# Challenges in takeoffs and cost estimating in the BIM technology, based on the example of a road bridge model

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# Challenges in takeoffs and cost estimating in the BIM technology, based on the example of a road bridge model

# Wyzwania w przedmiarowaniu i kosztorysowaniu w technologii BIM na przykładzie modelu wiaduktu drogowego

**Abstract**

Technical and economic analysis of a construction project carried out using BIM can improve the process of cost-estimating at all stages of design and construction works. More and more designers choose to use BIM within a range of cost estimates; however, in contrast to design software, cost-analysing BIM software is less widespread and used. The following paper presents problems and issues that could be encountered while performing cost estimates and quantity takeoffs applying BIM tools on the example of a model of a road bridge.

**Keywords:** BIM, cost-estimating, cost-analysing

**Streszczenie**

Analiza techniczno-ekonomiczna przedsięwzięcia budowlanego wykonywana przy wykorzystaniu technologii BIM może usprawnić proces wyceny na wszystkich etapach projektowania oraz wykonawstwa. Coraz więcej projektantów decyduje się na używanie BIM w zakresie obejmującym także oszacowania kosztowe; w przeciwieństwie jednak do programów do projektowania oprogramowanie do analizy kosztowej jest mniej rozpowszechnione i używane. W artykule przedstawiono na przykładzie wykonanego modelu wiaduktu drogowego problemy i przeszkody, na jakie natrafić może wykonujący kosztorysy i przedmiary stosujący narzędzia BIM.

**Słowa kluczowe:** BIM, kosztorysowanie, analiza kosztowa

## 1. Introduction

Technical and economic analysis of a building is one of the key elements of a project, often determinative regarding the decision to start or plan the construction phase. A well-prepared cost estimate leads to better planning of the construction process and the use of financing, while an incorrect or careless cost estimate can lead to problems and delays during the construction process, or even stop it outright.

Until recently, the software available changed little in the process of making the cost estimates. Cost-estimating programs contain many facilities and shortcuts for this process; however, they still remain specialised and well prepared spreadsheet programs. They have limited compatibility with takeoff programs and require manual input of all information.

A qualitative change in the way software affects the takeoff and cost estimates can be introduced by BIM (Building Information Modeling). It is a fast-developing technology of design, which changes the way a design process is perceived. A construction project is no longer perceived as a set of drawings, but as a dataset, which changes the way a building is designed, but also the process of takeoff and cost estimating [3].

This paper is an attempt to check the options and new possibilities opened by BIM in the field of quantity takeoff and cost estimating, with special attention paid to the software popular in Poland. A design project of a road bridge was conducted entirely in the BIM environment in a team, to simulate the conditions of a design company and observe how BIM affects the design process. The process of takeoff and cost estimating was a notable part of the project, and is described in the following paper.

## 2. Building Information Modelling in takeoff and cost-estimation

According to the definition in British standard BS 8536-1:2015 [1], BIM is a "digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition". This means that BIM creates an interactive data set for a building or object and its physical and functional characteristics at every stage of its life-cycle, instead of creating a set of drawings. It allows for more informed decision-making due to a more holistic approach to information concerning the object [8].

During the programming and conceptual design, BIM tools allow for better communication with the investor and better representation of their expectations, as well as creating a template for further work on the project. Detailed project and documentation are based on the conceptual design to a higher degree than in the case of traditional designing methods – conceptual design gets overwritten with details, rather than being a different drawing which shows the general structure of a designed object. The process of designing is also divided into phases, in which the project undergoes subsequent detail enhancements of all project elements (construction, installations) until reaching a set detailing level for the phase [10]. In traditional design work, the drawings are made already with the final detailing level [5].

### 2.1. Takeoff in BIM

Takeoff itself can be defined as the process of calculating the amount, type and installation method of all elements in the object, made before the construction process [9].

In the traditional way of designing, it is a time-consuming and labour-intensive process, susceptible to human error. While takeoff programs were available before the BIM technology, they only offer a less time-consuming way to count the amount of material, and still require mainly manual input [9].

The BIM technology introduces many improvements, both in the process of takeoff itself, but also in sharing information about the elements and their installation in the construction. Elements can contain additional information about each element, in addition to which they can be divided in the way they will be installed. The information can be processed automatically to create a takeoff table. The design software in BIM technology (i.e. Revit) usually has integrated options for the takeoff for modelled elements; however, the scope of possibilities and displayed information is different for each design program.

There are also additional BIM programs for takeoff (i.e. Vico Takeoff Manager), as well as BIM cost-estimating programs (i.e. Zuzia BIM) with those functions, usually with more possibilities for modifying and collecting data. It must be noted that programs have a different ways of displaying and reading data from the BIM models, which can lead to programs displaying data differently or not displaying it at all.

The automation speeds up the process of making the takeoff and leads to fewer mistakes and omissions caused by oversights in the human factor. However, using BIM tools creates new problems, such as the fact that the data pertaining to the takeoff must be input during the design stage. It requires close cooperation between the designers and the takeoff makers at every stage of the design work. Olatunji et al. [7] also point out that the automatically compiled takeoffs do not show the actual amount of materials used, but the amounts of materials included in the 3D model. It also does not show materials that are not included in the model. This can lead to the omission of some materials and labour.

To sum up, the BIM tools introduce automation of the takeoff making process, speeding it up and lowering the risk of miscalculations and omissions caused by human error. It can also include additional information vital for the takeoffs and cost-estimates, such as the assembly order. The effective use of BIM tools requires a model of the set detailing degree, with information and descriptions included in a way compatible with the takeoff.

### 2.2. Cost-estimation in BIM

The process of cost-estimating is tightly tied to the takeoff – a well-prepared takeoff can make cost-estimating less labour-intensive, faster and less prone to omissions due to human error. A well-prepared takeoff is vital for the cost estimate, as without a properly detailed record of the elements that need to be priced, the cost assessment will be incomplete.

In traditional design work, accurate cost-estimating is only possible after completion of the documentation, when the exact amounts of materials and labour are available. Before that moment, at the concept stage and during the designing process, the cost is estimated on the basis of previous experience with similar buildings, or set rates for a square metre of similar or the same construction type. The rates are calculated for standard constructions, and while there is a way to modify the rates to suit a particular construction, it is hard to obtain satisfactory accuracy. This is particularly pronounced in the case of atypical construction builds with new technologies.

Using BIM gives new opportunities to make cost estimates more accurate and detailed. In the conceptual stage, the model is more detailed than in the case of a traditional designing process, as it is a base for future changes [2]. That allows making a more detailed and more accurate estimate of the cost on this stage. Moreover, the automation of the takeoff process enables a faster analysis of the costs and variants of the construction.

Similarly to the takeoff, the main advantage of BIM-aided cost-estimates is the automation. Instead of having to manually input all the information, BIM tools create a spreadsheet structured correspondingly to the construction elements, with automatic or semi-automatic takeoff included. Also, the basic problem with using BIM tools for cost estimates is the fact that the automation is only possible if the model is created according to the standards set by the cost-estimator and corresponding to the programs used to estimate costs. Without this, the automation might give incorrect values, or be impossible to obtain.

Even when the cost estimate is calculated on the basis of a well-prepared model, it requires a lot of work from the cost estimator. The automation concerns the materials and their amount that are modelled in the design – it does not include additional materials and labour. In Poland, these elements are usually taken from National Contractor's Estimator (KNR).

Design programs such as Autodesk Revit or Tekla Structures have tools for basic cost-estimation on the basis of the automatic takeoff; however, the tools do not allow for any additional positions. More complex cost estimates can be carried out in add-ons for the design programs, or in BIM cost estimating software such as CostX BIM. In Poland, the most widely known cost estimating program is BIMestimate.

To sum up, cost estimating in BIM is strictly connected to takeoff and shares mostly the same advantages and disadvantages. It introduces higher process automation, but only in the case of a well-prepared BIM model, and this process is not fully automated.

## 3. Practical use of BIM

To conduct an analysis of how BIM tools affect the takeoff and cost estimating processes, the authors created a model of a road bridge with accompanying takeoff and cost estimate. The work was conducted by a team of 6 people, to approximate the groupwork usually conducted in the BIM designing process.

## 3.1. Model of a road bridge

The model of a road bridge was made on the basis of existing 2D documentation of a road bridge marked WD-179, which leads the national road no. 62 over the highway A1 in direction Toruń-Styków. The road class is G, meaning it is a main road. The documentation was made available by its authors [5].

The bridge is a post-tensioned concrete construction. It is a continuous, two-span slab and beam construction. The support is realised with two abutments on both ends of the slab and a reinforced concrete pillar in the midspan. All supports are founded on reinforced concrete high-diameter drilled piling. The superstructure is made of two main girders of changing width – over the main support, they widen to a max width of 1.50 m. The diaphragms in the structure have changing height – 1.40 m over the pillar and 0.70 m over the abutments.

## 3.2. Work organization

The project was done by a work group consisting of 6 people, with the intention of simulating work in a design studio [8]. The organisation chart for the work group is presented in Fig. 1.

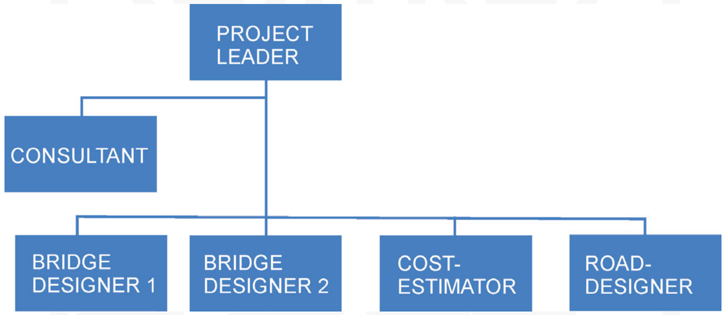


Fig. 1. Organization chart of the created BIM workgroup

The project leader prepared the work environment, set tasks, controlled the ongoing work and analysed the results of the work. The consultant was not directly involved in the project but assisted in case of issues with the BIM tools and their compatibility. Two bridge designers made the 3D model, the road designer was responsible for the project of the road leading to the bridge. The cost estimator prepared the takeoff and cost estimates for the object. Neither the designers nor cost estimator had previous solid experience with BIM technology and the BIM aspects of the software used. Cooperation within the work group was mainly conducted remotely. A meeting was held once a week, during which problems and issues were discussed and plans were made for future tasks. The model and file exchange was conducted using a server, namely Google Drive.

The bridge was modelled in the programs Autodesk Revit 2015 and 2016. For the road designing program AutoCAD, Civil 3D was used. Data from the model was then exported to the cost-estimating software, Zuzia BIM, which required an additional program, BIM Vision, which is a free IFC model viewer.

## 4. Issues of BIM-aided takeoff and cost-estimating

During the process of making the model and cost estimates, the team encountered many issues, which may be considered characteristic in working with BIM technology.

### 4.1. Choice of software

The first issue that became prominent during the project was choosing the right software. There are numerous programs for modelling in BIM, all of which offer slightly different functionality. The choice was made mostly on the basis of the availability of a student's version of the programs and previous experience of the workgroup with those programs or programs similar to those. The information given by the software developers was usually precise in describing the functionality and many of the programs considered had a demo or student's version available. There were also presentations and videos available showing the functions of the software.

In the case of takeoff and cost estimating software, the information obtained from the websites of the programs was scarce, and usually did not present the full abilities of the program, instead concentrating on listing the advantages of using BIM tools. There were also very few videos available to see the functions of the software. This affects the choice of suitable cost-estimating software for designers and design studios, as it does not allow for more informed decision making.

### 4.2. Team communication

The most basic problem which was present during the whole process of making the model and cost estimates was communication between the members of the workgroup.

Good communication was needed at every stage of the project, due to the specifics of working in the BIM environment. Each and every modelled element had to be coordinated between the members of the team, as its description of properties could potentially tie into the possibility of automation of data transfer between the programs. In the case of any issues with automation or information transfer the work had to be paused, and a proper modelling method had to be found.

The problem of constant communication between designers was present in part due to the fact that the workgroup had very little experience with BIM tools; however, even after acquiring better knowledge of the software, it was still necessary to keep each other informed about any changes and issues, or the compatibility of the created model with other BIM tools. In a traditional design process communication is also crucial; however, each designer works on their own copy and it is the end-result from each of them that matters, not the way an object or element is drawn or described. Therefore, it can be concluded that communication is one of the key issues while conducting a project in the BIM environment.

### 4.3. Element description

In the case of using BIM tools to make an automated or semi-automated takeoff and cost-estimate, it is necessary to describe the model elements in a way which will allow other BIM tools to correctly interpret the information. The absence of a description or different way of including the information can lead to mistakes or inaccuracies in the takeoffs and cost-estimates.

Including descriptions during the process of modelling is a rather simple action when it comes to elements prepared in the base design software. However, it was noticed that the options are quite limited in the case of elements downloaded or copied from other programs, for example, AutoCAD. During the course of the project, several elements were made in different programs, usually due to the fact that either pre-existing elements were found or the complicated geometry of an element was easier to model with different software. After uploading the elements into the program, there were extremely limited description options, not even a type of material could be assigned to the element. This hindered the automated takeoff process, as the elements did not appear in the takeoff lists compiled by Revit.

The issue was not solved, as the elements were just remodelled in Revit. It was an inconvenience especially in the case of experienced designers who are starting work with BIM tools – the library of non-BIM elements they might have accumulated is not fit to be used. In the case of small-scale buildings, such elements can be quickly found in an automated takeoff or cost-estimate; however, in the case of bigger or more complicated elements, it can be easily overlooked, leading to mistakes.

### 4.4. Simplifications in the model

During making the model, many simplifications were made. Elements such as railings were only symbolically drawn in, without keeping their geometry. In the case of traditional projects, it is of practically no importance, as those elements are usually described in the written description. It poses a problem, however, for the automatic takeoff and cost-estimation in BIM. Any simplification leads directly to inaccuracies in the takeoff, as the volume, length or amount of elements does not correspond to the real amount. The amounts can be taken from the description or comments in the model, but this stands in opposition to the automation of the process. It can also cause some elements not to be counted in at all if the simplification means they are not to be modelled at all.

The simplifications in the model play an important role in the designing and model-making – it saves time and labour while keeping the functionality and aesthetics of the model. Fewer elements keep the software from overloading and keep the working in the program smoother. Therefore, there is no reason not to use simplifications in the model.

In the project, the issue of simplifications was solved by continuous contact between the designers and the cost estimator, where it was determined which elements should and could be simplified. It was necessary to set a set of rules concerning the simplification of elements and units, as well as make comments about the missing layers or materials.

## 5. Conclusions

The aim of the paper was to explore the possibilities for using BIM technology in takeoff and cost-estimation. For that purpose, a literature review of the information about cost-estimating and takeoff in BIM has been done, as well as a team project showcasing the main issues cost-estimators and designers can encounter, especially if they do not have experience with BIM tools.

The most important aspect that has been observed is the change of the labour schedule for the cost estimator. Traditionally, after preparing an initial, conceptual cost-estimate, the cost-estimator starts work practically after the documentation is finished. After getting the finished project, making the cost estimate is labour-intensive work, mostly due to the takeoff. In the case of BIM technology, the cost estimator should be present during each phase of design to determine the way objects and elements are meant to be described and modelled if any automation of the process of cost-estimating is required. They should also give input on possible simplification of the elements in the model. However, during the cost estimating phase, the labour input from the cost estimator should be lower, as the takeoff and parts of cost estimate can be done automatically and semi-automatically.

On the basis of the literature and experience, it can also be concluded that the effective use of BIM is dependent on the communication within the workgroup. Regular communication amongst the designers and cost-estimators allows a working model to be created which can be used for further processing in different BIM tools. The need for constant communication imposes a better information flow. Future research should investigate the influence of BIM tools on the exact project duration, as well as, in the wider perspective, test how it translates to changes in the construction work itself.

To conclude, BIM technology introduces many simplifications in the work of the cost estimator, both in the case of takeoff and the cost estimate itself. It changes the way a project is managed, as it requires constant contact between the workgroup members. BIM technology is a step in the direction of better cost-management and more productive cost-estimating.

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