Financial Evaluation of the BIM Model Coordination Process in Construction

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Abstract

Although the decision whether to use the BIM method for a project has many factors, the purpose of this work is to describe financial benefits that comes with using the method in the field of project coordination in design phase.

On the following pages it will be described how the tools of the BIM method can be used to detect collisions in comparison to performing classical coordination only using 2D coordination and visual inspection. The cost of removing the collisions will be determined for the case in which it would not have been detected during the design phase, but the collision is dealt with during construction. The difference between BIM and classical detections will be determined as the added value of using BIM method.

Keywords

clash detection; digital information model; financial evaluation

JEL Classification

L74 Industry studies: Primary production and construction: Construction

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Introduction

The use of Building Information Modelling (BIM) in construction projects has undeniable advantages throughout the process, but in selected stages and on appointed parties it is also associated with increased costs, more time-consuming processes and greater demand on the expertise of the members involved. These are two sides of the coin that leads to the question which side is heavier. In other words what are the cost and benefits of using BIM method.

On the Following pages this article focuses on determining the benefit of using this method in design phase, specifically for coordination and automatic collision detection and its removal.

What is BIM and why to use it?

Introducing the BIM method and its essence could be done in variety of ways, some of which could be as follows:

BIM Initially represented the new, structured ways to represent buildings that went beyond lines and “implicit meaning” towards objects and “explicit meaning” [1, 2]

Building information modelling (BIM) is a platform for keeping accurate and interoperable records of building information to enhance pre-planning, design coordination, and maintenance throughout the life cycle of facilities. [3]

Building information modelling refers to a modern approach to construction projects throughout its life cycle, using digital technologies to increase efficiency, eliminate errors, improve information management and more. This method is based on digital models representing a given object in digital space, where it is an exact copy of the object. However, it is not only visual representation, the model also contains all the information about the materials used, its properties, the location of the object in a particular space and a lot of other information connected with the object. Such a model is called a BIM Model. BIM model utilization is gaining importance in European countries and so-called Virtual Design and Construction is experiencing an upswing in North American countries. [4]

In addition to the digital model filled with information, the most important part of the BIM method is the environment in which the construction project, in digital form, takes place. This is the so-called CDE (Common Data Environment), and it simplistically serves as a repository of all documents, an archive of communications, or versions of the proposed design, but above all, it is a tool for collaboration, which allows all project participants access to current information in real time.

One of the great benefits of BIM method is its complexity, as it is tool that can be used not only at design and construction phases. BIM method is utilized through the life cycle from the idea stage to the implementation, during design, construction, maintenance, up to the disposal of the object at the moment of fulfilling its potential. Notable examples include BIM model-based project management and facility management. [5, 6]

Clash elimination

Clash elimination is an essential part of all construction projects, and its importance increases with increasing the size or complexity of the project.

Collisions can be many different types, whether it is individual building elements such as walls, ceiling, mechanical, electrical, plumbing, medicinal, transport or other specific technologies.

To eliminate collisions, it is necessary to determine how it will be found in the first place. For the purpose of this article classical 2D visual coordination will be compared to coordination done with BIM tools, more specifically software allowing automated clash detection is utilized [7].

Methodology

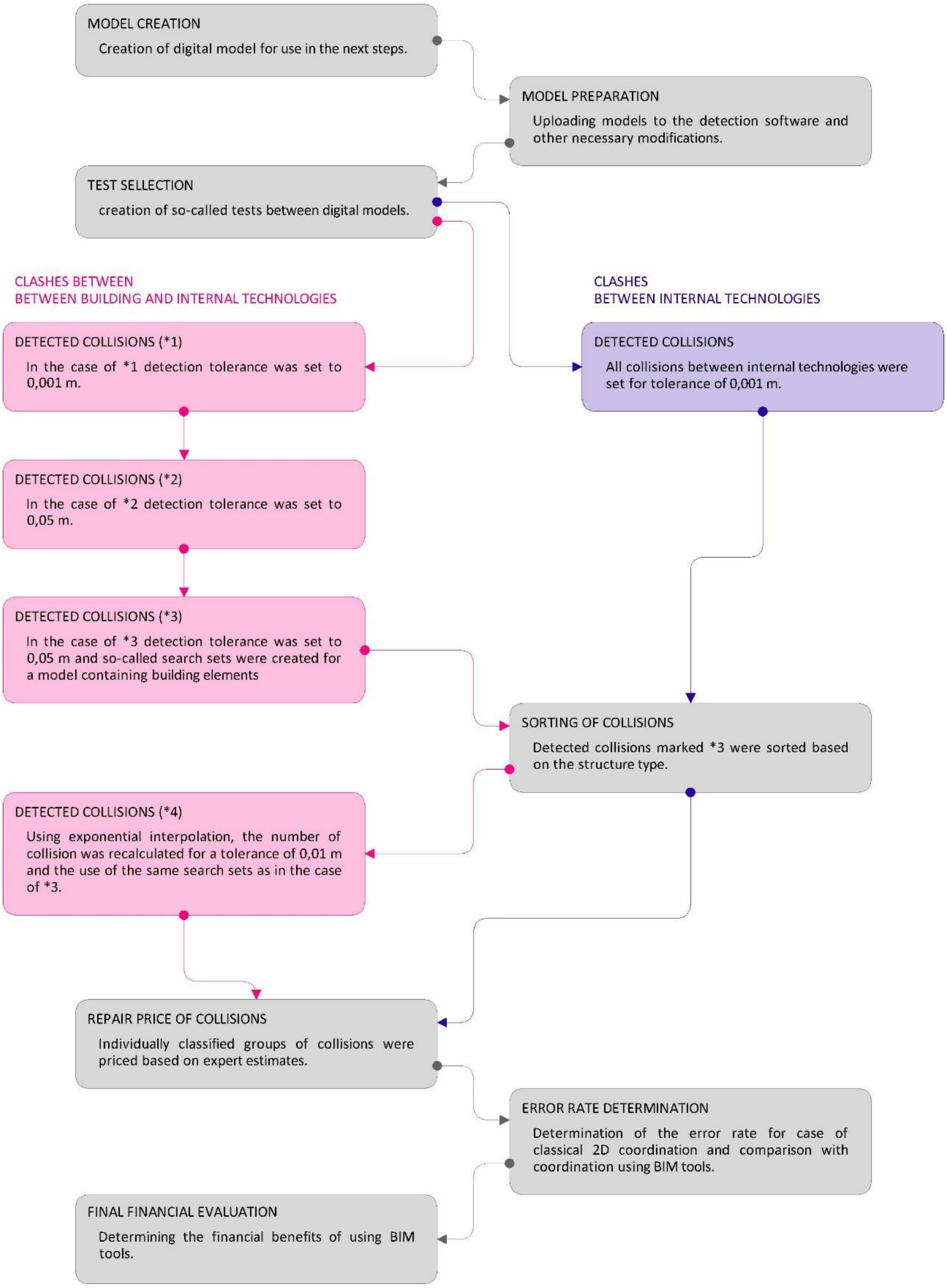

Figure 1: Visual representation of used methodology (source: Authors)

Model creation

The BIM model existence is necessary for the subsequent coordination. All used BIM models have been created in cooperation with large design and construction teams on large building projects.

BIM models

A Total of 6 BIM models were used to carry out the work, each representing a different type of building with different type of use.

Table 1: Digital models used for work (source: Authors)

Building	Building type	Area of all floors	Collisions before coordination and reduction
		m^2	pcs
Model n.1	Treatment centre	6 470	29 650
Model n.2	Stadium	45 600	139 815
Model n.3	Factory hall	38 280	8 589
Model n.4	Hospital	20 610	30 190
Model n.5	Senior home	12 410	47 945
Model n.6	Rehabilitation centre	11 940	9 935

Model preparation

The preparation in this work involves importing the individual models into the selected software. The IFC format was used for data transfer between individual projects. Data from individual projects (models 1-6) have been in 2.3.0.0, 2.3.0.1 and 4.0.0.0 versions. [8]. A common problem that can occur was spatial positioning of individual models. Mainly due to inappropriate setting of the coordination system, or its record in the relevant IFC class. In this case the coordinates of the individual models were modified as needed. Used software allows for additional editing options that are designed to improve the orientation during performing the process of coordination. BIM model created that way should be ready to thorough coordination.

Project preparation by the BIM method is financially demanding, the price increase is estimated at approximately 15 % during design phase compared to creating classical project documentation. As it was confirmed by the stakeholders, due to the involvement of software technologies, it cannot be stated that BIM model utilization would increase the time requirement. On the contrary, it is possible to use less time for complex projects, mainly thanks to the fact that the software tool and the BIM model allow designers to work in parallel (simultaneously), without the need to wait for each other with completed work. However, despite some time savings, the use of the BIM method is associated with greater expertise of the parties involved and, in most cases, also requires the involvement of other participants to ensure the functionality and proper setup of the system used. For this reason, the final cost of the project is considered higher. This value in consideration of the cost of the object examined was set at 212 224 €, recalculated to 4 €/m^3 or 14 €/m^2.

Test selection

Detection of collisions is done by setting up so-called tests, it is the determination of two models between which the detection was performed.

During the test set up, precision was improved by means of tolerance parameter, which determines the limit at which the detected collision will be reported, this value is given in length units. An example could be a situation where the ducts of ventilation and heat and cooling pipes are touching only at the edge, without the tolerance setting the collision would be reported but if the tolerance is set this collision would be eliminated from final report.

During the detection so-called search sets were created, which allowed to completely filter unwanted elements and eliminate it from the resulting detection. The filtering was done based on the parameters (IFC properties) of the elements that have been assigned to it in the model creation phase, the quality of the filtering is therefore directly dependent on the quality of the prepared model.

Detected collisions

During the execution of the work, collisions were detected using software tools and according to the parameters described below. Specifically, detection was performed between the models of building elements and the internal technologies and then between the models of internal technologies with each other.

Clashes between building elements and internal technologies

Following detections were created for all digital models and resulting detected collisions were recalculated as an average number of collisions per m^2 of total floor area and per m^3 of build-up space.

*1: For the first detection parameters set were only tolerances set for default value of 0,001 m with no further setting.

*2: In the second detection the value for tolerances was set for 0,05 m with no further setting.

*3: Tolerances in the third detection was also set for the value of 0,05 m. Furthermore, the search sets have been set up for the models containing building elements so only elements of load-bearing structures or non-load bearing walls, ceiling beams and other similar types of structures were reported as collisions.

*4: Values of the final detection were recalculated based on previous results using linear interpolation. The reason for using this method was to reduce the number of collisions that required further works with sorting, evaluating and so on, for this case the numbers of collisions from detection *3 was used. The recalculation was used to ensure a realistic tolerance value that is acceptable for construction, where a value of 0,001 m would be too small, and a value of 0,05 m would be too large.

Table 2: Average number of collisions between building elements and internal technologies (source: Authors)

Project		-						65263 m^3 22552 m^2
Type	Hard							
Tolerance	[m]	0,001	0,05	0,05	0,01			
		*1	*2	*3	*4			
Clash types		Clashes [pcs]	Clashes [pcs]	Clashes [pcs]	Clashes [pcs]	Ov. Reduct [pcs]	Ov. Reduct [%]	Note
Clashes per m^2		**2,168**	**0,415**	**0,169**	**0,642**	**1,561**	**67,111%**	
Clashes per m^3		**0,711**	**0,147**	**0,064**	**0,234**	**0,520**		
*1	Clashes detected without further settings							
*2	Clashes detected with tolerance set for 0,05 m							
*3	Clashes *2 with automatic and manual reduction							
*4	Interpolation between collision *1 - *3 representing setting the tolerance for 0,01 m							
*Ov. Reduct	Number of collisions reduced between step *1 and *4							

Clashes between internal technologies

For clashes between internal technologies the value of tolerance was set for 0,001 m with no further setting done. The number of collisions was afterward reduced by 10 %. Removal of 10 % of collisions was done based on manual assessment of each collision and its relevance. 10 % is an estimated value that was obtained by manual assessment, i.e. by reviewing each collision and their context in the BIM model, going through the reported collisions and eliminating the irrelevant ones.

Table 3: Average number of collisions detected between internal technologies after 10 % reduction (source: Authors)

	VENT	HC	HLT	ELE	SFE
VENT					
HC	450				
HLT	495	328			
ELE	507	165	239		
SFE	482	120	101	270	

Sorting of collisions

For the purpose of further obtained data assessment collisions were sorted into groups. The grouping was done according to material of the element and the purpose of use. For example, masonry walls, reinforced concrete ceiling structures or square galvanized piping in the case of ventilation pipes. For grouping in the case of collisions between building elements and internal technologies collisions from the detection *3 was used. In the case of collisions between internal technologies only one detection has been made.

Repair price of collisions

For each of the groups created, the cost of its repair was determined. The determination of the costs was based on the expert estimates of six persons from the construction industry. These persons were selected from design companies and construction companies. These persons may be considered as senior experts, they have had more than 10 years of experience in the construction field, and they were employed as designers, project managers, construction managers and site managers. Each of the person received a list of grouped collisions and was asked to fill in the price. From the obtained data an average value was calculated. The prices were increased by the contractor's margin and are therefore the costs that would be charged to the investor, as the main purpose of this work is to describe additional value for investor.

Table 4: Repair price per unit (source: Authors)

PROFESSION	TYPE	PRICE		
		min. eur/pcs	max. eur/pcs	average eur/pcs
BUILDING	Wall/beam			
	Hole in the supporting ceramic wall	33 €	56 €	44 €
	Hole in the supporting ceramic wall (firepro	200 €	264 €	232 €
	Hole in the plasterboard wall	23 €	80 €	52 €
	Nole in the OSB wall	16 €	18 €	17 €
	Hole in the concrete wall	66 €	229 €	147 €
	Slab			
	Hole in the plasterboard ceiling	26 €	28 €	27 €
	Hole in the concrete slab	168 €	340 €	254 €
VENTILATION	Pipelines			
	Square galvanized pipe	102 €	173 €	138 €
	Round galvanized pipe	31 €	59 €	45 €
	Square stainless steel pipe	122 €	205 €	163 €
	Round stainless steel pipe	41 €	72 €	56 €
	Components			
	Control damper	26 €	32 €	29 €
	Control damper (fireproof)	420 €	560 €	490 €
	Silencer	38 €	51 €	44 €
HEAT AND COLD DISTRIBUTION	Pipelines			
	Carbo-oxy pipe	42 €	48 €	45 €
	Copper pipe	73 €	82 €	77 €
	PP-RCT pipe	29 €	44 €	36 €
	Steel pipe	47 €	58 €	52 €
HEALT TECHNOLOGY	Pipelines			
	PP-HT pipe	38 €	48 €	43 €
	PVC-KG pipe	77 €	101 €	89 €
	POLO-KAL pipe	53 €	65 €	59 €
	Steel pipe	47 €	109 €	78 €
ELECTRICAL INSTALLATION	Components			
	Cable tray	41 €	81 €	61 €
STABLE FIRE EXTINGUISHING EQ.	Components			
	Carbon pipe	60 €	84 €	72 €

Error rate determination

During the performance of any coordination process in the project phase, the task is to eliminate as many collisions as possible. Due to the human factor involved in the coordination process and the high complexity of large projects, it is never possible to eliminate all collisions found in a project. The value of error rate is supposed to represent the percentage of collisions that fail to be detected during coordination or are not adequately solved during coordination. Mentioned values were determined based on expert estimates which were averaged afterwards.

Classical 2D coordination

Classical coordination in this case represents performing the coordination using 2D tools such as Computer Added Design (CAD) tool [9] and purely visual inspection. In this case a very high error rate is expected. Error rate was estimated to reach an average value of up to 94 %.

Coordination using BIM

Coordination using BIM tools includes all the steps mentioned above. There is a certain amount of automation involved and at the same time much better visual representation achieved by working with 3D digital models. For this method, experts estimated the average error rate of 3 %.

Difference

To determine the added value resulting from the use of BIM tools, the final error rate was calculated as the difference between previous two values with a result of 91 %.

Final financial evaluation

The Table 05 contains a breakdown into previously mentioned types of collisions occurring between the elements of the structure with the technologies and between the technologies with each other.

There is also a section determining the costs associated with SFE collisions, the separation from the rest was made because not all digital models included SFE, but it is crucial part of the modern buildings and so very important to include in the calculation.

Table 5: Final financial evaluation in the case of proper coordination (source: Authors)

Project	Area/volume 65263 m^3 22552 m^2			Area/volume SFE 72290 m^3 23317 m^2		
Clash type	Total clashes	Repaired	Repair price	Classical elimination	BIM elimination	difference
	pcs			* 94%	** 3%	*** 91%
BLD x VENT	982	-	93 543 €	87 462 €	2 806 €	84 656 €
BLD x HC	2451	-	274 528 €	256 683 €	8 236 €	248 448 €
BLD x HLT	4232	-	414 575 €	387 628 €	12 437 €	375 190 €
BLD x ELE	2007	-	208 645 €	195 083 €	6 259 €	188 824 €
VENT x HC	451	-	24 998 €	23 373 €	750 €	22 623 €
VENT x HLT	495	-	60 393 €	56 468 €	1 812 €	54 656 €
VENT x ELE	507	-	30 886 €	28 879 €	927 €	27 952 €
HC x HLT	328	-	19 470 €	18 205 €	584 €	17 621 €
HC x ELE	166	-	10 089 €	9 433 €	303 €	9 130 €
HLT x ELE	239	-	14 569 €	13 622 €	437 €	13 185 €
TOTAL	11857		1 151 696 €	1 076 836 €	34 551 €	1 042 285 €
per m^2	0,993		96 €	90 €	3 €	46 €
per m^3	0,315		31 €	29 €	1 €	16 €
BLD x SFE	2692	-	193 848 €	181 248 €	5 815 €	175 432 €
VENT x SFE	482	-	34 728 €	32 471 €	1 042 €	31 429 €
HC x SFE	120	-	8 640 €	8 078 €	259 €	7 819 €
HLT x SFE	101	-	7 272 €	6 799 €	218 €	6 581 €
ELE x SFE	271	-	19 488 €	18 221 €	585 €	17 637 €
TOTAL	3666		263 976 €	246 818 €	7 919 €	238 898 €
per m^2	0,157		11 €	11 €	0 €	10 €
per m^3	0,051		4 €	3 €	0 €	3 €
TOTAL						
TOTAL	**15523**		**1 415 672 €**	1 323 654 €	42 470 €	**1 281 184 €**
per m^2	**1,150**		**108 €**	101 €	3 €	**56 €**
per m^3	**0,366**		**34 €**	32 €	1 €	**19 €**
*	Number of remaining collisions after classical elimination					
**	Number of remaining collisions after BIM elimination					
***	Difference between * and **					

BLD: Elements from the digital model of building structures

VENT: Elements from the digital model of ventilation

HC: Elements from the digital model of heating and cooling system

HLT: Elements from the digital model of health technology

ELE: Elements from the digital model of electrical installation

SFE: Elements from the digital model of stable fire extinguishing equipment

Others

There are also other problems associated with the appearance of collisions on the construction site, whether it is an increase in construction time, the need for more major repairs, or a total change of design due to infeasibility of the existing solution.

These non-negligible points are not included in the work, but its importance should not be overlooked.

During the execution of the work, certain assumptions necessary for the execution of the work have been made, the assumptions being as follows:

- Any penetration of internal technology through the structure of the building reported as collision is considered a collision.
- For the pricing of collision repairs, it is always assumed that the repair can be carried out without problems.

- Collisions repair costs and error rates for each type of coordination are based on the expert estimates.
- The calculation does not include estimates of new collisions that appear during construction.

Conclusion

It is evident from the data produced that thorough coordination before starting the construction is an essential step that cannot be overlooked, especially for the large developments. It is alco clear that the difference in the quality between coordination performed classically and with using BIM tools is as high as 91 %. The average savings per m^2 set at 56 € and m^3 set at 19 € are in these cases significant and represent a large part of the construction budget.

It is also important to mention again that a project prepared by the BIM method is financially demanding, the price increase is estimated at approximately 15 % during design phase compared to creating classical project documentation. This value in consideration of the cost of the object examined was set at 212 224 €, recalculated to 4 €/m^3 or 14 €/m^2. However, despite this increase, the savings obtained are not negligible.

Finally, it is worth mentioning that precise coordination is only one of the advantages of using the BIM method and its benefits to the project are much greater than the values presented in this work. Effects such as order in the workplace, a reduction in the psychological burden of workers due to an easier course of the project, an increase in the attractiveness of the company / project due to the involvement of modern technologies in the project are some of the advantages that are not described in this article.

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