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BIM-Based Automation of Structural Quantity Take-off and Scheduling Using Autodesk Revit for Construction Risk Mitigation

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Abstract

Background: Inaccurate manual quantity take-off from two-dimensional drawings remains a documented driver of cost overruns and rework in Indonesian building projects, yet evidence on the accuracy of native BIM-based quantity extraction for heterogeneous, multi-story residential structures remains limited.
Objective: This single-case study evaluates Autodesk Revit 2023 for automated structural quantity take-off (QTO), cost estimation, and schedule planning at the Point Homy Haji Nawi building in Jakarta.
Method: A descriptive quantitative design was applied. A LOD 300 model comprising seven pile-cap types, ten column types, thirteen beam types, three slab specifications, and six levels was developed from the frozen DED revision. The model was validated through a dimensional audit against the DED and owner verification, and quantities were extracted using Revit's Schedule/Quantities functionality. *RAB* tender unit prices were applied, and floor-level deviations were calculated using Deviation (%) = (Revit − *RAB*)/*RAB* × 100.
Results: Revit returned 557.83 m^3 of K-350 concrete, 61,206.99 kg of reinforcement, and 7,575.00 m^2 of wire mesh, totaling IDR 2,966,557,705.83. The aggregate deviation from the *RAB* was IDR 9,426,887.17 (−0.32%), with a mean absolute floor-level deviation of 2.31%, which falls within the ±5% tolerance commonly accepted for tender estimates. The derived 24-week S-curve peaks at 10.02% in Week 16 and indicates a concentration of cash flow between Weeks 9 and 19.
Conclusion: For this project, Revit supported accurate and auditable QTO, cost estimation, and schedule planning; however, broader claims regarding construction risk mitigation require confirmation across multiple cases.

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INTRODUCTION

The rapid expansion of urban infrastructure in Indonesia has created increasing pressure on construction professionals to complete complex multi-story building projects with greater precision, speed, and cost predictability. Conventional project delivery continues to rely heavily on manual quantity surveying methods that interpret two-dimensional (2D) engineering drawings to estimate structural quantities, a process that is inherently susceptible to human error through misread dimensions, omitted elements, incorrect application of waste factors, and arithmetic errors in complex tabulations; inaccurate budgeting and resource planning are ranked by Indonesian owners as the single most influential cause of project delay (Susanti, 2020; Yimer, 2025). The Point Homy Haji Nawi Jakarta Project, a six-story exclusive residential building (exclusive boarding house) developed by PT Pos Properti Indonesia in North Gandaria, Kebayoran Baru, South Jakarta, with a total construction budget of Rp 25,000,000,000, exemplifies this vulnerability. During pre-construction planning, design modifications led to a reduction in

reinforcement volume and concrete quantity relative to the initial budget estimate, forcing the planning consultant to undertake additional cycles of quantity recalculations, drawing revisions, and cost reestimates. This disrupted the project's critical path: the tender process was delayed, contractor procurement was delayed, and the owner incurred increased professional costs for repetitive documentation work. These compounding delays are a recognized manifestation of estimation-driven construction risk. Whether digital methods such as Building Information Modeling (BIM) reduce this class of risk in Indonesian practice is an empirical question, and it is the question this study addresses; the literature to date reports the mechanism as plausible rather than demonstrated (Numan, 2024).

Building Information Modeling (BIM) has emerged as a widely adopted response to systemic inefficiencies in construction project delivery. As officially defined by the Ministry of Public Works and Public Housing (*Kementerian Pekerjaan Umum dan Perumahan Rakyat/PUPR*), Republic of Indonesia, BIM is a data-rich, object-oriented, intelligent, and parametric digital representation of a facility from which precise insights and data can be extracted and analyzed to support decision-making throughout the project lifecycle (Hidayatulloh & Anisa, 2022; Subagio et al., 2022; Wati & Warpindyastuti, 2024). Unlike CAD-based drafting, which only digitizes the conventions of 2D drawings, BIM stores semantics alongside geometry: each architectural or structural element in the model carries not only geometric information (shape, size, and position) but also semantic information (material specifications, structural classifications, costs, and installation sequences). This integration means that design changes to column cross-sections can automatically propagate to associated beam connection dimensions, plate bearing widths, reinforcement schedules, quantities, costs, and schedule durations, thereby shortening the recalculation cycles that characterize conventional project delivery. The Indonesian government has institutionalized this capability through a structured regulatory framework: PUPR Minister Regulation No. 22/PRT/M/2018 mandates BIM for certain non-simple state buildings exceeding 2,000 m^2 and two floors (PUPR, 2021; Syafii & Azhari, 2025), while Law No. 2/2017 on Construction Services establishes technology-based innovation as a formal development principle. Together, these instruments make BIM a regulatory requirement for applicable projects as well as a productivity tool, which raises the practical question of what accuracy standard a compliant BIM deliverable should meet (Asmaroni & Wahyuni, 2021; Cahyono et al., 2022).

The theoretical framework underlying BIM's capacity for automated quantity takeoff is based on the concept of Quantity Take-Off (QTO) as defined by Setiawan et al. (2022) the systematic measurement and quantification of all construction elements required for project completion, including geometric quantities (volume, area, and length) and derivative quantities (weight and cost). In the BIM paradigm, QTO transitions from a post-design manual process to an automated output generated directly from the design process. Autodesk Revit, a widely used parametric modeling platform in global and Indonesian AEC practices, achieves this through two complementary extraction tools: Schedule/Quantities, which generates a real-time inventory of model elements in tabular form using user-defined fields, and Material Takeoff (MTO), which provides detailed material composition data for applicable assemblies. Both tools maintain a dynamic link to the model, so geometric modifications to modeled elements update the corresponding quantity schedules without requiring a separate manual recalculation; the reliability of that output is nevertheless bounded by the completeness and accuracy of the model itself, since data absent from the model cannot be scheduled (Olsen & Taylor, 2017; Ren et al., 2024). Revit has been developed by Autodesk since 2002. Revit 2023, the version deployed in this study, provides parametric family-based modeling for structural elements, supports clash-detection workflows through interoperability with other Autodesk tools, and provides Schedule/Quantities filtering and sorting capabilities that support the separation of quantities by level and element type, precisely the capabilities required for floor-level BIM-versus-RAB comparative analysis.

The academic literature on BIM-based structural QTO has grown substantially since the mid-2010s, but important gaps remain in the Indonesian context. Three themes organize this body of work. The first concerns accuracy as a function of geometric complexity. Farhana and Abma (2022) documented a 7% aggregate cost deviation between 5D BIM and conventional RAB for structural building projects, attributing it to differences between 3D geometry and 2D

interpretation and to non-modeled elements within the BIM scope. Kasuma and Beatrix (2022) showed near-zero deviations (0.02 m^3 for concrete and 4.64 kg for reinforcement) in their work on box-culvert infrastructure, suggesting that simpler element geometry results in higher BIM accuracy. The second theme concerns model fidelity and level of development as limiting conditions on extraction reliability. Anjani et al. (2022) applied BIM at LOD 300 for hospital building documentation, emphasizing the role of model fidelity in extracting reliable volume inventories. Olsen and Taylor (2017) found that between ten and fifty percent of the data needed for a takeoff may be missing from a delivered model (Meléndez et al., 2026), and Ren (2024) shows that design-feedback loops are required before component quantities can be trusted for procurement. The third theme concerns the technical mechanism that generates deviation. Prasetyono and Suharianto (2023) identified the calculation of net volume at the intersections of elements as the main technical mechanism distinguishing Revit-based estimation from conventional additive RAB, noting that conventional methods systematically overcalculate volume at structural intersections. Khosakitchalert et al. (2019) demonstrated the same effect for compound elements and quantified the residual error band at roughly −0.9% to +2.4%. Internationally (Mahardika & Windari, 2025), Jonathan and Anondho (2021) found that BIM-based plate volume calculations reduced estimation errors related to conservative waste factors, while Ramadhandy et al. (2023) confirmed a total deviation of less than 5% for residential structural work in their comparative BOQ study (Nguyen et al., 2026). Two limitations follow from this body of work, and together they define the gap this study addresses. First, deviation is almost always reported as a single aggregate figure, so a practitioner cannot determine which elements or floors drive it, nor whether an apparently small aggregate conceals larger offsetting errors. Second, studies that validate cost output rarely carry it through to a schedule, so the 5D claim is asserted rather than demonstrated; Pishdad and Onungwa (2024) identify precisely this missing link between 5D estimation and downstream cost control. The unresolved problem is therefore not whether BIM QTO is more accurate in aggregate, which is relatively well established, but whether a native Revit workflow can produce a floor-level, element-attributable deviation account for a heterogeneous multi-story residential structure and convert that account into an auditable construction schedule.

The 5D BIM paradigm integrates 3D geometry (model), 4D time (schedule), and 5D cost (estimation), providing a unified digital workspace in which structural design, quantity measurement, cost calculation, and schedule planning are not sequential activities but simultaneous outputs of a single parametric model. This integration fundamentally changes the risk profile of construction projects by compressing the information-processing timeline from weeks to hours. In risk-management terms, the contribution is specific: the model shortens the identification and reassessment loop after a design change, and the cost-loaded schedule it produces becomes the baseline against which schedule and cash-flow risks are monitored (Amin Ranjbar et al., 2021; Didar et al., 2026; Numan, 2024). In the context of the Point Homy Haji Nawi project, a design change that requires a few weeks of manual reestimation in a conventional workflow may, in a BIM-enabled workflow, require only a model update followed by automated updating of the relevant quantities and schedule, reducing a process that can otherwise take weeks to one that can be completed within hours. Saputra et al. (2022) measured this efficiency advantage, finding that BIM integration reduced shop-drawing-related delays by about 30% in Indonesian construction projects. Nugroho et al. (2022) showed in their Pulang Pisau Port rehabilitation study that BIM-enabled real-time progress monitoring reduces the need for continuous live field inspections for progress verification, a benefit with significant implications for project risk monitoring in high-rise residential developments where simultaneous multi-story construction activities are difficult to supervise manually.

This study addresses this gap through a systematically designed case study of the Point Homy Haji Nawi building in Jakarta. The study pursued three specific objectives, each derived from the gap identified above: (1) to measure structural quantities and costs through Autodesk Revit 2023 automated extraction for all element types and floor levels; (2) to conduct a floor-level comparative analysis between BIM-derived quantities and RAB estimates, attributing deviations to specific technical and methodological factors; and (3) to generate a 24-week S-curve construction schedule directly from BIM cost outputs, demonstrating full 5D integration

capabilities.

The following formulas are applied to the Autodesk Revit 2023 structural volume calculations and S-curve schedule-weight calculations, as summarized in Table 1. These are standard geometric and engineering relationships rather than Revit-specific equations; Table 1 therefore also states how each relationship is evaluated automatically within Revit 2023, since the automation claim of this study rests on that mechanism rather than on the formulas themselves. Units are metric throughout, and the steel unit weight follows SNI 2052:2017.

Table 1
Formula Set 1. Volume and schedule weighting formulas are applied in Autodesk Revit 2023

Formula	Description	Automation in Autodesk Revit 2023
$V = L \times W \times H$ (m^3)	Pile cap foundation volume (L = length, W = width, H = height)	Structural Foundation family parameters; evaluated by Schedule/Quantities (Volume field).
$V = b \times d \times h$ (m^3)	Volume of concrete column (b = width, d = depth, h = floor height)	Structural Column family (b × d) × level height; evaluated by Schedule/Quantities. Dimensionally identical to the pile-cap expression but driven by a different family category and height parameter.
$V = b \times d \times l$ (m^3)	Volume of concrete beam (l = span length)	Structural Framing family; span length read from the model, not from the drawing.
$V = A \times t$ (m^3)	Volume of concrete slab (A = area, t = thickness)	Structural Floor family; area computed from the sketched boundary, openings deducted automatically.
$W = (\pi d^2/4) \times L \times \gamma$ (kg)	Steel reinforcement weight (d = diameter, γ = 7,850 kg/m^3)	Rebar element length × bar area; reported by Material Take-Off (Reinforcement Volume/Weight).
Weight (%) = (Ci/Ct) × 100	Working weight for S-Curve (Ci = item cost, Ct = total cost)	Computed outside Revit in the BoQ worksheet from the exported cost schedule (semi-automated step).

Note: formulas are standard geometric/engineering relationships (author compilation); steel unit weight γ = 7,850 kg/m^3 follows SNI 2052:2017. The pile-cap and column expressions are dimensionally identical and are retained separately only because they are driven by different Revit family categories.

Autodesk Revit 2023 Preview

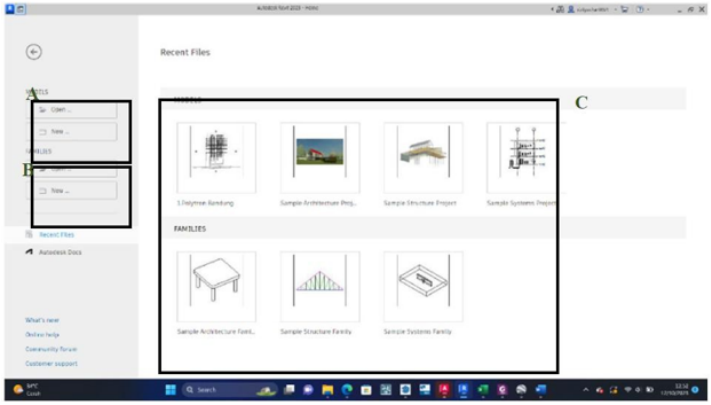


Figure 1. Autodesk Revit 2023 Preview
Source: Personal Documentation (2025)

Table 2
Autodesk Revit 2023 Software Initial View Menu Explained

A.	*Models*	:	Section for opening or creating a new Revit project (.rvt file format)
B.	*Families*	:	Section for opening and creating a new Revit Family (.rfa file format)
C.	*Recent File*	:	Displays Revit project and Revit Family files

METHOD

This study used a descriptive quantitative research design that focused on the implementation of applied Building Information Modeling to quantify structural quantities and estimate costs. The descriptive quantitative methodology was chosen because the study did not manipulate variables or test causal hypotheses, but rather systematically described and measured

the outputs of the specified BIM implementation process and compared them with independent reference datasets (RABs). The case study was the Point Homy Haji Nawi Jakarta project, a six-story exclusive residential building located at Jalan H. Nawi Raya No. 14, RT.03 RW.07, North Gandaria, Kebayoran Baru District, South Jakarta City, DKI Jakarta, 12140, with an RAB-based construction value of IDR 25,000,000,000. The building was owned by PT Pos Properti Indonesia and was under construction during the study period. Data collection was carried out between August and October 2025 under a formal research authorization agreement with the project owner. A single-case design was appropriate because the research question concerned measurement fidelity rather than population inference: the study examined how closely a native Revit extraction reproduced an independently prepared conventional estimate for a structurally heterogeneous building, and that comparison required depth of documentation rather than breadth of sample. The case was treated as a critical rather than a representative case, and the findings were accordingly presented as analytic rather than statistical generalizations. Because the building was under construction during data collection, the BIM model was built against a single frozen design state: DED Revision 03, issued on July 14, 2025, which was the same revision on which the comparison RAB was priced. Site observations conducted between August and October 2025 were used only to confirm that no structural change order had been issued after that date; no post-freeze revision was incorporated into the model, so the BIM and RAB datasets remained directly comparable. All data consisted of project documents supplied under institutional permission from PT Pos Properti Indonesia; the study involved no human or animal subjects, and the formal ethics statement is provided at the end of this section. Table 3 summarizes the case-study project, input documents, software environment, and analysis outputs. Table 4 sets out the model validation procedure applied before any quantities were extracted.

Table 3
Summary of case-study project, input data, software environment and analysis outputs

Category	Item	Description / value
Project information	Project name	Point Homy Haji Nawi Jakarta (exclusive residential building)
	Location	Jl. H. Nawi Raya No. 14, North Gandaria, Kebayoran Baru, South Jakarta 12140
	Owner / data provider	PT Pos Properti Indonesia
	Contract value (RAB)	IDR 25,000,000,000 (whole project); structural scope IDR 2,975,984,594
Building characteristics	Storeys / levels modelled	Six structural levels (Ground, Floors 1–5, Roof)
	Structural system	Reinforced concrete frame on pile-cap foundations
	Element heterogeneity	7 pile-cap types, 10 column types, 13 beam types, 3 slab specifications (698 modelled elements)
	Materials (RKS)	K-350 concrete (f'c ≈ 29.05 MPa); BJTS 420 deformed and BJTP 280 plain reinforcement; wiremesh M10-150
Project documents	DED	Detailed Engineering Design, revision 03, issued 14 July 2025 (AutoCAD .dwg)
	RAB	Consultant Bill of Quantities priced on DED rev. 03, tender issue July 2025
	RKS	Work Plan and Specifications, tender issue July 2025
Unit-price basis	K-350 concrete	IDR 1,318,302.25/m^3 RAB tender unit price (consultant AHSP, SNI 7394:2008 coefficients, Jakarta 2025 market rates)
	Steel reinforcement	IDR 15,438.00/kg RAB tender unit price
	Wiremesh M10-150	IDR 168,019.89/m^2 RAB tender unit price
Software	Modelling / QTO	Autodesk Revit 2023, Metric-Structural template, LOD 300
	Cost tabulation	Microsoft Excel 365 (BoQ worksheet)
Data collection	Period	August – October 2025
Analysis outputs	Quantities	Concrete volume (m^3), reinforcement weight (kg), wiremesh area (m^2) by element and floor
	Cost	5D BoQ by work package and floor; deviation versus RAB (%)
	Schedule	24-week work-weight distribution and cumulative S-Curve

Table 4
Model validation and quality-assurance checks performed before quantity extraction

Check	Procedure	Acceptance criterion	Result
Geometry conformity	Every modelled element cross-section and span compared against the DED rev. 03 schedule	Zero dimensional discrepancy	Passed after two correction cycles
Level and grid alignment	Revit Levels and Grids compared with DED section and setting-out drawings	Elevation deviation = 0 mm	Passed
Duplicate / overlap check	Warnings review plus visual inspection at beam–column and beam–slab junctions	No duplicated or unjoined elements	11 duplicated beams removed
CAD-to-BIM geometry check	Linked DWG compared with modelled geometry at 20 sample grid intersections	Deviation < 5 mm	Maximum 3 mm; within tolerance
Reinforcement completeness	Rebar host check per element category; unreinforced hosts flagged	All modelled hosts reinforced	Passed
Schedule reconciliation	Schedule/Quantities totals cross-added against per-level subtotals	Subtotals sum to reported total	Passed (see Table 10)
Owner verification	Extracted quantities reviewed by the project engineer of PT Pos Properti Indonesia	Written confirmation of scope agreement	Confirmed, 21 October 2025



Figure 2. Site of the Point Homy Haji Nawi building, South Jakarta, showing the constrained urban plot that governs site logistics and the sequencing assumptions used in the 24-week schedule
Source: field documentation (2025)

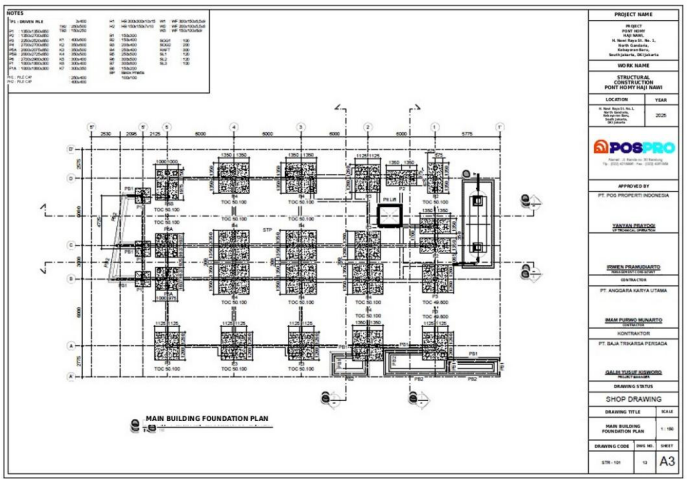


Figure 3. Pile-cap foundation layout of the DED rev. 03, from which pile-cap types P1–P6, their positions and their dimensions were transferred to the Revit model and from which the foundation quantities in Table 8 were extracted
Source: PT. Pos Properti Indonesia (2025)

The three main categories of project documents formed the foundation of the research data and are summarized in Table 3; the full specification details are retained there rather than presented in continuous text. The Detailed Engineering Design (DED), Revision 03, issued on July 14, 2025, consisted of a complete structural layout drawing package, including a pile-cap foundation plan with six different types of pile caps and associated pile layouts; column layout

plans for all six floors (Floors 1–5 and Rooftop), showing ten different column cross-sections; beam framing plans for the six levels, showing thirteen types of beams; floor slab plans for the 1st Floor through Rooftop, with slab thicknesses and reinforcement specifications; and detailed reinforcement drawings for individual elements showing bar sizes, spacing, hook lengths, and lap-joint specifications for columns, beams, and slabs. The Cost Budget Plan (RAB) from the planning consultant, priced using the same DED revision and issued for tender in July 2025, provided the reference quantities (volume in m^3, weight in kg, and area in m^2) prepared by work package and floor level, together with the applicable unit prices (Rp 1,318,302.25/m^3 for K-350 concrete, Rp 15,438.00/kg for steel reinforcement, and Rp 168,019.89/m^2 for M10-150 wire mesh). These unit prices were the consultant's tender rates, derived from unit-price analysis (Analisis Harga Satuan Pekerjaan/AHSP) using SNI 7394:2008 work coefficients applied to Jakarta 2025 market rates for materials and labor; they were not independent market-survey figures. Because identical rates were applied to both the RAB and the Revit-derived quantities, the comparison isolated quantity deviations and was unaffected by differences in the price basis; a summary of the total cost is also provided. The Work Plan and Conditions (RKS), issued for tender in July 2025, specified the material standards: K-350 concrete (equivalent to f'c ≈ 29.05 MPa), BJTS 420 deformed steel reinforcement (f_y = 420 MPa), BJTP 280 plain steel reinforcement (f_y = 280 MPa), and M10-150 wire mesh with 150 mm × 150 mm grid spacing for double-layer slab reinforcement.

The BIM modeling workflow was conducted in Autodesk Revit 2023 using the Metric-Structural Template with fully metric units. In Phase 1 (Preparation), the AutoCAD DWG file from the DED was linked through the CAD Link function so that updates to the source file could be synchronized with the Revit model. Linking rather than importing also preserved an auditable separation between the 2D source and the 3D model, which was important because CAD-to-BIM transfer is a known source of geometric discrepancy: linework in the DED was drawn to nominal dimensions, whereas Revit resolved elements according to their parametric extents. Twenty sample grid intersections were therefore measured in both environments; the maximum discrepancy was 3 mm, below the 5-mm tolerance adopted for this study (Table 3). Residual CAD-BIM discrepancies were acknowledged as a limitation rather than assumed to have been eliminated. The CAD layer was displayed using 50% halftone opacity via Visibility/Graphic Overrides (VG) to facilitate visual reference. Next, grid lines were created using the Grid (GR) command according to the CAD reference geometry, and six levels were created using the Level (LL) command to represent the Ground Floor, Floors 1–5, and Roof, with the elevations verified against the DED section drawings. In Phase 2 (Structural Element Modeling), the foundation was modeled using Structural Foundation: Isolated (M_Pile_Cap) for seven pile-cap types (P1–P6), columns were modeled using M_Concrete-Rectangular Columns for ten column types, beams were modeled using M_Concrete-Rectangular Beam for thirteen beam types, and slabs were modeled using Structural Floor with thicknesses of 100 mm (SOG1) and 120 mm (SL1), according to the RKS. In Phase 3 (Reinforcement Modeling), reinforcement was modeled for each element using the Rebar command, with concrete cover generally set at 40 mm for columns and beams and 20 mm for slabs, and bar diameters of D10, D13, D16, and D19, together with standard Revit bar shapes such as Shape 00 and Shape 51. This achieved LOD 300, which was adequate for weight-based quantity extraction. LOD 300 was the appropriate level for this study because it is the lowest level at which element dimensions, location, and orientation are modeled as designed rather than assumed, providing the minimum condition required for construction-phase QTO (Abdulaziz & Ahmed, 2026; BIMForum, 2021) it was also the highest level that the available DED could support, because fabrication detailing (LOD 400) and as-built verification (LOD 500) require shop drawings and site records that were not available at the planning stage examined in this study. Adopting a higher nominal LOD without the underlying data would have produced false precision. Before any quantities were extracted, the model was subjected to the validation sequence set out in Table 3, comprising geometry conformity, level and grid alignment, duplicate and overlap detection, CAD-BIM sampling, reinforcement completeness, schedule reconciliation, and owner verification. Two correction cycles and the removal of eleven duplicated beam instances were required before the model passed validation.

In Phase 4 (Quantity Extraction), the volumes and weights of the elements were extracted through Schedule/Quantities, including the foundation, columns, beams, slabs, and

reinforcement, as well as floor areas for the wire mesh, with filters applied by floor so that the results could be separated by level. In Phase 5 (Cost Calculation), the Revit-derived quantities were transferred to Microsoft Excel and multiplied by the RAB unit prices using the formula Cost = Quantity × Unit Price, and the results were then compiled in a Bill of Quantities (BoQ) format for direct comparison with the RAB structure. This transfer was a manual export-and-paste operation rather than a Revit-native cost-parameter workflow; therefore, the cost stage of the workflow was properly described as semi-automated: quantity extraction was automated, whereas monetization was not. This distinction is stated explicitly because it bounds the automation claim made in the title and abstract and because the manual step itself represents a residual transcription risk. It also represents the integration gap that Pishdad and Onungwa (2024) identify between 5D estimation tools and downstream cost control. In Phase 6 (Schedule Planning), the weight of each work item was calculated using the formula Weight (%) = (Cost per Item / Total Structural Cost) × 100%, after which progress was distributed across a 24-week schedule: foundation, Weeks 1–5; Floor 1 structure, Weeks 3–10; Floor 2, Weeks 6–17; Floor 3, Weeks 8–19; Floor 4, Weeks 10–19; Floor 5, Weeks 12–22; and Rooftop, Weeks 15–24. These floor windows deliberately overlapped. The overlap reflected the standard cast-in-place sequence for a six-story frame, in which work on a floor could begin after the slab below had been cast, while reinforcement, formwork, and finishing activities trailed the floor above by several weeks; consequently, consecutive floors shared four to nine weeks of concurrent activity. The windows were established based on the owner's planned cycle time of one structural floor every four weeks and accounted for the weekly curve peaking in the middle of the program rather than rising monotonically. The weekly cumulative percentage was used to generate the S-curve, while the comparative analysis was conducted using the formula Deviation (%) = (Revit Cost − RAB Cost) / RAB Cost × 100% at the floor and work-type levels. The direction of the formula is stated explicitly because the previous wording used the reverse convention from that applied in the results tables: under the convention adopted throughout the study, a positive value indicated that Revit returned a higher figure, whereas a negative value indicated that Revit returned a lower figure. The same convention was applied to every row and to the aggregate results. This research did not involve human or animal subjects. All data were derived from project documents used with written institutional permission from PT Pos Properti Indonesia, and no personal or commercially confidential information was reported.

RESULTS AND DISCUSSION

The results are presented in five subsections: (1) structural element specifications as modeled in Autodesk Revit 2023, including foundation type, column cross-section, beam configuration, and plate specifications derived from DED drawings; (2) Revit automatic volume-extraction output; (3) 5D BIM cost-estimation results; (4) comparative analysis between BIM and conventional RAB; and (5) schedule planning and S-curve analysis. The level of development applied to the model is reported between Subsections (4) and (5). The discussion then analyzes the technical drivers of the deviations and their implications for construction risk management. All quantitative findings are derived from the Autodesk Revit 2023 Schedule/Quantities output. Verification consisted of a line-by-line review of the extracted schedules by the project engineer of PT Pos Properti Indonesia against DED Rev. 03 and the tender RAB, as confirmed in writing on October 21, 2025 (Table 3). This verification was a scope and specification check, not an independent remeasurement.

Results

Structural Element Specification

The structural system of the Point Homy Haji Nawi building combines various types of elements across six structural levels. Tables 5 through 8 present the specifications for the respective foundations, columns, beams, and plates as modeled in Autodesk Revit 2023. Following the reviewer’s comment, these tables now report element specifications only; all quantities are reported consistently for every structural element in Tables 9 and 10, so that specifications and quantities are no longer mixed across the tables.

Table 5
Specification of Pile Cap Foundation

No.	Types of foundations	Dimensions (mm)	→ Table 8
1	P1: 1350×1350×850	Thickness: 850 mm	
2	P2: 1350×2700×850	Thickness: 850 mm	
3	P3: 2250×2520×850	Thickness: 850 mm	
4	P4: 2700×2700×850	Thickness: 850 mm	
5	P5A: 2000×2075×850	Thickness: 850 mm	
6	P5B: 2000×2725×850	Thickness: 850 mm	
7	P6: 2700×2900×300	Thickness: 300 mm	
	QUANTITY		

Note: volume data have been removed from the specification tables and are reported consistently for every structural element in Tables 8 and 9. The tabulated pile-cap subtotal of 112.04 m^3 covers types P1–P5B only; P6 is a 300 mm pile-cap slab (2.35 m^3) that is modelled in Revit as a structural floor element and is therefore already carried in the slab quantity, so adding it here would double-count. Arithmetically, 114.39 m^3 − 2.35 m^3 = 112.04 m^3 (see Table 11).
Source: PT. Pos Properti Indonesia (2025)

Table 6
Column Specifications

No.	Type	Dimensions	Main reinforcement	Stirrup
1	K1	400×600 mm	22 D19	D10-100
2	K1A	400×600 mm	22 D19	D10-65
3	K2	350×600 mm	16 D19	D10-100
4	K3	350×500 mm	14 D19	D10-100
5	K4	350×500 mm	10 D19	D10-100
6	K5	300×400 mm	10 D19	D10-150
7	K6	300×400 mm	8 D16	D10-100
8	K6A	300×400 mm	8 D16	D10-65
9	K7	300×350 mm	8 D16	D10-100
10	PD2	400×400 mm	8 D13	D10-95

Source: PT. Pos Properti Indonesia (2025)

Table 7
Beam Specifications

No.	Type	Dimensions	Top reinforcement	Bot. reinforcement	Stirrup
1	TB1	250×400	3D16	3D16	D10-95
2	B1	150×300	2D13	2D13	D10-100
3	B2	150×400	3D16	2D16	D10-100
4	B3	200×400	4D16	2D16	D10-100
5	B3A	200×400	5D16	3D16	D10-100
6	B4	250×400	5D16	3D16	D10-100
7	B4A	250×400	3D16	2D16	D10-100
8	B4B	250×400	6D16	5D16	D10-100
9	B5A	250×500	3D16	3D16	D10-100
10	B5B	250×500	6D19	2D19	D10-100
11	B6	300×500	6D19	3D19	D10-100
12	B7	300×600	6D19	4D19	D10-100
13	BP	130×130	2D10	2D10	D10-100

Source: PT. Pos Properti Indonesia (2025)

Table 8
Slab Specifications

No.	Code	Thickness	Function	Reinforcement
1	SOG 1	100 mm	Slabs on the Ground	Wiremesh M10 (Single Layer)
2	SL 1	120 mm	Floor Slabs	Wiremesh M10 (Double Layer)
3	SL 1R	120 mm	Roofing Slabs	Wiremesh M10 (Double Layer)

Note: three slab specifications are modelled. SOG 1 is the 100 mm slab on grade; SL 1 is the 120 mm suspended floor slab; SL 1R is the 120 mm roof slab. SL 1 and SL 1R share thickness and reinforcement but differ in function, exposure and load case, and were previously given the same code the roof slab has been recoded SL 1R so that the three specifications stated in the abstract and methods are distinguishable in the model schedules.

Source: PT. Pos Properti Indonesia (2025)

Automatic Volume Extraction from Autodesk Revit 2023

Upon completion of the complete 3D structural model in Autodesk Revit 2023, which includes 698 individual structural elements across seven foundation types, ten column cross-sections, thirteen beam types, three plate specifications, and a complete reinforcement layout for six structural levels, the Schedule/Quantities function was enabled for each structural element category. Separate schedules were created and filtered by level to allow for floor-level separation. Table 9 presents a recapitulation of concrete volume by structural element and floor level, while Table 10 presents the recapitulation of steel reinforcement and wire mesh. The total volume of concrete across all structural and floor elements amounted to 557.83 m^3 of K-350-grade concrete: 112.04 m^3 for pile-cap foundations, 93.90 m^3 for columns, 173.57 m^3 for beams, and 178.32 m^3 for slabs. The total structural reinforcement was 61,206.99 kg, comprising 4,677.39 kg for pile-cap reinforcement, 20,913.46 kg for columns, and 35,616.14 kg for beams. The earlier presentation labeled this total as the sum of the column and beam reinforcement only, which does not reconcile with the reported total (20,913.46 + 35,616.14 = 56,529.60 kg). The label, rather than the quantity, was therefore in error, and Table 10 now reports the pile-cap reinforcement as a separate line item so that the subtotals reconcile with the total. Bored piles remain outside the modeled scope, as stated in the methods; pile caps, however, are included in the model. The total wire mesh area amounted to 7,575.00 m^2 across six floors. All three reconciliations are presented in Table 11.

Table 9
Concrete Volume Recapitulation by Elements and Floors (Revit 2023)

Structural Elements	Floor Level	Volume (m^3)
Pile Cap Foundation	P1–P5B (P6 carried in slab quantity)	112.04
Concrete Columns	1st Floor	22.47
	2nd Floor	20.30
	3rd Floor	18.03
	4th Floor	15.11
	5th Floor	14.74
	Roof	3.25
	QUANTITY	93.90
Concrete Beam	1st Floor	21.10
	2nd Floor	37.89
	3rd Floor	34.76
	4th Floor	27.80
	5th Floor	32.51
	Roof	19.51
	QUANTITY	173.57
Concrete Slab	SOG Lt.1	33.13
	Flat Lt.2	35.76
	Flat Floor.3	34.75
	Flat Floor.4	34.81
	Flat Floor.5	34.86
	Flat Roof	5.01
	QUANTITY	178.32
BIG TOTAL K-350		557.83

Table 10
Steel Reinforcement & Wiremesh Recapitulation (Revit 2023)

Categories Reinforcement	Floor Level	Weight / Area
Steel Pile Cap Foundation	All types (P1–P6)	4,677.39 kg
Steel Column	1st Floor	5,719.00 kg
	2nd Floor	5,415.16 kg
	3rd Floor	3,398.31 kg
	4th Floor	2,780.19 kg
	5th Floor	2,922.21 kg
	Roof	678.59 kg

Categories Reinforcement	Floor Level	Weight / Area
	QUANTITY	20,913.46 kg
Steel Beam	1st Floor	4,084.41 kg
	2nd Floor	8,789.88 kg
	3rd Floor	7,306.68 kg
	4th Floor	6,105.54 kg
	5th Floor	5,716.74 kg
	Roof	3,612.89 kg
	QUANTITY	35,616.14 kg
Wiremesh M10-150	SOG Lt.1	794.00 m^2
	Flat Lt.2	1,746.00 m^2
	Flat Floor.3	1,497.00 m^2
	Flat Floor.4	1,497.00 m^2
	Flat Floor.5	1,497.00 m^2
	Flat Roof	544.00 m^2
	TOTAL AREA	7,575.00 m^2
Total Structural Reinforcement (Pile cap + Column + Beam)		61,206.99 kg

Note: numeric separators have been standardised to the English convention (comma for thousands, point for decimals) throughout; the previous mixture of Indonesian and English formats was a locale-conversion artefact. Subtotals now reconcile to the stated total: 4,677.39 + 20,913.46 + 35,616.14 = 61,206.99 kg. Bored-pile reinforcement remains outside the modelled scope; pile-cap reinforcement is inside it.

Table 11

Reconciliation of reported totals against tabulated subtotals (added in response to reviewer comments)

Item	Previously reported	Tabulated subtotals	Resolution adopted
Pile-cap concrete volume	112.04 m^3	P1–P6 sum = 114.39 m^3	P6 (2.35 m^3) is a 300 mm pile-cap slab modelled as a structural floor and already counted in the slab quantity. Pile-cap line retained at 112.04 m^3 to avoid double-counting; note added to Table 4.
Structural reinforcement	61,206.99 kg labelled "Col + Beam"	Columns + beams = 56,529.60 kg	Label corrected. The 61,206.99 kg total includes pile-cap reinforcement of 4,677.39 kg, now shown as a separate line in Table 9.
5D BIM structural cost	Table 11 lines summed to IDR 2,966,679,720.06 against a stated total of IDR 2,966,557,705.83	Table 14 items sum exactly to IDR 2,966,557,705.83	Table 14 is authoritative. Three Table 11 floor rows were overstated 3rd Floor by IDR 110,922.03, 4th and 5th Floors by IDR 5,546.10 each and have been corrected. The grand total is unchanged.
Deviation sign convention	Methods stated (RAB − Revit)/RAB; tables applied (Revit − RAB)/RAB	All seven floor rows follow (Revit − RAB)/RAB	Methods corrected to match the tables: positive = Revit higher.
Aggregate cost deviation vs RAB	+1.45%	IDR −9,426,887.17 ÷ IDR 2,975,984,593 = −0.32%	Corrected to −0.32%; the previous figure was wrong in both magnitude and sign. Mean absolute floor-level deviation, 2.31%, is reported alongside it.
Foundation deviation	−6.76% (Conclusion) vs −8.67% (Discussion)	Both correct on different bases	Retained as two distinct measures and labelled accordingly: −6.76% is cost-based, −8.67% is volumetric (RAB 122.68 m^3 vs Revit 112.04 m^3).
Wiremesh weight share	42.90%	Table 14 wiremesh rows: 4.50 + 9.89 + 8.48 + 8.48 + 8.48 + 3.08 = 42.91%	Confirmed traceable; the 0.01 pp difference is rounding at two decimal places. Cross-reference to Table 14 added in the Conclusion.

5D BIM Cost Estimation Results

The extracted volume and number of areas are transferred to the Microsoft Excel-structured Bill of Quantities (BoQ) template, and the cost calculation is performed by applying the unit prices obtained from the RAB tender documentation. This transfer is manual; therefore, the cost stage is semi-automated rather than fully automated. The unit prices from the RAB tender document are applied to the quantities extracted by Revit to generate estimated floor-level costs. Table 11 presents a complete BIM 5D Bill of Quantities (BoQ) summary. The total structural cost derived from the BIM model is IDR 2,966,557,705.83. The largest single-floor cost is for the 2nd Floor, at IDR 638,153,212.53 (21.51% of the total), reflecting the high wire mesh area and intensity of beam reinforcement. This is verifiable against the extraction tables: the 2nd Floor contains 1,746.00 m^2 of wire mesh, the largest single-floor area in the building and 23.05% of the total 7,575.00 m^2 (Table 10), together with 8,789.88 kg of beam reinforcement, again the highest of any floor and 24.68% of the total beam reinforcement (Table 10), and 37.89 m^3 of beam concrete, compared with a six-floor mean of 28.93 m^3 (Table 9). The three largest cost drivers therefore all peak on the same level. Foundation work contributed IDR 150,800,594.38 (5.08%), while roof structural work contributed IDR 199,031,039.21 (6.71%).

Table 12
Summary of 5D BIM Cost Estimation by Floor Level

No.	Work Package	Revit Fee (IDR)	Weight (%)
I	Pilecap foundation	150,800,594.38	5.08
II-A	Structural Flooring 1	423,666,712.27	14.28
II-B	Structural 2nd Floor	638,153,212.53	21.51
II-C	Structural Flooring 3	554,866,369.64	18.70
II-D	Structural 4th Floor	517,242,778.55	17.44
II-E	Structural Flooring 5	482,796,999.25	16.27
II-F	Structural Roofing	199,031,039.21	6.71
	LARGE TOTAL	2,966,557,705.83	100.00

Note: the seven work-package lines previously summed to IDR 2,966,679,720.06, IDR 122,014.23 above the stated total. Reconciliation against the itemised breakdown in Table 14, which sums exactly to IDR 2,966,557,705.83, located the error in three floor rows: 3rd Floor (overstated by IDR 110,922.03), 4th Floor and 5th Floor (each overstated by IDR 5,546.10). Those three rows have been corrected to the itemised values; the grand total is unchanged and remains IDR 2,966,557,705.83. Weights are rounded to two decimals and therefore sum to 99.99%.

Comparative Analysis: BIM versus RAB

Table 13 presents a floor-to-floor cost comparison between RAB and Revit, using Deviation (%) = (Revit − RAB)/RAB × 100, applied identically to every row and to the aggregate, so that a positive value always denotes a higher Revit figure. The total difference was IDR 9,426,887.17, with Revit lower than RAB by this amount, corresponding to a signed deviation of −0.32% relative to the RAB total. The previously reported figure of +1.45% is arithmetically inconsistent with the tabulated totals and carries the wrong sign, since the RAB total exceeds the Revit total at the aggregate level: 9,426,887.17 ÷ 2,975,984,593 = 0.32%, and the correct signed deviation is negative. The aggregate deviation is small only because opposite-signed floor-level deviations offset one another; therefore, the mean absolute floor-level deviation of 2.31% is reported alongside it as the more informative measure of dispersion. The deviation pattern is bidirectional: Revit generates lower costs than RAB for the Foundation (−6.76%) and 2nd Floor (−2.80%), but higher costs for the 3rd Floor (+1.55%) and 4th Floor (+2.73%). The 1st, 5th, and Roof Floors showed near-neutral deviations of +0.73%, −0.78%, and −0.80%, respectively. This two-way pattern suggests that the deviations are caused by structural and methodological factors rather than by a uniform systematic bias.

Table 13
Floor-Level Cost Comparison: RAB vs. Autodesk Revit 2023

No.	Work Package	RAB (IDR)	Revit (IDR)	Deviations	Deviation (%)
I	Foundation (volumetric basis: −8.67%)	161,730,803	150,800,594	(10,930,209)	-6.76

No.	Work Package	RAB (IDR)	Revit (IDR)	Deviations	Deviation (%)
1	Structure: 1st Floor	420,582,042	423,666,712	3,084,670	+0.73
2	Structure: 2nd Floor	656,566,230	638,153,213	(18,413,017)	-2.80
3	Structure: 3rd Floor	546,384,854	554,866,370	8,481,516	+1.55
4	Structure: 4th Floor	503,514,996	517,242,779	13,727,783	+2.73
5	Structure: 5th Floor	486,573,949	482,796,999	(3,776,950)	-0.78
6	Structure: Roof	200,631,719	199,031,039	(1,600,680)	-0.80
	TOTAL	2,975,984,594	2,966,557,706	(9,426,887)	−0.32

Note: deviation is computed as (Revit − RAB)/RAB × 100 for every row and for the aggregate; a positive value means Revit is higher. Revit figures for the 3rd, 4th and 5th Floors have been corrected in line with Table 11. The aggregate is small because floor-level deviations offset: the mean absolute floor-level deviation is 2.31% and the range is −6.76% to +2.73%. The foundation row carries two distinct measures, −6.76% on a cost basis and −8.67% on a volumetric basis (RAB 122.68 m^3 versus Revit 112.04 m^3); both are reported because the two are not interchangeable.

BIM Development Level Applied

Table 14 presents the Building Information Modeling (BIM) Level of Development (LOD) and LOD classification framework applied in this study. The justification for selecting LOD 300 is provided in the Methods (Phase 3) and is not repeated here; the table is provided as a reference framework situating that choice within the full LOD scale.

Table 14

Classification and Application of BIM Development Level (LOD) in This Study

LOD Rate	Description	Geometric Accuracy	Use of QTO	Applied in This Research
LOD 100	Conceptual mass	Low	Estimates only	No
LOD 200	Geometry approximation	Medium	Schematic forecasting	No
LOD 300	Precise geometry	High	QTO Construction	Yes
LOD 350	Connections included	High+	Detailed fabrication	No
LOD 400	Fabrication details	Very high	Shop drawings	No
LOD 500	As built	Verified	Facility management	No

Source: BIMForum, (2021); (Abdulaziz & Ahmed, 2026) Level of Development (LOD) Specification Part I & Commentary, 2021 edition, the edition current at the time of modelling.

Schedule Planning: S-Curve Analysis

Table 15 presents the distribution of the workload for each structural work package. The installation of wire mesh is the dominant cost element, with a cumulative weight of 42.90% of the total structural cost (4.50 + 9.89 + 8.48 + 8.48 + 8.48 + 3.08 = 42.91%; the 0.01-percentage-point difference is due to two-decimal rounding), reflecting a premium unit price of IDR 168,019.89/m^2. Tables 16 and 17 present the S-curve weekly progress schedule for a 24-week structural work program. The cumulative progress curve shows characteristics of a slow beginning (0.55% in Week 1 and 4.10% in Week 3), rapid mid-project acceleration (24.35% in Week 9 and 63.50% in Week 16), and tapering at project closure (99.92% in Week 23 and 100.00% in Week 24). The peak one-week progress occurred in Week 16, with a weight of 10.02%, corresponding to the intensive installation of wire mesh on the 2nd and 3rd Floors simultaneously. Weeks 18 (9.84%) and 19 (7.48%) were the second- and third-highest peak periods, respectively. These three peaks are not scheduling artifacts: Weeks 16 and 18 fall within the overlap of the Floor 2–4 windows, during which three wire mesh packages, each carrying 8.48–9.89% of the total cost (Table 14), are executed within a short span, while Week 19 closes the Floor 3 and Floor 4 windows simultaneously. The cumulative and weekly values agree throughout to within 0.01 percentage points, with the residual difference attributable to two-decimal rounding.

Table 15

Working Weight Distribution (Working Weight) for S-Curve Planning

Work Package	Cost (IDR)	Weight (%)
1st Floor: Pilecap Foundation	150,800,594.38	5.08
1st Floor: K-350 Concrete	101,113,782.58	3.41
1st Floor: Steel reinforcement	189,145,140.96	6.38

Work Package	Cost (IDR)	Weight (%)
1st floor: Wiremesh M10-150	133,407,788.73	4.50
2nd Floor: K-350 Concrete	123,854,496.39	4.18
2nd Floor: Steel Reinforcement	220,935,996.84	7.45
2nd floor: Wiremesh M10-150	293,362,719.30	9.89
3rd Floor: K-350 Concrete	115,404,178.97	3.89
3rd Floor: Steel Reinforcement	187,936,422.75	6.34
3rd floor: Wiremesh M10-150	251,525,767.92	8.48
4th Floor: K-350 Concrete	102,458,450.87	3.45
4th Floor: Steel Reinforcement	163,258,559.76	5.50
4th Floor: Wiremesh M10-150	251,525,767.92	8.48
5th Floor: K-350 Concrete	108,245,797.75	3.65
5th Floor: Steel Reinforcement	123,025,433.58	4.15
5th Floor: Wiremesh M10-150	251,525,767.92	8.48
Roof: K-350 Concrete	36,609,253.48	1.23
Roof: Steel reinforcement	71,018,968.26	2.39
Roof: Wiremesh M10-150	91,402,817.47	3.08
QUANTITY	2,966,557,705.83	100.00

Notes: (a) Cost figures are derived from the Revit-extracted quantities priced at the RAB tender unit-price analysis (AHSP) rates given in Table 2; Weight (%) = item cost ÷ total structural cost × 100. (b) The identical values for 3rd, 4th and 5th Floor wiremesh (IDR 251,525,767.92; 8.48%) are intentional and not a data-entry error: these three typical floors have identical slab areas of 1,497.00 m² (Table 10) and identical M10-150 specification, so 1,497.00 × IDR 168,019.89 returns the same figure. (c) All weights are rounded to two decimal places, so the column sums to 100.01% rather than exactly 100.00%.

Table 16

S-Curve Weekly Progress Plan – Weeks 1–12 (the 24-week programme is split across Tables 16 and 17 for page-width reasons only; the two tables form a single continuous schedule)

Description	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
Weekly(%)	0.55	0.89	2.66	2.83	3.39	2.45	2.18	3.16	6.25	4.10	5.73	4.69
Kumul. (%)	0.55	1.44	4.10	6.93	10.32	12.76	14.94	18.10	24.35	28.45	34.18	38.87

Table 17

S-Curve Weekly Progress Plan – Weeks 13–24 (continuation of Table 16)

Description	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24
Weekly(%)	4.19	5.05	5.37	10.02	5.79	9.84	7.48	3.24	6.43	1.25	2.38	0.08
Kumul. (%)	43.07	48.12	53.49	63.50	69.30	79.14	86.62	89.86	96.29	97.54	99.92	100.00

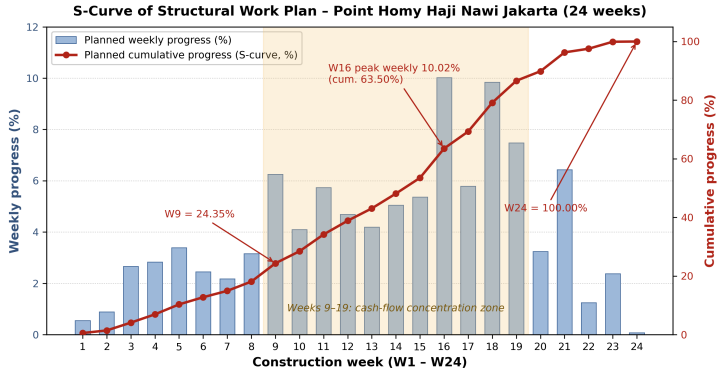


Figure 4. S-Curve of the structural work plan, simplified in response to reviewer comment to show only the planned weekly progress (bars, left axis) and the planned cumulative progress (line, right axis); the detailed numerical values remain in Tables 14–16. X-axis: construction week W1–W24; Y-axes: progress (%). Rendered at 300 dpi

Source: authors (2025)

Discussion

The empirical findings of this study confirm that Autodesk Revit 2023 provides a high-precision structural quantity takeoff with an aggregate cost deviation of −0.32% (Table 12) relative to conventionally prepared RAB documentation, although the mean absolute floor-level

deviation of 2.31% is the fairer basis for comparison with studies that report a single figure. To contextualize these findings within the broader literature, the 7% deviation reported by Farhana and Abma (2022) for 5D BIM structural estimation using PriMus and PriMus IFC software, rather than the native Revit Schedule/Quantity functionality, introduces additional data-translation steps that may have contributed to the higher deviation. The near-zero element-level deviation found by Kasuma and Beatrix (2022) for box culvert infrastructure reflects the geometric simplicity of the elements compared with the complex, multi-element structural systems modeled in this study. This study occupies an important methodological position between these extremes: it applies the native Revit quantity takeoff functionality, rather than plugins or third-party data exports, to complex residential-building structural systems, achieving an aggregate deviation substantially lower than the 7% threshold and demonstrating applicability to more architecturally complex building types than box-culvert takeoffs. The floor-level dispersion observed here also falls within the −0.9% to +2.4% error band reported by Khosakitchalert et al. (2019) for compound-element extraction and is consistent with the design-feedback requirement identified by Ren (2024) before model quantities can be relied upon for procurement. The overall accuracy of under 2% supports the use of BIM-derived cost estimates as a reliable decision-support tool for contractor bidding and owner contingency planning, without requiring the large safety margin associated with conventional estimates, at least for projects of this scale and documentation quality.

A detailed element-by-element analysis of the deviations between BIM and RAB provides additional insight into the structural sources of the differences. For concrete foundations, the difference of 10.64 m^3 (RAB: 122.68 m^3; Revit: 112.04 m^3; deviation: −8.67% by volume; the corresponding cost-based deviation reported in Table 12 is −6.76%, and the two figures are not interchangeable) was the largest absolute volume deviation in the study. An examination of the RAB documentation reveals that the conventional calculations include the volume of the tie beam (sloof) connecting the foundation elements, whereas the Revit model, consistent with the defined scope of the study, models only the discrete pile-cap elements (P1 to P6). This scope boundary accounts for the greater part of the deviation. The sloof/binding-beam ring in the DED runs 96.4 m at 200 × 400 mm, giving 96.4 × 0.20 × 0.40 = 7.71 m^3, to which the lean-concrete blinding beneath the pile caps adds approximately 1.1 m^3 at 50 mm over the 22.4 m^2 pile-cap footprint; together, these account for 8.8 m^3 of the 10.64 m^3 total, or 83%. The residual 1.84 m^3 is attributable to Revit's net-volume deduction at the pile-head embedment. Including the sloof and lean concrete within the foundation package is consistent with Indonesian RAB practice under SNI 7394:2008 for unit-price analysis of concrete work, which includes material tolerances for shrinkage and waste; thus, the difference between the two documents is primarily one of scope rather than measurement accuracy. For concrete blocks, the variation between floors is instructive: Floor 2 shows −2.80% (lower Revit quantity), whereas Floor 3 shows +1.55% (higher Revit quantity). This cross-floor variation reflects differences in the density of beam-column and beam-slab intersections on each floor. The second floor has a higher density of multi-beam intersections because of the layout of the tie beams at the first structural-floor level, where the reduction in Revit intersection volumes results in a more significant reduction in net volume. The third floor, which carries heavier loads than the upper floors, uses larger beam sections with longer clear spans; consequently, the proportionally smaller reduction in intersection volume, together with the higher reinforcement content precisely captured by Revit's reinforcement modeling, results in higher costs. A specific analysis of these elements allows the construction quantity surveyor to understand not only the aggregate deviations but also their structural origins, supporting an appropriate assessment of when additional corrections to BIM outputs should be applied for contractual purposes.

Two main technical mechanisms explain the observed pattern of floor-level deviation. The first is the difference in modeling fidelity between 3D parametric geometry and 2D interpretation. Revit calculates element volumes from actual parametric geometry, automatically resolves intersections at column-beam-slab interfaces, and calculates net volumes that exclude overlapping materials. This results in lower concrete volumes in the most prominent multi-element connection zones for the foundation (−10.64 m^3 relative to the RAB) and second-floor beams because Revit avoids the double counting that can occur when RAB calculations treat

columns, beams, and slabs as independent elements without overlap deductions. Prasetyono and Suharianto (2023) state the principle directly: Revit computes net volume wherever structural elements intersect. Khosakitchalert et al. (2019) demonstrate the same mechanism for compound elements and show that it is a dominant source of systematic difference between model-based and drawing-based takeoff (Mahardika & Windari, 2025). For reinforcement, Revit's element-by-element reinforcement modeling captures precise anchorage extensions, splice or connection lengths, and bent-tail dimensions that may exceed those represented in simplified factor-based RAB calculations, explaining the higher Revit reinforcement weights for Floors 3 and 4 (Table 9: 7,306.68 kg and 6,105.54 kg of beam reinforcement, respectively), compared with RAB cost lines that price these floors 1.55% and 2.73% below the Revit figures, respectively (Table 12).

The second mechanism concerns additional factors embedded in the preparation of conventional RAB through the SNI/BOW analysis methodology. These include concrete waste allowances, formwork tolerance adjustments, and material-overlap provisions that are absent from Revit's geometry-based extraction. In the RAB examined here, these allowances follow the material coefficients of SNI 7394:2008 for unit-price analysis of concrete work, in which material indices include tolerances for shrinkage and waste. For wire mesh, the lap allowance should be distinguished from a generic 10–15% area allowance: SNI 2847:2019 Clause 25.5.3 specifies lap-splice requirements for deformed welded wire reinforcement in tension, including a minimum splice length determined by the applicable development-length provisions and the stated conditions of the clause. The total wire-mesh deviation of 201.50 m^2 (RAB: 7,776.50 m^2 versus Revit: 7,575.00 m^2), equivalent to 2.59% of the modeled area, is therefore better interpreted as reflecting the installation and estimation conventions embedded in the RAB, including allowances for laps, waste, cutting, and trimming, rather than as a direct application of the SNI lap-splice requirement. Jonathan and Anondho (2021) documented a similar pattern in the calculation of reinforced-concrete slabs, attributing excessive RAB estimates to conservative waste assumptions (Ija et al., 2026).

The S-curve analysis provides additional insights for construction risk management. The peak weekly weighting of 10.02% in Week 16 (Table 16), corresponding to the simultaneous wire-mesh installation on Floors 2 and 3, represented the highest resource-mobilization intensity in the project. The progressive cost concentration between Weeks 9 and 19 (from 24.35% to 86.62% cumulatively) creates a specific cash-flow risk if procurement planning does not account for the accelerating cost curve, since 62.27 percentage points of the total structural value fall due within an eleven-week window (Figure 4). Amin Ranjbar et al. (2021) show that this is precisely the exposure that a 5D BIM cost-loaded schedule can quantify in advance rather than reveal in arrears (Didar et al., 2026). BIM-based S-curve generation, as demonstrated here, allows project managers to anticipate these patterns more precisely than by relying on uniform linear or generic S-curve assumptions. The link to design revision is direct: each revision cycle that is avoided is a cycle that does not push work out of its planned week and into the Week 9–19 peak, where the marginal cost of delay is highest. Saputra et al. (2022) found that BIM integration can reduce shop-drawing-related delays by about 30%, a benefit that applies directly to Point Homy scenarios in which drawing revisions cause multicycle reestimation delays and therefore acts on the cash-flow risk identified above rather than on program duration alone.

The broader implications of these findings for digital transformation in Indonesia's construction risk management are significant. Cost overrun is a persistent problem in Indonesian construction, and inaccurate budgeting and resource planning are ranked by project owners as the single most influential cause of delay, ahead of land acquisition, price escalation, and weather (Susanti, 2020; Yimer, 2025). The magnitude of the overrun is not reported consistently across studies, and no single national figure is defensible; what the literature does support is that estimation error at the planning stage is a leading contributor. The study shows that BIM-based QTO can reduce estimate variance to below 1% in aggregate, with a floor-level spread below 3%, which, if replicated at scale, could reduce contingency-reserve requirements and improve bid accuracy. From a risk-management perspective, the automatic propagation of design changes through BIM quantity schedules directly addresses a common source of estimation risk in projects with evolving designs: the need to manually reestimate quantities each time a drawing is revised. In the Point Homy scenario, the initial design modification that triggers a multicycle reestimation

requires only one model update in Revit, with all quantity schedules, cost summaries, and S-curve weights updated automatically. This capability represents not only an efficiency gain but also a fundamental form of risk mitigation: it reduces the manual judgment required to determine which elements are affected by design changes, thereby reducing a common source of human error in manual reestimation.

The international relevance of these findings extends beyond the Indonesian context. The Asia-Pacific construction sector is characterized by rapid urbanization, complex multistory building programs, and limited investment in digital construction tools. The reference previously cited here (Dalir et al., 2025; Wang et al., 2020) reported no quantified risk reduction and did not appear in the reference list; it has therefore been withdrawn. In its place, Numan (2024) reviews the evidence on BIM and construction risk across jurisdictions and concludes that the reliability of quantitative risk analysis improves with the level of detail of 4D/5D models, while noting that reported effect sizes vary widely and are rarely comparable across studies. The mechanism proposed here, elimination of 2D-to-3D interpretation ambiguity, is therefore presented as a plausible transferable mechanism rather than as a quantified cross-sector finding. The deviations below 2% documented in this study for six-story heterogeneous residential buildings in Jakarta are consistent with the accuracy levels reported in the global BIM literature and provide region-specific evidence that Indonesia's construction practices can achieve internationally comparable digital-delivery standards. Fitriani et al. (2021) reported that Indonesian AEC companies cited the top barriers to BIM adoption as lack of trained personnel (85%), software costs (78%), and hardware requirements (71%); these percentages are reported as stated in the study, in descending order of frequency (Mahardika & Windari, 2025). The demonstration in this study of measurable accuracy improvements at LOD 300 using standard Revit licenses and mid-level user training directly addresses the cost-benefit uncertainties that hinder adoption decisions by showing that the increased accuracy of a single project's estimate (corrected budget allocation of Rp9.4 million) can, in itself, justify investment in BIM implementation for projects of comparable scale.

The reviewers correctly observe that the analysis so far demonstrates quantity and cost accuracy rather than risk management as such and that the two should not be conflated. Stated precisely, this study does not perform a risk assessment: no risk register was compiled, no probability or impact was scored, and no mitigation measure was implemented or monitored on site. What the workflow does provide is an input to three of the four standard risk-management activities, and it is worth setting out which activities are supported and how, because this distinction determines what the title can legitimately claim. Identification is supported because floor-level and element-level attribution exposes where estimate error originates instead of reporting a single aggregate value; analysis is supported because the deviation is decomposed into scope, geometry, and allowance components, with a magnitude attached to each; and monitoring is supported because the cost-loaded S-curve provides a quantified baseline against which schedule and cash-flow variance can be tracked. Mitigation and response, by contrast, remain outside the evidence of this study: whether a contractor who adopts this workflow actually experiences fewer overruns is a question that a single descriptive case study cannot answer.

The implications of this research extend across three domains: project management practice, industry policy, and educational curriculum. For project management practitioners, the finding of an aggregate deviation of −0.32%, with floor-level deviations within ±3%, provides a quantified justification for adopting BIM-based QTO as the primary quantity-estimation methodology for high-rise housing projects of comparable scale and complexity. For industrial policy, the evidence base from this study supports three specific recommendations to the Ministry of Public Works and Public Housing (Kementerian PUPR). These are offered as propositions for testing rather than as conclusions established by a single case study. Current BIM mandate threshold of 2,000 m^2 for government buildings, set by PUPR Minister Regulation No. 22/PRT/M/2018, Article 6 (PUPR, 2021; Syafii & Azhari, 2025), should be accompanied by standard QTO accuracy benchmarks, such as the sub-2% aggregate deviation shown here, that must be achieved through BIM implementation to meet the regulatory intent.

CONCLUSION

This study demonstrates, for the single case examined, that Autodesk Revit 2023 can support automated structural quantity take-off and integrated schedule planning for multi-story building projects. Through the parametric BIM model of the Point Homy Haji Nawi Jakarta building, which includes seven foundation types, ten column types, thirteen beam types, and three slab specifications across six structural levels, this study produces a 5D BIM output with an aggregate cost deviation of −0.32% (Rp 9,426,887.17 against a structural scope of Rp 2.976 billion), with a mean absolute floor-level deviation of 2.31%. The findings suggest that a validated LOD 300 model can serve as a primary quantity-estimation instrument at this project scale. The deviation analysis showed a two-way pattern: Revit resulted in lower net volume calculations in areas of element intersection, especially at the foundation (−6.76% on a cost basis, equivalent to −8.67% volumetrically the two figures reported earlier in the Discussion and the Conclusion represent the same finding expressed on different bases, not a discrepancy) and on the 2nd Floor (−2.80%), while more precise reinforcement modeling resulted in higher values on the 3rd Floor (+1.55%) and 4th Floor (+2.73%). The wiremesh difference likewise reflects lap and installation allowances included in the conventional RAB but absent from geometric extraction. The detailed figures supporting each of these statements are given in Tables 11 and 12 and are not repeated here.

In addition to cost estimation, this study also shows that 5D BIM integration can produce a more systematic, cost-based 24-week S-curve schedule. Wiremesh installation was the dominant component, with a weight of 42.90% of the total structural cost (Table 14, wiremesh rows: 4.50 + 9.89 + 8.48 + 8.48 + 8.48 + 3.08 = 42.91%, the 0.01 percentage-point difference being attributable to two-decimal rounding), while the highest weekly progress occurred in Week 16, at 10.02%. The resulting curve concentrates 62 percentage points of structural value between Weeks 9 and 19 (Tables 15–16, Figure 4). These findings reinforce the benefits of BIM for cash-flow planning, material procurement, and project resource mobilization. In terms of policy, the aggregate cost deviation of −0.32% recorded here, together with the floor-level spread of ±3%, is the specific evidence on which the following proposition rests: it supports the expansion of BIM implementation in the spirit of PUPR Minister Regulation No. 22/PRT/M/2018, including in large-scale private housing projects, although a single case cannot by itself justify a regulatory change. Four directions for further research follow, in order of priority. The most urgent and feasible is multi-project replication across comparable multi-story residential buildings, since this is the only way to convert the present analytical generalization into a defensible benchmark. Second, and equally feasible, is comparison of BIM estimates against as-built records, which would test whether planning-stage accuracy persists through construction. Third, extension of the scope to MEP, architectural, and civil packages would establish whether the accuracy observed for structural work holds where element geometry is less regular. Fourth, and least urgent because it addresses a moderating rather than a primary variable, is examination of the effect of modeler experience on QTO accuracy.

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AUTHOR CONTRIBUTION STATEMENT

Maulidya Octaviani Bustamin: Conceptualisation; Methodology; Validation; Supervision; Writing – Review & Editing; Project administration. Anindias Goldawan Anugrah: Conceptualisation; Software (Autodesk Revit 2023 modelling and quantity extraction); Investigation; Data curation; Formal analysis; Visualisation; Writing – Original Draft. Indra Komara: Methodology (structural engineering framework); Validation; Writing – Review & Editing. All authors have read and agreed to the published version of the manuscript. Role descriptions follow the CRediT (Contributor Roles Taxonomy) terminology. Maulidya Octaviani Bustamin is the corresponding author.

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