



Volumetric Evaluation of Column Reinforcement using Building Information Modeling

H. R. Husni^{1*} and B. Bayzoni²

¹ Department of Civil Engineering, Faculty of Engineering, Lampung University, Gedong Meneng, Rajabasa, Bandar Lampung, Indonesia. 35141

² Department of Civil Engineering, Faculty of Engineering, Lampung University, Gedong Meneng, Rajabasa, Bandar Lampung, Indonesia. 35141

*hasti.riakara@eng.unila.ac.id

Abstract. This study aims to determine the volumetric results of column reinforcement in reinforced concrete/Quantity Take Off (QTO) based on Building Information Modeling (BIM) and compare them with conventional calculations. With a case study of 4 buildings, namely, the Integrated Surgical Treatment Building of RSUD Dr. H. Abdul Moeloek (Zone A), the Integrated Surgical Treatment Building of RSUD Dr. H. Abdul Moeloek (Zone B), the Neurology Treatment Building of RSUD Dr. H. Abdul Moeloek, and the UT Lampung Distance Learning Unit (UPBJJ) Building. The building modeling is done using Autodesk Revit software. Based on the modeling results, the BIM-based Quantity Take Off is able to calculate the column reinforcement volume in more detail according to the design drawing. The QTO value of column reinforcement is 74197.51 kg for Case 1, 74011.09 kg for Case 2, 27671.78 kg for Case 3, and 31597.29 kg for Case 4. Comparison of Quantity Take Off shows the results, BIM is lower by 2%–3.15%, or an average of 2.75%, but BIM has modeled the reinforcement as a whole including the hook length and channel length of column reinforcement.

Keywords: Autodesk Revit, Building Information Modeling (BIM), Quantity Take Off (QTO).

1 Introduction

Rapid technological advances continue to drive change and innovation in the construction industry, making the use of BIM in design and construction limitless. BIM is both a technology and a process. BIM technology digitally creates accurate building models in virtual form [1]. BIM was initially considered an alternative to 3D building drawings with parametric capabilities. As it has evolved, BIM is not only useful for modeling building geometry but can also help manage construction projects. The most commonly cited benefits associated with implementing BIM in projects are cost reduction, project control, and time savings [2].

Building Information Modeling (BIM) is a documentation process that consists of various information about different phases of any project, such as construction design,

© The Author(s) 2024

A. Zakaria et al. (eds.), *Proceedings of the 1st International Conference on Industry Science Technology and Sustainability (IConISTS 2023)*, Advances in Engineering Research 235,

https://doi.org/10.2991/978-94-6463-475-4_34

construction planning, facility management, and operations. It is a comprehensive documentation process that is beneficial for operational visualization and construction applications such as estimating, scheduling, and design coordination [3]. BIM can support design according to its phases, thus enabling better analysis and control than manual processes [4].

This is supported by the ability of BIM-based software such as Autodesk Revit to extract a lot of information from the building model to obtain Quantity Take Off (QTO) automatically. Estimation of quantity take off material with Autodesk Revit software is considered more effective, fast, reliable, and minimal error [5].

The process of estimating volume is called Quantity Take Off (QTO). In general, QTO is a process that involves identifying elements and their relationships on drawings, obtaining dimensions, and calculating units of measurement such as length, area, and volume [6]. BIM provides faster, more accurate, and more reliable quantity take off capabilities than QTO with conventional methods [7].

Building Information Modeling (BIM) is a digital modeling approach that represents geometric and detailed information of facilities that has revolutionized the quantity take off process. Quantity can be measured automatically from the BIM model by extracting geometric data and information from each building element. This method is called BIM-based quantity take off [8].

QTO estimation is an important component that must be considered in organizing a construction project. Planning the quantity take off of materials in detail requires accuracy in calculating the volume of work. Therefore, the use of computer software is a solution to improve accuracy in estimating the quantity take off of materials to be more effective and efficient [9;10].

Accurate QTO is recognized as an important factor in increasing project value. The BIM-based QTO approach is feasible for projects due to its accuracy and convenience. The BIM-based QTO approach shows a higher level of accuracy than the conventional method approach [12]. In the construction world, concreting work is one of the most important parts of reinforced concrete structure projects. Its quality affects the overall quality of the structure. One of them is the calculation of the volume of reinforcement required for column structures, which is also a challenge due to its high complexity. Therefore, it is necessary to estimate the quantity take off of the material accurately.

2 Research methods.

The research objects include case 1: Integrated Surgical Treatment Building of RSUD Dr. H. Abdul Moeloek (Zone A), case 2: Integrated Surgical Treatment Building of RSUD Dr. H. Abdul Moeloek (Zone B), case 3: Neurology Treatment Building of RSUD Dr. H. Abdul Moeloek, case 4: UT Lampung Distance Learning Unit (UPBJJ) Building. All of these buildings are in Lampung province, Indonesia.

This research discusses the comparison of quantity take off reinforcement in reinforced concrete column structures by implementing Building Information Modeling (BIM) using Autodesk Revit software. The results will be compared with the conventional QTO method.

The research method starts from the literature study stage, data collection, and modeling with Autodesk Revit software. Followed by a comparison of the quantity take off

column reinforcement for column structural elements in each case study. Thus, the level of variation in quantity take off will be obtained in 4 (four) projects that have been implemented.

2.1 Preparation

Preparation is the first step in the modeling process. It aims to prepare the modeling process by setting up the Autodesk Revit software by creating a new project, setting the units to be used in the project unit, creating the necessary planes according to the image data, and creating a grid to be used later in the building modeling process.

2.2 Modeling of structural element family

The structural family is modeled for each floor to facilitate the classification process at the quantity take off stage to display the volume according to the classification. Begin by modeling the foundation family, columns, beams, and slabs. This family template can be downloaded from the official Autodesk website.

2.3 Structural modeling

The modeled structures include the Integrated Surgical Treatment Building of RSUD Dr. H. Abdul Moeloek (Zone A and B), the Neurology Treatment Building of RSUD Dr. H. Abdul Moeloek, and the UT Lampung Distance Learning Unit (UPBJJ) Building. The following modeling results for each case are shown in Fig. 1. to Fig. 4.

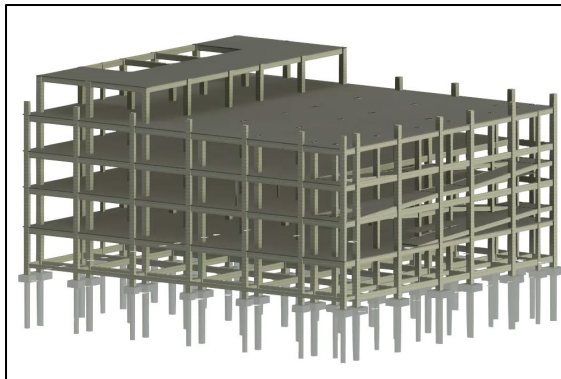


Fig. 1. 3D view of the Integrated Surgical Treatment Building model of Dr. H. Abdul Moeloek Hospital (Zone A).

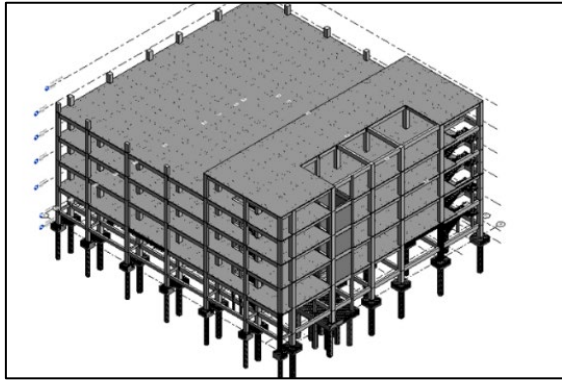


Fig. 2. 3D view of the Integrated Surgical Treatment Building model of Dr. H. Abdul Moelock Hospital (Zone B).

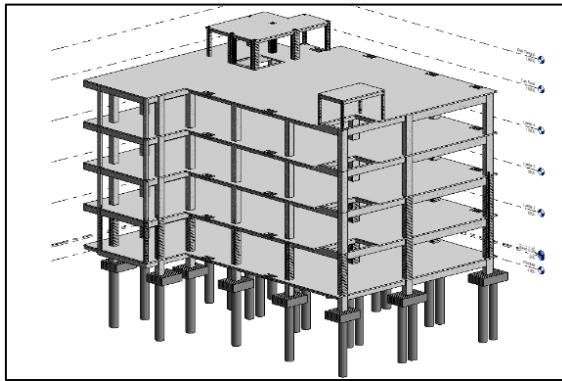


Fig. 3. 3D view of the Neurology Treatment Building model of RSUD Dr. H. Abdul Moelock.

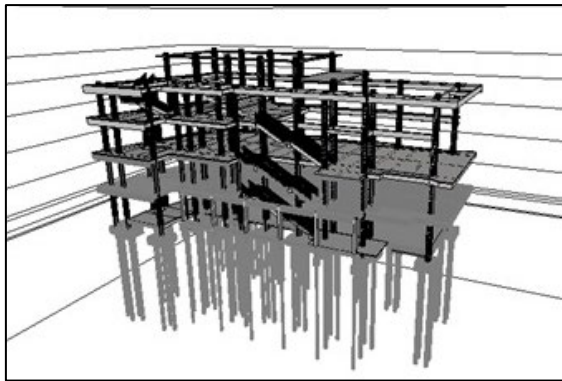


Fig. 4. 3D view of the UT Lampung Distance Learning Unit (UPBJJ) Building model.

2.4 Reinforcement modeling

To begin reinforcement modeling, select the "Section" icon to create a section. Then, navigate to the desired column and choose "Rebar". Next, select the appropriate type of reinforcement from the Rebar Shape Browser and set its placement. The Reinforcement modeling process is shown in Fig. 5 to Fig. 9.

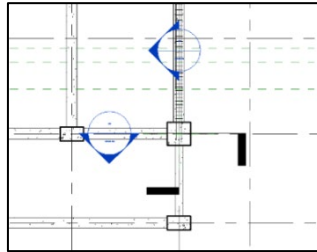


Fig. 5. Make a cut on a column.

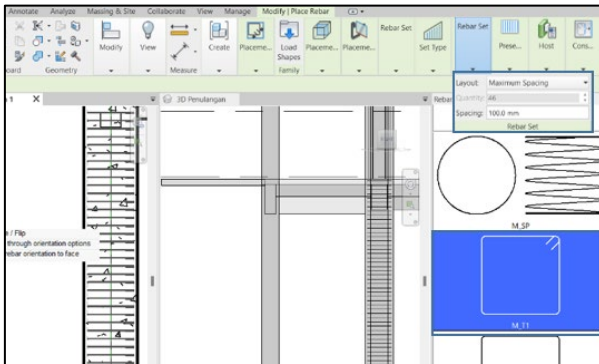


Fig. 6. Set the type and spacing of column stirrups.

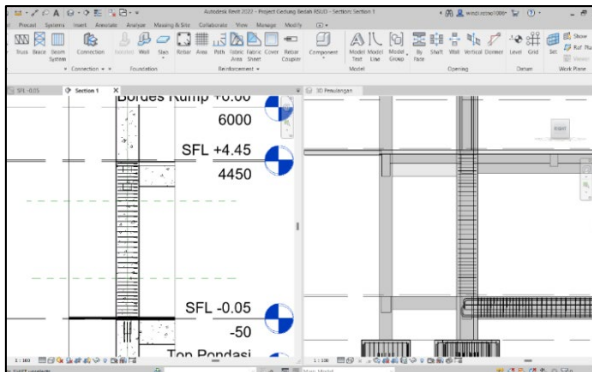


Fig. 7. Setting up the column's support region and stirrup field.

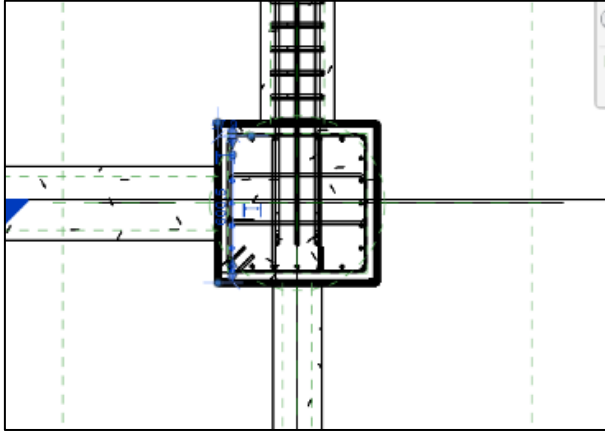


Fig. 8. Placement of main reinforcement in columns.

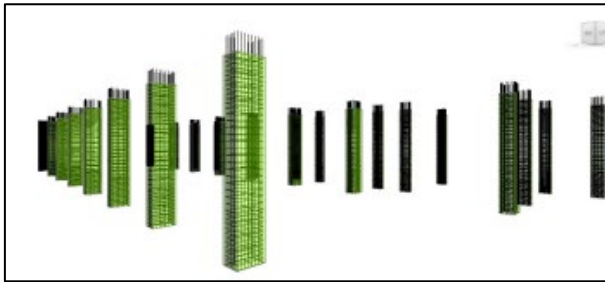


Fig. 9. Column reinforcement modeling results.

2.5 Input information to the model

Entering information about the model into Autodesk Revit software can be done by creating Shared Parameters or Project Parameters. The Shared Parameter feature allows users to add parameters to the project that are stored separately and can be used in other projects. Next, enter information about each structural element in the “identity data” section of the properties.

2.6 Clash check detection.

After all modeling operations have been performed, a complete 3D model representation is obtained. The next step is to check the model for errors during the modeling phase by performing the Clash Check Detection process. The step to perform the clash check is to click on "Collaborate" and then select "Interference Check".

2.7 Quantity take off of column reinforcement

After modeling all elements and completing the information input process, the subsequent step involves generating Schedule Quantities or conducting reinforcement quantity take off.

BIM-based software performs the calculation of column reinforcement volume for reinforcement quantity take off. BIM-based software performs the calculation of column reinforcement volume for reinforcement quantity take off. This method can automatically compute the column reinforcement volume. The results of the QTO for each scenario are shown in Table 1 to Table 4.

Table 1. Results of BIM-based QTO at the Integrated Surgical Treatment Building of Dr. H. Abdul Moeleok Hospital (Zone A).

Case 1			
Floor	Type	Bar Diameter	Reinforcement Mass (Kg)
1 st Floor	K1	D19	10425.76
		Ø10	3193.32
	K2	D16	1883.59
		Ø10	671.5
	K3	D16	465.36
		Ø10	134.95
2 nd Floor	K1	D19	11195.1
		Ø10	3382.87
	K2	D16	2031.32
		Ø10	719.35
	K3	D16	504.75
		Ø10	145.6
3 rd Floor	K1	D19	10320.13
		Ø10	3040.91
	K2	D16	1867.17
		Ø10	656.03
	K3	D16	459.3
		Ø10	131.4
4 th Floor	K1	D19	9999.56
		Ø10	3039.73
	K2	D16	1800.72
		Ø10	656.03
	K3	D16	432.91
		Ø10	131.4
Top Floor	K1	D19	4738.2
		Ø10	1584.3
	K2	D16	322.61
		Ø10	130
	K3	D16	105.23
		Ø10	28.41
Total			74197.51

Table 2. Results of BIM-based QTO at the Integrated Surgical Treatment Building of Dr. H. Abdul Moelock Hospital (Zone B).

Case 2			
Floor	Type	Bar	Reinforcement Mass
1 st Floor	K1	D19	11815.09
		Ø10	3590.87
	K2	D16	1089.12
		Ø10	427.43
	K3	D16	481.25
		Ø10	150.8
	K4	D13	289.3
		Ø10	156.6
2 nd Floor	K1	D19	12558.78
		Ø10	2987.90
	K2	D16	1265.52
		Ø10	528
	K3	D16	472.11
		Ø10	149.94
	K4	D13	125.96
		Ø10	167.06
	K6	D13	36.2
		Ø10	17.52
3 rd Floor	K1	D19	10176.65
		Ø10	3227.59
	K2	D16	842.78
		Ø10	373.91
	K3	D16	472.11
		Ø10	135.74
	K4	D13	94.03
		Ø10	371.08
	K6	D13	36.2
		Ø10	16.02
4 th Floor	K1	D19	10176.65
		Ø10	3237.59
	K2	D16	871.02
		Ø10	338.87
	K3	D16	472.11
		Ø10	135.74
	K4	D13	93.99
		Ø10	262.75
K6	D13	36.2	
	Ø10	16	
Top Floor	K1	D19	4548.31
		Ø10	1252.3
	K2	D16	184
		Ø10	88
	K3	D16	134
		Ø10	108
Total			74011.09

Table 3. Results of BIM-based QTO in the Neurology Treatment Building of RSUD Dr. H. Abdul Moeloek.

Case 3			
Floor	Type	Bar Diameter	Reinforcement Mass (Kg)
1st Floor	K1	D19	2481.33
		Ø10	385.72
	K2	D19	1971.65
		Ø10	341.29
	K3	D19	1131.31
		Ø10	204.65
	K4	D16	113.41
		Ø10	36.13
2nd Floor	K1	D19	2481.33
		Ø10	385.72
	K2	D19	1971.65
		Ø10	341.29
	K3	D19	1131.31
		Ø10	204.65
	K4	D16	113.41
		Ø10	36.13
3rd Floor	K1	D19	2481.33
		Ø10	385.72
	K2	D19	1971.65
		Ø10	341.29
	K3	D19	1131.31
		Ø10	204.65
	K4	D16	113.41
		Ø10	36.13
4th Floor	K1	D19	2257.97
		Ø10	371.03
	K2	D19	1794.42
		Ø10	321.74
	K3	D19	1027.08
		Ø10	308.88
	K4	D16	104.24
		Ø10	34.84
Top Floor	K3	D19	621.57
		Ø10	2481.33
	K4	D16	385.72
		Ø10	1971.65
	K8	D12	341.29
		Ø8	1131.31
Total			27671.78

Table 4. Results of BIM-based QTO at UT Lampung Distance Learning Unit (UPBJJ) Building.

Case 4			
Floor	Type	Bar Diameter	Reinforcement Mass (Kg)
1 st Floor	K1	D19	3937.31
		Ø10	937.65
	K2	D19	1921.68
2 st Floor	K1	Ø10	473.25
		D19	3973.81
	K2	D19	1078.17
3 rd Floor	K1	D19	1862.69
		Ø10	497.6
	K2	D19	3973.81
Mezzanine Floor	K1	Ø10	1078.17
		D19	3630.73
	K2	D19	1299.91
Top Floor	K1	Ø10	1824.29
		D19	457.34
	K2	D19	1658.21
		Ø10	453.84
		D19	138.21
		Ø10	37.48
Total			31597.29

3 Results and discussion

Based on the data presented, the BIM-based quantity take off is able to estimate the volume of the column reinforcement in more detail. Volume calculations using conventional methods are performed by measuring each building element based on 2D drawings. However, in practice, there is often a lack of information in the drawings, especially the presence of reinforcement termination, channel length, and hook length, so calculating the volume of column reinforcement using conventional methods is more time-consuming and risks misinterpretation of the drawings. BIM-based Quantity Take Off is able to produce volumes faster and more accurately than traditional methods. BIM-based QTO saves more time and is not affected by human error when the modeling process is done correctly and comprehensively. Below is a comparison chart of QTO results for each case analyzed.

Table 5. Comparison of BIM-based QTO against conventional methods for each case.

Case	Conventional Method (kg)	BIM-Based Method (kg)	Difference (%)
1	76493.53	74197.51	3.00
2	76421.12	74011.09	3.15
3	28235.41	27671.78	2.00
4	32517.53	31597.29	2.83

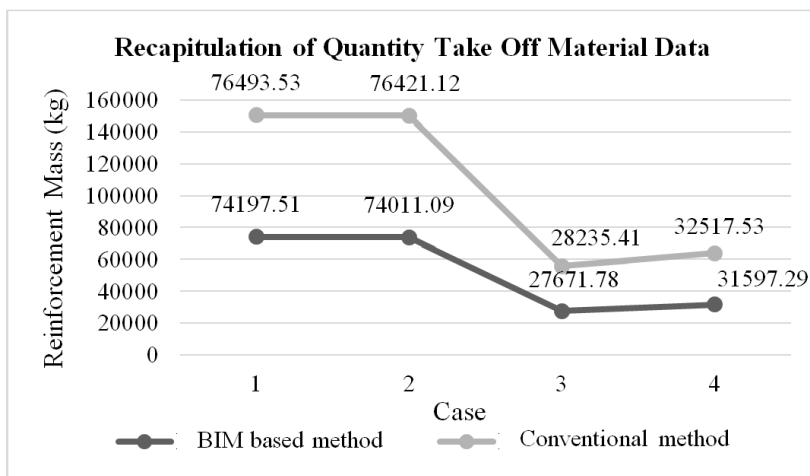


Fig. 20. Comparison chart of QTO results in each case.

It is important to note in the comparison results presented in Table 5 and Fig. 10. that although the difference in volume obtained with BIM is only about 2.00% - 3.15% smaller, the volume calculated in BIM is the total volume including the presence of bends/hooks and the length of the channel/lap splice at the end of the reinforcement implementation, so that project implementers can more accurately determine the reinforcement requirements at each stage of the project. Meanwhile, the conventional method generally does not consider the length of lap splice, requiring the project implementer to prepare working drawings and then recalculate the reinforcement requirements to be provided. The difference in the concept of reinforcement calculation will certainly affect the method of calculating the unit price of the work, because variations in material shortages can be included in the unit price analysis component of the work. For reinforced concrete reinforcement works, SNI Unit Price Analysis provides a 10% factor for reinforcement calculated by conventional methods to account for the existence of calculation errors due to the the length of lap splice and hooks and waste materials. Further studies can be developed to calculate bar scheduling to obtain the installed reinforcement requirements and the reinforcement to be provided so that it will have a different impact on the calculation of the unit price analysis of the work.

4 Conclusions

Based on the results of this study, it can be concluded that the Integrated Surgical Treatment Building Modeling of Dr. H. Abdul Moeloek Hospital (Zone A) obtained a column reinforcement QTO of 74197.51 kg. Modeling of Integrated Surgical Treatment Building of Dr. H. Abdul Moeloek Hospital (Zone B) obtained QTO reinforcement column 74011.09 kg. Modeling of Neurology Treatment Building of RSUD Dr. H. Abdul Moeloek obtained QTO reinforcement column 27671.78 kg. Modeling of UT Lampung Distance Learning Unit (UPBJJ) Building obtained QTO column reinforcement 31597.29 kg. Comparison of Quantity Take Off between BIM and conventional shows that BIM results are lower by 2% - 3.15% or an average of 2.75%, but BIM has modeled the reinforcement as a whole including the hook length and lap splice length of column reinforcement.

Acknowledgments. Thank you to the Unila Faculty of Engineering for supporting the service team through DIPA FT 2022 funds. Thank you to the Unila Civil Engineering Department for providing the opportunity to carry out this activity.

References

1. *Azhar, S.*: Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for The AEC Industry. Leadership and Management in Engineering, 2011, 241-252, DOI:10.1061/(ASCE)LM.1943-5630.0000127
2. *Azhar, S., Khalfan, M. and Maqsood, T.*: Building Information Modeling (BIM): Now and beyond. Australasian Journal of Construction Economics and Building, 12, 4, 2012, 15-28, DOI:10.5130/ajceb.v12i4.3032
3. *Khochare, S.D. and Waghamare, A.P.*: 3D, 4D and 5D of Building Information Modeling For Real Estate Projects. Journal of Advances and Scholarly Researches in Allied Education, 15, 2, 2018, 293-298, DOI:10.29070/15/56833
4. *Eastman, C. et al.*: BIM Handbook, a Guide to Building Information Modeling 2nd ed, John Wiley & Sons Inc, Hoboken, Canada (2011)
5. *Laily, F.N., Husni, H.R. and Bayzoni.*: Perbandingan Perhitungan BoQ dengan Menggunakan Revit 2019 Terhadap Perhitungan BoQ dengan Menggunakan Metode Konvensional pada Pekerjaan Struktur (Studi Kasus: Gedung G Fakultas Pertanian Universitas Lampung). REKAYASA: Jurnal Ilmiah Fakultas Teknik Universitas Lampung, 25, 2, 2021, 27-31, DOI:10.23960/rekrjits.v25i2.30
6. *Shen, Z. and A Issa, R.R.*: Quantitative Evaluation of the BIM-Assisted Construction Detailed Cost Estimates. Journal of Information Technology in Construction (ITcon), 15, 2010, 234-257
7. *Khosakitchalert, C., Yabuki, N. and Fukuda, T.*: Improving the Accuracy of BIM-Based Quantity Takeoff for Compound Elements. Automation in Construction, 106, 2019, 102891. DOI:10.1016/j.autcon.2019.102891
8. *Eastman, C.M, Teicholz, P.Sacks, R. and Liston, K.*: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors. Third Edit, Wiley & Sons, Inc., Hoboken, New Jersey (2018)

9. *Olsen, D. and Taylor, J.M.*: Quantity Take-Off Using Building Information Modeling (BIM), and Its Limiting Factors. *Procedia Engineering*, 196, 2017, 1098–1105, DOI:10.1016/j.proeng.2017.08.067
10. *Cepni, Y., Akcamete, A. and Klein, R.*: Automated BIM-Based Formwork Quantity Take-Off. *Proceedings of the 20th International Conference on Construction Applications of Virtual Reality- Enabling The Development And Implementation of Digital Twins*, 2020, 220–227
11. *Whang, S.W. and Park Min, S.*: Building Information Modeling (BIM) for Project Value: Quantity Take-Off of Building Frame Approach. *International Journal of Applied Engineering Research*, 11, 12, 2016, 7749–7757, <https://repository.uel.ac.uk>

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

