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PERCEIVED AND EXPECTED COST OPTIMISATION AFFORDANCES OF BUILDING INFORMATION MODELLING IN SRI LANKAN CONSTRUCTION PROJECTS

J. Logendran[1], S. Sivanraj[2], V. Lingasabesan[3], Himal Suranga Jayasena[4] and B.A.I. Eranga[5]

ABSTRACT

Building information modelling (BIM) has been widely recognised for its potential within the construction sector to optimise the construction process. This study aims to investigate the cost optimisation affordances of BIM and analyse the perceived and expected affordances within the Sri Lankan construction sector. The study adopted a mixed-method research approach where semi-structured interviews with industry experts were conducted to identify and validate key affordances, followed by a questionnaire survey to assess their significance. Content analysis and the Relative Importance Index (RII) technique were used for data analysis. The findings reveal that cost estimation accuracy, improved project coordination and reduction of variation and claims are the most significant cost optimisation affordances of BIM. Furthermore, strategies for enhancing the realization of BIM's potential were identified, emphasising stakeholder training and policy development. This study contributes to theory by addressing the knowledge gap in affordances related to cost optimisation and provides practical insights for practitioners in the Sri Lankan construction industry to maximise the benefit of BIM for cost optimisation.

Keywords: *Affordances; Building Information Modelling; Cost Optimisation; Strategies.*

1. INTRODUCTION

The construction sector faces several difficulties, such as schedule and cost overruns, labour shortages, productivity problems, and health and safety concerns (Abioye et al., 2021). One of the primary issues faced by Sri Lankan construction projects is cost overrun (Fernando & Gunarathna, 2023). Kamaruddeen et al. (2020) identified that the most influential factors for cost overruns include insufficient material supply, resource shortages, modifications to the scope of work or material specifications, client requests for acceleration, errors made during construction, cost variations, a lack of qualified

[1] Quantity Surveyor, Key Cost Engineering, Sri Lanka, logendranj.19@uom.lk
[2] Lecturer, Department of Building Economics, University of Moratuwa, Sri Lanka, sivanrajs.19@uom.lk
[3] Lecturer, Department of Building Economics, University of Moratuwa, Sri Lanka, vithushal@uom.lk
[4] Senior Lecturer, Department of Building Economics, University of Moratuwa, Sri Lanka, suranga@uom.lk
[5] Lecturer, Department of Building Economics, University of Moratuwa, Sri Lanka, isurue@uom.lk

personnel, ineffective project management, an inability to control costs, and the award of the project to the bidder with the lowest price. In addition to that, delays in project completion can lead to substantial financial burdens (Kumar Karn & Raj Dahal, 2021).

Cost optimisation is the standard operating procedure in the majority of developing and undeveloped country construction companies (Zhang et al., 2020). Building Information Modelling (BIM) represents a comprehensive suite of information technologies widely employed within the architectural, engineering, and construction (AEC) sectors. BIM positively influences the collaboration of stakeholders by integrating information and technology within the construction projects (Zhang et al., 2020). Through this integration, various software tools are consolidated into a digital platform to improve communication among all stakeholders involved in a project, as emphasised by Kumar et al. (2017). A key aspect of BIM is the creation of virtual project models with both physical and functional data, enabling detailed analysis of project scope and enhancing project control. Jayasena et al. (2019) identified three different sets of affordances, including real, perceived, and expected affordances, for examining innovations.

The concept of expected affordances was introduced by Jayasena et al. (2019), however, none have comprehensively investigated cost optimisation affordances for BIM within the Sri Lankan context. In recent years, technological advancements in the Sri Lankan construction sector have led to increased adoption of various technologies (Epasinghe et al., 2018), including BIM. Despite this progress, there remains a lack of research on how BIM affordances contribute specifically to cost optimisation within this context. Thus, this study aims to bridge this knowledge gap by investigating the cost optimisation affordances of BIM in Sri Lanka. The objectives of this study are:

1. To identify the building cost optimisation affordances of BIM
2. To analyse the perceived and expected affordances of BIM
3. To identify strategies to bridge the gap between the expected and perceived affordances of BIM for cost optimisation

This research includes a comprehensive literature review, a detailed description of the research methodology, an in-depth analysis of the findings, and a conclusion including the key outcomes, providing valuable insights for both academia and industry stakeholders.

2. LITERATURE REVIEW

2.1 SIGNIFICANCE OF BIM IN CONSTRUCTION PROJECTS

Ibrahim et al. (2019) identified that BIM offers benefits in all phases of the construction process. The advantages of the BIM are discover and reduce errors or conflicts, automatically insert and adjust modifications in all dimensions of 3D, 4D (time), and 5D (cost) models (Ebada et al., 2021), assess time and cost during the construction phase, monitor and track progress during construction, increase productivity and project efficiency, reduce and identify clashes (Al-Ashmori et al., 2020). In addition to that, reduction in construction cost and project duration, speed up the process, improve safety performance, and provide life cycle data (Chan et al., 2019).

Wang and Chen (2023) mentioned that BIM has been widely used as a digital tool for construction and as a management technique and it is anticipated that BIM will be crucial to project management. In comparison to traditional procedures, this technological

approach allows for greater and more efficient communication among project participants by encapsulating all project aspects into a single 3-dimensional model (Mahamadu et al., 2019). It is considered imperative that stakeholders representing different specialities in construction work together to create novel procedures and techniques that complement the integrated character of BIM (Onungwa et al., 2017).

2.2 COST OPTIMISATION AFFORDANCE OF BIM

BIM is appropriate for the entire cost management process in construction projects. It can be applied to efficiently reduce cost and enhance cost management effectively (Tang & Liu, 2022). The two main advantages of BIM technology are cost reduction and high documentation quality (Mesároš & Mandičák, 2017). BIM affordances mean comprehension of the decision-making process used by a specific adopter when choosing BIM tools and functions in the context of subjectivity (Jayasena et al., 2023). The real affordance is based on what BIM can provide to each user. Expected affordances and perceived affordances are concepts from design and technology that describe how users relate to a tool, system, or interface, based on what they think it can do versus what it does for them. According to Jayasena et al. (2019), perceived affordances of BIM mean what the adapter believes is achieved with the chosen BIM technology, whereas expected affordance is what the user expects to achieve. Table 1 provides the cost optimisation affordances of BIM highlighted by various studies.

Table 1: Affordances of BIM in cost optimisation

Cost optimisation affordances for BIM	Citations
Utilise the parametric functions and components.	[2], [5]
Prepare accurate cost estimation	[5], [19]
Decrease repetitive work.	[2], [3], [4], [5], [8]
Reduce paperwork.	[5], [9], [13]
Reduce the errors in the drawing.	[3], [10], [15], [18], [19]
Assess the planned and actual status of the work.	[6], [18]
Provide effective communication between stakeholders	[3], [5], [6], [12], [17], [19], [21]
Ensure data security.	[7], [16]
Forecast the risk of construction.	[1]
Expect to receive a rate of investment.	[14], [20]
Clash Detection.	[3], [10], [15], [18], [19]
Improve company reputation.	[15]
Satisfy the client.	[11], [22]

[1] - Abanda et al. (2020); [2] - Afshari (2022); [3] - Bagcal et al. (2019); [4] - Bilov et al. (2023); [5] - Park et al. (2022); [6] - Dakhil and Underwood (2016); [7] - Das et al. (2021); [8] - Gao et al. (2016); [9] – Okoye and Obi (2013); [10] - Halttula et al., (2015); [11] - Hafeez et al. (2016); [12] - Jung and Häkkinen (2018); [13] - Khatib and Alzoubi (2022); [14] - Kocakaya et al. (2019); [15] - Lahiani (2020); [16] - Maksudovna et al. (2023); [17] - Okereke et al. (2021); [18] - Smith (2014); [19] - Thurairajah and Goucher (2013); [20] - Ullah et al. (2019); [21] - Wang and Chen (2023); [22] - Zima and Mitera-Kiełbasa (2021)

2.3 STRATEGIES TO IMPLEMENT BIM FOR COST OPTIMISATION

Various studies have identified several strategies for successful BIM implementation. Liu et al. (2015) emphasised that the government and BIM education institutions should establish strategic implementation plans and promote BIM education to overcome barriers to BIM adoption. Furthermore, financial support from funding agencies and government organisations is crucial for investment in BIM (Zima & Mitera-Kiełbasa, 2021). Developing BIM standards at both local and global levels, establishing protocols for stakeholder liabilities and data security, providing BIM training and certification, fostering teamwork for BIM execution with top management support, ensuring sufficient technological facilities, and clearly defining roles and responsibilities in BIM operations are essential strategies (Asma et al., 2016; Darwish et al., 2020; Ma et al., 2023; Smith, 2014)

Famadico (2023) highlighted the need to establish feasible pathways for transitioning from traditional practices to BIM, increasing BIM-related research, making BIM widely accessible, and developing guidelines to facilitate BIM implementation. Educational support is significant in addressing knowledge-related barriers, as Ma et al. (2023) noted, which suggested that proper BIM training enhances practitioners' knowledge. Rafindadi et al. (2023) further advocated providing free trial access to BIM software, continuous workshops, and seminars, while Aka et al. (2021) emphasised the efficiency of offering BIM training to fresh graduates. Increasing public awareness about BIM can spread knowledge of its key benefits, enhance client trust through improved working environments, and reduce miscommunication among stakeholders (Farouk et al., 2023; Zaini et al., 2020). Finally, government policies and guidelines are indispensable, providing the necessary procedures for BIM implementation, mandating its use in government-funded projects, reducing tax policies for BIM software acquisition, and organising platforms for BIM education and awareness (Olugboyega et al., 2019; Rani et al., 2023).

3. METHODOLOGY

The study analysed the perceived and expected cost optimisation affordances of BIM in Sri Lankan construction projects. It is significant to obtain expert perspectives and experience to interpret the cost optimisation affordances of BIM and to gain a more comprehensive understanding of the two major types of affordances in this study. In-depth discussion based on the professionals' experience in the field is necessary to obtain a more comprehensive understanding of the subject matter (Saunders et al., 2023).

In research, a mixed-methods approach combines several research methods, which is useful for overcoming the limitations of mono-methods (Kothari, 2021). The mixed-method approach allowed for the collection of relevant data from various sources through a combination of qualitative and quantitative paradigms. The research methodology was structured as follows: an initial literature review was conducted to understand the background of cost optimisation real affordances of BIM. Subsequently, the mixed method approach enabled the validation of data obtained from the literature, distinguished between perceived and expected affordances, and identified suitable strategies to bridge the gap between perceived and expected affordances of BIM in cost optimisation. Data collection was conducted in two stages: interviews in the first phase, which allowed for validation of the findings of the literature and identification of new cost optimisation

affordances of BIM and questionnaires in the second phase to quantitatively assess the cost optimisation affordances and to categorise them as expected and perceived affordances. Experts for interviews were selected using purposive sampling, and their profiles are presented in Table 2.

Table 2: Profile of interview experts

Expert	Designation	Experience in the construction industry (at least 15 years)	Experience in BIM (more than 5 years)	Bachelor's/ Postgraduate Degree
E1	Contract Manager	✓	✓	✓
E2	Senior Quantity Surveyor	✓	✓	✓
E3	Senior Quantity Surveyor	✓	✓	✓
E4	Senior Quantity Surveyor	✓	✓	✓
E5	Senior MEP Quantity Surveyor	✓	✓	✓
E6	Contract Manager	✓	✓	✓
E7	Contract Manager	✓	✓	✓
E8	Senior MEP Quantity Surveyor	✓	✓	✓
E9	Senior Quantity Surveyor	✓	✓	✓
E10	Senior Quantity Surveyor	✓	✓	✓
E11	Contract Manager	✓	✓	✓
E12	Senior Quantity Surveyor	✓	✓	✓
E13	Senior Quantity Surveyor	✓	✓	✓

In-person recorded interviews were conducted, which lasted around thirty minutes. The findings from the interview were analysed using a three-phase manual content analysis. In qualitative research, this tool allowed us to find selective codes (Williams & Moser, 2019). Firstly, the interview outcomes were transcribed, followed by a critical review to identify the affordances of cost optimisation. Finally, affordances were standardised and classified according to deductive and inductive codes.

The results from the previous stages were used to conduct a questionnaire survey. Data was collected from 40 professionals, including quantity surveyors from various organisations within Sri Lanka. These professionals were selected based on their years of experience within the construction industry (minimum of 5 years) and their knowledge on cost optimisation affordances of BIM. This phase identified the level of perception and expectation for each cost optimisation affordance. Participants were asked to rank each affordance based on their level of perception and expectation.

4. RESULTS AND DISCUSSION

4.1 COST OPTIMISATION AFFORDANCES OF BIM IN THE SRI LANKAN CONSTRUCTION INDUSTRY

The first step involved validating the cost optimisation affordances of BIM identified in the literature review and identifying any additional affordances. Table 3 presents the cost

optimization affordances of BIM based on responses from industry experts. As indicated in the table, all affordances were acknowledged by the majority of experts. Additionally, experts identified nine (9) new cost optimisation affordances of BIM, including the ability to create multiple design scenarios, accurate quantity take-offs, improved collaboration, minimised variations and claims, automated lifecycle cost analysis, enhanced asset management, reduced visualisation time, accelerated processes, and decreased reliance on human resources.

Among the identified affordances, a few were unanimously recognised by all experts, including BIM's ability to generate accurate cost estimates, perform precise quantity take-offs, reduce visualisation time, and accelerate processes. Meanwhile, some affordances were less commonly acknowledged. These include BIM's capability to decrease reliance on human resources and utilise parametric functions and components for enhanced efficiency and automation.

4.2 ANALYSIS OF PERCEIVED AND EXPECTED AFFORDANCES OF COST OPTIMISATION USING BIM

A questionnaire survey was used to evaluate the significance of the real affordances of BIM for Cost optimisation and to identify the extent to which those affordances are expected and perceived. Table 4 provides the outcomes of the survey, starting with the most significant affordance at the top of the table. From the data obtained using the Questionnaire, cost-related and quality-oriented cost optimisation affordances of BIM emerged as the highest-ranked in terms of significance. Specifically, the ability of BIM to prepare accurate cost estimation (A2) recorded the highest RII (0.955), followed closely by the ability to assess the planned and actual status of the work (A6), accurate Quantity Take-off (A15), and minimize variation and claims (A17) all with the same RII of 0.950. These findings underscore those participants prioritise BIM's capacity to streamline budgeting, cost control, and project scope management in cost optimisation affordances.

Despite the strong significance ratings for many cost optimisation affordances of BIM, a notable portion remained largely expected rather than perceived in practice. In this survey, participants were asked to classify each affordance as either perceived (if they had experienced it) or expected (if they believed in its potential but had not yet observed it). According to the responses, even for highly significant affordances, the majority of respondents indicated they were still expected rather than perceived. This discrepancy can be due to a variety of factors, including the maturity level of BIM implementation (Martin et al., 2019), the duration of projects (Mahamadu et al., 2019), or limited training and awareness among team members. Additionally, certain affordances, such as Asset Management (A19), which gained an RII of 0.875, had a perceived rate of 0. This suggested that although it is recognised as a significant affordance, its benefit had not been encountered. This may be perceived only under specific project circumstances (for large-scale infrastructure development). Hence, while the industry values these BIM capabilities, the full realisation of many benefits may require extended exposure, proper skill-building, and organisational readiness to utilise them effectively.

Table 3: Cost optimisation affordances of BIM in SL construction industry as per interview outcomes

	Code	Affordances of BIM in Cost Optimisation	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	Total
Affordances as per Literature	A1	Utilise the parametric functions and components.	✓			✓	✓			✓			✓	✓	✓	7
	A2	Prepare accurate cost estimation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	13
	A3	Decrease repetitive work.	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓		10
	A4	Reduce paperwork.	✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	10
	A5	Reduce the errors in the drawing.	✓	✓				✓	✓	✓	✓	✓			✓	8
	A6	Assess the planned and actual status of the work.	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	11
	A7	Provide effective communication	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
	A8	Ensure data security.	✓	✓		✓	✓	✓	✓		✓	✓		✓		9
	A9	Forecast the risk of construction.		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
	A10	Expect to receive a rate of investment.	✓	✓		✓	✓	✓	✓	✓		✓	✓		✓	10
	A11	Clash Detection.	✓	✓	✓			✓		✓	✓	✓	✓		✓	9
	A12	Improve company reputation.		✓					✓	✓	✓	✓	✓	✓	✓	8
	A13	Satisfy the client.	✓	✓		✓		✓	✓		✓	✓		✓	✓	9
Additional Affordances after interviews	A14	Create multiple design scenarios	✓	✓		✓		✓	✓		✓			✓	✓	8
	A15	Accurate Quantity Take-off	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	13
	A16	Improve Collaboration	✓	✓	✓			✓		✓	✓	✓	✓		✓	9
	A17	Minimise variation and claims	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	11
	A18	Automated lifecycle cost analysis	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	11
	A19	Asset management	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	11
	A20	Reduce time for visualisation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	13
	A21	Speed up processes	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	13
	A22	Decrease dependency on human resources	✓	✓				✓		✓	✓	✓			✓	7

Table 4: Perceived and Expected affordances of cost optimisation using BIM

Code	Affordances of BIM in Cost Optimisation	Significance of the affordances	Affordances	
			Expected	Perceived
A2	Prepare accurate cost estimation	0.955	68%	32%
A6	Assess the planned and actual status of the work.	0.950	55%	45%
A15	Accurate Quantity Take-off	0.950	13%	87%
A17	Minimise variation and claims	0.950	60%	40%
A5	Reduce the errors in the drawing.	0.940	40%	60%
A14	Create multiple design scenarios	0.930	68%	32%
A11	Clash Detection.	0.925	65%	35%
A13	Satisfy the client.	0.900	58%	42%
A19	Asset management	0.875	100%	0%
A9	Forecast the risk of construction.	0.865	13%	87%
A12	Improve company reputation.	0.865	0%	100%
A7	Provide effective communication between stakeholders	0.855	68%	32%
A16	Improve Collaboration	0.855	33%	67%
A18	Automated lifecycle cost analysis	0.840	48%	52%
A8	Ensure data security.	0.800	43%	57%
A20	Reduce time for visualisation	0.800	40%	60%
A21	Speed up processes	0.775	43%	57%
A10	Expect to receive a rate of investment.	0.755	65%	35%
A1	Utilise the parametric functions and components.	0.740	43%	57%
A3	Decrease repetitive work.	0.740	58%	42%
A4	Reduce paperwork.	0.690	13%	87%
A22	Decrease dependency on human resources	0.625	68%	32%

4.3 STRATEGIES TO BRIDGE THE GAP BETWEEN EXPECTED AFFORDANCES AND PERCEIVED AFFORDANCE

The expert interviews were used to identify and evaluate strategies to help stakeholders experience the cost optimisation affordances of BIM. The identified measures were quantitatively assessed through the questionnaire survey in the second phase. The outcomes have been summarised in Table 5. Analysis of the RII results revealed that comprehensive training and upskilling (S1) scored the highest RII with 0.895, highlighting that training and skill development are essential for leveraging BIM tools effectively, particularly for cost estimation and budget management. This was followed by government policies (S9) with RII of 0.885. This supports the findings of Albtoush et al. (2020), Abusafiya and Suliman (2017) and Amri and Marey-Pérez (2020) indicating

that regulatory and standards-based strategies are critical for motivating consistent, high-quality adoption of BIM across the sector. Standardising the workflows & protocols (S5) and technology integration and updates (S7) also emerged as highly effective strategies to bridge the gap between the expected and perceived affordances. These findings suggest that focusing on workforce competence, standardised processes, and supportive policies can significantly improve how stakeholders perceive and experience the cost optimisation affordance of BIM.

Table 5: Strategies to bridge the gap between expected and perceived affordances

Code	Strategies to Bridge the Gap	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	RII
S1	Comprehensive Training and Upskilling	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	0.895
S9	Strengthen Government Policies	✓	✓		✓	✓		✓	✓	✓		✓	✓	✓	0.885
S5	Standardised Workflows and Protocols	✓		✓	✓	✓	✓		✓	✓		✓	✓	✓	0.865
S7	Technology Integration and Updates	✓	✓	✓		✓		✓	✓	✓	✓		✓	✓	0.860
S8	Frequent workshops		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	0.840
S6	Management and Leadership Support	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	0.830
S3	Clear Implementation Roadmaps					✓	✓					✓	✓	✓	0.755
S4	Cross-Functional Collaboration	✓		✓							✓	✓			0.660
S2	Pilot Projects and Incremental Adoption	✓				✓	✓	✓	✓	✓					0.640

5. CONCLUSION

This study has explored the cost optimisation affordances of BIM in Sri Lankan construction projects. The findings revealed that BIM significantly contributes to preparing accurate cost estimation, improving project coordination, minimising rework, reducing errors in drawings and facilitating decision-making by creating multiple design scenarios. Moreover, the differentiation between perceived and expected affordances highlighted the potential for optimising BIM's implementation strategies to bridge existing gaps and maximise its benefits. The study also emphasises the necessity for strategic initiatives, including governmental support, industry-wide standardisation, enhanced training programs, and financial incentives, to facilitate BIM adoption. Implementing these strategies can help to overcome barriers such as insufficient technical expertise, high initial investment costs, and resistance to change within the industry.

This research contributes to the existing theory and literature by addressing a significant gap in the study of affordances within the Sri Lankan context. While numerous studies

have explored the three types of affordances, such as real, perceived and expected, there has been a lack of investigation into how these affordances are experienced in the Sri Lankan construction industry. By examining these affordances in the Sri Lankan context, this study identified the major affordances that remain in the expected stage and have yet to be actualized. This contribution is crucial for developing targeted strategies to facilitate the full realization of BIM's potential in terms of cost optimisation. However, this study has some limitations. Firstly, this study was conducted for construction projects in the Sri Lankan context, so the results can differ for other countries depending on the social and economic structure. This research was carried out for a generic view of all types of construction projects in Sri Lanka. Hence for further studies, this investigation can be repeated for specific types of construction projects.

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