The survey was carried out in the form of a questionnaire, where the respondents included construction companies operating in Slovakia. The questionnaire contained the general characteristics of the research sample and the second focused on the content of the issue, i.e. the impact on selected aspects (environmental aspect, social aspect and economic aspect). The survey involved 55 respondents. The survey respondents
were participants in construction projects (contractor 50.91%, sub-contractor 23.63%, designer 18.18% and investor 7.27%). The survey involved large enterprises as well as medium and small enterprises. The representation of large companies is encouraging, as their flow rate on construction projects is also significant. Respondents answered questions where they had to determine the level of impact on a given aspect. These values were given based on a Likert scale from 1 to 5, where a value of 1 represented a very low level of impact and a value of 5 represented a very strong impact. Based on these primary data, an arithmetic mean was made on the basis of which the ranking was performed, and the survey results were processed. These results point to a certain trend of perception of BIM implication on selected aspects. Based on this methodology, the following facts were found. BIM technology can be beneficial on more aspects. Current state of BIM technology is not satisfied. However, it’s increasing too. Figure 4 describes level of BIM implication on environmental aspects. Range of scope was done on Likert scale from 1 to 5. The highest value achieved reducing the use of resources (e.g. use of materials, energy, fuels and so on). Secondly, it’s environmental impact.

Figure 4. Implication of BIM on environmental aspects in the current construction projects

![Environmental aspect graph]

Figure 5 describes level of BIM implication on social aspects. Social aspects represent health of users, safety for people and internal comfort. The most important according survey results (described above) was chosen internal comfort. That means thermal, visual comfort in the building and quality of air, acoustic and light [23]. Very important is parameter of safety.

Figure 5. Implication of BIM on social aspects in the current construction projects

![Social aspect graph]
Survey shows to economic aspects. Tangible results are in operating costs. It achieved the highest level of BIM implication. BIM implications has visible in all economic aspects.

4. Design of parameters structure of element – sustainability parameters

Within the project called APVV-17-0549 “Research of knowledge-based and virtual technologies for intelligent designing and realization of building projects with emphasis on economic efficiency and sustainability” will be created database of elements, models. Individual models will include graphical information in the form of a 3D model, economic information - costs, information taking into execution time requirements, information on the service life of the element and selected information concerning the impact of the element on environmental parameters so called environmental burden [26].

Building materials have to perform their intended function for some friendly time. The lifetime can last for the lifetime of the building or only a few years. The lifetime of an element is always related to a specific combination of environmental factors to which it is exposed. The service life of the element refers to the relevant conditions. Most building materials are complex in nature due to their chemical and physical nature [26].

Life cycle assessment – LCA is a generally accepted approach to determine the environmental impact of a product throughout its entire production cycle. The LCA assessment identifies the true potential of the evaluated product and identifies environmental risk points in the product chain. The aim of the evaluation is to draw attention to possible risks and to propose preventive measures to reduce the negative impact on the environment [27] [28].

The element is assessed across the whole life cycle. The product is monitored from the initial extraction and processing of raw materials through production, distribution and use to final disposal. In addition to identifying the environmental impact of a product or activity, the LCA identifies also the life cycle activities of the product that contribute most to this impact. The following parameters are most closely monitored [29]:

- **PEI** – Primary energy intensity – represents the amount of energy that has been consumed from mining to the location and use of the resulting product. This parameter is derived from renewable (wood, hydropower, solar and wind energy) and non-renewable sources (oil, natural gas, coal and uranium) of energy. The primary non-renewable energetic content (PEI ne) is calculated by calculating the gross calorific value of all non-renewable resources used in the process. The primary renewable energy (PEI e) content summarizes all the renewable energy sources used in the process,

- **GWP** – Global Warming Potential – parameter expresses the relationship of the product to carbon dioxide emissions. GWP defines the effect of a given substance on global warming,
- AP – Acidification Potential – is the measure of the acidity of a component. Acidification occurs primarily through the reaction of nitrous oxides (NOx) and sulphur dioxide with other components in the air such as hydroxyl (radical).

For example Air-brick with volume weight \((\text{kg/m}^3)\) equal to 800 has the following values Primary energy intensity – \(\text{PEI}=2.490 \text{ MJ/kg}\), Global Warming Potential – \(\text{GWP}= 1.760 \text{ kgCO}_2\text{eq/kg}\), Acidification Potential – \(\text{AP} = 0.00055 \text{ kgSO}_2\text{eq/kg}\) [29]. The construction industry affects the quality of the environment and requires enormous consumption of natural resources and energy. Construction production generates a huge amount of waste and pollution. The main negative consequences of construction production are redundant use of natural resources, pollution, and disruption of ecosystems, but also negative socio-cultural impacts and lifestyle changes. The lower the values of selected environmental parameters (GWP, AP, PEI), the more environmentally suitable the element can be considered. Based on the above facts, the aim will be to consider and integrate selected environmental aspects into the structure of the database as much as possible.

5. Conclusion
Assessing the environmental properties of building elements and materials is a challenging process. When assessing it is important to take into account a wide range of comprehensive criteria. The paper provides a brief overview of the certification systems used in the life cycle assessment of building materials and elements. In principle, the individual certification systems presented do not differ. The objective of environmental assessment of buildings is the sustainable design of buildings, which requires cooperation between engineers, architects, environmentalists, and other experts from various areas of environmental assessment of buildings. The article provides an overview of surveys, focused on the functionality of individual certification systems, specifically on the evaluation of aspects of social, economic and environmental sustainability.

The paper results bring to point out and propose a structure of environmental parameters based on the acquired knowledge, which will be incorporated into the emerging database of elements - information models. Based on the theoretical analysis, the structure of the proposed database was determined, which takes into account cost parameters, time parameters, environmental parameters and life parameters. The result of the work in the proposed database will be a structural element that will provide graphical and non-graphical information (see Figure 7). The user of the database will obtain information about the design (construction) solution, the need for financial and time resources in individual phases, information about the durability of the design element and information about the impact on the environment, specific parameters about Global Warming Potential, Acidification Potential and Primary energy intensity.
Currently, there are many applications that allow you to manage and control only a specific type of information. The main advantage of the proposed database is the summary of individual information into a single environment, which eliminates the work in several software applications. Possible barriers and the aim of further research are to identify ways to update the data contained in the proposed database (to accept the fact that there is a large amount of information that the database must include) and analyze the impacts of selected environmental aspects on the life cycle of buildings.

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