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BIM 5D QUANTITY TAKE-OFF: DEVIATION AND ERROR SOURCE ANALYSIS IN REINFORCED CONCRETE

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Abstract: Accurate quantity take-off is essential for reliable construction cost estimation, particularly in reinforced concrete works, which involve complex and error-prone calculations. This study evaluates the accuracy of BIM 5D-based quantity take-off and examines cost deviations compared to conventional contractor estimations. A three-story dormitory building was modeled using BIM 5D (Cubicost TAS and TRB), and the results were validated against manual analytical calculations. The validation shows strong agreement, with a maximum deviation of 0.75% and a high linear correlation across concrete, reinforcement, and formwork quantities. A comparative analysis with the contractor's Bill of Quantity reveals a cost difference of approximately 3.4%, with the contractor's estimate being higher. This deviation is primarily attributed to simplifications in conventional methods, including double counting at element interfaces, generalized reinforcement detailing, and the inclusion of material allowances. In contrast, BIM 5D enables a more integrated and precise estimation by accounting for element interactions and optimizing reinforcement configurations. However, the results also highlight that BIM-based estimation is sensitive to modeling assumptions and parameter settings. Therefore, aligning BIM models with actual construction practices is essential to ensure reliable and applicable results. Overall, this study demonstrates the potential of BIM 5D to enhance the accuracy, consistency, and transparency of construction cost estimation.

Keywords: BIM 5D, Quantity Take-Off, Reinforced Concrete, Cost Estimation.

Abstrak: Perhitungan volume (*quantity take-off*) yang akurat merupakan hal yang sangat penting dalam estimasi biaya konstruksi yang andal, khususnya pada pekerjaan beton bertulang yang melibatkan perhitungan kompleks dan rentan terhadap kesalahan. Penelitian ini bertujuan untuk mengevaluasi akurasi perhitungan kuantitas berbasis BIM 5D serta menganalisis deviasi biaya dibandingkan dengan estimasi konvensional oleh kontraktor. Sebuah gedung asrama tiga lantai dimodelkan menggunakan BIM 5D (Cubicost TAS dan TRB), dan hasilnya divalidasi melalui perhitungan analitis secara manual. Hasil validasi menunjukkan tingkat kesesuaian yang tinggi, dengan deviasi maksimum sebesar 0,75% serta korelasi linear yang kuat pada volume beton, tulangan, dan bekisting. Analisis perbandingan dengan *Bill of Quantity* (BOQ) kontraktor menunjukkan adanya perbedaan biaya sekitar 3,4%, dengan estimasi kontraktor lebih tinggi. Deviasi ini terutama disebabkan oleh penyederhanaan dalam metode konvensional, seperti perhitungan ganda pada pertemuan elemen, generalisasi detail penulangan, serta penambahan faktor kehilangan material. Sebaliknya, BIM 5D memungkinkan estimasi yang lebih terintegrasi dan presisi dengan mempertimbangkan interaksi antar elemen serta optimasi konfigurasi tulangan. Namun demikian, hasil penelitian juga menunjukkan bahwa estimasi berbasis BIM sangat dipengaruhi oleh asumsi pemodelan dan pengaturan parameter. Oleh karena itu, keselarasan antara model BIM dan praktik konstruksi di lapangan menjadi penting untuk menghasilkan estimasi yang andal dan aplikatif. Secara keseluruhan, penelitian ini menunjukkan bahwa BIM 5D memiliki potensi dalam meningkatkan akurasi, konsistensi, dan transparansi dalam estimasi biaya konstruksi.

Kata kunci: BIM 5D; *Quantity Take-Off*; Beton Bertulang; Estimasi Biaya

1. INTRODUCTION

The cost estimation phase plays a crucial role in the successful delivery of construction projects, as it directly influences budgeting, tender competitiveness, and overall project feasibility. One of the most critical components in cost estimation is the quantity take-off process, where the accuracy of calculated quantities significantly determines the reliability of the project cost. Accurate quantity take-off ensures that cost estimates align closely with actual project expenses, reducing the risk of cost overruns (Jafary et al., 2025; Sherafat et al., 2022; Tamrin et al., 2024). Structural works, particularly in reinforced concrete buildings, not only contribute dominantly to the total project cost but also involve complex calculation procedures that require substantial time and effort. The complexity of these calculations increases the likelihood of human error, especially when performed manually. Inaccuracies in quantity estimation may ultimately lead to significant financial losses, either due to underestimation resulting in cost overruns or overestimation leading to reduced competitiveness during the tendering process. Therefore, improving both the accuracy and reliability of quantity take-off in structural works is of paramount importance.

In reinforced concrete construction, the primary structural components, beams, columns, and slabs, consist of multiple work items, including concrete volume, reinforcement, and formwork, each presenting unique calculation challenges. Concrete volume estimation, while generally based on geometric dimensions, is prone to errors due to overlapping volumes at structural intersections. Traditional 2D methods for construction volume management often result in duplicated or omitted calculations (Nguyen et al., 2021). For instance, double counting may occur at beam-column joints or at the interface between beams, columns, and slabs if the estimator does not carefully account for shared volumes. Reinforcement quantity estimation represents the most complex and time-consuming component, as it requires detailed consideration of bar diameters, spacing, anchorage lengths, lap splices, hooks, and other reinforcement detailing rules. Achieving accurate reinforcement quantities often demands meticulous interpretation of structural drawings and repetitive calculations, making it highly susceptible to errors. Meanwhile, formwork estimation involves calculating surface areas that are directly influenced by the interaction between structural elements. Interfaces between beams, columns, and slabs can lead to overlapping formwork areas, which are frequently double-counted if not properly defined. These inherent complexities highlight the challenges of conventional quantity take-off and explain why errors in structural quantity estimation are relatively common.

Conventional quantity take-off methods, which rely heavily on manual calculations and two-dimensional drawings, present several limitations. Previous studies have highlighted that manual estimation processes are not only labor-intensive but also highly dependent on the experience and interpretation skills of the estimator (Logan et al., 2011; Saenpaeng et al., 2025). Errors may arise from misreading drawings, overlooking structural details, simplifying assumptions, or inconsistencies in measurement approaches. Additionally, manual methods often lack standardization, leading to variations in results between different estimators. These issues can result in significant discrepancies between planned quantities and actual quantities used in construction. Such discrepancies may manifest either as underestimation, which can cause budget shortfalls and project delays, or overestimation, which may reduce the contractor's competitiveness during the tender stage.

To address these challenges, Building Information Modeling (BIM), particularly in its 5D application, has been introduced as a digital solution that integrates three-dimensional modeling with quantity take-off and cost estimation. BIM tools like Autodesk Revit and Cubicost TAS allow for detailed modeling and automated quantity extraction, which are more accurate than traditional methods (Al-Musawi & Naimi, 2023; Soon et al., 2024; Tamrin et al., 2024). BIM 5D tools enable automated extraction of quantities directly from digital models, thereby reducing reliance on manual interpretation of drawings. Automated quantity take-off also significantly reduces the time and effort required for cost estimation compared to manual methods (Abdulwahhab et al., 2022; Aditya Varma et al., 2016; Al-Musawi & Naimi, 2023). This is particularly beneficial for contractors handling multiple bids or complex projects. As a result, BIM has gained increasing attention in both academic research and industry practice as a means to enhance the accuracy and reliability of construction cost estimation.

Recent studies have consistently demonstrated the advantages of BIM-based quantity take-off in terms of accuracy and efficiency. Several researchers have reported that BIM-based estimation produces smaller deviations compared to conventional methods, with cost differences generally ranging from 4% to 12% depending on the project type and scope (Haider et al., 2020; Saiyad et al., 2023; Yuliana et al., 2025). In addition, BIM has shown improved accuracy in specific structural components, such as concrete and reinforcement works, due to its ability to extract quantities directly from digital models.

In terms of accuracy, previous findings indicate that BIM-based estimation can achieve very small deviations when compared to actual or manually calculated quantities. For instance, deviations as low as 0.11%–0.30% have been reported, along with strong correlations between BIM and conventional methods (Hardi Saputra et al., 2024; Khosakitchalert et al., 2020). However, other studies suggest that the level of accuracy may vary depending on modeling assumptions, software platforms, and the level of detail applied in the model (Saputra et al., 2024). These variations indicate that while BIM has strong potential for improving accuracy, its performance is not entirely independent of user-defined parameters.

Beyond accuracy, BIM-based methods also offer significant improvements in efficiency by reducing the time required for quantity take-off and cost estimation. This advantage is particularly relevant in tender preparation, where rapid yet reliable estimation is essential. Despite these benefits, discrepancies in quantity estimation may still occur due to differences in modeling assumptions, input data quality, and adherence to measurement standards (Lee & Yun, 2025; Maulana et al., 2025). Such factors highlight that the effectiveness of BIM is closely related to how the model is developed and interpreted.

Despite the growing adoption of BIM in quantity take-off processes, existing studies predominantly focus on comparing BIM-based results with conventional manual calculations to evaluate accuracy and efficiency. However, relatively limited research has investigated the comparison between BIM-generated quantities and actual quantities used or estimated by contractors in real projects. Furthermore, most studies tend to emphasize the magnitude of deviation without providing an in-depth analysis of the underlying causes. The identification of error sources, such as discrepancies in interpretation, methodological differences, omissions in detailing, or inconsistencies in modeling assumptions, remains insufficiently explored.

Given these gaps, this study aims to provide a more comprehensive analysis by not only validating the accuracy of BIM 5D in comparison with manual calculations but also evaluating its deviation against contractor-estimated quantities. More importantly, this research seeks to identify the sources of discrepancies in quantity estimation, thereby offering insights into where and why such deviations occur. Understanding these sources of error is essential for developing strategies to minimize inaccuracies, improve estimation practices, and enhance the reliability of project cost planning. In addition, this study also considers how such deviations may be anticipated and mitigated in practical applications.

The urgency of this study is further emphasized by the significant implications of quantity deviations in construction projects. Inaccurate estimation of structural quantities may lead to substantial financial consequences (Nnadi & Najjobyo, 2025), including material shortages, cost overruns, or inefficient resource allocation. Conversely, overestimation may result in inflated bid prices, reducing the likelihood of winning competitive tenders (Chao & Liou, 2007; Rastegar et al., 2021). By identifying the root causes of deviations and analyzing their potential impacts, this study is expected to contribute to more accurate, transparent, and competitive cost estimation practices. Ultimately, the findings of this research can support both academics and practitioners in improving quantity take-off methodologies, particularly through the effective implementation of BIM-based approaches.

Based on these considerations, this study is conducted to analyze the accuracy of BIM 5D Cubicost in estimating structural quantities, evaluate deviations compared to contractor calculations, and investigate the underlying factors contributing to such discrepancies, along with their potential cost implications in construction projects.

2. METHODS

The object of this study is a dormitory building located in East Nusa Tenggara Province, Indonesia. The building is designed as a three-story reinforced concrete structure with a total floor area of approximately 5,842.5 m². The concrete has a specified compressive strength of 25 MPa, while the reinforcement material is BJTS 420B. This study focuses on structural works, including foundations (bored piles and pile caps), beams, columns, and floor slabs.

The data used in this study were obtained from the project contractor, including structural drawings, Bill of Quantity (BOQ), and Cost Budget Plan (RAB). Based on these data, a detailed breakdown of structural work items was developed to facilitate the quantity take-off process. The Work Breakdown Structure (WBS) of structure works is presented in Figure 1.

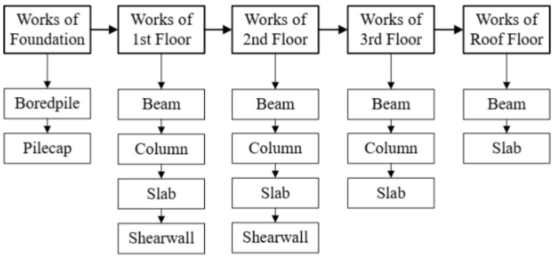

Figure 1. WBS of structure works

BIM 5D modeling was carried out using Cubicost software developed by Glodon, utilizing two main modules: Cubicost TAS (Take-off for Architecture and Structure) and Cubicost TRB (Take-off for Rebar). The TAS module was used to model concrete structural elements from foundation to roof level, while the TRB module was used to model reinforcement detailing, including main bars and stirrups. Parameters such as bending, splicing, and anchorage were defined through the software's calculation settings, allowing the model to follow standard detailing practices similar to those used in Bar Bending Schedule (BBS) preparation.

The software enables relatively fast modeling, interactive three-dimensional visualization, and automated quantity extraction. It also accounts for element intersections, reducing the risk of double counting in concrete and formwork calculations. The primary outputs include quantities of concrete, reinforcement, and formwork, supported by 3D visualization and detailed calculation reports used to verify the modeling results.

In addition to BIM-based modeling, analytical calculations were independently carried out by the authors as a basis for validation. While this conventional approach is more time-consuming, particularly in reinforcement estimation, it offers a reliable benchmark for evaluating the accuracy of the BIM results. Validation was conducted using linear regression analysis and deviation calculation. A correlation coefficient approaching 1 indicates strong agreement between the two methods, while smaller deviation values reflect better consistency. These measures were used to ensure that the BIM-based results are sufficiently reliable for further analysis.

Subsequently, the quantities and associated costs obtained from BIM modeling were compared with contractor data derived from the RAB. Elements with relatively large deviations were further analyzed to identify potential sources of discrepancies, including differences in calculation methods, assumptions, level of detailing, and possible omissions. The overall research workflow is illustrated in Figure 2.

This study adopts measurement standards applicable in Indonesia, namely *Standar Metode Pengukuran Pekerjaan Konstruksi Indonesia* (SPMI), First Edition (2003), and SNI 2847:2019 *Persyaratan Beton Struktural untuk Bangunan Gedung dan Penjelasan*. These standards are used as a reference to ensure consistency in measurement and calculation approaches throughout the study.

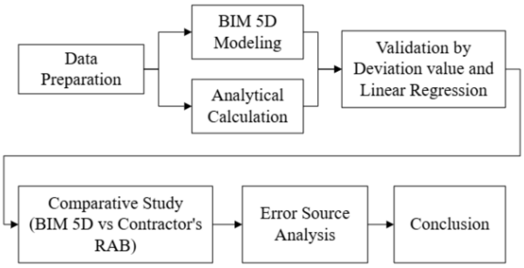

Figure 2. Research Stages

3. RESULT AND DISCUSSION

Cubicost TAS and TRB modeling

The three-story dormitory building was successfully modeled using BIM 5D Cubicost with both TAS (Take-off for Architecture and Structure) and TRB (Take-off for Rebar) modules. All structural elements, including foundations, beams, columns, and slabs, were represented according to the design drawings. The modeling process ensured proper definition of element connectivity, particularly at beam–column joints and slab–beam interfaces, allowing accurate identification of intersections and reducing the risk of overlapping volumes. As a result, the TAS module generated reliable outputs in the form of concrete volumes and formwork areas for each structural component.

Reinforcement modeling was performed using the TRB module by defining main bars and stirrups based on the structural drawings, while detailing parameters such as bending, splicing, and anchorage were controlled through the software settings. This approach enabled consistent representation of reinforcement configurations across structural elements. The model produced reinforcement quantities in the form of total weight, which could be further classified by element and bar type. In addition to numerical outputs, the 3D visualization and detailing features supported model verification, ensuring that the generated quantities were consistent and ready for subsequent validation and comparative analysis.

Model validation of BIM-based quantity take-off

The model validation stage was conducted by comparing the quantities obtained from BIM 5D modeling (Cubicost TAS and TRB) with those derived from manual analytical calculations. Although the BIM-based method requires significantly less time than conventional calculations, this stage primarily focuses on evaluating the consistency and accuracy between the two approaches.

The comparison shows that the maximum deviation between the two methods is only 0.75%, which occurs in beam reinforcement quantities. This small deviation indicates a high level of agreement between the BIM-based and analytical results. Furthermore, linear regression analysis was performed to assess the correlation between the two datasets and is presented in Figure 5, Figure 6, and Figure 7. The correlation coefficients for the main outputs concrete volume, reinforcement weight, and formwork area are equal to or very close to 1, demonstrating a very strong linear relationship.

These results confirm that the BIM-based modeling provides reliable and consistent quantity estimates. Therefore, the developed model is considered valid and suitable for further comparative analysis with contractor data.

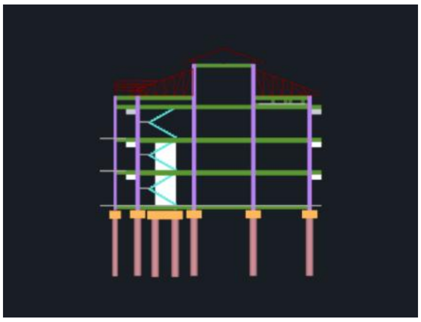

Figure 3. Cross Section of BIM Model

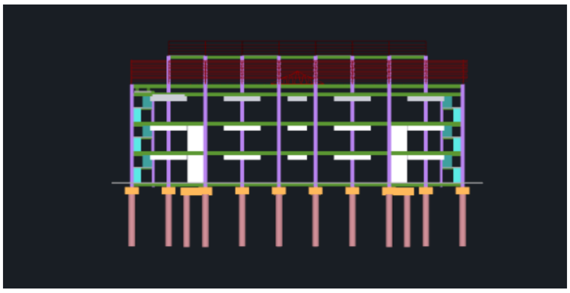

Figure 4. Cross Section of BIM Model

Table 1. Comparison of Cost Estimation Based on Cubicost and Contractor

Work	Unit	Volume Analytical Calculation	Volume Cubicost BIM 5D	Deviation
(a)	*(b)*	*(c)*	*(d)*	*(e) = [(c)-(d)]/(d)*

Concrete				
Boredpile	m^3	142.05	142.13	0.05%
Pilecap	m^3	106.05	106.05	0.00%
Beam	m^3	163.24	163.64	0.25%
Column	m^3	106.14	106.46	0.30%
Slab	m^3	312.54	312.37	0.05%
Shearwall	m^3	12.47	12.45	0.14%
Reinforcement				
Boredpile	kg	14826.93	14782.02	0.30%
Pilecap	kg	8347.02	8391.54	0.53%
Beam	kg	39939.00	39642.11	0.75%
Column	kg	20494.06	20396.07	0.48%
Slab	kg	41474.84	41492.04	0.04%
Shearwall	kg	4289.95	4289.95	0.00%
Formwork				
Pilecap	m^2	252.22	252.22	0.00%
Beam	m^2	1730.40	1729.06	0.08%
Column	m^2	955.52	952.84	0.28%
Slab	m^2	2013.58	2013.58	0.00%
Shearwall	m^2	123.77	123.78	0.01%

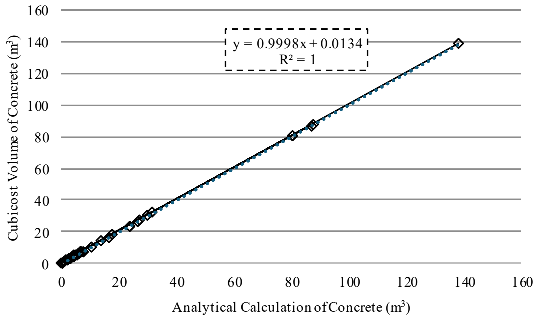

Figure 5. Linear Regression of Concrete Volume Between Cubicost and Analytical Calculation

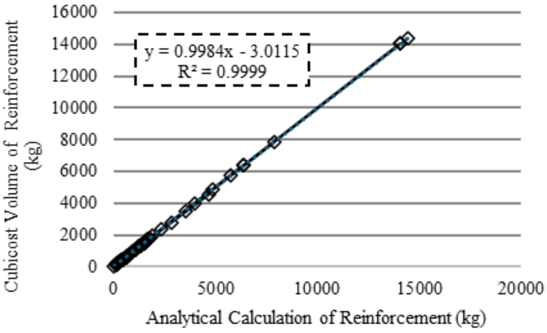

Figure 6. Linear Regression of Reinforcement Volume Between Cubicost and Analytical Calculation

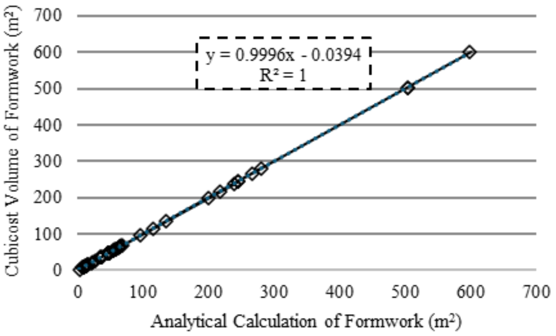

Figure 7. Linear Regression of Formwork Volume Between Cubicost and Analytical Calculation

Comparative cost analysis: cubicost vs contractor estimate

The comparison between BIM-based estimation and contractor data reveals a noticeable difference in total structural cost. The contractor's estimate amounts to IDR 5,579,169,701, while the BIM 5D (Cubicost) result is IDR 5,389,855,677. This represents a cost difference of IDR 189,314,024, or approximately 3.4%, indicating that the contractor's calculation is higher. This finding suggests the presence of systematic differences in quantity estimation and calculation approaches between the two methods.

A more detailed analysis was conducted at the level of individual work items to identify the main contributors to this deviation. The percentage contribution of each element to the total deviation is illustrated in Figure 8. The results highlight that slab reinforcement has the most significant impact, contributing 21.8% of the total deviation. Other notable contributors include slab concrete and column reinforcement works, both of which exhibit relatively high deviation values.

These findings indicate that the overall cost difference is not evenly distributed across all elements but is concentrated in specific components with higher complexity and interaction. Therefore, these elements were selected for further investigation to identify the underlying sources of discrepancies in the subsequent analysis.

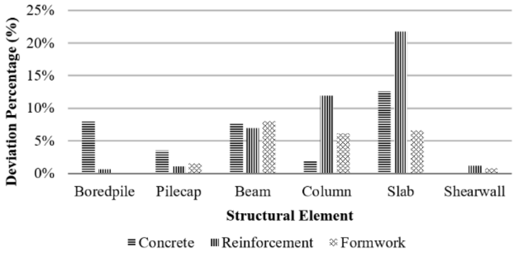

Figure 8. Deviation Percentage Comparison Between Elements

Error source analysis

The results indicate that the deviation between contractor estimates and BIM 5D outputs is systematic rather than random, primarily driven by differences in calculation approaches and underlying assumptions.

1. Slab Reinforcement Work

One of the main sources of deviation lies in the reinforcement layout strategy. In practical construction, slab reinforcement is commonly divided into zones, where bars are terminated or anchored at supporting beams. This results in shorter bar lengths and increases the need for anchorage and lap splices at each discontinuity. In contrast, the BIM 5D model applies a more continuous reinforcement approach, optimizing bar lengths up to the maximum available length (typically 12 m). This reduces the number of splices and anchorage points, leading to a lower total reinforcement quantity compared to the contractor's estimation.

Another contributing factor is the treatment of slab openings, such as shafts and voids. The BIM model explicitly accounts for these features by deducting them from the slab area, resulting in a more precise calculation. Meanwhile, the contractor's method may rely on simplified assumptions by considering gross slab areas without fully accounting for such openings, leading to overestimation.

In addition, the inclusion of waste factors in contractor calculations further increases the total reinforcement quantity. These allowances account for cutting losses, handling, and on-site uncertainties, but are not inherently included in BIM calculations unless explicitly defined. As a result, the combined effect of zoning, simplified assumptions, and material allowances explains the higher reinforcement quantities observed in contractor estimates.

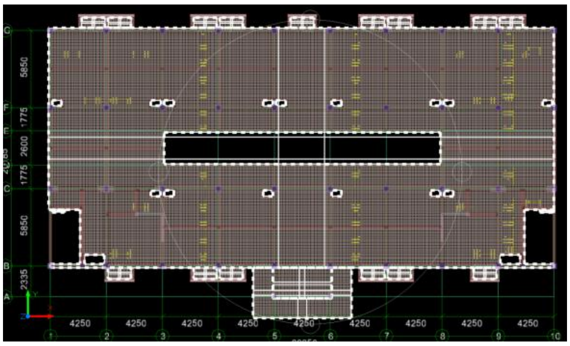

Figure 9. Slab Reinforcement Configuration in Cubicost

Table 2. Comparison of Cost Estimation Based on Cubicost and Contractor

Work	Cubicost BIM 5D (IDR)	Contractor (IDR)	Deviation (IDR)	Deviation Percentage
(a)	*(d)*	*(b)*	*(c) = (b) - (d)*	*(d) = (c) / S(c)*
Concrete	**1,074,104,304.00**	**1,137,389,795.36**	**63,285,491.36**	**33.4%**
Boredpile	181,068,524.00	196,057,643.60	14,989,119.60	7.9%
Pilecap	135,105,152.00	141,811,488.00	6,706,336.00	3.5%
Beam	208,477,360.00	222,758,900.00	14,281,540.00	7.5%

Column	135,631,314.00	139,162,842.00	3,531,528.00	1.9%
Slab	397,960,654.00	421,730,181.60	23,769,527.60	12.6%
Shearwall	15,861,300.00	15,868,740.16	7,440.16	0.0%
Reinforcement	**3,182,275,146.41**	**3,264,609,116.39**	**82,333,969.98**	**43.5%**
Boredpile	364,672,310.05	365,780,398.78	1,108,088.73	0.6%
Pilecap	207,019,193.12	209,010,560.45	1,991,367.33	1.1%
Beam	977,970,878.37	991,111,847.27	13,140,968.90	6.9%
Column	503,171,022.23	525,782,508.09	22,611,485.86	11.9%
Slab	1,023,608,651.47	1,064,821,588.70	41,212,937.23	21.8%
Shearwall	105,833,091.17	108,102,213.10	2,269,121.93	1.2%
Formwork	**1,133,476,227.00**	**1,177,170,789.90**	**43,694,562.90**	**23.1%**
Pilecap	56,371,170.00	59,339,250.00	2,968,080.00	1.6%
Beam	386,444,239.50	401,640,675.00	15,196,435.50	8.0%
Column	212,959,293.00	224,525,865.00	11,566,572.00	6.1%
Slab	450,035,800.50	462,476,257.50	12,440,457.00	6.6%
Shearwall	27,665,724.00	29,188,742.40	1,523,018.40	0.8%
Total (S)	**5,389,855,677.41**	**5,579,169,701.65**	**189,314,024.24**	**3.4%**

2. Slab Concrete Work

The results show that the concrete volume calculated by the contractor is higher than that obtained from the BIM 5D model. This difference is primarily associated with the calculation approach used. In the contractor's method, slab volume is derived by multiplying the total floor area extracted from drawings by the slab thickness, ensuring full area coverage.

However, the main source of deviation arises at the interface between slab and beam elements. The slab is treated as a continuous surface without deducting the volume occupied by beams, resulting in double counting at these intersections. Consequently, the same concrete volume is included both in slab and beam calculations.

In contrast, the BIM 5D model defines these elements as interconnected components and automatically deducts overlapping volumes. This leads to a more accurate representation of the actual concrete volume. Therefore, the discrepancy is largely explained by how element interfaces are treated in each method.

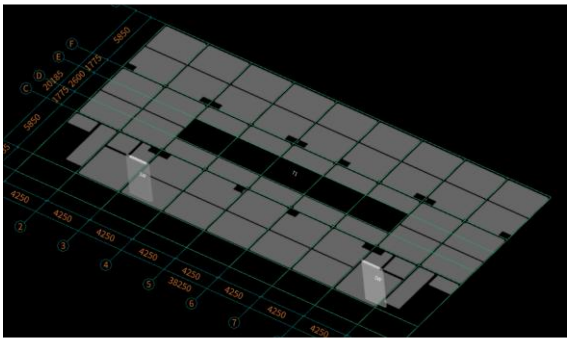

Figure 10. Slab Volume Deduction by Beam, Column, and Shear Wall in Cubicost

3. Column Reinforcement Work

The comparison of column reinforcement quantities shows a relatively small deviation between the BIM-based calculation and the contractor's estimate. However, a difference can be observed in the assumed location of reinforcement splices along the column height. In the contractor's practice, column reinforcement is spliced at approximately mid-height of the first floor, which is consistent with the provisions of SNI 2847:2019 that recommend splice locations to be placed around the mid-height of structural members. This results in reinforcement being terminated and continued at that level.

In the BIM 5D model, reinforcement is extended over a greater height, allowing splices to be placed at higher levels, such as the next floor level. While both approaches remain acceptable within design standards, this difference in splice location affects the total calculated reinforcement length. The contractor's approach introduces more frequent termination and continuation of bars, leading to a higher total quantity compared to the BIM-based model.

This finding indicates that differences in detailing assumptions, particularly in the placement of reinforcement splices, can influence quantity take-off results. It also suggests that BIM-based calculations are sensitive to the parameter settings used during modeling. Therefore, to obtain results that better reflect actual construction practices, it is important to align modeling assumptions with the intended execution method on site.

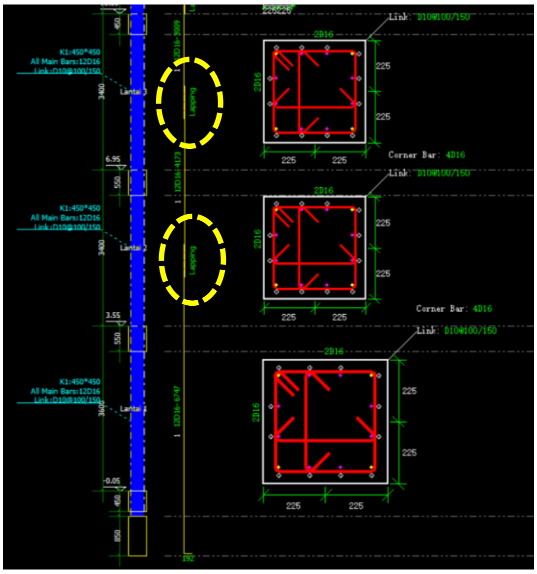

Figure 11. Column Main Reinforcement Splicing in Cubicost

4. Beam Element

The comparative analysis shows that beam elements exhibit noticeable deviations not only in reinforcement quantities but also in concrete volume and formwork area. For concrete and formwork, the main source of discrepancy is related to the treatment of interfaces between beams and adjacent structural elements, such as columns and intersecting beams. In conventional calculations, beams are often measured independently, and the contact zones at beam–column joints or beam intersections are not always deducted. As a result, portions of concrete volume and formwork area at these interfaces may be counted more than once. In contrast, the Cubicost model defines these elements as interconnected components, allowing automatic deduction of overlapping regions and resulting in a more precise quantity calculation.

For reinforcement, the deviation is mainly influenced by differences in detailing approaches. In the Cubicost, reinforcement bars with the same diameter are often modeled to continue across adjacent spans whenever possible, resulting in a more optimized configuration with fewer terminations. On the other hand, conventional estimation tends to treat beams as separate elements based on zones or types, where reinforcement is terminated and anchored into the nearest supporting element. This approach introduces additional anchorage lengths and increases the total reinforcement quantity. Consequently, the contractor's calculation generally results in higher reinforcement weights compared to the BIM-based estimation.

These findings reinforce that quantity take-off results are not solely determined by calculation accuracy, but are significantly influenced by modeling assumptions and practical construction considerations.

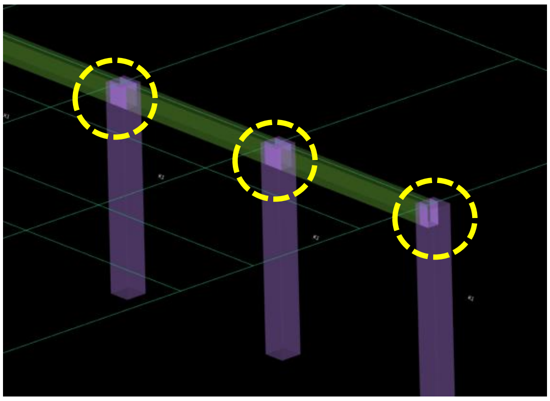

Figure 12. Beam Formwork Deducted by Column in Cubicost

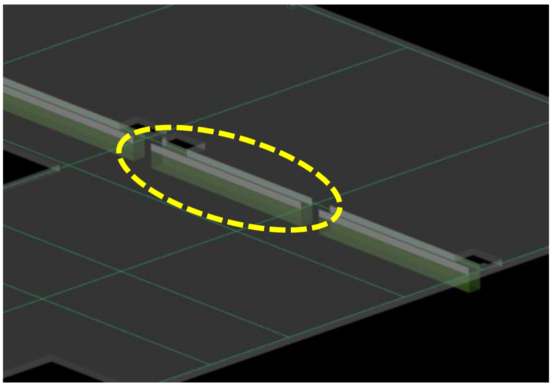

Figure 13. Beam Formwork Deducted by Slab in Cubicost

The overall analysis shows that the observed deviations between BIM 5D-based estimation and contractor calculations are primarily influenced by differences in calculation approaches, assumptions, and levels of detail. In conventional practice, simplifications are commonly applied to accelerate the estimation process, particularly during tender preparation, where time constraints are significant. These simplifications include generalized treatment of element interfaces, independent calculation of structural components, and the use of conservative assumptions in reinforcement detailing. While practical, such approaches may introduce systematic overestimation, especially when element interactions are not explicitly considered.

In contrast, the BIM 5D method provides a more integrated modeling approach, where structural elements are defined as interconnected components. This allows automatic handling of overlapping volumes and supports more optimized reinforcement configurations. As a result, BIM-based calculations tend to produce more consistent and precise quantity outputs. However, the findings also indicate that BIM results are highly dependent on modeling parameters and assumptions, particularly in reinforcement detailing and construction sequence representation. Therefore, the accuracy of BIM-based estimation is not only determined by the software capability but also by how well the model reflects actual construction practices.

Furthermore, the magnitude of deviation varies across structural elements. Slab and beam elements show more significant differences due to their higher level of interaction and complexity, while column elements tend to have relatively smaller deviations. This highlights that the complexity of geometry and detailing plays a critical role in influencing quantity take-off accuracy. Overall, the results emphasize the importance of balancing efficiency and accuracy in cost estimation, as well as the need to align digital modeling approaches with practical construction considerations.

4. CONCLUSION

This study confirms a systematic deviation between BIM 5D-based quantity take-off and contractor estimations, with the contractor's cost being higher by approximately 3.4%. The main sources of deviation can be summarized as follows:

1. Slab Reinforcement: Higher quantities in contractor estimates due to zonation, additional anchorage and lap splices, simplified treatment of openings, and inclusion of waste factors.
2. Slab Concrete: Overestimation caused by double counting at slab-beam interfaces, where beam volumes are not deducted from slab calculations.
3. Column Reinforcement: Differences in splice location assumptions, with contractor methods resulting in slightly higher reinforcement quantities.
4. Beam Elements: Double counting at element interfaces affects concrete and formwork, while differences in reinforcement continuity and anchorage increase quantities in contractor calculations.

Overall, deviations are mainly driven by simplified and conservative assumptions in conventional methods. BIM 5D provides a more integrated and precise approach, but its results depend on modeling assumptions. Therefore, proper alignment between BIM models and actual construction practices is essential to ensure reliable estimation outcome

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