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Improving Efficiency and Accuracy of Quantity Take-Off Through BIM Integration: A Case Study of the D Lecture Hall Building at Malikussaleh University

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Abstract. Quantity Take-Off (QTO) calculation is a crucial step in construction planning to determine material needs with high accuracy. However, traditional methods such as manual calculations often fail to meet accuracy demands, especially in projects with complex designs. This study compares manual methods, Revit, and Clash Detection in generating QTO for the D Lecture Hall building project at Malikussaleh University. The aim of this research is to analyze the quantitative differences between methods and assess which method is the most effective. The research method involves calculating the QTO for structural and architectural elements using the three methods, followed by an analysis of the average differences in results. The findings show that the manual method has an average difference of 35.76% for structural elements and 43.14% for architectural elements when compared to Revit. The difference between manual and Clash Detection is slightly smaller, with 33.09% for structural elements and 42.41% for architectural elements. Conversely, the difference between Revit and Clash Detection is very small, only 1.51% for structural elements and 3.98% for architectural elements. While the QTO results between Revit and Clash Detection are almost identical, Clash Detection offers the additional advantage of validation, ensuring that the design is free from clashes between elements. This study concludes that Clash Detection is the most effective method in generating QTO because it not only provides accurate results but also ensures that the design is ready for implementation without technical errors. By integrating BIM technology, this research offers a more efficient and accurate approach to QTO calculation, serving as a guideline for construction project managers in handling complex designs more effectively.

Keywords: *Quantity Take-Off (QTO), Clash Detection, Building Information Modeling (BIM).*

1. Background of the Research

Infrastructure development in Indonesia is one of the main priorities of the government at present (Indrayani, 2022). Infrastructure development in Indonesia is becoming increasingly massive, requiring greater efficiency, accuracy, and quality in construction projects. One of the crucial steps in construction projects is Quantity Take-Off (QTO), which is used to calculate the material requirements of a project. QTO is an effort by contractors to calculate the volume, which will later be used as material for preparing the Bill of Quantities (BOQ) in tenders and also serve as a basis for procurement. (Laorent et al., 2019). However, traditional methods such as manual calculations often fail to meet the standards of efficiency and accuracy, especially for projects with complex designs.

With the advancement of technology, Building Information Modeling (BIM) has become a modern solution that allows for more accurate QTO calculations through 3D digital modeling. The application of BIM results in more accurate calculations, faster work, and facilitates communication and integration (Setiawan & Abma, 2021). Software such as Revit and Navisworks enable model integration and clash detection between elements, providing more consistent results and eliminating design errors. This study uses the D Lecture Hall building at Malikussaleh University as a case to evaluate the effectiveness of manual methods, Revit, and Clash Detection in generating QTO.

2. Problem Statement

How does the comparison of QTO results using manual methods, Revit, and Revit-Navisworks integration in the D Lecture Hall building project at Malikussaleh University?
Which method is the most effective in producing accurate and efficient QTO?

3. Research Objectives

Comparing the QTO results between manual methods, Revit, and Clash Detection.
Determining the most effective method to improve the efficiency and accuracy of QTO in the context of construction projects.

4. Research Significance

This research is expected to provide the following benefits:
QTO Method Selection Guide: Providing a data-driven foundation for construction practitioners to choose the appropriate QTO method based on project needs.
Improvement in Efficiency and Accuracy: Offering insights into the effectiveness of BIM technology in minimizing errors and enhancing project productivity.

5. Caku Scope of Analyzed Elements

This table presents the structural and architectural elements that are the focus of the QTO analysis in this research.

Table 1. Structural and Architectural Elements Compared

NO	Structural	Architectural
1	Footing and Pile Cap	Ceramic Flooring
2	Columns K1, K2, and Pedestal	Masonry and Plastering
3	Practical Columns	Facade
4	Pit Lift Column	Ceiling (Interior Area)
5	Sill Beam	Ceiling (Exterior Area)
6	Sill Beam and Pit Lift Beam	Conwood
7	Beam	0.3 mm Spandek Metal Roof Tiles
8	Floor Beam	
9	Floor Slab	
10	Staircase	

11	Steel Roof Truss	

6. Basic Concepts of QTO and BIM

QTO is the calculation/measurement of materials and labor required to complete a construction project based on the working drawings and specifications that have been determined. (Wiranti et al., 2022). QTO is often used as the basis for preparing the Bill of Quantity (BoQ) and project cost estimation. The traditional QTO method is done manually using spreadsheets based on two-dimensional drawings, which are often prone to errors.

BIM is a process that begins with creating a 3D digital model, which contains all the information about the building. It serves as a tool for planning, designing, constructing, and maintaining the building. (Suasira et al., 2021). The advantages of BIM include accuracy, efficiency, and collaboration among stakeholders. BIM dimensions can extend up to 7D, including geometry (3D), time (4D), cost (5D), sustainability (6D), and maintenance (7D).

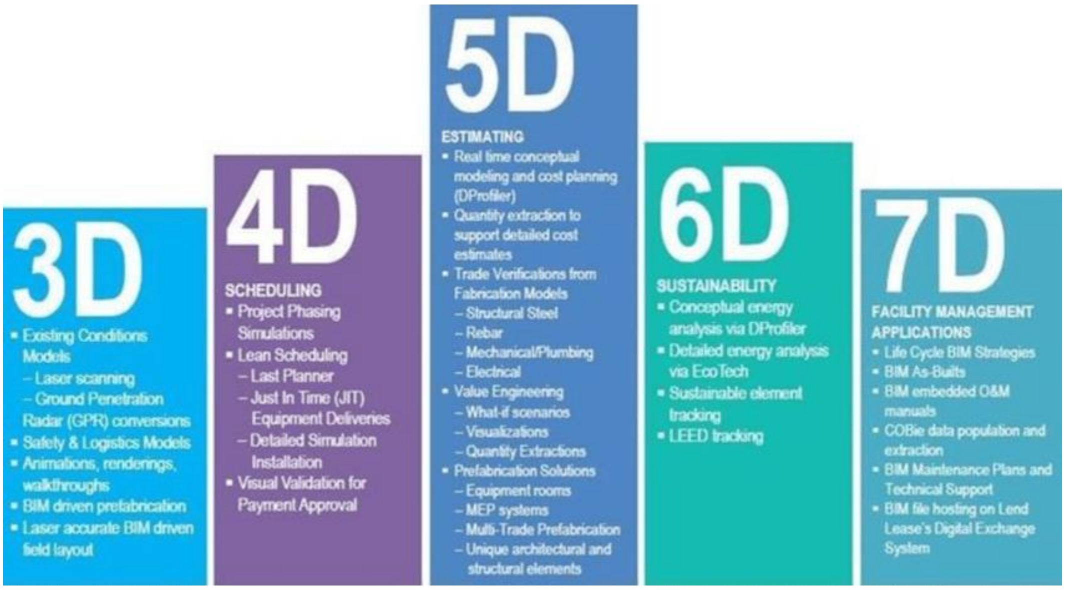


Figure 1. BIM Dimension Terminology
Source: https://www.researchgate.net

7. Software Used

Revit is a BIM software from Autodesk for architectural, structural, and mechanical, electrical, and plumbing (MEP) design. With this software, users can design buildings from structure to MEP by modeling 3D components and displaying 2D working drawings, as well as analyzing QTO simultaneously across all work disciplines (Arissaputra & Yaya, 2023).

Navisworks is an application that assists in the design and scheduling process of structural, architectural, mechanical, electrical, and plumbing work within a project (Afriani et al., 2024). In complex construction projects, collaboration between various disciplines becomes crucial.

8. Research Methodology

This research uses a quantitative approach to evaluate the effectiveness of three Quantity Take-Off (QTO) methods:

Manual Method: This method involves analyzing working drawings and BoQ using spreadsheets. It serves as a reference for comparing the results of the calculations.

Revit Method: This method involves modeling structural and architectural elements in 3D format using Autodesk Revit software, which automatically calculates volumes and material requirements.

Clash Detection Method: This method integrates the Revit model with Navisworks to detect and resolve clashes between design elements. This process ensures the accuracy and validity of the QTO results.

The statistical analysis method in this study aims to compare the QTO results from the three methods: manual, Revit, and Clash Detection. The comparison is made by measuring the absolute differences between methods to identify variations in results. The percentage difference is used to evaluate the relative differences between the methods. Additionally, the average difference identifies trends in errors between methods, while the average percentage difference measures the average deviation compared to the manual method. This analysis helps assess the accuracy and efficiency of each method.

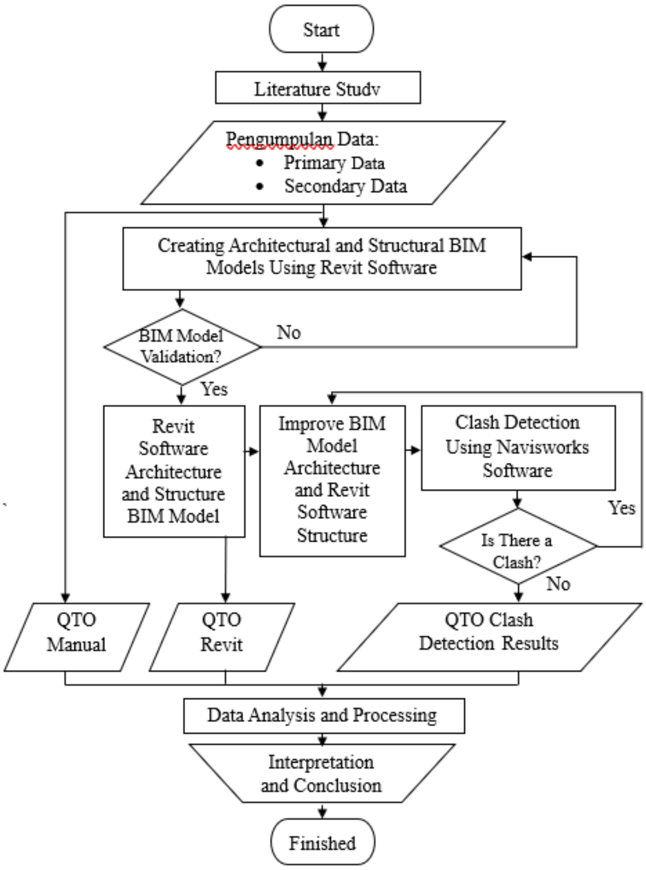


Figure 2. Research Flowchart

9. Data Collection Techniques

Primary Data: QTO data calculated directly using Revit software (with and without Clash Detection).

Secondary Data: BoQ documents and working drawings (As-Built Drawings) of the General Lecture Building D project at Universitas Malikussaleh.

10. Results and Discussion

Table 2 presents the QTO calculation results for structural elements using the manual, Revit, and Clash Detection methods. These calculations include concrete volume, steel weight, and formwork area for the structural elements.

Table 2. Calculations of Methods for Structural Elements

Structural Elements							
N0	**Elements**	**Sub-Elements**	**Code**	**Unit**	**Method**		
					Manual	**Revit**	***Clash Detection***
1	Shallow Foundation and Pile Cap	Concrete Volume	S1	m3	1.00	1.00	1.00
2		Steel Weight	S2	kg	1.00	0.98	0.98
3		Formwork Area	S3	m2	1.00	1.00	1.00
4	Columns K1, K2, and Pedestal	Concrete Volume	S4	m3	1.00	0.99	0.99
5		Steel Weight	S5	kg	1.00	0.88	0.88
6		Formwork Area	S6	m2	1.00	1.07	1.07
7	Practical Columns	Concrete Volume	S7	m3	1.00	1.84	1.60
8		Steel Weight	S8	kg	1.00	1.52	1.34
9		Formwork Area	S9	m2	1.00	3.68	3.20
10	Pit Lift Columns	Concrete Volume	S10	m3	1.00	1.12	1.12
11		Steel Weight	S11	kg	1.00	1.23	1.23
12		Formwork Area	S12	m2	1.00	1.15	1.15
13	Sill Beam	Concrete Volume	S13	m3	1.00	1.03	1.02
14		Steel Weight	S14	kg	1.00	1.02	1.02
15		Formwork Area	S15	m2	1.00	1.08	1.08
16	Sill Beam and Pit Lift Beam	Concrete Volume	S16	m3	1.00	1.87	1.87
17		Steel Weight	S17	kg	1.00	0.72	0.72
18		Formwork Area	S18	m2	1.00	4.10	4.10
19	Beam	Concrete Volume	S19	m3	1.00	0.90	0.91
20		Steel Weight	S20	kg	1.00	0.85	0.85
21		Formwork Area	S21	m2	1.00	1.30	1.30
22	Floor Beam	Concrete Volume	S22	m3	1.00	0.89	0.89
23		Steel Weight	S23	kg	1.00	0.92	0.92
24		Formwork Area	S24	m2	1.00	1.24	1.24
25	Floor Slab	Concrete Volume	S25	m3	1.00	1.00	1.00
26		Steel Weight	S26	kg	1.00	1.17	1.17
27		Formwork Area	S27	m2	1.00	0.98	0.98
28	Staircase	Steel Weight	S28	kg	1.00	0.78	0.76
29	Steel Roof Truss	Pipe SCH 40, 10 Inch Diameter, 9.3 mm Thickness	S29	kg	1.00	0.67	0.65
30		SCH 40 Pipe, 6 Inch Diameter, 7.1 mm Thickness	S30	kg	1.00	0.91	0.89

31		SCH 40 Pipe, 3 Inch Diameter, 5.5 mm Thickness	S31	kg	1.00	0.85	0.85

Figure 3 shows the visualization of the structural model generated using Revit, covering key elements such as foundations, columns, and beams. This modeling illustrates the coordination between elements in the final design.

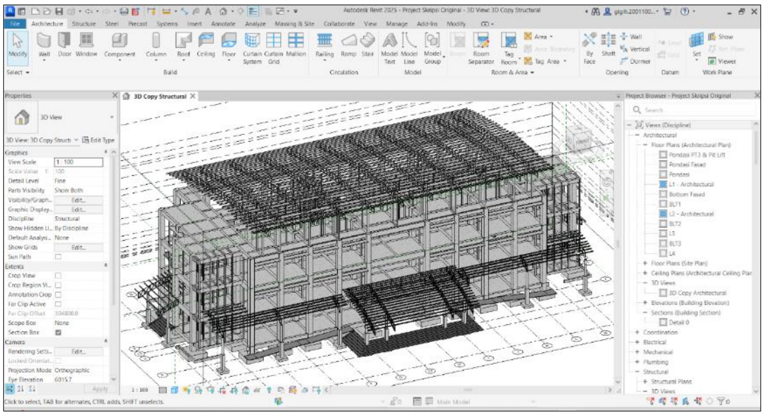
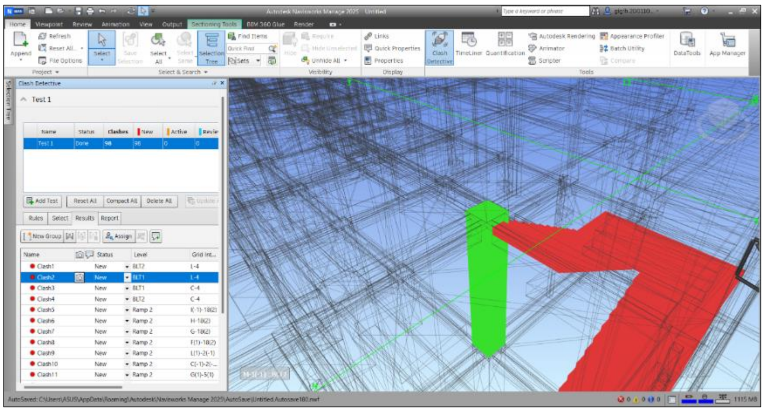


Figure 3. Structural

Figure 4 shows the results of Clash Detection analysis on the structure using Navisworks, with a total of 98 clashes detected between structural elements.



Name	Status	Clashes	New	Active	Revie
Test 1	Done	98	98	0	0

Name	Status	Level	Grid Int...
Clash1	New	BLT2	I-4
Clash2	New	BLT1	I-4
Clash3	New	BLT1	C-4
Clash4	New	BLT2	C-4
Clash5	New	Ramp 2	K(-1)-18(2)
Clash6	New	Ramp 2	H-18(2)
Clash7	New	Ramp 2	G-18(2)
Clash8	New	Ramp 2	F(1)-18(2)
Clash9	New	Ramp 2	L(1)-2(-1)
Clash10	New	Ramp 2	C(-1)-2(-...
Clash11	New	Ramp 2	G(1)-5(1)

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Figure 4. *Clash Detection* Structural

Table 3 presents the results of QTO calculations for architectural elements using the manual method, Revit, and Clash Detection, including calculations for ceramic flooring, brickwork, ceilings, and roofing.

Table 3. Calculation Methods for Architectural Elements

Architectural Elements							
No	**Elements**	**Sub-Elements**	**Code**	**Unit**	**Method**		
					Manual	**Revit**	***Clash Detection***
1		Floor 1	A1	m2	992.96	1011.19	1003.70

2	Ceramic Flooring	Floor 2	A2	m2	1015.75	861.91	861.02
3		Floor 3	A3	m2	1034.96	861.93	861.91
4	Masonry and Plastering	Brick Wall Masonry 1:4	A4	m2	2491.20	2939.14	2339.78
5		Plaster 1:4, thickness = 10 mm	A5	m2	4982.40	5878.28	4679.56
6		Installation of Gypsum Partition Wall, thickness = 9 mm	A6	m2	53.89	274.35	274.20
7	Fasade	FD1, FD2, FD3	A7	m2	487.49	446.53	445.91
8	Ceiling (Interior Area)	Floor 1	A8	m2	947.15	868.91	865.15
9		Floor 2	A9	m2	1028.08	858.45	857.80
10		Floor 3	A10	m2	1043.32	921.85	921.85
11	Ceiling (Exterior Area)	Floor 1	A11	m2	390.66	317.47	266.01
12		Floor 3	A12	m2	209.95	324.50	323.52
13	Conwood	Conwood	A13	m2	231.32	281.49	281.30
14	Metal Roof Tile Spandek 0.3 mm	Floor 2	A14	m2	390.69	280.95	278.85
15		Floor 3	A15	m2	1012.46	1017.63	1017.63

Figure 5 shows the architectural modeling generated using Revit, including key elements such as ceramic flooring, brickwork, ceiling, and metal tile roofing. This modeling allows the QTO calculation to be performed automatically and with higher accuracy.

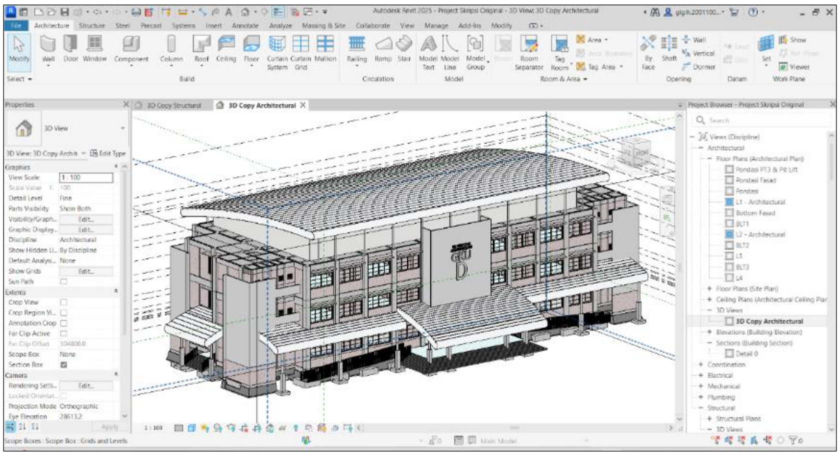
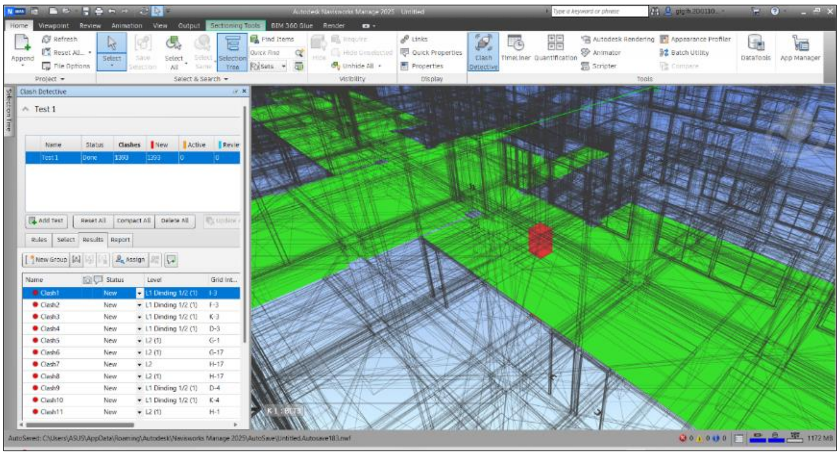


Figure 5. Architectural

Figure 6 shows the results of Clash Detection analysis on architectural elements using Navisworks, with 1,393 clashes detected between structural and architectural elements.



Test 1

Name	Status	Clashes	New	Active	Revie
Test 1	Done	1393	1393	0	0

Name	Status	Level	Grid Int...
Clash1	New	L1 Dinding 1/2 (1)	I-3
Clash2	New	L1 Dinding 1/2 (1)	F-3
Clash3	New	L1 Dinding 1/2 (1)	K-3
Clash4	New	L1 Dinding 1/2 (1)	D-3
Clash5	New	L2 (1)	G-1
Clash6	New	L2 (1)	G-17
Clash7	New	L2	H-17
Clash8	New	L2 (1)	H-17
Clash9	New	L1 Dinding 1/2 (1)	D-4
Clash10	New	L1 Dinding 1/2 (1)	K-4
Clash11	New	L2 (1)	H-1

Figure 6. Architectural *Clash Detection*

Table 4 shows the average difference comparison between Manual, Revit, and Clash Detection methods for structural and architectural elements.

Table 4. Average Difference Comparison Between Manual, Revit, and Clash Detection Methods

Elemen	Manual - Revit (%)	Manual - *Clash Detection* (%)	Revit - *Clash Detection* (%)
Structural	35.76%	33.09%	1.51%
Architectural	43.14%	42.41%	3.98%

Figure 7 displays a graph illustrating the average difference comparison between the Manual, Revit, and Clash Detection methods for structural and architectural elements. This graph provides a visual representation of the differences among the three methods in calculating QTO and highlights the high level of consistency between Revit and Clash Detection for both analyzed elements.

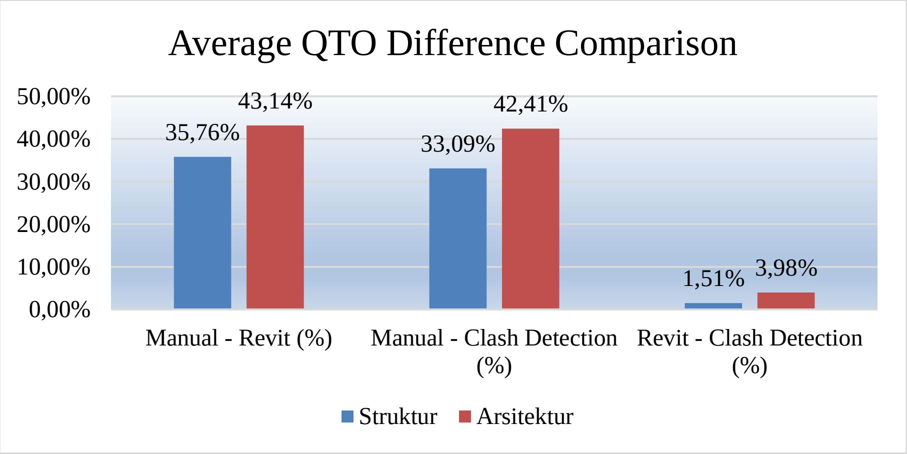


Figure 7. Quantitative Comparison of QTO Results

- For structural elements, the difference between Manual and Revit is 35.76%, while the difference between Manual and Clash Detection is smaller at 33.09%. The difference between Revit and Clash Detection is very small, at just 1.51%, indicating a high level of consistency between the two BIM-based methods.

- For architectural elements, the difference between Manual and Revit is 43.14%, and between Manual and Clash Detection is 42.41%. However, the difference between Revit and Clash Detection is much smaller at 3.98%, indicating a very high level of consistency between the two BIM-based methods.

11. Conclusion

This study compares three methods for performing Quantity Take-Off (QTO) in the General Lecture Building D project at Malikussaleh University: the manual method, Revit, and Clash Detection integrated with Navisworks. Based on quantitative analysis, the research findings reveal significant differences in accuracy and consistency among the three methods:

- The manual method shows greater differences compared to the two BIM-based methods. The average difference between Manual and Revit is 35.76% for structural elements and 43.14% for architectural elements, while the average difference between Manual and Clash Detection is 33.09% for structural elements and 42.41% for architectural elements.
- Revit and Clash Detection show very consistent results, with an average difference of only 1.51% for structural elements and 3.98% for architectural elements, indicating that both BIM methods produce nearly identical QTO results.
- *Clash Detection* has proven to provide additional benefits, including design validation, reducing clashes between elements, and improving design coordination between structural and architectural components—benefits that cannot be achieved by the manual method.

12. Suggestions

- Based on the research findings, it is recommended to enhance the use of BIM, particularly by integrating Revit and Navisworks (Clash Detection) in construction projects. Both BIM-based methods provide more consistent and efficient QTO results compared to traditional manual methods. Additionally, Clash Detection offers added benefits, including design validation that can minimize the risk of clashes between elements and implementation errors in the field.
- Although Revit and Clash Detection show good consistency in structural elements, architectural elements still exhibit greater variation, particularly in volume and area calculations. Therefore, further development in BIM-based architectural modeling is highly recommended to improve QTO accuracy, especially for more complex designs.
- Considering the importance of using BIM in construction projects, it is recommended to provide training to project teams to maximize the use of this technology. The training should include the use of Revit and Navisworks for automated QTO generation, as well as the application of Clash Detection for design validation.
- Penelitian Further research can focus on comparisons between various other BIM tools and their performance, as well as the implementation of Clash Detection in larger and more complex-scale projects. This could provide deeper insights into the effectiveness of BIM technology across different types of construction projects.

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