Development of an Owner Estimate Model Based on WBS Integrated with 3D, BIM and Risk to Improve Cost Estimation Accuracy

Deby Amalia[1], Yusuf Latief[1]
[1]*Department of Civil Engineering, Faculty of Engineering, University of Indonesia, Depok, Indonesia.*

ABSTRACT: *Accurate cost estimation at the early planning stage is a crucial component in ensuring the success of construction projects. However, traditional methods often fail to capture the full complexity of a project, which may lead to discrepancies between estimated and actual costs. This study aims to develop a structured Owner Estimate model based on the Work Breakdown Structure (WBS), integrated with 3D visualization technology, Building Information Modeling (BIM), and risk analysis. The model is expected to improve cost estimation accuracy through a systematic, visual, and data driven approach. The methods used include literature review, data collection through interviews and questionnaires, and model validation. The development results indicate that a WBS based model integrated with 3D, BIM, and risk can provide more precise and transparent cost estimates. This model is also considered effective in supporting decision-making processes and time efficiency. Therefore, the proposed model can serve as a strategic solution for more accurate and professional construction cost management.*

KEYWORDS - *Owner Estimate, WBS, 3D, BIM, Risk, Cost Estimation Accuracy.*

I. INTRODUCTION

The implementation of government procurement of goods and services in Indonesia's construction sector is crucial for supporting national development. However, construction projects are frequently challenged by difficulties in meeting the triad constraints of cost, time, and quality. Within the project management lifecycle, the Owner Estimate (OE) serves as the most critical instrument during the early planning phase. OE functions as the primary basis for budget planning, a crucial cost control tool, a standard for evaluating contractor bids, and a guarantee for transparency in the utilization of public funds [1](Latief & Hidayat, 2020). The accuracy of the Owner Estimate is therefore a direct determinant of overall project success.

Despite its central role, the inaccuracy of the Owner Estimate is frequently cited as the leading cause of cost overrun in construction projects across Indonesia. Case studies indicate that this inaccuracy stems primarily from four dominant factors: outdated unit price assumptions, immature design and technical specifications, changes in work scope, and external risk factors. The detrimental effects of an inaccurate Owner Estimate (OE) cascade across all project stages, beginning with Micro Level failures such as Cost and Time Overruns and stakeholder conflicts; these then translate into Meso Level consequences, including reputational damage and severe financial strain for organizations; ultimately, these failures escalate to the Macro Level, resulting in Public Budget Inefficiency and an erosion of public trust in infrastructure development.

Fig. 1 Impact of Owner Estimate Inaccuracy

This research aims to develop and validate a Work Breakdown Structure (WBS)-based Owner Estimate Model that is integrated with 3D technology, Building Information Modeling (BIM), and Risk Management. This integration is expected to yield two primary benefits: (1) Providing an accurate and transparent estimation framework through the automation of Quantity Take-Off (QTO) based on the 3D model, and (2) Transforming the OE into a dynamic instrument capable of mitigating uncertainty through probabilistic risk calculation [2]. The proposed model is expected to contribute significantly to improving cost estimation accuracy and strengthening comprehensive cost control in Indonesian construction projects.

II. Literture Review

II.I Current Owner Estimate (OE) Process and Activities

The current construction business process at large-scale property developers in Indonesia, such as PT. X, follows a structured series of stages, commencing from strategic planning and culminating in project Handover. Crucially, the formulation of the Owner Estimate (OE) is a core activity performed during the Design & Engineering phase, where the OE serves as the primary benchmark for Procurement and Cost Control & Monitoring throughout the project lifecycle.

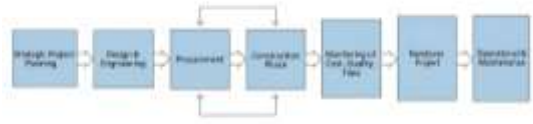

Fig. 2 Construction Business Process Flow PT. X

Currently, OE preparation is dominated by two primary technical approaches: the Data Inquiry method and the Cost Structure method [3]. While the Data Inquiry method, sourced from current vendor and market prices, offers essential adaptability to external dynamics, its process is time-intensive, requiring extensive negotiation and data collection. Conversely, the Cost Structure method is highly systematic as it relies on internal company cost components but tends to be rigid and less responsive to rapid fluctuations in external material or labor prices.

The inherent duality and limitations within these conventional methods create a significant gap in the accuracy of initial project cost estimation. This deficiency urgently drives the need to adopt smart technology-based solutions. Research has already demonstrated that OE inaccuracy can be substantially remedied through digital integration. For instance, [4] proposes developing machine learning algorithms that use historical project data (such as work type, location, and volume) as inputs for a predictive model. This process involves digital data collection, statistical modeling, model training, and validation against actual data. The application of such intelligent technology is proven to enhance the precision of the OE and effectively narrow the gap between the owner's estimate and the final contractor bid value.

II.II Concept of Owner Estimate Accuracy Level at PT. X

Inaccuracies in preparing the Owner Estimate (OE) are a persistent issue in construction projects, primarily driven by three core factors: scope definition changes, design maturity, and external market volatility. Literature confirms that scope change (often appearing as variation orders) is a dominant contributor to cost escalation as additional work is not identified during initial planning. Furthermore, incomplete design documents or late changes in material specifications invalidate initial estimates [5], while field conditions often result in significant discrepancies between estimated and actual volumes, particularly for earthwork and utility infrastructure [6]. Compounding these internal issues is external market fluctuation, where rising prices for materials like steel and cement are major factors in cost

overrun, especially when the estimate fails to incorporate adequate price escalation components or contingencies [7].

To standardize and address this challenge, the AACE International Recommended Practice No. 17R-97 classifies cost estimates into five categories (Class 5 to Class 1) based on design maturity and required accuracy. This research specifically utilizes the AACE Class 2 Estimate (30–70% design maturity, ±10% to 15% deviation) as its benchmark. This choice aligns with the typical pre-tender phase of projects at PT. X, where design documentation is detailed but not fully final, and is considered relevant to the company's internal tolerance policy of ±10% for cost deviation.

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	END USAGE	METHODOLOGY	EXPECTED ACCURACY RANGE
Class 5	0% to 2%	Functional area, or concept screening	SF or in^2 factoring, parametric models, judgment, or analogy	L: -20% to -30% H: +30% to +50%
Class 4	1% to 15%	or Schematic design or concept study	Parametric models, assembly driven models	L: -10% to -20% H: +20% to +30%
Class 3	10% to 40%	Design development, budget authorization, feasibility	Semi-detailed unit costs with assembly level line items	L: -5% to -15% H: +10% to +20%
Class 2	30% to 75%	Control or bid/tender, semi-detailed	Detailed unit cost with forced detailed take-off	L: -5% to -10% H: +5% to +15%
Class 1	65% to 100%	Check estimate or pre bid/tender, change order	Detailed unit cost with detailed take-off	L: -4% to -5% H: +3% to +10%

Fig. 3 Cost Estimation Classification Matrix for the Building and Construction Industry

However, empirical comparison between the OE and the Revised Budget (RAB Update) for several PT. X projects in 2022 revealed consistent deviations ranging from 10.46% to 15.84%. This systematic trend of cost underestimation significantly exceeds the internal ±10% tolerance, validating the research problem.

Tahun 2022			
Proyek	Owner Estimate (Rp)	RAB Update (Rp)	% RAB Update Thp OE
Proyek A	16.167.000.000	17.857.565.000	10,46%
Proyek B	9.226.800.000	10.676.016.000	15,71%
Proyek C	2.630.700.000	3.047.382.000	15,84%
Proyek D	2.630.700.000	3.047.382.000	13,67%

Fig. 4 Owner Estimate Table with Updated RAB for PT. X in 2022

This substantial deviation confirms that the current estimation methodology is fundamentally flawed lacking a comprehensive Work Breakdown Structure (WBS), 3D/BIM integration, and systematic risk analysis thus demanding that research pivot towards a dynamically integrated model that retains the systematic Cost Structure while incorporating geometric data and probabilistic risk capabilities to significantly enhance cost accuracy and efficiency throughout the project lifecycle.

II.III Concept of Work Breakdown Structure (WBS) for Owner Estimate Process

Work Breakdown Structure (WBS) is paramount in preparing the owner estimate, serving as the foundational framework for systematically identifying, grouping, and allocating cost elements aligned with the actual project work structure. WBS acts as a central theoretical and practical anchor for integrating risk and cost management. Studies confirm its application in structuring comprehensive safety plans for high-risk projects by detailing hazard identification and classifying safety-related expenditures [1].

Fig. 5 WBS Standards for Apartment Development Projects

To ensure greater estimation reliability and accountability, research advocates for expanding the WBS into technical tools such as a WBS Dictionary and Checklist [8]. These instruments provide granular detail on work packages, resources, deliverables, and associated risks, effectively mitigating ambiguities and hidden costs that frequently arise from complex designs or resource identification challenges.

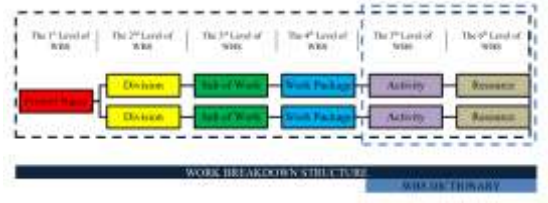

Fig. 6 WBS Structure and WBS Dictionary

Collectively, these findings solidify the WBS as a versatile and essential tool for modern

project management. The WBS is demonstrated not merely as a simple scope division tool, but as the structured basis for comprehensive data integration from work scope and cost requirements to risk mitigation proving its indispensable role in developing a reliable and integrated Owner Estimate model.

II.IV Concept of 3D Model based on Work Breakdown Structure (WBS) for Owner Estimate Process

The development of a Work Breakdown Structure (WBS) integrated with 3D modeling represents a modern approach to significantly enhance the accuracy and efficiency of the owner estimate (OE) process. By linking the hierarchical WBS to the project's visual three-dimensional model, every work element is not only systematically identified but also spatially visualized, giving the project owner a clearer understanding of the scope, volume, and complexity of the required expenditure. The Building Information Modeling (BIM) platform is central to this paradigm shift, allowing for the simultaneous integration of geometric data (3D), cost information (5D), and the structured scope (WBS).

The primary advantage of this 3D-WBS integrated model lies in its ability to support automated and dynamic estimation. Through digital modeling, any modification to a design element instantly influences the corresponding cost estimate via established links between the model objects and the WBS cost components. This key functionality drastically minimizes human error inherent in manual calculations, saves considerable time, and enables faster, data-driven budget planning decisions. Furthermore, the system allows project owners to continuously monitor the cost structure based on the project's physical elements, which greatly improves transparency and accountability. This integration is also beneficial for developing the owner estimate based on construction phasing and scheduling, as every WBS element linked to a 3D object can be analyzed for its execution time and associated cost.

II.V Concept of Building Information Modeling (BIM) based on WBS and 3D for Owner Estimate Process

Building Information Modeling (BIM) has emerged as a strategic technology fundamentally enhancing the efficiency and accuracy of cost estimation, particularly during the critical owner estimate (OE) phase. The primary strength of BIM lies in its capacity to integrate the project's three-dimensional (3D) model with crucial non-geometric data, encompassing quantities, scheduling (4D), and costs (5D). This integration allows for the automatic derivation of work quantities from the 3D representation, minimizing reliance on error-prone manual 2D processes and directly addressing challenges posed by design complexity and data uncertainty often found in pre-tender estimation [9].

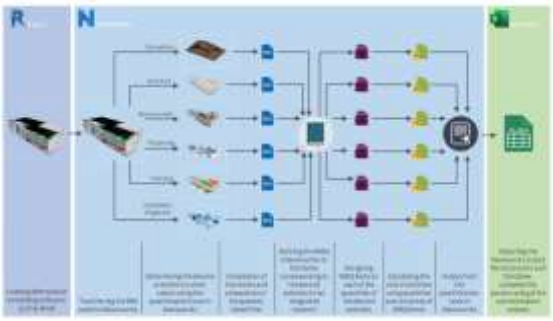

Fig. 7 Measurement and Estimation Stage Based on BIM Model

By connecting the cost dimension (5D) to the design model, any design modification is instantly reflected in cost calculations, providing rapid, transparent, and accurate cost predictions that minimize deviation between the initial estimate and final project realization. The utilization of BIM extends deeper into project management by supporting fine cost control at a granular level. As a real-time data integration platform, BIM connects design information, work volumes, and cost data in a dynamic feedback loop [10].

Fig. 8 BIM-Based Cost Control Process for Construction Phase

The WBS based BIM 5D model is confirmed as an indispensable tool for modern project management, enabling continuous cost tracking at a granular component level and facilitating the early identification of cost deviations, thereby transforming the estimation function into a robust, data driven instrument for planning, control, and strategic decision-making throughout the entire project lifecycle (Zhan, 2024; Khatimi & Afif, 2023).

II.VI Risk Concepts that Significantly Influence the Accuracy Level of the Owner Estimate Process

The stability of project cost estimation is severely compromised by various risks spanning technical, safety, and market domains. High accident rates in the Indonesian construction sector, particularly in mechanical and electrical (M&E) works, are frequently linked to design issues that overlook safety considerations. To address this, a risk-based Work Breakdown Structure (WBS) standard has been developed, integrating preventative and corrective actions directly into the design and construction phases. This standard specifically tackles common high-risk factors such as outdated standards, inadequate data, and technical personnel weakness proving that the systematic integration of risk management across the WBS is essential not only for worker safety but also for achieving project objectives in terms of cost and quality performance.

External market factors further exacerbate cost risks, notably intense competition which pushes service providers to submit significantly low bids (often below 80% of the Owner Estimate). This practice is shown to have a direct and negative influence on project performance unless the contractor possesses high managerial capacity and sufficient risk understanding [11]. To counteract these systemic and external uncertainties, AACE International Recommended Practice (56R-08) emphasizes that risk must be proactively identified, analyzed, and allocated across every project stage. Given that uncertainty is highest during the conceptual and early planning phases due to limited data, the OE must strategically incorporate mitigation strategies, such as contingency cost, to bridge the gap between estimated and actual costs [12]. Therefore, integrating comprehensive risk assessment into the WBS and OE process is paramount, transforming the initial cost estimate from a mere calculation into a strategic governance instrument for project control and investment sustainability.

III. Research Methodology

III.I Research Design

This chapter outlines the research design structured to first evaluate the current Owner Estimate (OE) (X1) process and its associated activities , which directly influence cost estimation accuracy (Y). The subsequent primary objective is to develop a novel OE model based on the Work Breakdown Structure (WBS) (X2), dynamically integrated with 3D visualization (X3), Building Information Modeling (BIM) (X4), and systematic risk analysis (X5), thereby establishing an OE process with significantly improved accuracy.

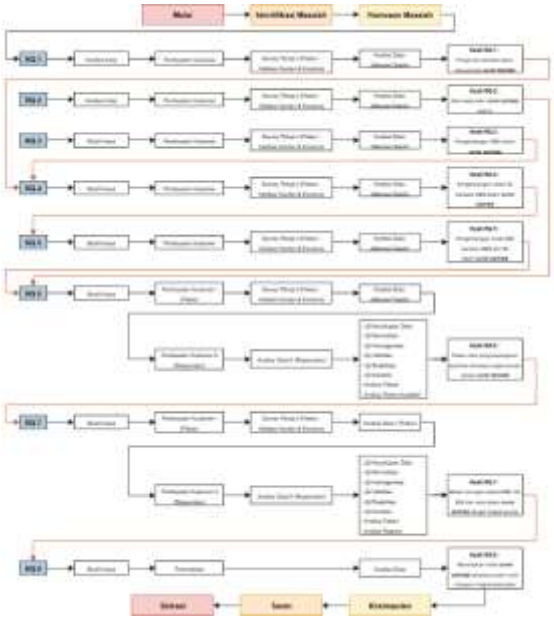

Fig. 9 Research methodology framework

III.II Data Collection Methods

Data collection involved three main techniques. First, archival analysis was conducted by reviewing current documents and standards. Second, a structured questionnaire was distributed to 62 construction professionals. The questionnaire consisted of items measuring the owner estimate

process and activities (X1), WBS development (X2), 3D (X3), and BIM (X4), and risks (X5) to the level of cost estimate accuracy (Y). Responses were measured using a five-point Likert scale.

III.II Data Analysis Methods

The data analysis consisted of two main approaches:

1. Qualitative Analysis = Literature review, regulatory review was conducted to identify owner estimate elements and indicators.
2. Quantitative Analysis to statistically validate test such as data adequacy test, normality test, homogeneity test, validity test, reliability test, correlation test, factor analysis and risk analysis.

IV. Result and Discussion

IV.I Current Owner Estimate Process And Activities

Addressing RQ 1 on the most influential Owner Estimate (OE) processes and activities for cost accuracy commenced with a Content and Construct Validation by five experts, confirming the validity of all 18 OE activity indicators but necessitating refinements to enhance planning comprehensiveness and contingency transparency. Following expert validation, the finalized questionnaire was distributed to 62 main respondents.

The survey results demonstrated a strong professional consensus (87%–98% agreement per indicator) regarding the importance of all tested activities. The most crucial indicators identified by respondents relate to post-estimation control: formalizing the OE as the project's cost baseline (Approval and Control phase) and deviation analysis to identify cost variances (Evaluation and Learning phase). Conversely, the indicator concerning team certification and experience (Planning phase) received the lowest relative agreement, suggesting that practitioners prioritize the quality of data input (design completeness and verified price databases) and systematic procedures (Validation and Review) over formal team qualifications as the direct drivers of cost estimation accuracy.

IV.II Current Owner Estimate Accuracy Level

Addressing RQ 2, which focuses on the indicators for the current level of Owner Estimate (OE) cost accuracy, began with a Content and Construct Validation by five construction experts, where all 12 indicators covering five sub-variables (Estimate Deviation, Project Scope Completeness, Estimation Methodology, Project Data, and External Factors) were declared valid and relevant for measuring accuracy. The subsequent survey of 62 construction professionals demonstrated a very strong professional consensus (average agreement level reaching approximately 85% per indicator) on all tested factors, confirming that these indicators reflect practitioners' understanding of the elements that define OE accuracy.

Specifically, the indicator deemed most crucial for defining OE accuracy is the Accuracy of work volume (96.8% of respondents Agree/Strongly Agree), followed by the Clarity level of WBS and scope of work and the use of the Cost Variance percentage between the OE and project realization as an accuracy metric. This highlights the priority given by construction professionals to the quality of initial technical data and deviation measurement as the fundamental benchmarks for accuracy. Conversely, external factors such as Field conditions (logistics, weather, and socio-political factors) and Scope changes after the OE is finalized had the lowest relative agreement scores among all indicators, implying that while acknowledged to affect costs, these elements are not considered to directly define the accuracy level of the initial estimate, which is instead primarily determined by input completeness and data validity.

IV.III Developing of Work Breakdown Structure (WBS) for The Owner's Cost Estimation Process

The research examining the development of the Work Breakdown Structure (WBS) for Owner Estimate (OE) cost estimation (RQ 3) began with a Content and Construct Validation by five construction experts. This stage successfully confirmed the validity and relevance of 20 indicators across five WBS sub-variables (Project Scope, Usefulness in Estimation, Project Monitoring, Communication, and Flexibility), demonstrating

that the proposed WBS framework has a strong theoretical foundation. The subsequent survey of 62 construction professionals revealed a very strong professional consensus (average agreement above 90% for most indicators) on the urgency of a structured WBS in construction projects.

The indicators deemed most crucial by the respondents were those that directly link the WBS to cost planning and control, specifically WBS serves as the basis for preparing the Budget Plan (RAB) and Owner Estimate and WBS is used as the basis for preparing the project baseline for cost and time targets. This focus underscores that the WBS's main value for practitioners is its function as a bridge between technical scope and cost control. Conversely, the indicator related to the ease of updating the WBS when changes in work scope occur (Flexibility aspect) had the lowest relative agreement, implying a practical challenge in maintaining WBS flexibility amidst the dynamic changes of a project. Overall, these findings reinforce the necessity of strengthening the WBS not only as a scope definition tool but as the primary foundation for an accurate cost baseline.

IV.IV Developing of 3D Model based on Work Breakdown Structure (WBS) for The Owner's Cost Estimation Process

The research aiming to develop a Work Breakdown Structure (WBS) based 3D Model as a vital input for the Owner Estimate (OE) process (RQ 4) began with a Content and Construct Validation by five construction experts. This stage successfully validated 12 indicators grouped into four main sub-variables: Visualization, Inter-Discipline Coordination, Geospatial Data Completeness, and Function for Estimation. The subsequent survey of 62 construction professional respondents showed a very strong consensus (high level of agreement) on all these indicators, affirming that an integrated 3D Model is a fundamental requirement for enhancing the quality and accuracy of current project cost estimates.

The indicators rated as the most crucial by the respondents are those directly linked to the cost quantification function, specifically the model's ability to automatically generate work volume (quantity take-off) and the accuracy of the quantity data derived from the 3D model. This high priority is also reflected in the acknowledged importance of having the appropriate Detail Level of Development (LOD) and the availability of complete metadata on objects (such as materials, dimensions, and specifications) as key prerequisites for ensuring cost data integrity. Meanwhile, indicators related to the ease of model navigation (Visualization aspect) and Integration with GIS (Geospatial Data aspect) received relatively lower agreement scores, suggesting that practitioners' primary focus for the 3D Model in the cost estimation context is the reliability of volume output and the completeness of internal technical information within the model, which are the main determinants of calculation accuracy.

IV.V Developing of BIM Model based on Work Breakdown Structure (WBS) and 3D Model for The Owner's Cost Estimation Process

The research addressing the level of Building Information Modeling (BIM) implementation as a prerequisite for accurate Owner Estimate (OE) (RQ 5) began with a Content and Construct Validation by five construction experts. This stage successfully validated 23 indicators grouped into five sub-variables: Implementation Level, Technology, Project Management, Project Benefits, and BIM Dimensions (3D-7D). The survey results from 62 construction professional respondents showed a very strong consensus (very high level of agreement) on the urgency of these indicators, confirming that the structured adoption of BIM is a crucial foundation for improving the quality and efficiency of project cost estimation in Indonesia.

The indicators rated as the most crucial by the respondents were the specific use of the BIM 5D Dimension for project cost estimation, indicating that the primary focus of 3D Model practitioners in a cost context is the direct benefit of quantification. Furthermore, indicators highlighting project cost and time efficiency through BIM implementation, as well as the need to strengthen the integration of BIM with the Work Breakdown Structure (WBS), estimation, and project schedule, also received the highest levels of agreement. This suggests that current implementation challenges lean more towards strengthening the functional integration of

BIM with existing project management frameworks, while aspects such as 6D/7D Dimensions (sustainability/facility management) and the readiness of IT Infrastructure (CDE), while important, are slightly lower in immediate implementation priority compared to the more immediate benefits of cost and schedule (5D/4D).

IV.VI Significant Risk Factors Affecting the Accuracy Level of Owner's Cost Estimate

The research for Research Question (RQ) 6, which identified the opportunities and impacts related to the integration of WBS and 3D BIM Models in Owner Estimate (OE) preparation, demonstrates that Indonesian construction professionals face highly critical challenges during the early stages of a project. Based on the survey results, the most significant challenges (rated as occurring "Often" to "Very Often") lie in the areas of Design for WBS and Data in BIM. Specifically, respondents highlighted the inconsistency between the WBS structure and the 3D BIM model as a major source of error, which is compounded by insufficient Quality of input data in the BIM model, and frequent design changes and revisions. This complexity is further aggravated by organizational and managerial constraints, such as the lack of an integrated historical cost database and the need to enhance the team's competence and experience in managing BIM data. This confirms that while the potential of BIM technology is recognized, implementation challenges focused on data and process integration remain the primary hurdles.

The impacts of these challenges were rated as having a "Very High Impact" across almost all indicators related to project performance. The most severe consequences of WBS and BIM integration failure are the high deviation between the OE and actual costs (OE accuracy), which directly triggers the potential for cost overruns and project delays. Furthermore, significant difficulties are also experienced in the cost control process, including difficulty in establishing and monitoring the cost baseline and an increased potential for contractual disputes due to scope creep. These findings conclude that failure to resolve the integration and data quality challenges within WBS and BIM will fundamentally undermine the financial integrity and manageability of the overall project, positioning cost estimation accuracy as a major risk factor.

Overall, the most significant risk factors (with the highest Risk Value) were dominated by issues related to Changes in Design and Scope of Work; the "Changes in design" factor recorded the highest average frequency (0.700), while "Changes in scope of work" recorded the second-highest average impact (0.502). This finding highlights that initial design uncertainty and changes in scope during the project are the main sources of cost deviation. Additionally, factors related to BIM Data Quality and Estimator Competency were also identified as critical managerial risks requiring mitigation.

V. Conclusion

Overall, the findings of this research present a summary and conclusion of the answers to the six research questions (RQ 1 to RQ 6) regarding the Owner Estimate (OE), covering aspects of process, accuracy, WBS implementation, 3D models, BIM, and risk factors :

- The most crucial activities in the OE process are the formalization of the estimate as the project's cost baseline and deviation analysis, with a primary emphasis on the quality of input data rather than the preparation team's certification.
- Current OE accuracy is heavily determined by the precision of Quantity Take-Off (QTO) calculation and the clarity level of the Work Breakdown Structure (WBS)/scope of work, while external factors are considered less dominant in the initial estimate's accuracy.
- The WBS is considered most important because it serves as the main basis for preparing the Bill of Quantities (BoQ) and the project baseline, although its flexibility to accommodate scope changes remains a challenge.
- WBS-based 3D models are highly crucial due to their ability to automatically and accurately generate the volume of work (quantity take-off), which strictly requires the appropriate Level of Development (LOD) and the availability of accurate

object metadata.

- BIM implementation is heavily focused on utilizing 5D BIM for cost estimation to achieve project time and cost efficiency, but its functional integration with the WBS and schedule still needs to be strengthened.
- Design changes/revisions and changes in the scope of work are the most significant risk factors that frequently occur and have the highest impact on OE accuracy, potentially triggering a cost overrun.

These findings provide a significant contribution to identifying critical points in the cost estimation process and form the basis for practical recommendations that will be outlined in the next chapter for improving Owner Estimate accuracy in the construction industry.

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