Building Information Modeling Using Cubicost TME for Electrical Quantity Take-Off and Website-Based Cost Estimation at BTN Ecopark Gandul

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Abstract: Conventional quantity take-off (QTO) of electrical works relies on two-dimensional drawings and cannot capture the actual three-dimensional routing of feeder cables, cable trays, and cable ladders, causing volume and cost inaccuracy. This research optimizes electrical works QTO using Building Information Modeling (BIM) Cubicost Take-off for Mechanical and Electrical (TME) and implements the validated results into a website-based cost estimation system. Its novelty is an applied, integrated workflow connecting Cubicost TME-based electrical QTO, engineering verification under the General Requirements for Electrical Installations (PUIL) 2020/SNI 0225:2020, and web-based cost reporting within a single Indonesian case study; although each component is established, their end-to-end integration for electrical works is rarely reported. The contribution is a reproducible workflow that converts model-derived quantities into standard-verified, openly accessible cost information, repositioning engineering validation as an integral gate within QTO. Using a quantitative descriptive-comparative method at the BTN Ecopark Gandul project, the installation was modeled three-dimensionally and validated through voltage drop, ampacity, and power demand calculations. On the conventional baseline, BIM-based cable volumes are 8.59% lower with an identical panel count, and the BIM cost estimate is 3.95% lower; all routes satisfy the 5% voltage drop limit, peaking at 1.641%. On an equivalent net basis (after removing the 5% waste allowance present only in the conventional data), the volume deviation narrows to 4.02%, showing that about half of the gross gap reflects the waste allowance and the remainder genuine routing differences; the cost difference is thus an estimated, case-specific figure, not a confirmed saving.

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Introduction

The construction of buildings increasingly demands efficiency at every stage, from planning to execution. Building Information Modeling (BIM) supports this through three-dimensional modeling that captures complete information on construction elements, including dimensions, materials, and quantities (Eastman et al., 2011; Borrmann et al., 2020). In Indonesia, BIM use is mandated for state buildings larger than 2,000 m² and higher than two floors through Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR) Regulation Number 22/PRT/M/2018 (PUPR, 2018). Nevertheless, BIM adoption in electrical works remains limited: conventional quantity take-off (QTO) is typically performed manually from two-dimensional drawings, measuring feeder cable, cable tray, and cable ladder lengths from drawing scales without accounting for actual routing (bends, vertical risers, and structural adjustments), which is prone to volume inaccuracy. Although existing literature confirms that BIM-based QTO improves speed and accuracy, key limitations remain. Structural-level comparisons often overlook the complex routing required for electrical systems (Rahayu & Suseno, 2023). Furthermore, reported speed and efficiency gains frequently lack technical validation against electrical engineering standards (Anindya & Gondokusumo, 2020; Khalis, 2024), while other 5D BIM applications fail to link output data with accessible reporting platforms (Husin et al., 2020; Mahendra et al., 2023; Zahro et al., 2021). Consequently, previous works generally accept raw model outputs without incorporating mandatory technical verification or multi-stakeholder data sharing Cable length also carries direct electrical-engineering consequences: it is a key parameter in voltage drop, which under PUIL 2020/SNI 0225:2020 must not exceed 5% of nominal voltage, enforced as a mandatory standard through Kementerian Energi dan Sumber Daya Mineral (ESDM) Regulation (2018). Power demand recapitulation likewise underlies the connected-capacity application to PT PLN (Sugianto & Muis, 2021). Prior studies calculate these checks (Sumarno et al., 2024; Andriyan & Winarso, 2021; Cholish et al., 2020), but as stand-alone analyses disconnected from the QTO that produced the cable lengths in the first place a disconnection this research closes by using these calculations as a verification gate for BIM-derived quantities. Electrical cost estimation results are also commonly presented as static documents such as spreadsheets, limiting accessibility. Web-based systems have simplified centralized project-data presentation (Darmawan & Ratnasari, 2020) and cost-estimation management (Agusti et al., 2024), and automated BIM-based cost estimation has been demonstrated (Farooq & Sreerama Kumar, 2018); none, however, combine a BIM-based QTO source, standard-based verification, and web-based reporting in one workflow the gap this research addresses. Rather than proposing a new modeling algorithm, this study offers novelty through an applied, integrated workflow. It bridges Cubicost TME-based electrical QTO, engineering compliance under PUIL 2020/SNI 0225:2020, and web-based reporting into a single framework applied to the BTN Ecopark Gandul project. Based on this gap, the research aims to: (1) optimize the QTO of electrical works at BTN Ecopark Gandul using BIM Cubicost TME and compare results with the conventional method; (2) verify the resulting quantities via voltage drop, ampacity, and power-demand calculations referring to PUIL 2020/SNI 0225:2020; and (3) implement the validated quantity and cost results into a website-based cost information system and evaluate its functionality.

Research Method

Research Design

This research uses a quantitative descriptive-comparative approach with a single case-study strategy, appropriate for objectively measuring, comparing, and analyzing verifiable numerical data cable lengths, voltage drop, ampacity, power demand, and cost estimates (Sugiyono, 2019) in a real-life context (Yin, 2018). The process (Figure 1) proceeds: (1) literature and technical-document study; (2) three-dimensional BIM modeling and QTO extraction in Cubicost TME; (3) comparison of BIM-based and conventional QTO; (4) technical validation via voltage drop, ampacity, and power-demand calculations, with an iterative check that triggers re-examination of non-conforming results; (5) preparation of the bill of quantities (RAB); and (6) implementation into a website-based information system with functional testing.

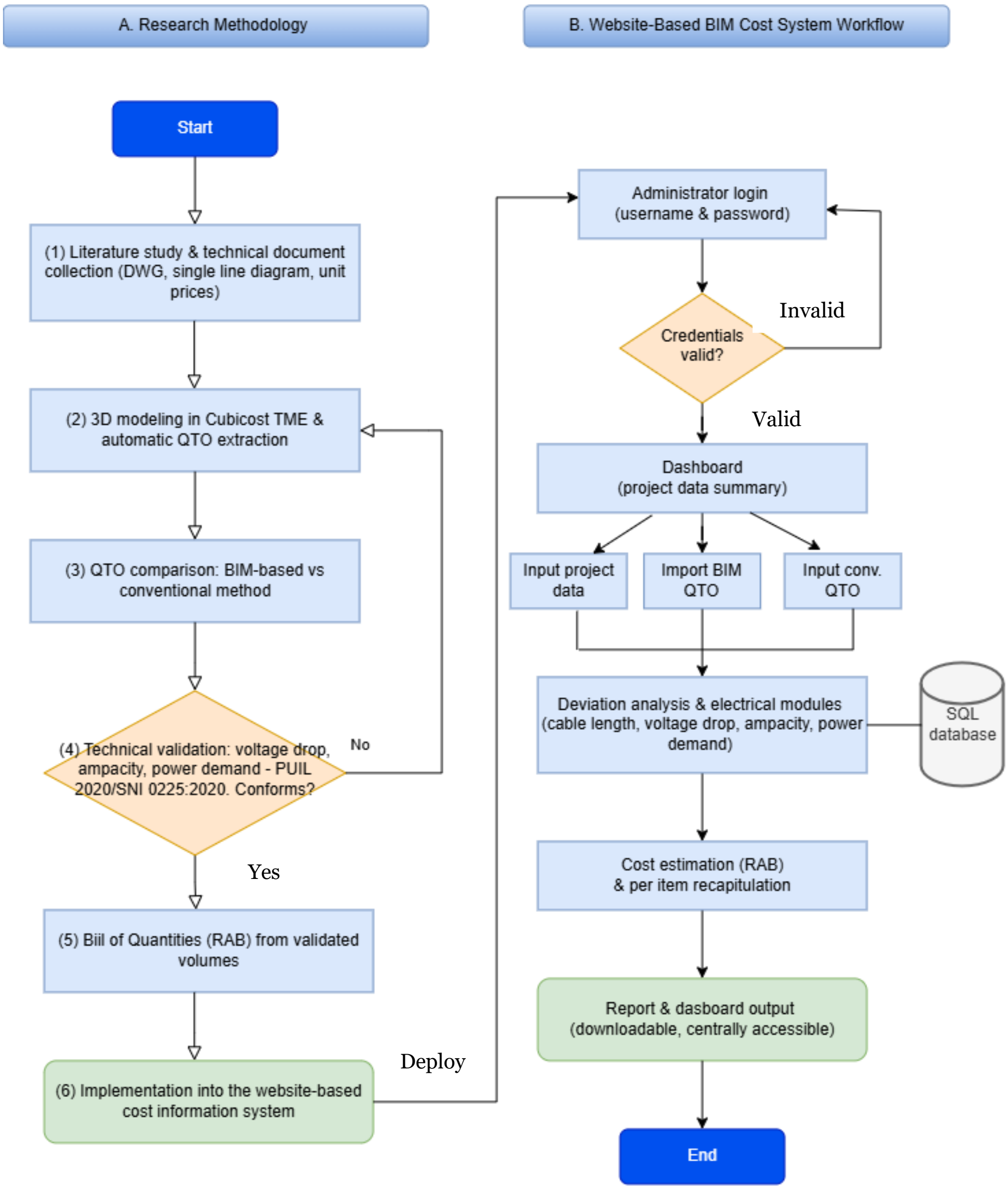

Figure 1 Workflow of the website-based BIM cost system

Research Object and Its Representativeness

The research object is the BTN Ecopark Gandul project in Gandul, Cinere, Depok, West Java a high-rise mixed-use development eligible for mandated BIM use, whose cable routing (ceiling runs, shaft risers, 90-degree bends) exposes the three-dimensional conditions under which 2D-based QTO is expected to deviate. Complete DWG working drawings support comprehensive modeling. As a single, purposively selected case, it supports analytical rather than statistical generalization; findings should be transferred to projects with comparable routing complexity and documentation quality.

Data Collection

Data were collected between November 2025 and February 2026. Primary data came from the Cubicost TME modeling process: automatic QTO output (feeder cable, cable tray, and cable ladder lengths per segment), panel counts/types, and the electrical bill of material. Secondary data came from project technical documents: DWG drawings (revision LAK 401–407, dated 26 July 2025), single line diagrams, Supreme cable-catalogue resistance/reactance values, panel load recapitulation, and AHSP PUPR (Direktorat Jenderal Bina Konstruksi, 2025) unit prices. Observed variables were cable length, cross-section, load current, voltage drop, corrected ampacity, power demand, and unit cost, limited to feeder cables, cable trays, cable ladders, and power panels. Project documents were used with the project team's permission for academic purposes, with commercially sensitive figures reported only as needed to reproduce the analysis.

Conventional QTO Procedure and BIM Modelling Protocol

The conventional QTO was measured on-screen in AutoCAD from drawing revision LAK 401–407 (1:100 scale): horizontal lengths from floor plans, vertical drops/risers from section heights, 90-degree bends as straight segments, a 0.5 m termination slack, lengths rounded to the nearest 0.5 m, and a uniform 5% waste factor — consistent with the contractor's bill of quantities (BoQ) practice — prepared by one estimator with ten years of MEP experience and cross-checked against the contractor's BoQ. The BIM model was built in Cubicost TME 2021 (Glodon) v.1.0.0.800 on the same drawing revision, scale-calibrated per floor, at cable-route and cross-section level with a 10 mm snapping tolerance, no clash check (single discipline), visual review against the single line diagram, and export to Excel by cable type and cross-section. Modeled routes follow the working drawings rather than site-verified as-built conditions. Unlike the conventional figures, BIM quantities are net modeled lengths excluding the termination slack and waste allowance; this basis difference is reconciled in Table 1.

Calculation and Validation Methods

QTO results of both methods were compared per category, with percentage deviation calculated relative to the conventional volume. BIM-based cable lengths were then used as inputs for technical validation: voltage drop was calculated by equations (1)-(2) (Badan Standardisasi Nasional, 2022; International Electrotechnical Commission, 2009)

$$\Delta V = \sqrt{3 \, x \, I \, x \, L \, x \, (R \cos\varphi + X \sin\varphi} \quad (1)$$

$$\%\Delta V = (\Delta V / V_{nominal}) x \, 100\% \quad (2)$$

where ΔV = voltage drop (V); I = load current (A); L = one-way cable length (km); R, X = conductor resistance/reactance (Ω/km); cosφ = 0.85; V_nominal = 380 V (LV) or 20 kV (MV). Conductors are copper, with R and X from the Supreme cable catalogue at 70–90 °C operating temperature. Results were evaluated against the 5% PUIL 2020 clause 525 limit. Ampacity was checked via equation (3), with design load current from equation (4) (Badan Standardisasi Nasional, 2022):

$$I_b \leq I_n \leq I_z \quad (3)$$

$$I_b = P/\sqrt{3 \, x \, V_{LL} \, cos\varphi} \quad (4)$$

where Ib = design load current (A); In = protective-device rating (A); Iz = corrected ampacity (A), from PUIL 2020 clause 523 with temperature/grouping correction; P = load power; V_LL = line-to-line voltage. Power demand recapitulation summed panel loads on the PDTR (equation 5) (Sugianto & Muis, 2021), and cost estimation multiplied each validated volume by its unit price (equations 6-7) (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2018)

$$S_{total} = \sum\left(\frac{P_{beban}}{cos\varphi}\right)[kVA] \quad (5)$$

$$Cost_i = Volume_i x HSP_i \quad (6)$$

$$RAB_{total} = \sum Biaya_i \quad (7)$$

For the balanced three-phase circuits, the one-way cable length is used together with the √3 factor; single-phase branches such as the UPS route were treated separately with the appropriate single-phase relation, and because their drop is small (1.013%) this does not affect the overall conclusion.

Website Based Cost Information System

The validated QTO and cost estimation results were implemented into a website-based cost information system with a standard three-tier architecture: a client interface, an application/API layer, and a relational database holding project, QTO, validation, and cost-estimate tables. Role-based access control separates administrator, engineer, and viewer roles at both module and data levels. Input-validation rules constrain uploaded QTO and price data to expected types, ranges, and completeness before they are written to the database, and BIM-to-database traceability logs preserve a record from each Cubicost TME export field to its corresponding database entry and displayed report value, supporting auditability. These elements were verified functionally, as reported in the Website Implementation subsection of Results and Discussion.

Result and Discussion

Quantity Take-Off Comparison

The electrical installation was modeled by importing the DWG working drawings into Cubicost TME, producing three-dimensional cable routing for feeder cables, cable trays, and cable ladders across all floors of both towers.

Table 1 Deviation of electrical work quantities between Cubicost TME and the conventional method

No	Item category	Cubicost	Conventional	Deviation	Dev. %
1	Feeder cable (m)	1,760.24	1,922.30	-162.06	-8.43%
2	Cable tray (m)	191.50	215.00	-23.50	-10.93%
3	Cable ladder (m)	68.70	73.00	-4.30	-5.89%
4	Panel (unit)	30	30	0	0.00%
	Total cable (m)	2,020.44	2,210.30	-189.86	-8.59%

Based on Table 1, the BIM-based QTO gives smaller cable volumes in every category, a total of 2,020.44 m versus 2,210.30 m conventionally (−8.59%), with an identical panel count. The difference concentrates in cable tray, and the identical panel count indicates the deviation lies in length estimation rather than component count — the basis for the reconciliation in Table 2.

Table 2 Reconciliation of BIM and conventional cable quantities on an equivalent net basis

Category	BIM net (m)	Conv. gross, +5% (m)	Conv. net (m)	Gross dev.	Net dev.
Feeder cable	1,760.24	1,922.30	1,830.76	-8.43%	-3.85%
Cable tray	191.50	215.00	204.76	-10.93%	-6.48%
Cable ladder	68.70	73.00	69.52	-5.89%	-1.18%
Total	**2,020.44**	**2,210.30**	**2,105.05**	**-8.59%**	**-4.02%**

On this equivalent net basis, the total deviation narrows from −8.59% to −4.02%. About half of the gross gap is attributable to the 5% waste allowance present only in the conventional data, and the remainder reflects genuine three-dimensional routing differences.

Voltage Drop Evaluation

Using equations (1)– (2) against 380 V (and 20 kV for the MV segment), Table 3 presents the main routes.

Table 3 Voltage drop of the main routes based on BIM QTO lengths

No	Route	Size	L (m)	I (A)	ΔV (V)	%ΔV
1	PLN substation → MV cubicle (20 kV)	120 mm²	230	23.64	1.52	0.008%
2	Transformer → PDTR (2 parallel)	300 mm²	19.3	1,244.22	1.72	0.453%
3	PDTR → SDP.AC	240 mm²	37.0	286.83	1.76	0.463%
4	PDTR → P. OU.VRF	240 mm²	91.0	253.73	3.83	1.007%
5	PDTR → SDP.1	95 mm²	36.5	100.74	1.28	0.337%
6	PDTR → SDP. PUMP	95 mm²	24.5	80.83	0.69	0.181%
7	PDTR → SDP. ROOF	50 mm²	69.7	32.42	1.43	0.377%
8	PDTR → P. FIRE	FRC 70 mm²	78.2	73.29	2.63	0.691%
9	PDTR → P. AL	FRC 16 mm²	79.0	44.69	6.24	1.641%
10	PDTR → UPS 2 kVA (1φ)	2.5 mm²	19.3	9.09	2.23	1.013%

All routes are far below the 5% limit of PUIL 2020/SNI 0225:2020, the highest being 1.641% on the PDTR → P. AL route (FRC 16 mm², 79 m). The cross-sections therefore satisfy the voltage drop requirement. To assess the worst-case condition, the cumulative voltage drop was also evaluated along the full supply chain to the most critical feeder, PDTR → P. AL, since the final load experiences the sum of the drops across every segment it is fed through rather than the drop of the last segment alone. Summing the drops from the PLN source through the transformer and the PDTR to the final load — 0.008% (PLN → MV cubicle) + 0.453% (transformer → PDTR) + 1.641% (PDTR → P. AL) — gives a cumulative voltage drop of 2.102%, which remains well below the 5% limit of PUIL 2020 clause 525. This confirms that even the electrically most distant load satisfies the voltage drop requirement once the complete source-to-load path is considered, not only the final segment.

Current-Carrying Capacity (Ampacity) Evaluation

The ampacity evaluation shows Ib ≤ Iz on all routes. However, the nominal breaker rating exceeds the derated ampacity on some large feeders, so full protection coordination cannot be confirmed until the thermal setting (Ir) is verified not to exceed Iz; status is therefore reported as Pass/Conditional per route. This conditional status reflects PUIL 2020 practice of distinguishing cable ampacity compliance from breaker coordination, which requires confirmed thermal settings beyond this study's scope.

Power Demand Recapitulation and PLN Capacity

Table 4 Power demand recapitulation and PLN connected capacity determination

No	Load group / panel	Power (kVA)	Remarks
1	SDP.AC (cooling panels P.AC-1 to P.AC-5)	188.78	cosφ 0.85
2	P. OU.VRF (outdoor VRF)	167.00	cosφ 0.85
3	SDP.1 (lighting & power)	66.31	cosφ 0.85
4	SDP.PUMP	53.20	cosφ 0.85
5	P. FIRE	48.24	cosφ 0.85
6	P. AL	29.41	cosφ 0.85
7	SDP.ROOF	21.33	cosφ 0.85
8	UPS 2 kVA	2.00	cosφ 1.0
9	Other direct loads on PDTR	242.65	aggregate
	Total installed power (PDTR)	818.92	≈ 1,244.22 A
	Total actual power demand	488.94	load recap
	PLN connected capacity	555	PLN standard
	Transformer capacity	630	standard
	Demand factor (actual demand ÷ installed load)	0.60	488.94 / 818.92

Total installed power on the PDTR is 818.92 kVA (≈ 1,244.22 A at 380 V), while actual (maximum) demand is 488.94 kVA, giving a demand factor of 0.60 (488.94/818.92) — correcting an earlier value that conflated this ratio with the PLN-contract-to-installed-load ratio. This demand is adequately served by the 555 kVA PLN connected capacity and 630 kVA transformer (Table 4).

Cost Estimation

The validated volumes were multiplied by AHSP unit prices to produce the RAB. Table 5 compares the BIM-based and conventional cost estimates.

Table 5 BIM-based electrical works cost estimate versus the conventional method

No	Work item	BIM cost (Rp)	Conv. cost (Rp)	Difference (Rp)	Dev. %
1	Feeder cable (incl. excavation & backfill)	1,622,569,031	1,812,587,726	190,018,695	10.48%
2	Cable tray & ladder	103,525,156	121,228,763	17,703,607	14.60%
3	Panel	3,326,235,704	3,326,235,704	0	0.00%
	TOTAL	5,052,329,891	5,260,052,194	207,722,303	3.95%

The total BIM-based RAB of Rp 5,052,329,891 is Rp 207,722,303 lower than the conventional RAB of Rp 5,260,052,194 (3.95%). This is an estimated cost difference, not a confirmed saving or an efficiency improvement, since it has not been verified against procurement or final-account data and inherits the non-equivalent quantity basis discussed under Table 1. The difference concentrates in cable tray, and ladder works (14.60%) and feeder cables (10.48%); the panel cost is identical because the panel count is the same. The cost estimation methodology adopted in this study is based on the Indonesian Standard Unit Price Analysis (Analisis Harga Satuan Pekerjaan—AHSP) issued by the Ministry of Public Works and Housing (PUPR) and applicable at the time the research was conducted, using material unit prices and labor costs adjusted to the project region. The cost components considered in the analysis include material, labor, and equipment costs required for building electrical installation works. In addition, the cost calculation incorporates overhead costs, contractor profit, and applicable taxes in accordance with prevailing regulations. For cable installation works, the conventional method applies a 5% waste allowance to account for material requirements arising from cutting, cable termination, and material losses during the installation process, whereas the BIM-based method utilizes net modeled cable lengths obtained from the three-dimensional model without including the waste allowance. This study does not consider price escalation factors because all cost estimations are based on unit prices from the same reference period. Furthermore, excavation and backfill costs for feeder cables are excluded from the analysis, as the scope of the study is limited to internal building electrical installations. Unit prices were validated against prevailing market prices for the dominant cable and panel items, and a sensitivity analysis varied route length (±5%), waste allowance (0–10%), and unit prices (±10%); the quantity and cost differences remained relatively stable across scenarios. Power factor and ampacity correction were excluded from this sensitivity analysis, as they affect the technical checks rather than QTO and cost directly.

Website Implementation

The QTO and cost estimation results were implemented into the website-based cost information system described in Research Method. The dashboard presents QTO, deviation-analysis, voltage-drop, ampacity, power-demand, and cost-estimation modules, alongside a PDF report-generation function. Usability and acceptance testing with 20 participants produced a System Usability Scale (SUS) score of 87.5 and a 95% acceptance rate. Response-time testing averaged 1.12 s (maximum 2.48 s) across Chrome, Firefox, Edge, and Opera. Security controls include role-based access, input validation, and daily automated backups with restoration testing. Functional verification (Table 7) confirmed correct behavior across data import, cost calculation, RAB totaling, access control, and dashboard-report consistency.

Discussion

The findings demonstrate a sequential process: net quantities generated by BIM are first verified for voltage drop, ampacity, and power demand under standard regulations before being processed for cost estimation and web deployment. This structure emphasizes verification and data accessibility rather than claiming absolute quantity accuracy over manual methods. These testing outcomes confirm that the web platform maintains full traceability from the BIM export to the database, ensuring consistent and auditable cost reporting for project stakeholders.

Table 6 Comparison of previous studies and the findings of this research

Previous study	Focus	Reported result	This research
Anindya & Gondokusumo (2020)	MEP QTO, process speed	Up to 58% faster; ±3% difference	−8.59% deviation, plus technical validation
Rahayu & Suseno (2023)	Structural QTO	Small deviation	Extended to three-dimensional electrical routing
Khalis (2024)	5D BIM, electrical works)	Improved accuracy, no standard validation	Validated against PUIL 2020/SNI 0225:2020
Husin et al. (2020)	MEP QTO, high-rise	3.56% cost efficiency	3.95% cost efficien

Previous study	Focus	Reported result	This research
Mahendra et al. (2023)	BIM cost estimation	3.45% lower than conventional	3.95% lower than conventional
Farooq & Sreerama Kumar (2018)	Automated BIM estimation	No web presentation layer	Integrated web-based system
Agusti et al. (2024)	Web cost platform	No BIM QTO data source	Data sourced from BIM QTO

Compared with prior studies, the −8.59% figure is not directly comparable with the ~3% differences reported for structural or general-MEP comparisons (Anindya & Gondokusumo, 2020; Rahayu & Suseno, 2023), since the present figure is electrical, three-dimensional, and partly driven by a waste allowance that must still be reconciled. This work adds value in that its cost figure derives from quantities that first passed a mandatory-standard check (Khalis, 2024) and are then exposed through a data-linked web layer (Farooq & Sreerama Kumar, 2018 ; Agusti et al., 2024). Theoretically, the work reframes engineering validation as an integral gate within quantity take-off rather than a downstream check. Practically, it indicates how BIM implementation in Indonesian electrical works could evolve toward standard-verified, stakeholder-accessible reporting. This research has limitations: a single case study, so generalization must consider differences in routing, complexity, and loads; a scope limited to feeder cables, trays, ladders, and panels; QTO accuracy dependent on modeling quality and DWG completeness; assumptions such as cosφ = 0.85 and PUIL correction factors; and a web system limited to presentation, input, and reporting without real-time BIM integration. Because the comparison basis has not yet been fully equalized and no as-built or procurement reference was available, the differences are reported as case-specific estimates rather than proven accuracy or savings.

Table 7 Website verification test cases

No	Scenario / input	Expected result	Actual result	Status
1	Import BIM QTO file for project X	Segment cable lengths stored identically to source	The system successfully imported the BIM QTO file and displayed the cable quantities in the QTO feeder cable, ladder, and tray cable, and QTO panel module.	Pass
2	Per-item cost = volume × unit price	Matches manual computation	The system automatically calculated each item cost by multiplying the volume by the unit price, and the	Pass

No	Scenario / input	Expected result	Actual result	Status
			displayed result matched the manual calculation.	
3	Total RAB recapitulation	Σ item cost equals displayed total	The system correctly calculated the total RAB, and the displayed total equalled the sum of all item costs.	Pass
4	Login with invalid credentials	Access denied; error shown	The system rejected the login attempt and displayed an "invalid username or password" error message.	Pass
5	Dashboard figures vs downloaded report	Identical values (see MC-03)	The dashboard values were consistent with the downloaded report, with no differences found.	Pass

As shown in Table 7, the website-based cost information system was verified through five functional (black-box) test cases covering the core data-processing and access-control paths of the application. Every scenario returned the expected result, so all cases were recorded as Pass. The first three cases confirm the integrity of the quantitative pipeline: the imported BIM QTO segment lengths were stored identically to the source, the per-item costs computed automatically by the system matched the manual volume-by-unit-price calculation, and the recapitulated RAB total equalled the sum of all individual item costs. This demonstrates that no data loss or arithmetic error is introduced as quantities move from import through cost calculation to reporting. The fourth case verifies access control: a login attempt with invalid credentials was correctly rejected and an appropriate error message was displayed, confirming that the role-based authentication layer behaves as designed. The fifth case establishes dashboard-report consistency, in which the figures shown on the dashboard were identical to those in the downloaded PDF report, with no discrepancy found. Taken together, these results confirm that the system preserves BIM-to-database traceability and reproduces the validated QTO and cost-estimation values consistently from end to end, supporting the auditability and reliability required for stakeholder-accessible cost reporting.

Conclusions

This study contributes a practical, reproducible workflow integrating Cubicost TME-based electrical QTO, PUIL 2020/SNI 0225:2020 compliance verification, and web-based cost reporting. Findings from the case study show that BIM yields 8.59% lower total cable quantities than conventional estimation. However, when adjusted on an equivalent net basis (removing the conventional 5% waste allowance), the deviation decreases to 4.02%, indicating that routing differences account for roughly half of the gross discrepancy. The resulting 3.95% cost reduction represents a scenario-based estimate rather than a guaranteed financial saving. Nevertheless, these results remain context-bound due to single-case boundaries and unverified as-built procurement data.

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