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Value engineering research on construction materials cost efficiency for electronic storage warehouse project

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Abstract. Budget management becomes especially difficult for electronic warehouses' materials because of the overspending that occurs from the use of substandard structural materials. Reinforced concrete and Wide Flange (WF) steel sections are the two materials that most people consider for the construction of warehouses. A case study focusing on an electronic warehouse model in Depok. The modelling used Building Information Modelling tools, and only focused on beams and columns which are crucial structural components. This study utilizes a systematic Value Engineering (VE) approach, focusing on integrating functionality and costs to preserve construction integrity while optimizing project value in these two aspects. The study concludes reinforced concrete for the main columns and beams not only supports construction with 25% less material than steel WF options, but also provided the project a cost saving of 21,106,579.93 IDR. This is vital for large projects where budget restrictions are very strict. Furthermore, the use of reinforced concrete is economical and, with lower weight, mobile cranes and other heavy construction machines become unnecessary. This not only reduces the cost of the project, but also simplifies construction and accelerates the saving of money.

1 Introduction

Electronic warehouses construction in Indonesia shows significant rapid growth from the country's digital economy and e-commerce sectors, which leads to increasing logistics and warehousing infrastructure demands. Key urban and industrial centers like Jakarta and Java serve as focal points for warehouse construction to meet increasing demand for storage and distribution of electronic goods. This trend is highly influenced by demographic characteristics and socioeconomic dynamics, labor availability, and logistic strategies, especially in Depok City of West Java[1].

Depok's strategic location near Jakarta and its increasing population—over 2.1 million as of 2024 with a high population density of 10,823 persons/km²—has made it a prime

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area for warehouse development to support regional supply chains [2]. Recent projects of Depok's Warehouses' highlight the scale and urgency of warehouse infrastructure growth in the region, accommodating the needs of fast-moving consumer goods and electronics distribution [3].

Conventional warehouse construction methods present numerous challenges that frequently lead to human errors, project delays, and cost overruns. These traditional approaches rely heavily on manual processes that are inherently prone to mistakes, coordination difficulties, and inefficiencies[4]. Specifically, if the project falls behind the scheduled plan or when the design needs a swift in action adjustment for another contract addendum which can lead to a Change of Order (COO). Traditional warehouse construction projects are particularly susceptible to extensive change orders due to design errors, omissions, and coordination failures[5]. The top causes of change orders in construction include owner's additional works, errors and omissions in design, and lack of coordination between construction parties. Design adjustment also can lead to bill of quantity changes. If the quantity take off are done manually, generating it with new adjustment can cause several errors[2-5]. Manual quantity take-off processes are notorious for generating inaccuracies that cascade throughout warehouse construction projects.

Therefore, to optimize the planning, design, and construction phases of these warehouses, Building Information Modeling (BIM) is employed. BIM significantly enhances material quantity estimation and comprehensive construction analysis, particularly for structural components such as beams and columns, by providing automated extraction capabilities[9]. BIM platforms like Autodesk Revit create intelligent 3D models with embedded parametric data that automatically generate precise material quantities for structural elements, eliminating the time-consuming manual calculations traditionally prone to error[10]. When structural components such as beams and columns are modeled with specific dimensions, reinforcement details, and material properties, the software automatically calculates concrete volumes, steel reinforcement weights, and other related quantities with optimal accuracy[8].

Some researches demonstrates that BIM-based quantity take-off achieves remarkable precision, with studies showing differences as minimal as 1-3% compared to conventional methods for structural components, while reducing calculation time by up to 80%[11]. The adoption of BIM in Indonesian construction projects is still emerging but demonstrates clear benefits in project coordination and cost control[12]. Those benefits in cost controlling can be used in implementation of Value Engineering (VE) Principles[10]. VE helps the delivery projects maximizing cost benefits thorough trial and error of findings optimum designs. This method helps saving more time on the systematic analysis by generates more complex design choices in preliminary design phase[13]. That way, utilizing BIM-generated Quantity Take-Off (QTO) data and evaluating construction costs and explore alternatives, will be much easier.

This method can be implemented in modelling a warehouse construction. Hence, this study proposes to model a warehouse construction project in Depok using BIM and subsequently analyze it through value engineering by observing the final QTO results derived from the model. Such an integrated approach is expected to provide valuable insights into improving warehouse construction efficiency aligned with the rapid infrastructural development in the region.

2 Methodology

2.1 Problem identification and project selection

The primary problem identified in this study concerns the optimization of planning and execution in the construction of an electronic goods storage facility. Specifically, this research addresses the challenge of material selection between two viable structural systems—reinforced concrete and structural steel—when cost constraints are significant and design efficiency is critical. This optimization must account for both material costs and functional performance while integrating Building Information Modeling (BIM) technology and applying Value Engineering (VE) principles.

Determining VE outcomes requires a multi-perspective evaluation and should be based on total installed cost and schedule, because steel's faster, crane-dependent erection can offset higher material costs, whereas concrete requires formwork, placement, and curing that extend durations and indirect costs[14]. However, this study covers only material costs and fixed heavy equipment (e.g., cranes) and excludes other scopes such as scheduling and earthworks.

The case study project is an electronic materials warehouse located in Depok, West Java, built on a ±1,000 m² site. The warehouse comprises a single-story structure measuring 15 × 24 m (floor area 360 m²) designed for electronic goods storage. Depok was selected as a representative urban warehouse location due to its strategic position near Jakarta and its status as a rapidly developing logistics hub. The project was selected because complete engineering documentation was available, and the warehouse structural system could be reasonably modeled in both reinforced concrete and steel alternatives.

Research Questions The research questions are as follows, RQ1: Can BIM-generated quantity take-off (QTO) provide more accurate material quantities compared to manual estimation methods for warehouse structural components? - RQ2: What is the cost differential between reinforced concrete and steel WF alternatives for the structural frame (columns and beams) under current unit prices? - RQ3: Which material alternative provides superior value when considering material costs, construction methods, and equipment requirements?

The study yields two sets of modeling outputs for alternative structural materials, namely reinforced concrete and steel, with member dimensions calibrated according to the respective design approaches for each material.

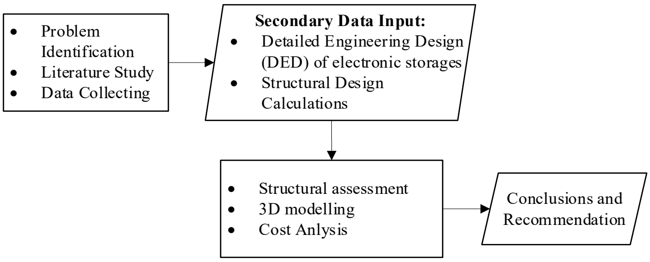

Fig 1. The Research's Flowchart

2.2 Data collection

The research requires the collection and utilization of data to support 3D modeling through Autodesk Revit 2024. These data also underpin the analysis for the application of Value Engineering. These data are secondary which are obtained from case study project workers. The secondary data are Detail Engineering Design (DED) Documents and Structural Design Calculations. The DED includes floor plans and elevations of the warehouse construction project, such as project floor plan and beam layout for the second floor, front elevation and structural steel height, and side elevation that shows the steel frame and second-floor height.

The structural system specifies on this project included reinforced concrete with 28-day compressive strength f_c'=21 MPa, steel reinforcement using deformed bars F_y=400 MPa (BJTD 40) and plain bars F_y=240 MPa (BJTP 24), and structural steel ASTM A36/BJ 41 with F_y=250 MPa. While the warehouse frame (columns and beams) was initially planned in steel, an alternative adopts reinforced concrete for these members to reduce material costs, acknowledging that steel enables faster construction; this trade-off positions reinforced concrete as a viable, value-driven option for the project.

2.3 Structural modelling and assessment

Structural assessment of columns and beams was conducted after implementing optimized design alternatives to ensure continued structural functionality, with profiles adjusted according to updated project requirements (shown as Fig. 2).

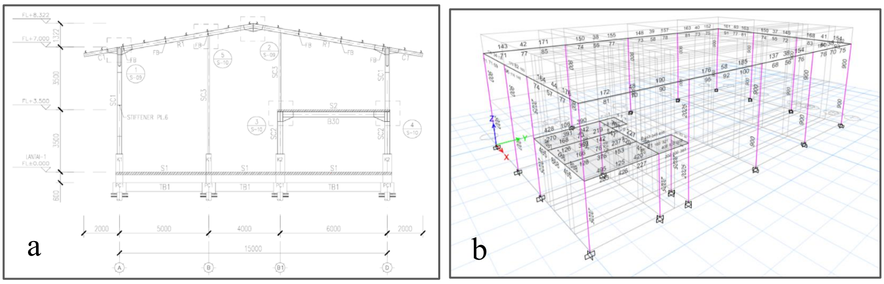

Fig 2. a) Frontal View Initial Design; b) Structural Modelling and Assessment Output

Three-dimensional modeling was performed using Autodesk Revit 2024 as part of a BIM-based methodology, utilizing Detail Engineering Design (DED) data alongside the optimal alternative for accurate simulation and visualization. The modeling procedure followed systematic steps; begins with model setup and importing DED drawings including the specific parameter and establishing coordinate system placement. Second step is material properties definition with specifications as mentioned before. Third steps, structural element modeling, followed by model validation, and schedule configuration.

Finally, a comparative cost analysis evaluated material efficiency and project expenses by calculating and comparing planned costs for both the initial and alternative designs from a value engineering perspective, resulting in a methodology that rigorously integrates assessment, advanced modeling, and comprehensive cost evaluation for electronic warehouse construction. The comparison covers structural materials for an electronic materials warehouse, focusing on columns and beams only. Quantities originate from the BIM model (Revit output) and unit rates from the project price list, with totals reported per material category (concrete, reinforcement, steel shapes, bolts, and connection plates).

Aplicable design standards use SNI 2847:2019 for reinforced concrete design, and SNI 1729:2015 for structural steel design. While Dead load (DL) and Live Load (LL) criteria based on SNI 1727:2020 for load combinations and live load determination.

2.4 Quantity take-off (qto) extraction

The QTO extraction only needs a few steps as most of the data done by integrating the structural models, with the schedule and parameter extraction. The systematic process as followed:

Step 1 - Schedule Creation in Revit: - Generate element schedules for all columns and beams - Configure schedules to include geometric parameters (volume, area, length, weight) - Create material-specific schedules for concrete, reinforcement, and steel

Step 2 - Parameter Extraction: - Extract concrete volumes (m^3) from column and beam schedules - Extract steel reinforcement weights (kg) from reinforced concrete element schedules - Extract wide-flange steel section weights (kg) from steel alternative schedules - Extract connection hardware data (bolts and connection plates)

Step 3 - Data Processing: - Consolidate extracted quantities into master QTO tables - Organize data by material type and structural element category - Prepare data for cost analysis and value engineering evaluation

Step 4 - Verification: - Cross-reference extracted quantities against DED documents - Compare BIM-generated volumes with manual calculations - Validate weight calculations using material properties and section specifications - Document any discrepancies and reconcile differences

3 Results and discussion

3.1 Input quantities and unit prices

Based on the modeled quantities and unit rates, the direct material cost is predominantly driven by wide-flange steel mass on the steel option and by reinforcement mass on the reinforced concrete option, yielding a clear cost differential in favor of reinforced concrete for the column–beam system at the stated prices. The summary of QTO shown in Table 1.

Table 1. Quantity Take-Off (QTO) Analysis Results Summary based on each materials

Item	Unit	Columns Qty	Beams Qty	Subtotal Qty	Unit Price (IDR)	Notes
Concrete (readymix)	m^3	11.19	4.36	15.55	1,028,000/m^3	From DED/Revit output and unit-rate list
Reinforcement (rebar)	kg	2,042.67	958.05	3,000.72	15,800/kg	BJTD 40/BJTP 24 as applicable
WF Steel (profiles)	kg	2,552.14	834.72	3,386.86	24,000/kg	Wide-flange sections
Bolts	kg	—	—	19.57	39,000/kg	Connection hardware
Connection plates	kg	—	—	197.61	12,433/kg	Steel gusset/plate connections

From Table 1 implied cost drivers differ markedly between the two systems: for reinforced concrete, the dominant contributor is reinforcement mass (3,000.72 kg) at Rp 15,800/kg, whereas concrete volume (15.55 m³) at Rp 1,028,000/m³ is secondary; this implies that any redesign reducing bar tonnage (e.g., rationalizing bar diameters, spacing, or lap lengths) will yield larger savings than modest reductions in concrete volume. For structural steel, the wide-flange profiles (3,386.86 kg) at Rp 24,000/kg account for nearly all of the direct cost, while connectors—bolts (19.57 kg at Rp 39,000/kg) and connection plates (197.61 kg at Rp 12,433/kg)—are marginal adders, suggesting that section optimization to trim WF mass is the most effective lever.

Column quantities dominate beam quantities in both materials, indicating that value engineering efforts should prioritize column sizing and detailing. Overall, the data supports reinforced concrete's material-cost advantage under the stated unit rates, but emphasizes that the outcome is most sensitive to rebar and WF mass rather than to auxiliary items.

The unit rates applied in this analysis are specific to the Depok region in West Java as of late 2024. These rates reflect current market conditions in a major urban warehousing center. The 21% cost advantage for reinforced concrete under these prices would shift if regional market conditions change significantly, particularly with volatility in steel import prices.

3.2 Methods and equipment implications

Construction means differ materially: WF steel erection relies on a mobile crane (Rp. 1,062,500 per hour), whereas concrete placement uses a truck mixer (Rp. 300,000 per hour). Although crane hourly rates are higher, steel erection can shorten installation duration relative to reinforced concrete, which requires formwork, reinforcement placement, casting, and curing. Consequently, schedule compression with steel may offset some direct cost differences when indirect costs and time-related overheads are considered.

Results are sensitive to market volatility in steel prices, variations in concrete unit rates, and labor productivity for both alternatives. Steel WF price shows the highest sensitivity (1.78), meaning a 1% change in steel price produces a 1.78% change in cost differential. Rebar price has moderate sensitivity (0.90). While concrete price and crane rate have low sensitivity.

Additional scope items not included in the reported totals—formwork supply and stripping, shoring, concrete pumping, curing, steel fabrication and shop detailing, fire protection coatings, corrosion protection, base plates and anchor rods, transport, and waste factors—can materially affect the relative economics[15]. A focused sensitivity analysis on ±10–20% changes in steel price per kg, concrete price per m^3, and inclusion of formwork and fabrication allowances is recommended to establish break-even thresholds.

Self-weight differences may influence foundation sizing, with steel offering lower dead loads that can reduce foundation quantities. Conversely, fire protection requirements for a warehouse storing electronic materials may add cost to steel solutions. Durability, corrosion exposure, and maintenance regimes should be evaluated within the warehouse's operational environment.

4 Conclusion and recommendation

Under the modeled quantities and unit rates, reinforced concrete for the column–beam system achieves approximately a 25% lower direct material cost than structural steel, with cost drivers concentrated in rebar tonnage for concrete and wide-flange mass for steel; however, the final selection should be based on total installed cost and schedule because steel's faster, crane-dependent erection can offset material premiums while concrete imposes duration through formwork, placement, and curing. Accordingly, adopt reinforced concrete as the working baseline and pursue low-risk savings via rebar optimization (bar sizes, spacing, lap detailing) and rationalized concrete volumes without compromising performance. Expand the estimate to a like-for-like total installed cost by adding formwork, shoring, pumping, and curing for concrete and shop detailing, fabrication, fire/corrosion protection, anchors/base plates, and erection for steel. It is very recommended to conduct sensitivity analyses of ±10% to ±20% on steel price per kg, rebar tonnage, and concrete unit rates, incorporating realistic crane and mixer utilization to identify break-even points under market volatility and productivity scenarios for future researches. It is also recommended to leverage BIM-enabled 5D workflows to validate quantity completeness (including connections and secondary items) and integrate schedule impacts to support a robust, procurement-ready decision.

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