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Research Article

LEARNERS' PERCEPTION OF COLLABORATIVE VALUE MANAGEMENT THROUGH BUILDING INFORMATION MODELLING

Rehan Masood[1], Nick Wilson[1], Nayani Landage[1] and Omer Altaf[2]

[1]OTAGO POLYTECHNIC, DUNEDIN

[2] OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

This study evaluates learners' perceptions of collaborative value management through automated quantity take-off.

The construction industry is known for delays, cost overruns, poor quality, and a high number of accidents. Collaborative value management is a strategy to determine the effectiveness of possible solutions to the problem. The fragmented nature of the construction industry leads to communication constraints among stakeholders. The intervention of Building information modelling helps in the digitalization of the information, improving the process integration and creating a collaborative environment to achieve value for the projects.

Construction Management Quantity Surveying learners learn how to do quantity take-off from two-dimensional drawings and interpret the information in their first year. In the last year, they get hands-on training on using automated quantity take-off using building information modelling. However, the shift from a manual to automated quantity take-off has inherent challenges that impact learning.

A qualitative research approach has been used. Fifteen learners' reports were reviewed to assess their reflection on automated take-off, by using a building information modelling approach, to achieve collaborative value management in design development using an artificial intelligence open-access online tool. The learners were in year three and most of them were working in industry. Content analysis was performed to determine the key aspects highlighted by the learners.

All learners reported that the automated take-off is productive in comparison to manual work. Key aspects include instant quantities, elements integration, realistic features, dynamic point of view, interactive representation, quick pricing, alteration provision, data sharing, buildability, and low human cost. Learners mentioned that this building information modelling-based automated approach is subject to client awareness, construction company capability, selection of the level of developments, technology integration, and compatibility. A small number mentioned using conventional and automated approaches for verification purposes and shared understanding.

This study established the need for automated take-off and identified the key aspects that hinder the learning process. This study highlights the significance of automated quantity take-off from learners' perspective of having practical experience.

Keywords: Value Management, Building Information Modelling, Collaboration, Quantity Take-off, Buildings, Learners

INTRODUCTION

The New Zealand construction industry is known for delays, cost overruns, poor quality, and a high number of accidents (Babaeian et al., 2021). Collaborative value management (CVM) is a strategy used to determine the effectiveness of possible solutions to the problem (Li et al., 2022). The fragmented nature of the construction industry leads to communication constraints among stakeholders (Tiazi et al., 2020). The intervention of building information modelling (BIM) helps in the digitalisation of the information, improving the process integration and creating a collaborative environment to achieve value for the projects (Oraee et al., 2017). Construction management and quantity surveying (CMQS) learners learn how to do quantity take-off (measurement) from two-dimensional (2D) drawings and interpret the information in their first year. In the last year (year three), they get hands-on training on using automated quantity take-off using BIM.

The shift from manual to automated quantity take-off has challenges that impact learning (Smithwick et al., 2014) but the practices significantly improved over time. However, perception plays a vital role in continuing the best practices on the job with the realization of the effectiveness of the technology for the digitalization of construction processes.

According to the BIM Acceleration Committee (2021) report BIM's use on construction projects grew from 34% in 2014, to 70% in 2021 in New Zealand. However, BIM capacity needs to be amplified with the integration of emerging technologies (Ministry of Business, Innovation and Employment (MBIE), 2024). Doan et al., (2021) reported multiple issues related to BIM in the construction industry in New Zealand like inconsistent awareness and understanding of BIM definition by construction practitioners. However, timesaving is a key benefit, and lack of BIM understanding a key barrier. The most critical barriers were reported as interoperability, government regulations, software cost, and client demand (Hall et al., 2023). The barriers were classified in the comparative study based on knowledge, technology, and internal and external strategy, which varied among Chinese professionals (Ma et al, 2023). Nevertheless, there is a knowledge and skill gap regarding BIM in the construction industry in New Zealand (Puolitaival et al., 2017). Developing clarity about BIM during and including within formal qualifications has a direct impact on quantity take-off practices.

OBJECTIVES:

This study evaluated the perceptions of CMQS learners towards collaborative value management through automated quantity take-off through BIM using Revit Autodesk. Learners were asked to compare the traditional tendering using 2D drawings with BIM-based collaborative value management for procurement.

LITERATURE REVIEW:

Building information modelling in the construction industry in New Zealand can be defined as "a collaborative set of processes, supported by technology, that adds value through the sharing of structured information for building and infrastructure assets" (New Zealand Building Information Modelling (NZBIM) Handbook, 2023). There are n-dimensions of BIM applications (Masood et al., 2014) not limited to three-dimensional (3D) coordination, designated constructability reviews, 4D scheduling and sequencing, 5D cost estimation, six-dimensional (6D) procurement, prefabrication, structural analysis, lightning analysis, mechanical (heating, ventilation and air conditioning (HVAC)) analysis, energy analysis, seven-dimensional (7D) operation and maintenance, geographic information system (GIS)-based visualisation, eight-dimensional (8D) modelling with prevention through design (PTD), nine-dimensional (9D) Lean construction and continuing. However, the application of BIM is beyond dimensions as practitioners from the architecture, engineering, and construction industries explore its vitality. The core difference between the traditional 2D drawing approach and BIM is that changes in any element such as plans, sections, and elevations, require changes in all drawings. On the other hand, the BIM model can be modified or rectified, and every element revised automatically (Yin et al., 2020).

Quantity surveying entails measuring the quantities of construction materials and estimating the cost of the construction projects (Altaf, 2023). The most critical aspect of quantity surveying is the accuracy of the quantity's estimation and measurement (Valinejadshoubi et al., 2024). Five-dimensional (5D) is the most promising dimension of BIM to get quick and accurate estimates with less rework and better collaboration (Altaf, 2023). However, quantity surveyors are still lagging in BIM skills especially 5D (Harrison & Thurnell, 2015).

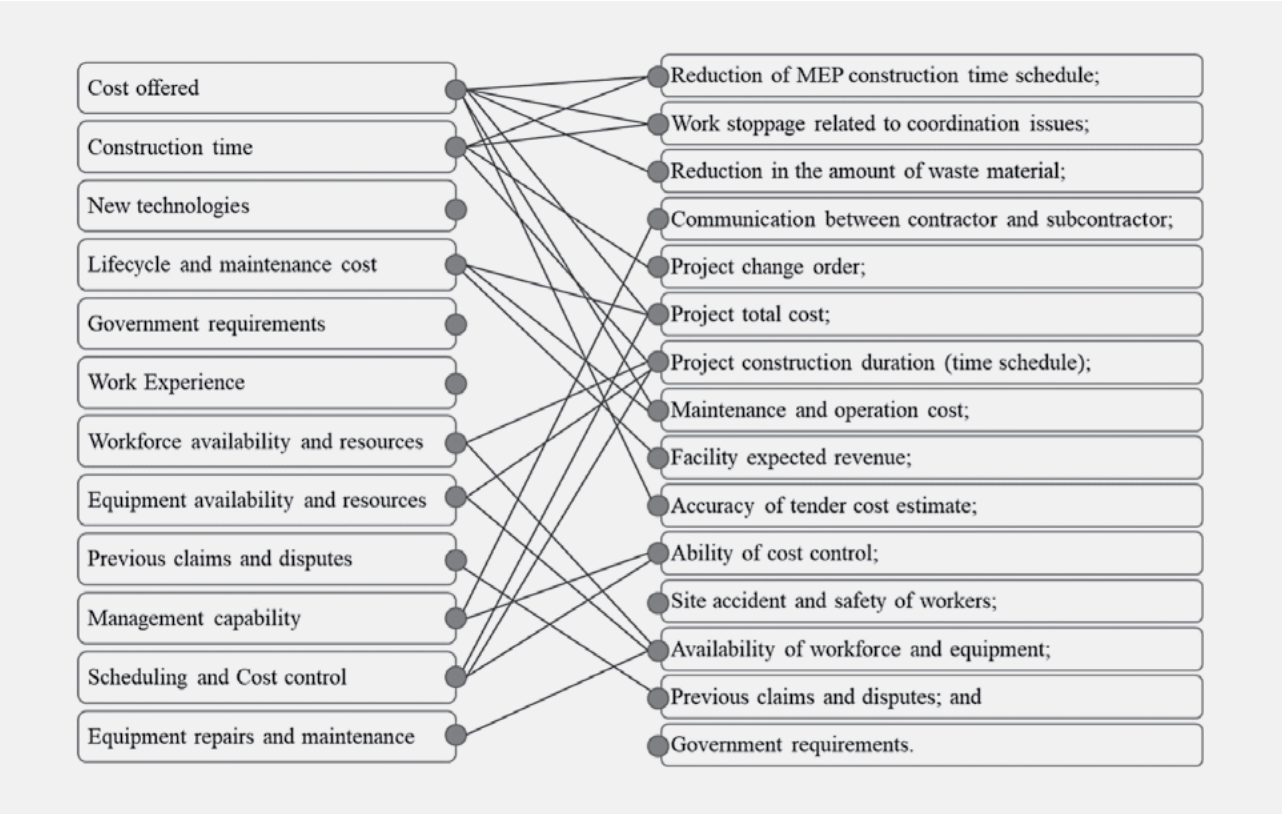

Figure 1: Mapping between BIM advantages and Tender Selection Criteria (Majzoub & Eweda,2021),

Tendering theory determines the prices through a tendering process for competitive equilibrium which demonstrates it as the sum of a valuation and a strategy (Runeson & Skitmore, 1999). This is the initial procurement stage where the contractor is selected based on competitive bids (Semaan & Salem, 2017). Building information modelling supports all the steps in the pre-bid stage (Tecture, 2024). However, requests for information leading to design reviews delay the tender process as 2D drawings require a significant amount of time to revise (Brooks, Zantinge, & Elghaish, 2023). Figure 1 shows the BIM advantages are very well mapped for tender selection criteria (Majzoub & Eweda, 2021). Building information modelling can be implemented in several procurement procedures; it is more effective if collaborative and integrated behaviour is promoted (Ciribini et al., 2015). Building information modelling intervention in the tendering process is a demonstration of CVM strategy through integrative BIM to quantify cost optimisation (Alfahad & Burhan, 2023). Collaborative value management demands project information completeness and stakeholder active engagement to attain innovative solutions (Rostiyanti et al., 2023). Nevertheless, automating the take-off with BIM provides an opportunity to address the changes by applying iteration in the building design for the agreed solution among the stakeholders. This eventually enhances the efficiency and effectiveness of the project in the early stage till completion and avoids claims.

RESEARCH METHODOLOGY:

A qualitative research approach was used to determine the perception of the CMQS learners (Fross et al., 2015). Fifteen CMQS learners' reports were reviewed to assess the reflection on automated take-off for CVM in design development which had been asked through an open-ended question. The CMQS learners are in the third year of their Bachelor of Construction Management (Quantity Surveying) qualification and most of them are currently working in industry (having a practical perspective). Research ethics category B was approved to access the assessment data of learners. Content analysis was performed to determine the classification based on the most frequent key aspects highlighted by the CMQS learners (Opoku & Egbu, 2018), refer to Table 1. CMQS learners answered the open-ended question focused on "Comparison of CVM and BIM with traditional 2D tendering". The most frequent content related to opportunities and challenges was compiled through ChatGPT and manually checked with samples for accuracy, consistency, and coverage. An approach widely applied to ensure the effectiveness of the content analysis (Firat, 2023). The ChatGPT tool used techniques of artificial intelligence (AI) to generate natural language responses based on prompts (Kalla & Smith, 2023). However, human intervention to review helps the moderation of the outcome, and accuracy is critical (Hung & Chen, 2023). This helped to ensure the relevancy of the findings in the given context.

Table 1: Most frequent benefits and challenges reported by CMQS learners.

BENEFITS		CHALLENGES	
Cost and timesaving	7	Data quality and consistency	6
Visualisation and clash detection	7	Lack of integration and standardization	4
Efficiency and collaboration	4	Lack of expertise	4
Risk Reduction and Safety enhancement	4	Cost of implementation	2
Improved planning and design	3	Reluctance to change	1
Post construction benefits	2	Prolonged learning curve and tech. familiarity	1
Buildability	2		

FINDINGS AND DISCUSSION:

The following are key benefits of using BIM identified by the CMQS learners:

Cost and Time Savings (Rank 1):

This benefit ranked at the top. Building information modelling minimises project management requirements by realising errors in the early stage of the project. Faster communication, coordination, and 3D visualisation through BIM have proven to contribute to time and cost savings (Bryde et al., 2013). The tendering phase has limited time to award the project so utilising the BIM model helps to reduce the time to address the request for information. Further, during this phase, various issues raised by contractors and subcontractors help to avoid costly scope variation claims. Quantification of materials is the core of achieving the benefit of estimation accuracy and appropriate control budget. Five-dimensional BIM implementation is inevitable to achieve this benefit, especially in quantity surveying (Altaf, 2023). This helps to not only quantify the material but also the cost of the materials which reduces the chances of a material variation claim. Time and cost are both crucial performance dimensions for the realisation of value addition.

Visualisations and Clash Detection (Rank 2):

Another benefit the CMQS learners mentioned, is the visualisation of the buildings, through BIM which helps to address the constructability issues. This leads to scope change variation later in the execution phase of the projects. However, visualisation brings the stakeholders to the table to evaluate the aspects of the project beyond constructability such as sustainability and safety (Barros & Sotelino, 2023). Nevertheless, stakeholders' efforts are reduced in the tendering process as there is no need to go through all the project documentation as all the information is embedded within the model. Similarly, BIM helps to identify the overlapping (or conflicts) of building elements or services through clash detection. This broadly helps in addressing the coordination issues between consultants and contractors, as well as contractors and subcontractors. Further, it is easier to revise the design in a BIM setting and communicate to stakeholders for updated information. This feature helps in cost-benefit analysis to optimise the design solutions to gain value and efficiency on construction projects (Chahrour et al., 2021). Both visualisation and clash detection brought transparency and accountability in the tendering process to share the risks among the parties on a mutual basis. This avoids the chances of potential conflict on the projects.

Efficiency and Collaboration (Rank 3):

Building information modelling provides a collaborative platform to exchange information for decision-making which helps in achieving efficiency. This is ranked third by the learners. However, the decision-making needs to be mutual among the project stakeholders to identify and rectify the issues but relational and contractual obligations play a vital part (Noor et al., 2021). The changes made within the BIM model are reflected across all models, allowing for real-time collaboration and data sharing. Any change is visible to everyone and provides an opportunity to accept or reject. The collaboration among services engineers, structural engineers, and architects is enhanced, enabling immediate detection of service clashes and ensuring everyone works on the latest version of the project (Mamatlepa & Mazenda, 2024). Building information modelling helps in achieving integrated project delivery which is essential to achieve collaboration through BIM induction. Building information modelling has redefined and reorganised the roles and responsibilities of the clients, architects, and contractors (Sebastian, 2011). Building information modelling collaboration greatly impacts efficiency by reducing delays and improving productivity (Eze et al., 2024). However, there is a need for alignment of understanding, interpretation, and communication to ensure successful collaboration to value the construction project (Park & Lee, 2017). It is critical that stakeholders set the agreement of the level of development (LOD) of the BIM models, normally ranging up to 500. However, LOD changed by discipline and services. Further, procurement strategies such as two-stage early contractor involvement (Finnie et al., 2024) support the collaborative platform.

The remaining benefits highlighted by CMQS learners in descending order are risk reduction and safety enhancement, improved planning and design, post-construction benefits, and buildability. Building information modelling helps in automating checking the safety rules to avoid the risk of accidents on construction projects (Zhang et al., 2013). Building information modelling-based approaches in virtual reality helps in collaborative decision-making (Du et al., 2018). Building information modelling is useful for developing the as-built model to compare with the model developed from construction drawings (Lin et al., 2016). Building information modelling helps in the constructability analysis of the proposed design of the buildings (Zhang et al., 2016). Nevertheless, the understanding of the construction project with virtual modelling is a prime benefit that helps the stakeholders realise their needs during the tendering process.

The following are key challenges of using BIM identified by the CMQS learners:

Data Quality and Consistency (Rank 1):

Learners reported that the most critical challenge associated with BIM implementation was data quality. This leads to inconsistencies in the model, especially when drawings come from different sources, which can make it difficult to upload and use the model accurately. Building information modelling authorship plays a significant role in who will create, manage, update, and retain the models (Masood et al., 2014). There is a need for standardisation across several avenues, but the BIM object library should be centralised and shared to address the data quality issues (Tsay et al., 2023). The inaccuracies or errors in the 2D drawings can potentially lead to hurdles in BIM implementation. However, BIM can rectify the deviation in drawings during the modelling process depending on the standardised input (Gharouni et al., 2021). It has been widely said in the construction industry that garbage in will be garbage out, which is absolutely right with BIM implementation and adds no value. Nevertheless, the scrutiny of the BIM models is essential to ensure the quality and consistency of the model.

Lack of Integration and Standardization (Rank 2):

Lack of integration between software and file formats can pose challenges. There are possible issues around interoperability and compatibility of the model built by subcontractors to the main model e.g. HVAC (Jaskula et al., 2014). The absence of universal standards for incorporating details may result in mislabelling and overlooked errors. This happens when there is a lack of assessment for interoperability as parametric information is lost during the exchange (Bataw et al., 2016). Several approaches such as CostX software in quantity surveying successfully integrate BIM functionalities (Zhang et al., 2024). The absence of standardisation in BIM software can be a barrier. Different companies may use different types of BIM software, leading to a lack of consistency and potentially hindering collaboration. There is no consistency in international, national, and cross-discipline levels for BIM standardisation (Edirisinghe & London, 2015). There is a need to advance the standardisation of BIM to enhance collaborative efforts. In the tendering process, the BIM model development protocol should be introduced and agreed upon among the stakeholders. The client may provide a BIM model of the construction project as part of tender documents. Otherwise, contractors and subcontractors need to invest in the development of the BIM models despite having low certainty of acquiring the project.

Lack of expertise (Rank 3):

Low adoption of BIM primarily due to a lack of skilled construction practitioners competent to use BIM tools. Building information modelling competency is based on interlinkage at individual, firm, industry, and global levels but it follows the process of assessment, acquisition, and application (Succar et al., 2013). However, BIM practitioners have created special groups within the construction industry from technicians, managers, coordinators, and collaborators. However, there is still a lack of expertise. On a recent account, a designated occupation has been assigned to deal with BIM models including technicians and managers. BIM education, formal, informal, or continuing, plays a significant role in training the new generation to implement BIM on projects. However, the focus should be beyond a single course to integrate BIM with other digital technologies (Wang et al., 2020). The availability of educational resources potentially improves the skill set of the construction workforce. Building information modelling in the New Zealand construction industry has developed guidelines to create BIM models with appendices from A to K covering all key aspects. (**https://www.biminnz.co.nz/nz-bim-handbook**)

The remaining challenges highlighted by learners in descending order, are the cost of implementation, reluctance to change, and prolonged learning curve. Upfront costs of BIM are key hindrances in adoption including expenses of software, training, and licenses (Gracia et al., 2018). There is still a reluctance to change current practices for BIM. Building information modelling has reshaped the practices, processes, and transactions in the construction industry in New Zealand which allows the construction workforce to change (Vass & Gustavsson, 2017). Like other technological interventions in construction for which it takes years to mature, BIM is not exceptional. The learning curve for BIM depends on several aspects but the most critical is the firm-level engagement that is associated with the client, construction project, and regulatory requirements to determine the BIM maturity level (Xue et al., 2018). Nevertheless, the engagement of quantity surveyors in the BIM process is crucial.

CONCLUSION:

The adoption of BIM in the construction industry in New Zealand offers a comprehensive and transformative approach, positively impacting efficiency, collaboration, risk management, cost savings, and the overall quality of construction projects from planning to post-construction phases. Building information modelling holds immense potential for digitalisation and revolutionising the construction industry in New Zealand, and addressing these challenges is crucial for its widespread and effective adoption. Overcoming issues related to learning, data quality, cost, expertise, and resistance to change will be key to unlocking the full benefits of BIM and ensuring its seamless integration into construction industry practices in New Zealand. This study established the need for BIM practices taking the example of automated take-off in the learning and training process for CMQS learners and highlights the benefits and challenges that learners perceived during the process from academia to the real-life world. It is vital to capture the transition from manual to automated practice and analyse the learning process of technology through the lens of benefits and challenges capturing the theory and practical viewpoint. The CMQS learners shared their experience of BIM implementation which helped them to enhance their cognitive skills through visualisation. The construction practitioner with the hat of learners helped to gauge the construction industry insight for advanced practices but also raised the need for improvement. Learners also demonstrated the realisation of BIM's potential to achieve value on projects through collaboration among the stakeholders. Automated quantity take-off based on BIM provides a collaborative platform to create value through efficient information exchange and decision-making. The main limitation of this study is the sample size of the CMQS learners and secondary data through final reports. Quantitative studies need to be conducted to evaluate the benefits and challenges of using BIM. Further, the case study approach is another potential way to validate the findings.

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