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Analysis of the first Polish BIM-Based cost estimation application

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Abstract

The ability to automate the process of preparing the bill of quantities is one of the key advantages for the estimator. Such a possibility is provided by the BIM model. The paper discusses key approaches to BIM-based cost estimating, such as exporting quantities, using a specialized BIM measurement tool and a cost estimation system. The opportunities and solutions offered by the Polish application seem to be a significant contribution to software development. This paper attempts to provide a new cost estimation system operating on the BIM model and aims to analyze the attributes required from BIM applications. Hopefully the BIM Vision system and the BIMestiMate presented in the paper will be regarded as appropriate and ready to be applied in BIM-based cost estimation.

1. Introduction

One of the most useful tasks that can be automated through the BIM use is quantity takeoff (QTO) [1, 2]. A BIM-based QTO is assumed to provide a simpler, though more detailed and accurate cost estimation of the project, reducing time and expenses [3].

In this article, the authors present a costing system, BIMestiMate, which fulfills all these requirements. This makes it the first Polish application that allows to estimate costs directly on the basis of the BIM model.

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2. Literature review

Recently several BIM-based cost estimation software programs have been developed to improve the efficiency of estimators. Widely known BIM-based cost estimation programs include the following: Innovaya Visual Estimating [4], Vico Estimator 2009 [5], Tokmo Production System [6], Success Design Exchange [7], Timberline Extended [8] and Winest Design Estimation Pro [9]. However, the combinations between different software types were frequently unique and hardly generally applicable. Previous research extensively elaborated on the issue of facilitating the estimation of the bill of quantities and computation of costs with the use of BIM.

Ok et al. [10] proposed the methodology of BIM property information modeling that could support the quantity take-off of a structural element for reflecting the cost estimate feature of a public building. Kwon et al. [11] suggested ways of securing BIM quality for correct quantity take-off. Koo et al. [12] provided a work item matching process model to help users identically recognize work items with different expressions so that they could reuse historical unit costs from the previous projects. Ma et al. [13] established a framework for BIM-based construction cost estimating (CCE) software that utilized the Chinese standards. Hartmannet al. [1] described the implementation of BIM-based tools to support the activities of the estimating department of a construction company on a large infrastructure project. In [14] authors proposed an ontological inference process to automate the process of searching for the most appropriate work items, which is limited to tiling in this case study. The model presented in [15] provided an intuitive method to incorporate cost (and multi-level) estimation into the early stage of design. [16] presented time and cost planning in construc¬tion projects using building information modeling (BIM) approach. Firat et al. [17] presented two case studies of the application of BIM-based QTO. An investigation of the utility of neural network methodology to overcome cost estimation problems in early phases of building design processes can be found in [18]. [19] presented a conceptual approach to cost estimation of a structural skeleton using an interactive automation algorithm. Ma at al. [20] provided a framework design for BIM-based construction cost estimating software. A comparative study of commercially available BIM-based cost estimation software and an investigation of the changes in work practices and workflows incurred by the adoption of such software by a construction company is presented in [21]. A number of case studies reporting on the results of BIM-based cost estimations are also available in, for example, [22,23,24,25].

3. The BIM approach

A traditional approach to cost estimation and schedule preparation is presented in Figure 1. The BIM approach is schematically presented in Figure 2. The first step on the investor's part is to prepare a 3D model of a building along with a knowledge base, that is, all the vital information available at each stage of the investment. Next, errors resulting from the intersection of elements in superimposed drawings of successive industries are detected. The detection is often performed by means of a free program, Tekla BIM Sight. Moreover, a correction of the information in the model and its systematic supplementation is also necessary. Collecting information about the building structure using a facility BIM model, projections, sections and guidelines, as well as cost estimations, ends this phase of the approach.
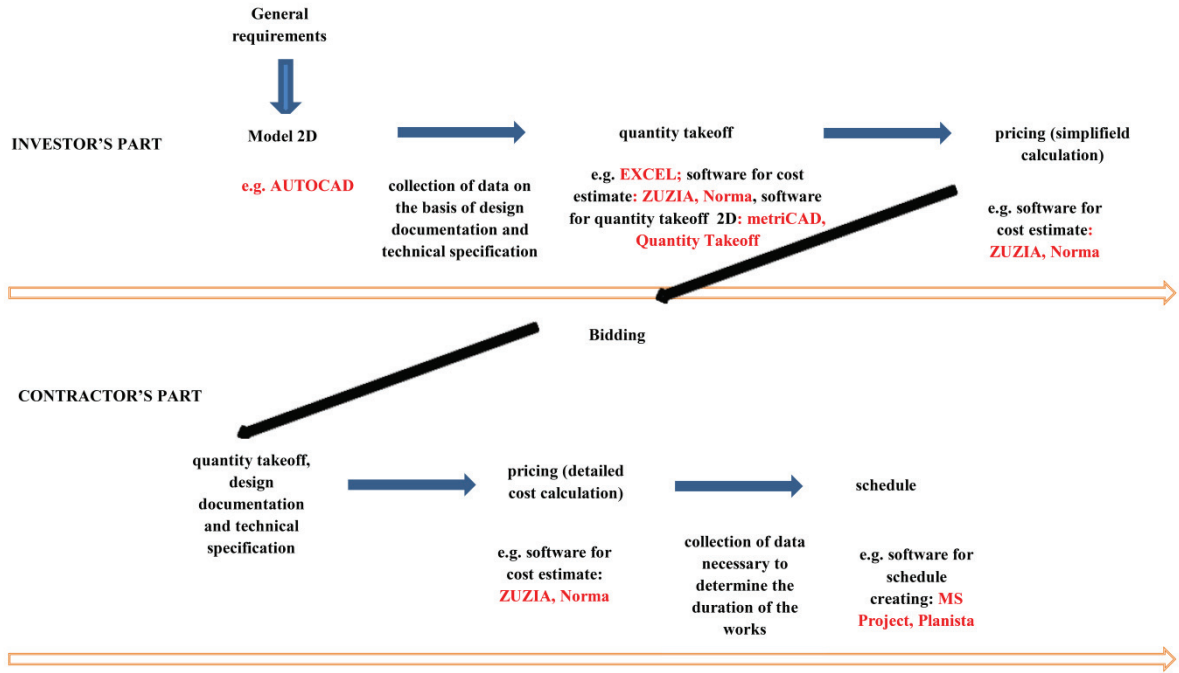
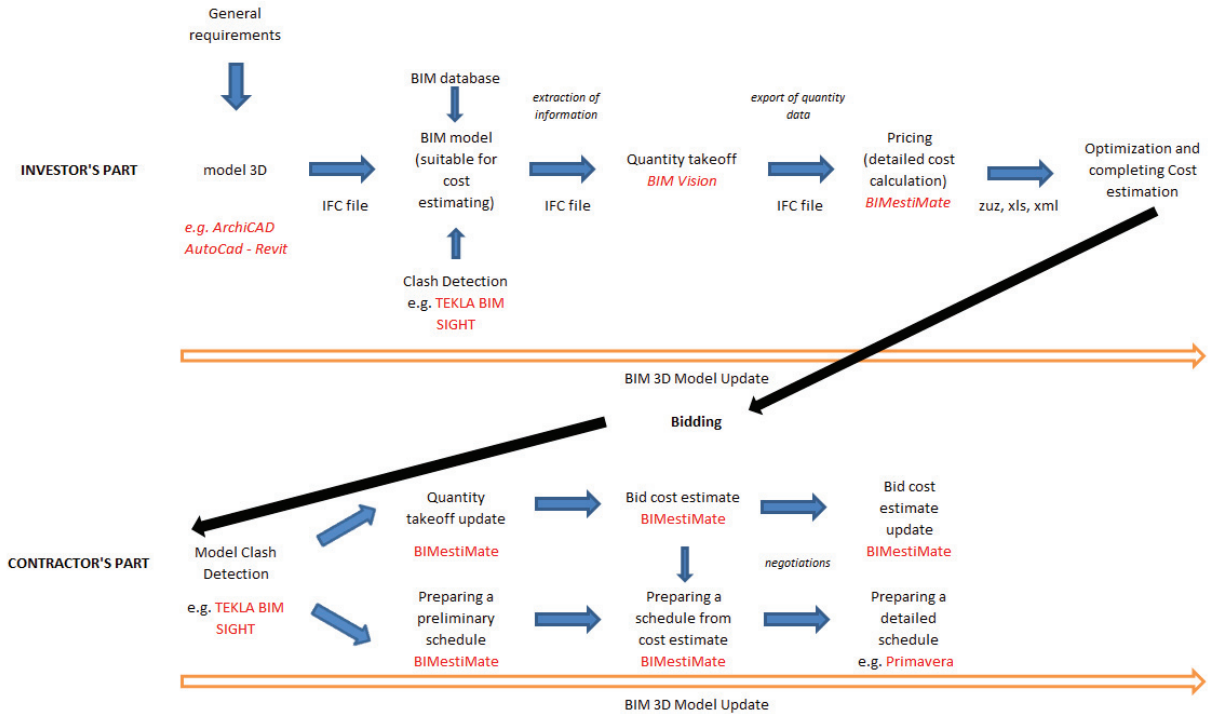Figure 1. The traditional approach in the cost estimation process.

Figure 2. BIM-based cost estimation process.

In the second step, quantities are transferred directly from the model (IFC file) or are extra-added if it is necessary for cost estimation. As the model is object-based with parametric information, it is easier to capture the quantities directly from the 3D model. Such calculations are more accurate with fewer errors and omissions. The basic steps in this phase include: adopting measurement units for particular items, elements and works, extracting quantities from the BIM model and transferring quantities to cost estimation software.

When the quantity take-off is completed and both descriptions of the identified items (introduced in the design process from a library or adopted individually) and their quantities are prepared, the actual cost estimation may begin.

As the unit rates are computed for all items, the items are priced automatically. Costs of all items are calculated automatically "on the fly" on the basis of adopted or computed prices. A list of the elements that are estimated is created automatically as records in the cost estimation application, which makes it ready for valuation.
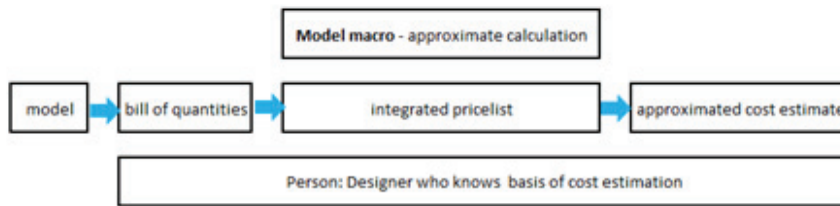
Figure 3. Schemes of the Macro BIM-based cost estimation process (source: based on [27]).

A quick estimated valuation (Macro BIM) is possible on any step of the project and it does not require any knowledge of costing from the designers. To automate the Macro BIM valuation one needs to calculate the combined prices which are related to the BIM library (Figure 3). To ensure agreement between the elements of the BIM element library, a price list or a set of specifications, a classification system needs to be applied. Most of the known CAD systems used globally employ the OmniClass construction classification system (OmniClass, 2006), designed originally in the USA and Canada and further developed in many other countries. OmniClass uses standards that are already known and that were already applied for various construction needs, such as MasterFormat, Uniclass, UniFormat, EPIC i ASTM [26].

In Poland, classification systems have not become popular yet, which significantly hinders the use of unit pricing of the assigned elements. Nowadays, the estimator can find unit prices manually in price newsletters. The main activities in this phase include collecting cost information (for instance, published unit rates or historical cost data), estimation of construction costs based on relevant regulations and methodology, gathering cost information and optimization of the estimate.

The contractor performs a preliminary verification of the data included in the model, updates the bill of quantities and makes detailed calculations in order to prepare a bid.
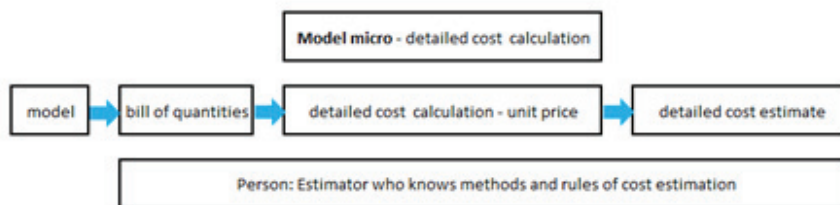
Figure 4. Schemes of the Micro BIM based cost estimation process (source: on basis [27])

In Poland, a detailed calculation (Micro BIM) is based on a system of catalogues including unit pricing as well as prices of production factors. As a result, one obtains a unit price of a particular type of an element. All elements of this type are automatically priced according to the calculated unit price and the bill of quantities downloaded from the IFC file.

4. BIMestiMate and BIM vision system

To use the BIM model and to benefit from the BIM technology in costing it is necessary to have access to software and a database of prices. Thus, functional and technical opportunities of using BIM for costing in Poland have been studied, basing on the only accessible product. The study involved the information published by software providers, user reviews of products and authors' own experience. Another source of information included opinions concerning the application. To ensure uniformity and objectivity, the research was based on a set of defined criteria. The first verification included the six requirements described by Ma et al [13]. The analysis of IFC uses and BIM-based costing software revealed that their major characteristics, except MS Excel, are the following [13]:

- Operating on a 3D-based platform could be obtained either from an independent development or professional BIM based design software.
- Input data could be extracted from an IFC file.
- Since there was no enforced specification, the software followed the coding system developed by the industry association.
- Estimation could be performed from conceptual design to detailed design.
- The quantity extraction was not subjected to uniform calculation rules but was based on object types and their dimension.
- Cost estimation was based on the item costs generated by the professional and experienced cost estimators.

The costing systems BIMestiMate and BIM Vision (Figure 5) fulfill all these requirements, which makes them the first Polish applications that allow to estimate costs directly on the basis of the BIM model.
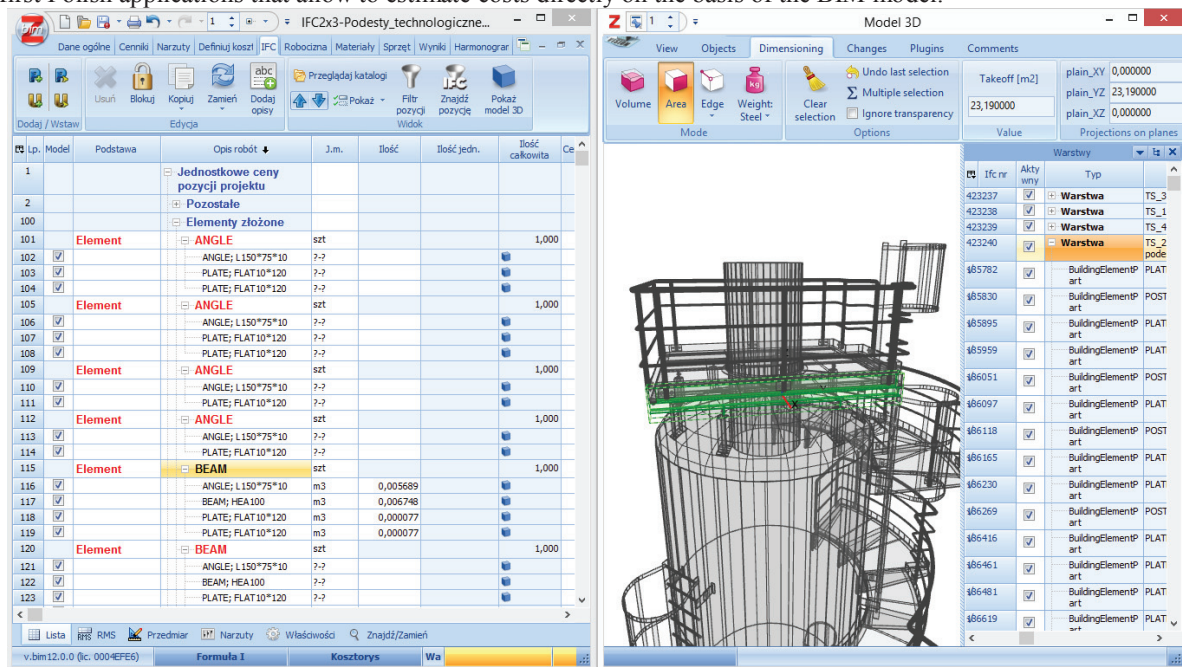

Figure 5. BIMestiMate and BIM Vision system.

The research concerned the features of the BIM Vision browser (Figure 6) used to analyse the BIM model and to calculate the bill of quantities, as well as the costing system BIMestiMate working with the application BIM Vision.
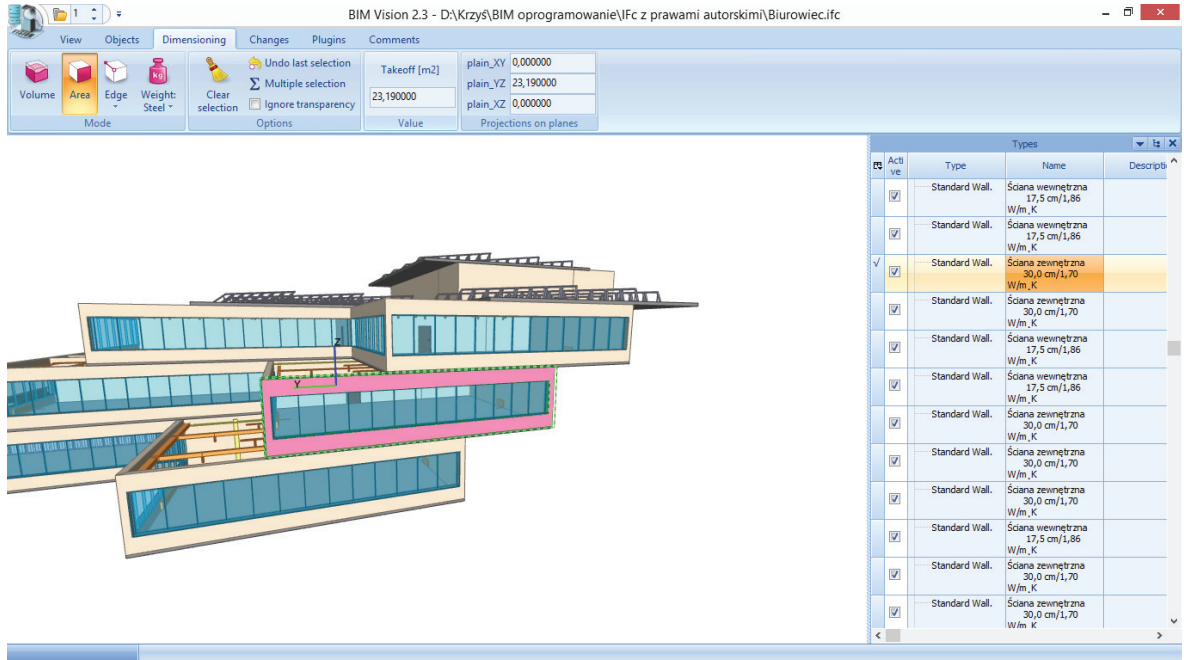

Figure 6. Building model in BIM Vision as storey slide view.

The most vital features of the browser are presented in Table 1.

Table 1. Features of the BIM Vision application in relation to its usability for the bill of quantities

Model View	2D, 3D, Projections in space
Language	Polish, English, Spanish
File format	IFC
Transparency	Solid, Partial transparency, Full transparency
Viewing options	cross-section; hiding elements; cutting; storey slide in X, Y, Z surface; selecting objects
Element list display form	IFC structure, types of elements, model zones, model layers.
Mode of taking dimensions	Volume, area, edges, line length by selected vertices, distance between surfaces, distance between element's center of gravities, weight of elements.
Measuring method	Single element quantity, multiple selection of chosen elements, automatic quantity by groups of element
Advanced options	Comparing models (old and new IFC files), finding elements, filter elements, adding comments,
Export/import	Fully integrated with BIMestiMate (cost estimation software) and DDS CAD (system for electro and HVAC design)

The main features of BIM Vision include the following.

1. **Information exchange** – the application reads IFC files (therefore, it is independent of design programs) and exports calculated amounts of works directly to the costing program BIMestiMate.
2. **Visualisation** – it enables 2D and 3D object presentations along with projections in space where storeys can be spread apart in planes x, y and z, in partial or complete transparency. Such a presentation of a 3D model of a building in which it is possible to make intersections is a considerable facilitation for the cost estimator.
3. **Quantification process** – evaluation of the simplicity and speed in the execution of bills of quantities is positive too. The application allows to choose the way and method of count (Table 2). Menu is intuitive and allows to select the mode of creating a bill quickly. A significantly high speed of computation is obtained for an automatic bill of quantities for a group of elements, such as walls, in the model. The bill for the whole object is completed within several seconds or a few minutes. The program is based on an automatic detection of elements, which is performed along a number of steps, as in the following example involving the identification of elements described as walls:
a) Searching for the biggest two surfaces out of those available, for example, Area 1a, Area 1b, Area 2a, Area 2b, Area 3a and Area 3b (Figure 7) and studying their interdependencies. Figure 7 shows that the greatest surfaces are Area 1a and Area 1b. When: |Area 1a-Area 1b| <5% the elements qualify for automatic calculations for the element wall (Figure 7). The 5% value is the default one, which can be changed by the user.
b) Testing whether the surfaces of the planes found A1a and A1b are significantly larger than the surfaces of other planes, Area A2a, Area A2b, Area 3a i Area 3b – by default, they should be 8 times bigger.

To avoid calculation errors when the wall contains, for example, a niche, the algorithm additionally checks the outer and inner surfaces and computes the arithmetic mean of the surface. In the future, the application is to allow the user to select the minimum or maximum surface value, or the mean of the inner and outer surface.
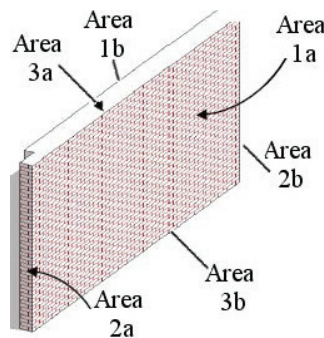

Figure 7. Criterion for element identification as a wall in BIM Vision

The other element of the system is a costing program BIMestiMate. Contrary to BIM Vision, which may function as an IFC file reader, BIMestiMate opens together with the BIM Vision application.

On the basis of the bill of quantities generated in BIM Vision, which is later transferred to BIMestiMate, cost estimates are performed by means of two calculation methods in Poland: a simplified method and a detailed one. The foundation of the estimate, though, is the information stored in the BIM model within the scope of construction works, including, for example, the scope of works, quantity, technology and materials. The process of works estimation itself can be based on the knowledge about unit prices of objects in the base of the simplified method. Yet nowadays, due to the lack of appropriate libraries of elements used in designing and to the commonly used classification of construction works, it is not possible to use the databases correlated with the elements stored in the BIM model. Therefore, the calculation is based on the estimator's assigning appropriate unit prices to particular works resulting from the scope of works specified in the BIM model. This is done by using the consolidated price

list associated with the library of BIM elements. Consolidated prices include average costs of materials, labour and equipment. Knowing the amount of works and consolidated prices it is possible to specify the estimated cost of the building easily and quickly, basically without resorting to complex cost estimating systems and without the knowledge of detailed cost estimating methods. An example of such a calculation is presented in Figure 8.

| 102 | | ⊟ **External wall; Partition wall with full-thickness brick half a brick, finish: double-sided kat.IV plaster, wallpaper.; Airbrick Porotherm; gr.=0,3000[m]; Plaster on the reinforcing grid; thickness=0,0100[m]; Mineral plaster; thickness=0,0100[m]** | m2 | | 444,485 |
| 103 | Knowledge database | Plaster on the reinforcing grid; thickness=0,0100[m] | m2 | 444,485 | |

| | 20 104,06 |

Outlays	Price	Value
Labor		
Material		
Equipment		
SUM (without tax)	45,23	20 104,06

Figure 8. An example of a simplified calculation for external plaster based on a knowledge base containing unit prices

In the case of a detailed calculation, the calculation procedure must take into account the precise calculation of construction works prices. It therefore requires manual work in the selection of the factual basics (standards for labour and equipment, standards for material consumption), the prices of the factors of production (labour, materials, equipment), and the determination of the level of overheads, such as indirect costs, and profit (Figure 9). The advantage of a detailed calculation, as in the case of a simplified calculation, is the automation of cost estimation calculations. However, the subsequent steps consisting of searching for the works in the available database of prices and the valuation of the factors of production, such as labour, materials and equipment or the introduction of own calculations, must be performed by the estimator. The calculation of the precise price of the works in an inflation does not allow to fully automate the process of pricing, which, by definition, should be the price for which contractors are willing to perform the works and the price for which they will perform the works if they win the bidding procedure, and which therefore can be written into the contract.

1.4	Element	⊟ **External Walls**									194 893,64	194 893,64	100,00
1.4.1	KNR 27/163/3	Multistorey building walls from airbrick Porotherm P+W, wall thickness 30·cm	m2	Σ 1 452,000						113,75	165 163,31	84,75
		Nakład (1)	J. m.	Norma	Ilość jedn.	Ilość	Typ inw.	Ilość inw.	Cena wyjśc.	Kz	Cena	Wart. bezp.	Wart. z narz.
⊟ **Labour**												32 898,25	60 543,57
	Carpenter		r-g	0,11	0,11000	159,72000			14,34		14,34	2 290,38	
	Bricklayer		r-g	0,85	0,85000	1 234,2000			14,34		14,34	17 698,43	
	Worker		r-g	0,62	0,62000	900,24000			14,34		14,34	12 909,44	
⊟ **Materials**												129 783,88	129 783,88
	Airbrick POROTHERM 30,0x24,8x23,8·cm,		szt	16,3	16,30000	23 667,600			5,20		5,20	123 071,52	
	Cement mortar		m3	0,017	0,01700	24,68400			194,23		194,23	4 794,37	
⊟ **Equipment**												2 481,18	4 566,19
	Construction Hoist		m-g	0,24	0,24000	348,48000			7,12		7,12	2 481,18	

Figure 9. An example of a detailed calculation of the cost of external plaster on the basis of builder's

To conclude, the advantages of the BIMestiMate applications include the following:

- the possibility to select a calculation method (MacroBIM or MicroBIM);
- automatically importing the bill of quantities in the form of an IFC file from the BIM Vision application;
- shortening of the cost estimation time due to the access to the data downloaded from a virtual model of the building;

- automatically associating quantities generated from the design objects and resulting estimate items with the objects.
- The drawbacks of BIMestiMate involve:
- lack of automatic simplified cost estimation;
- inability to organize and save quantities by different classifications, such as Omniclass or Uniformat;

5. Conclusion

The ability to automate the process of preparing a bill of quantities is one of the key advantages for the estimator. Such a possibility is provided by the BIM model. Moreover, apart from the sole calculations, the use of the appropriate application allows to link the elements of the model with the amount of works and price. However, the implementation of BIM-based measurements and cost estimation in Poland is still at its early stage.

The paper shows the key approaches of Polish BIM-based cost estimating applications which use a specialized BIM measurement tool and a cost estimate system. It also identifies difficulties in taking a full advantage of BIM, especially in data exchange issues in BIM tools and in the Macro BIM cost estimation process. The application under analysis fulfills all the requirements of the cost estimate program based on BIM. Moreover, the BIM Vision browser possesses many useful functions for cost estimators. Drawing attention to solutions and opportunities offered by the Polish applications may become a significant contribution to software development in Poland and abroad. The authors hope that the BIM Vision system and BIMestiMate will be evaluated as appropriate and ready to be applied in the BIM-based cost estimation. In addition, specifying flaws in the software will allow to indicate such future development which will advance the introduction of the requirement to systematize construction works in Poland by means of, for instance, OmniClass, and exporting the calculated costs to the BIM model.

The BIM Vision and BIMestiMate system belong to important resources necessary for quantity surveyors to perform BIM-based cost estimating. There are a few BIM based cost estimating tools, including Vico, Innovaya, Tocoman or CostX available on the market but only one of them begins its development in Poland. In this context, the research reviewing the most well-known tool in the Polish market is crucial indeed.

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