

BIM-Enabled Quantity Surveying for Automated Cost Estimation, Measurement and Commercial Decision-Making

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Abstract: Building Information Modelling (BIM) is changing quantity surveying from document-based measurement toward model-based, data-rich commercial management. This review examines how BIM-enabled quantity surveying can automate quantity take-off, strengthen cost estimation, improve change control and support faster commercial decision-making, with particular relevance to Saudi Arabia's rapidly expanding construction and infrastructure market. An integrative review approach was adopted, drawing on recent peer-reviewed research on 5D BIM, automated quantity take-off, model-based cost control, machine-learning-supported estimating, BIM adoption and Saudi construction management. The evidence indicates that BIM can improve measurement speed, traceability, visualization and consistency, but automation is not inherently reliable. Quantity outputs depend on model completeness, classification, level of information need, measurement rules, object parameters and disciplined model governance. The review therefore distinguishes between automated extraction and professionally validated measurement. It also shows that 5D BIM creates greater value when quantities are connected to cost libraries, work breakdown structures, procurement packages, change records, progress data and forecast-at-completion processes rather than being used only to produce an initial bill of quantities. A BIM-enabled Commercial Intelligence Framework is proposed that integrates model assurance, automated measurement, cost intelligence, change management, risk and dashboard-based decision support across project stages. In the Saudi context, this approach can support Vision 2030 objectives by improving transparency and commercial control on complex programs while developing digitally capable quantity-surveying teams. The paper concludes that the future quantity surveyor is not displaced by automation; instead, professional value shifts toward data assurance, commercial interpretation, scenario analysis, contractual judgment and governance of model-based decisions.

Keywords: Building Information Modelling, BIM, Quantity Surveying, 5D BIM, Automated Quantity Take-Off, Cost Estimation, Commercial Management, Saudi Arabia, Vision 2030, Digital Construction.

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1. INTRODUCTION

Quantity surveying has traditionally depended on drawings, specifications, schedules and

manually coordinated measurement records. These methods remain professionally robust when carefully managed, but they can become slow and

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fragmented when projects contain thousands of design objects, frequent revisions and multiple procurement packages. BIM changes this information environment by representing physical assets as coordinated digital objects carrying geometric and non-geometric information. For quantity surveyors, the significance is not simply three-dimensional visualization. The deeper change is the possibility of connecting measurable objects with classification codes, rates, work breakdown structures, procurement packages, programme activities and commercial records. This connection provides the foundation for 5D BIM, in which cost information is integrated with the digital model and can be updated as design and construction information develops (Baldrich Aragó *et al.*, 2021; Mustafa *et al.*, 2023; Pishdad and Onungwa, 2024).

Recent research demonstrates substantial progress in BIM-based quantity take-off. Automated systems can extract quantities directly from architectural and structural models, check data inconsistencies and present results through analytical dashboards. Valinejadshoubi *et al.*, (2024) show that automated BIM-based quantity workflows can improve speed and identify errors that would otherwise influence procurement and cost decisions. Alathamneh *et al.*, (2024), reviewing BIM-based quantity take-off literature, similarly identify productivity, accuracy and completeness as central benefits while emphasizing persistent problems concerning skills, software capability and implementation. These findings are important because a model does not become a dependable commercial source merely because quantities can be generated automatically. Measurement reliability remains dependent on modelling rules, object parameters, classification, information completeness and professional checking.

The commercial potential of BIM is therefore wider than automatic measurement. When model quantities are linked with cost databases and project controls, quantity surveyors can assess design options, test budget consequences, monitor cost variance, evaluate change and communicate emerging commercial exposure. Research on 5D BIM increasingly frames the technology as an integrated lifecycle system rather than a pre-contract estimating tool. Pishdad and Onungwa (2024) argue that standardized classification and integration with progress monitoring, artificial intelligence and digital payment mechanisms could connect cost estimation, control and payment processes. Yilmaz *et al.*, (2025) likewise demonstrate that BIM can reinforce cost planning, budgeting, monitoring and control, while identifying limitations in quantity-cost linkages, reporting flexibility and risk-based analysis. The

professional challenge is thus to transform BIM outputs into auditable commercial intelligence.

This challenge is especially relevant to Saudi Arabia. Vision 2030 is associated with a large and complex portfolio of construction, infrastructure and destination-development programs, and the national transformation agenda emphasizes technology, efficiency, accountability and new delivery capabilities. Saudi studies report growing interest in BIM alongside continuing barriers involving skills, interoperability, implementation procedures and organizational readiness (Alaboud and Alshahrani, 2023; Algahtany *et al.*, 2023; Alghuried, 2023; Iqbal *et al.*, 2025). Cost overruns and cost-influencing risks remain material concerns in the local construction sector (Alnaser *et al.*, 2024; Mosly, 2024). BIM-enabled quantity surveying therefore deserves examination not as a software trend but as a commercial governance capability that may support better decisions on major programs.

2. Aim, Objectives and Research Questions

The aim of this study is to critically evaluate how BIM-enabled quantity surveying can automate measurement and cost estimation while improving commercial decision-making across construction project lifecycles, and to formulate an implementation framework suitable for complex projects in Saudi Arabia. Four objectives guide the review: first, to examine the reliability and limitations of BIM-based automated quantity take-off; second, to evaluate integration between BIM quantities, cost data and 5D cost-management processes; third, to assess how model-based information can improve change, risk, procurement and commercial decisions; and fourth, to identify the organizational, contractual and data-governance conditions required for effective implementation. The study addresses three questions: How can BIM convert model information into dependable quantities and estimates? Which integrations create value beyond initial estimating? What governance and professional capabilities are necessary to use BIM outputs as auditable commercial evidence rather than unverified software results?

3. REVIEW METHODOLOGY

An integrative review methodology was selected because the research problem spans technology, professional practice, project controls, commercial management and national adoption conditions. The review synthesized peer-reviewed literature published predominantly from 2020 onward, while using selected earlier foundational research where necessary to explain persistent BIM and quantity-surveying issues. Searches focused on combinations of the terms building information modelling, BIM, 5D BIM, quantity surveying, quantity

take-off, automated measurement, cost estimation, cost control, commercial management, machine learning, Saudi Arabia and Vision 2030. Priority was given to studies indexed in major scholarly databases and published in established construction-management, engineering, built-environment and automation journals. Recent Saudi studies were intentionally included to ensure that the synthesis reflected local adoption conditions rather than assuming that international BIM maturity transfers directly to the Kingdom.

Evidence was screened for direct relevance to at least one of five analytical domains: model-based measurement, cost estimation and 5D integration, commercial decision support, information governance and implementation capability. Studies focused only on design visualization without a measurable connection to cost or commercial processes were treated as contextual rather than core evidence. Review articles were used to identify recurring trends and research gaps, while empirical case studies were used to evaluate practical performance and limitations. Official Vision 2030 sources were used only for strategic context and were not treated as substitutes for peer-reviewed evidence on BIM performance. The synthesis was thematic rather than meta-analytic because the literature reports heterogeneous outcomes, tools, project types and performance measures.

Quality interpretation emphasized whether studies described data sources, model conditions, validation processes and limitations. This is particularly important for automated quantity research because impressive extraction speed is commercially irrelevant if the model is incomplete or if measurement rules are ambiguous. Findings were therefore evaluated through a quantity-surveying lens: traceability, repeatability, compliance with defined measurement logic, ability to reconcile revisions, linkages to cost structures and usefulness for decisions. The resulting themes were organized into a proposed BIM-enabled Commercial Intelligence Framework. The framework is conceptual and should be tested through future project-based research using measurable indicators such as take-off time, reconciliation variance, estimate accuracy, change-cycle time, forecast accuracy and dispute frequency.

4. BIM-Enabled Quantity Surveying: From Digital Model to Commercial Information

BIM-enabled quantity surveying begins with a fundamental distinction between geometry and commercial information. A model may contain walls, slabs, ducts, equipment and finishes, yet a quantity surveyor requires more than object existence.

Measurement needs consistent object boundaries, correct dimensions, material definitions, classification, location, phase, status and sufficient detail to apply the relevant measurement rule. Where these attributes are standardized, quantities can be filtered and aggregated rapidly. Where they are inconsistent, automated outputs may simply reproduce modelling errors at greater speed. This explains why Alathamneh *et al.*, (2024) identify implementation and professional skills as continuing challenges even while confirming the productivity advantages of BIM-based quantity take-off.

The quantity surveyor therefore becomes an information assurance professional as well as a measurer. Before extraction, the commercial team should define a model measurement specification stating which objects will be measured, the required information fields, unit logic, treatment of openings and overlaps, classification system, level of information need and responsibility for model corrections. The model can then be tested against these requirements. Automated checks should identify missing types, duplicated objects, unclassified elements, inconsistent units and abnormal parameter values. Valinejadshoubi *et al.*, (2024) demonstrate the value of pairing quantity extraction with precision checking and visualization. This approach is more defensible than treating a software-generated schedule as inherently correct.

A further transformation occurs when quantity data are structured for reuse. In traditional workflows, take-off sheets often become static deliverables disconnected from later design changes. BIM can establish persistent identifiers and mappings that enable the cost team to compare model versions and isolate changed quantities. The commercial significance is substantial: revisions can be evaluated by exception rather than repeatedly remeasuring the entire design. However, this requires disciplined version control and a stable classification structure. If designers remodel objects, alter naming conventions or change coding practices without governance, the apparent digital continuity can break. BIM-enabled quantity surveying is therefore a socio-technical system in which modelling standards, software configuration and professional controls must operate together.

The strongest model-based workflow separates four layers: source model, validated quantity dataset, cost intelligence and decision output. Keeping these layers distinct improves auditability. The source model remains the designer's controlled information container; the validated dataset records the quantity surveyor's accepted measurement; the cost layer applies rates, allowances, escalation and risk; and the decision

layer communicates budgets, options and forecasts. This structure prevents accidental changes to the design model from silently altering approved

commercial baselines and provides a clear trail from a management decision back to the underlying object and measurement rule.

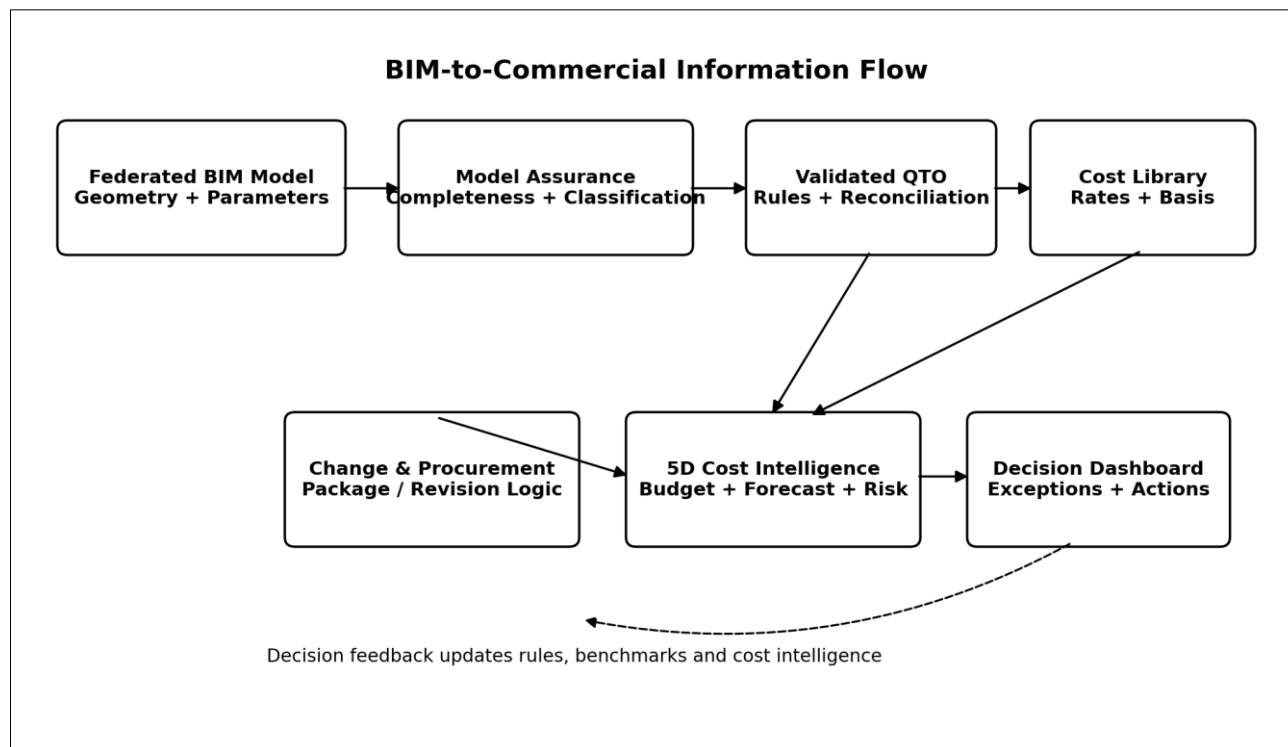


Figure 1: BIM-to-commercial information flow for quantity surveying and cost management

5. Automated Quantity Take-Off and Measurement Reliability

Automated quantity take-off is the most immediate BIM application for quantity surveying. Traditional 2D measurement requires interpretation of drawings, repeated checking across disciplines and manual reconciliation when revisions occur. BIM allows software to query object geometry and parameters directly, which can reduce repetitive measurement effort and improve consistency. Wahab (2022) found material differences between BIM-based and traditional quantity take-off approaches and emphasized the factors that influence comparative performance. Baldrich Aragó *et al.*, (2021) likewise show that 5D BIM changes professional workflows and creates a cross-disciplinary role around the model database. More recent research moves beyond simple extraction toward automated quality control, data transfer and visualization (Valinejadshoubi *et al.*, 2024).

Nevertheless, measurement automation should be understood as conditional automation. A concrete slab volume may be straightforward if the element is modelled as one clean object with reliable dimensions. More complex work items may depend on construction method, temporary works, wastage, laps, joints, accessories or contractual measurement conventions that do not exist as explicit model

geometry. Some preliminaries and attendance items are inherently time- or method-related. Excavation quantities may depend on working space and temporary slopes rather than the permanent model. Reinforcement quantities can depend on detailing maturity. Finishes may require rules for openings, returns and interfaces. The quantity surveyor must therefore classify which items can be directly extracted, which require rule-based derivation and which require professional allowances.

A robust automated workflow should contain three controls. First, model assurance verifies that required information exists and that object geometry is commercially measurable. Second, extraction logic translates objects into measurement outputs using explicit rules. Third, reconciliation compares model-derived quantities with independent checks or historical expectations. Saenpaeng *et al.*, (2025) illustrate how visual programming can automate reinforced-concrete quantity take-off and cost estimation, demonstrating the potential of rule-based workflows. Yet rule-based automation also creates a governance obligation: scripts and mappings must be version-controlled and tested because an incorrect rule can affect thousands of quantities simultaneously.

Measurement reliability should be quantified rather than assumed. Projects can establish tolerance bands for selected high-value items and require periodic sample checks against manual measurement or independent model queries. Variance can be analyzed by element type, discipline and model author. This transforms quality assurance from a final checking activity into a data-

improvement loop. Over time, recurring errors can inform modelling templates, employer information requirements and training. The most valuable automation outcome is therefore not the elimination of human checking but the concentration of professional attention on exceptions, high-risk quantities and commercial interpretation.

Table 1: BIM quantity take-off reliability controls and quantity-surveying responses

Control area	Typical risk	Recommended control	Commercial outcome
Model geometry	Incorrect joins, overlaps, missing objects or duplicated elements	Automated model checks plus targeted visual review	Validated measurable geometry
Object information	Missing classification, material, location or type parameters	Required-parameter rules and exception lists	Consistent filtering and aggregation
Measurement logic	Model geometry does not directly match contractual measurement rules	Controlled extraction rules, derivation formulas and documented assumptions	Auditable quantity logic
Revision control	Model changes overwrite earlier commercial positions	Versioned models and quantity datasets with change comparison	Traceable quantity movement
Professional validation	Software output accepted without independent challenge	Sample reconciliation, tolerance thresholds and senior QS approval	Commercially defensible quantities

6. 5D BIM and Automated Cost Estimation

Quantity extraction becomes 5D BIM when measurable objects are linked with cost information. The cost connection can operate at several levels: elemental benchmarks for early design, detailed rates for developed design, resource-based build-ups for tendering, committed values for procurement and actual costs for control. The principal advantage is responsiveness. When the design changes, quantities can be refreshed and the budget impact can be recalculated more rapidly than in disconnected spreadsheets. Mustafa *et al.*, (2023) identify cost-management potential across 5D BIM applications, while Pishdad and Onungwa (2024) show that the technology is increasingly considered as part of an integrated system for estimating, monitoring, control and payment.

Automated cost estimation is strongest when cost databases are structured, governed and context-sensitive. A rate is not merely a number attached to an object. It may include material, labour, plant, subcontractor quotations, waste, logistics, location factors, productivity assumptions, preliminaries, overheads and risk. On Saudi mega-projects, rates may also be influenced by package scale, imported materials, local-content strategies, remote logistics, market capacity and accelerated programmes. BIM can automate arithmetic, but it cannot remove the need to judge whether a rate is commercially appropriate. The cost library should therefore record source, date, currency, location,

inclusions, exclusions and confidence level so that automated estimates remain transparent.

Machine learning creates a further opportunity by identifying cost patterns across historical project data. Recent reviews show expanding interest in ML-based building cost estimation because algorithmic approaches may reduce subjectivity and support prediction from complex datasets (Karadimos and Anthopoulos, 2024; Wang *et al.*, 2025). BIM can provide structured geometric and specification features to such models. However, predictive accuracy depends on comparable historical data, market normalization and explainability. For professional cost advice, black-box outputs are problematic if the estimator cannot explain major cost drivers or demonstrate how an estimate responds to scope change. Hybrid systems that combine model quantities, transparent rate build-ups and predictive analytics are therefore more suitable than replacing professional estimating with opaque predictions.

A mature 5D workflow should preserve cost-baseline governance. Model updates should not automatically overwrite an approved budget. Instead, the system should distinguish current design cost, approved budget, pending changes, commitments and forecast-at-completion. This allows managers to see whether variance arises from design development, market movement, instructed change, quantity growth or delivery performance. Yilmaz *et al.*, (2025) identify the importance of

integrating BIM with formal cost-management processes and also note limitations in risk-oriented budgeting and customizable reporting. The lesson is that 5D BIM must be embedded within commercial controls rather than treated as a standalone estimating application.

7. Commercial Decision-Making, Change Control and Procurement

The value of BIM-enabled quantity surveying is ultimately measured by decisions rather than by the number of extracted quantities. Commercial managers need to determine whether a design remains affordable, whether a proposed change provides value, how a procurement package should be structured, what contingency is required and where forecast exposure is increasing. Model-linked quantities can accelerate these decisions by providing a shared spatial and numerical representation of scope. Instead of debating abstract spreadsheet changes, stakeholders can identify affected objects, visualize the scope, review quantity movement and understand cost consequences in context.

Change control is a particularly strong use case. Construction projects often experience design development, authority comments, user changes and site-driven adjustments. Conventional change records may describe scope in narrative form while measurement and cost analysis occur separately. BIM can connect change identifiers to model objects and allow quantity surveyors to compare approved and revised model states. The resulting workflow can show added, removed and modified quantities, link them to estimate items and record the commercial status of each change. Saudi research has highlighted

the importance of managing cost variance, cost overrun factors and disputes, making transparent change information especially valuable (Alnaser *et al.*, 2024; Alotaibi, 2024; Mosly, 2024).

Procurement decisions can also benefit from model-based information. Quantities can be grouped by location, system, trade or work package to test packaging options and tender strategies. When procurement returns are received, tendered rates can update the cost intelligence layer and expose variance against the pre-tender estimate. Model visualization can support scope clarification and reduce ambiguity at package interfaces. However, contractual documents must define whether the model is an information source, a contractual deliverable or both. Without clear status, reliance on model quantities can create disagreements concerning precedence, completeness and responsibility. The commercial team must therefore align digital workflows with contract conditions and information protocols.

For management reporting, dashboards can combine model quantities with budget, commitments, changes and forecasts. Such dashboards are powerful only when each indicator is traceable to governed data. A visually sophisticated dashboard built on uncontrolled model parameters can create false confidence. The quantity surveyor's role is to ensure that reported metrics reconcile to approved commercial records. When this assurance exists, BIM can shorten the cycle between design information and management action, allowing earlier intervention when quantities, rates or package forecasts move outside agreed thresholds.

Table 2: Commercial decisions strengthened by BIM-enabled quantity and cost data

Decision	BIM/commercial inputs	Key outputs	Management action
Design affordability	Current model quantities + benchmark/rate library	Cost plan variance; cost/m ² ; high-growth elements	Redesign, value engineering or budget adjustment
Change evaluation	Baseline model + revised model + change ID	Added/removed quantities; net cost; risk effect	Approve, reject, negotiate or seek alternatives
Procurement packaging	Model classification + location + trade breakdown	Package quantities; tender variance; interface exposure	Package strategy and tender recommendation
Forecast-at-completion	Commitments + model quantities + approved/pending changes	Forecast variance; contingency drawdown; exposure trend	Management intervention and funding action
Payment/progress	Model-linked scope + verified progress data	Value completed; quantity progress; payment reconciliation	Certification and cash-flow decision

8. Data Standards, Interoperability and Auditability

Interoperability is one of the central constraints on BIM-enabled commercial management. Quantity surveying commonly involves

authoring platforms, model viewers, estimating systems, spreadsheets, enterprise resource planning tools, scheduling software and business-intelligence dashboards. If object identifiers, classification and data mappings are inconsistent, information must be

manually reworked at each interface and automation benefits diminish. Pishdad and Onungwa (2024) identify standardization across the project lifecycle as a key requirement for integrated 5D processes. Saudi adoption studies similarly identify compatibility, procedures and skilled personnel as important implementation conditions.

The commercial information architecture should therefore be designed before detailed measurement begins. Each object or measurable assembly should map to a classification and, where appropriate, to a cost breakdown structure, work breakdown structure and procurement package. Naming standards should be machine-readable rather than dependent on individual modeller habits. Model status and revision information should be explicit. For exchanged data, open standards can reduce dependence on a single software ecosystem, but open exchange does not automatically preserve every commercial parameter. Testing is required to determine which fields survive transfer and whether geometry changes during export.

Auditability is equally important. A commercial decision may later be reviewed by a client, auditor, contractor, dispute board or management committee. The organization should be able to reproduce the quantity and cost position used when the decision was made. This requires controlled model versions, archived extraction files, documented rules, cost-library versions and approvals. A practical principle is that every reported cost movement should be traceable backward to a change in quantity, rate, allowance or risk. BIM improves this traceability when data structures are governed; without governance, dynamic models can make historical reconstruction harder because information is continuously overwritten.

9. Saudi Arabia and Vision 2030: Strategic Relevance

Saudi Arabia provides a compelling environment for BIM-enabled commercial management because Vision 2030 combines large capital programs with objectives for efficiency, technology adoption, institutional capability and economic diversification. Official Vision 2030 materials describe giga-projects as vehicles for creating new ecosystems, unlocking sectors and advancing technology. The scale and speed of this development increase the commercial consequences of design coordination, quantity growth, procurement pressure and change. A digital quantity-surveying capability can therefore support national transformation not by technology branding but by improving the quality and speed of capital-allocation decisions.

Local research shows that BIM adoption is progressing but uneven. Alaboud and Alshahrani (2023) identify interrelated factors affecting adoption in the Saudi construction industry, while Algahtany *et al.*, (2023) examine government initiatives that can accelerate implementation. Alghuried (2023) reports benefits and barriers in sustainable construction practice, and Iqbal *et al.*, (2025) identify efficient construction planning and management among the important driving forces for BIM adoption. These studies collectively suggest that technical availability is not the primary issue; organizational readiness, skills, standards and coordinated implementation remain decisive.

For quantity surveying, this means Saudi organizations should avoid implementing 5D BIM as an isolated software purchase. Employer information requirements should define commercial data needs from the beginning of a project. Design consultants should understand which model attributes support measurement. Cost consultants should participate in classification and information planning, not wait until models are issued for take-off. Contractors should align procurement and cost coding with the agreed data structure. Clients should define model status, approval gates and the relationship between digital information and contractual documents. Such integration is particularly important on multi-package programs where inconsistent coding across consultants can prevent portfolio-level cost analytics.

The Saudi context also creates opportunities for localized cost intelligence. As more projects adopt structured models, organizations can build databases linking asset characteristics, quantities, rates and outcomes across regions and project types. This can strengthen benchmarking and improve early-stage estimates for future programs. However, commercial confidentiality and data ownership must be governed. The strategic opportunity is a learning system in which each project improves the cost models, measurement templates and risk assumptions used on the next project. That capability would support the Vision 2030 emphasis on institutional efficiency and knowledge development while raising the professional value of quantity surveying.

10. Professional Capability, Roles and Contractual Implications

BIM does not remove the need for quantity surveyors; it changes where professional judgment is applied. Routine measurement can increasingly be automated, but the surveyor remains responsible for deciding what should be measured, validating model information, selecting appropriate rates, assessing uncertainty, interpreting contract conditions and advising decision-makers. Baldrich Aragó *et al.*,

(2021) describe the emergence of cross-disciplinary profiles in 5D BIM practice, and Alathamneh *et al.*, (2024) identify professional skills as a continuing adoption challenge. The future capability profile therefore combines measurement expertise with data literacy, model interrogation, classification, cost analytics and commercial communication.

Organizations should distinguish between BIM technicians and commercially accountable quantity surveyors. Technical specialists may configure model queries, scripts and data exchanges, while senior quantity surveyors approve measurement logic, cost assumptions and advice. This separation strengthens control because automation development and commercial authorization are not concentrated in one role. Training should include model federation, parameter checking, 5D software, visual programming, data visualization and basic database concepts, but it should also reinforce traditional competencies in contracts, procurement, claims and cost planning.

Contractually, parties must address model reliance. Agreements should define information responsibilities, required model deliverables, permitted uses, level of information need, exchange formats, status codes, update frequencies and responsibility for errors. A BIM-derived bill of quantities may still require rules for precedence against drawings and specifications. Model-based change assessment should not bypass contractual notice and valuation procedures. Saudi research on BIM and dispute mitigation indicates that digital integration can improve transparency, but benefits depend on aligning BIM processes with contractual mechanisms rather than operating them as parallel systems.

11. Proposed BIM-Enabled Commercial Intelligence Framework

The synthesis supports a six-stage BIM-enabled Commercial Intelligence Framework. Stage one is information planning. The client, designers and commercial team define classification, model measurement requirements, data responsibilities and exchange standards. Stage two is model assurance, in which automated and manual checks test geometry, object parameters, completeness and measurability before quantities are accepted. Stage three is validated measurement. Quantities are

extracted through controlled rules, reconciled against sample checks and stored as a versioned commercial dataset rather than an uncontrolled live schedule.

Stage four is cost intelligence. Validated quantities are mapped to cost items using governed rate libraries with recorded basis, date, inclusions, location and confidence. The system distinguishes benchmark, estimate, tender, commitment and actual-cost data. Stage five is commercial control. Model revisions and change identifiers are compared against approved baselines so that quantity movements, rate changes, risk allowances and procurement outcomes can be analyzed separately. Dashboards present exceptions, trend indicators and forecast impacts, while each value remains traceable to source data. Stage six is decision and learning. Management decisions are recorded against the evidence used, and project outcomes are fed back into cost libraries, benchmark models and measurement rules.

The framework deliberately inserts professional validation between model automation and commercial decision-making. This control addresses a major weakness in simplistic BIM narratives that assume direct model-to-cost connectivity guarantees accuracy. In practice, a commercially reliable system needs checkpoints for model maturity, measurement rules and cost-data suitability. The framework also supports progressive automation: organizations can begin with controlled model-based take-off, then add cost libraries, change comparison, dashboards and predictive analytics as data maturity improves. This is preferable to attempting full digital integration without stable foundations.

Performance should be measured through indicators that reflect commercial outcomes. Suggested metrics include time required for quantity take-off, percentage of quantities automatically extracted, reconciliation variance, number of model-data defects, estimate accuracy, time to price design changes, forecast-at-completion accuracy, rate-library reuse, tender reconciliation speed and frequency of quantity-related disputes. These metrics allow organizations to distinguish genuine productivity gains from visually impressive but weakly governed BIM implementation.

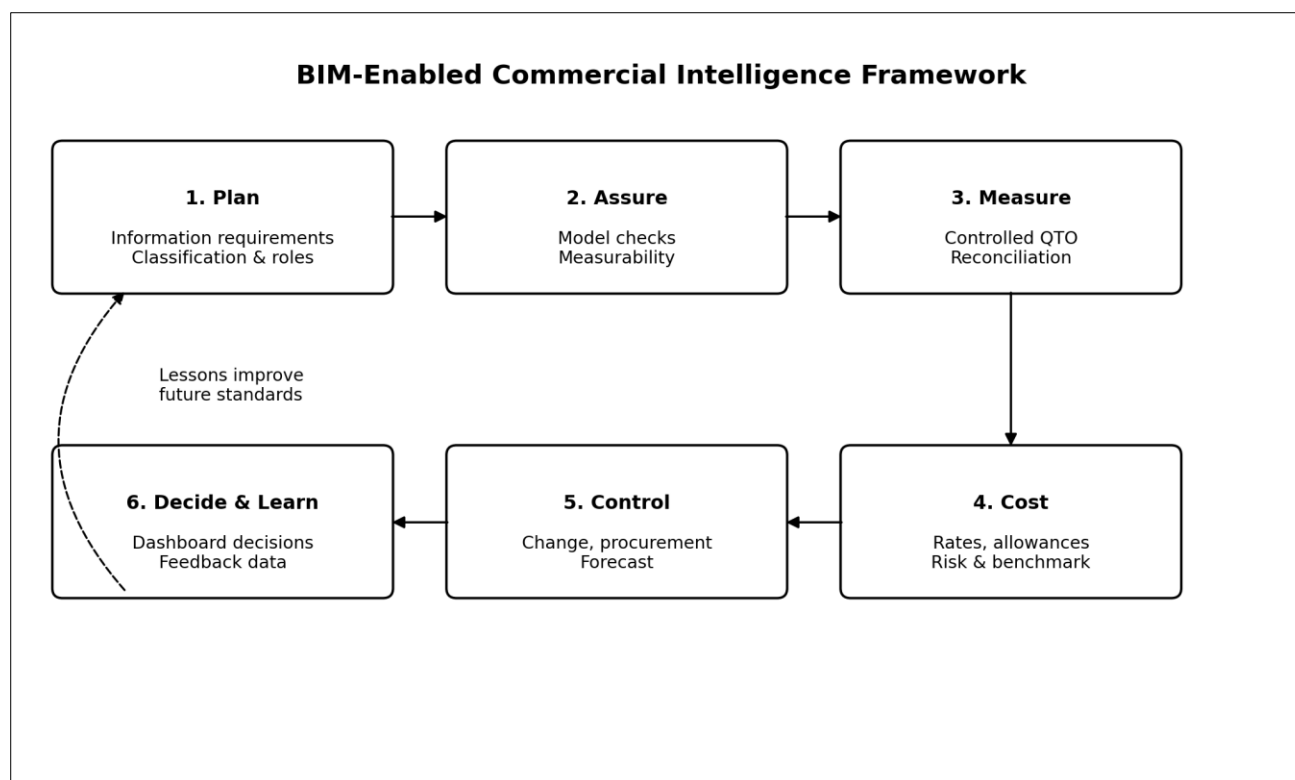


Figure 2: Proposed BIM-enabled Commercial Intelligence Framework

12. DISCUSSION

The literature demonstrates that BIM can materially strengthen quantity-surveying productivity and cost visibility, yet the main constraint is not the absence of software. The constraint is the reliability of connections between model objects, measurement logic, cost structures and commercial processes. Automated quantity take-off is valuable because it reduces repetitive work and enables rapid response to design change. Its limitation is that models are created for multiple purposes and may not contain every attribute required for contractual measurement. The quantity surveyor therefore moves from drawing interpretation toward rule definition, model assurance and exception management.

The same pattern applies to automated cost estimation. Linking quantities to rates can produce fast estimates, but cost intelligence depends on context, market conditions and risk. Machine learning may enhance prediction, but professional advice requires explainable assumptions and controlled data. Consequently, BIM should be treated as an information infrastructure for commercial reasoning rather than a replacement for reasoning. This interpretation is consistent with evidence that 5D BIM delivers the greatest value when integrated with budgeting, control, progress and payments rather than being confined to pre-construction estimation (Pishdad and Onungwa, 2024; Yilmaz *et al.*, 2025).

For Saudi Arabia, the implication is that BIM adoption should be connected to commercial governance on Vision 2030 projects. The national project environment creates strong incentives for rapid, transparent decisions, but it also magnifies the cost of inconsistent data standards. Portfolio clients can create significant value by standardizing classification, cost coding, model measurement rules and dashboard definitions across programs. Such standards would make project data comparable and create a foundation for national or organizational benchmarking while reducing repeated setup effort on each new project.

An additional implication concerns portfolio governance. Organizations managing multiple projects can standardize model classifications, cost codes, rate libraries, measurement rules and reporting definitions so that commercial evidence becomes comparable across assets instead of remaining locked within isolated project files. Comparable datasets can strengthen benchmarking, reveal recurring relationships between design choices and cost outcomes, and support more disciplined challenge of optimistic budgets during early business cases. They can also improve assurance because independent reviewers can reproduce quantity and cost positions from controlled model versions rather than relying on screenshots or manually consolidated spreadsheets. In practice, successful digital commercial management is likely to develop incrementally. A

project may begin with reliable model-based measurement, then add governed rate mapping, model comparison for change, procurement analytics, progress valuation and predictive forecasting as information maturity increases. Sequencing capabilities in this way reduces implementation risk because each new layer depends on verified data structures rather than assumptions that all project information is already standardized. It also makes benefits measurable: teams can compare take-off cycle time, reconciliation variance, change-pricing duration, tender reconciliation speed and forecasting performance before and after each capability is introduced. Portfolio learning can then feed back into employer information requirements, templates, cost libraries and training plans. For quantity-surveying practice, this evidence is important because it demonstrates that digital adoption improves commercial outcomes rather than merely changing the software used to produce traditional deliverables. Mature BIM commercial systems should therefore preserve professional accountability, transparent assumptions, controlled baselines, documented approvals, reliable audit trails and disciplined exception review. Automation should make commercial judgment more timely, traceable and evidence-based while leaving responsibility for interpretation, contractual advice and material decisions with appropriately qualified professionals. This governance also supports continuity when personnel, consultants or software platforms change, because the commercial record remains structured around agreed identifiers and rules. Over time, consistent data can become a strategic asset for estimating, procurement planning, risk calibration and reporting.

13. Research Gaps and Future Research

Several research gaps remain. First, more empirical studies should compare BIM-derived quantities with professionally measured contractual quantities across Saudi project types and quantify variance by discipline and model maturity. Second, longitudinal research should examine whether 5D BIM improves forecast-at-completion accuracy and change-cycle time during construction, not only estimating efficiency at design stage. Third, research should investigate how Saudi measurement practice, contract forms and procurement strategies affect model-based valuation. Fourth, predictive cost models should be tested for explainability and transferability between regions, project types and market conditions. Fifth, future work should evaluate whether integrating BIM with progress capture, enterprise systems and payment processes reduces disputes and improves cash-flow reliability. The proposed framework provides measurable variables that can support such testing.

14. Practical, Managerial and Policy Implications

For practitioners, the priority is to establish model assurance before pursuing sophisticated automation. Quantity surveyors should define measurement information requirements, approve extraction rules and maintain versioned quantity datasets. Cost libraries should be governed as professional evidence rather than informal spreadsheets. For managers, BIM dashboards should focus on decisions: budget movement, change exposure, procurement variance and forecast risk. Every dashboard value should reconcile to the approved commercial system. For clients and policymakers, consistent information requirements and classification across major programs could accelerate adoption and create reusable cost intelligence. Training initiatives should target dual competence in quantity surveying and digital information management. Procurement documents should clarify model status and responsibility so that digital working supports, rather than complicates, contractual administration.

15. Limitations

This study is an integrative review rather than a statistical meta-analysis. The literature uses different software, project types, maturity definitions and performance measures, so reported benefits cannot be converted into one universal productivity factor. Saudi empirical evidence on fully integrated 5D commercial control remains limited, and rapid market development may outpace peer-reviewed publication. The proposed framework should therefore be validated through live-project case studies before being treated as a prescriptive standard.

16. CONCLUSION

BIM-enabled quantity surveying offers a credible pathway from manual measurement toward faster, more integrated and more transparent commercial management. The strongest evidence supports automated quantity extraction, improved visualization, revision comparison and more responsive cost analysis. However, automation does not guarantee accuracy. Commercial reliability depends on model completeness, classification, measurement rules, cost-data governance, interoperability and professional validation. The essential transformation is therefore not from human measurement to software measurement; it is from fragmented documents to governed digital evidence.

5D BIM creates greater value when quantity data are linked with cost libraries, procurement, change records, progress and forecasts. This integration allows quantity surveyors to focus on exceptions, commercial risk and decision support while repetitive calculations become increasingly

automated. Machine learning and advanced analytics may extend this capability, but explainability and data quality remain essential for accountable cost advice. The proposed BIM-enabled Commercial Intelligence Framework places model assurance and professional validation at the center of the digital workflow and connects them to cost intelligence, commercial control and organizational learning.

For Saudi Arabia, this approach aligns with the scale and digital ambition of Vision 2030. Standardized information requirements, capable professionals and auditable model-to-cost processes can help major projects respond more quickly to design change, strengthen cost control and generate reusable commercial knowledge. The future quantity surveyor should therefore be understood as a digitally enabled commercial professional who governs the conversion of model information into decisions, rather than as a measurer whose role is eliminated by automation.

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