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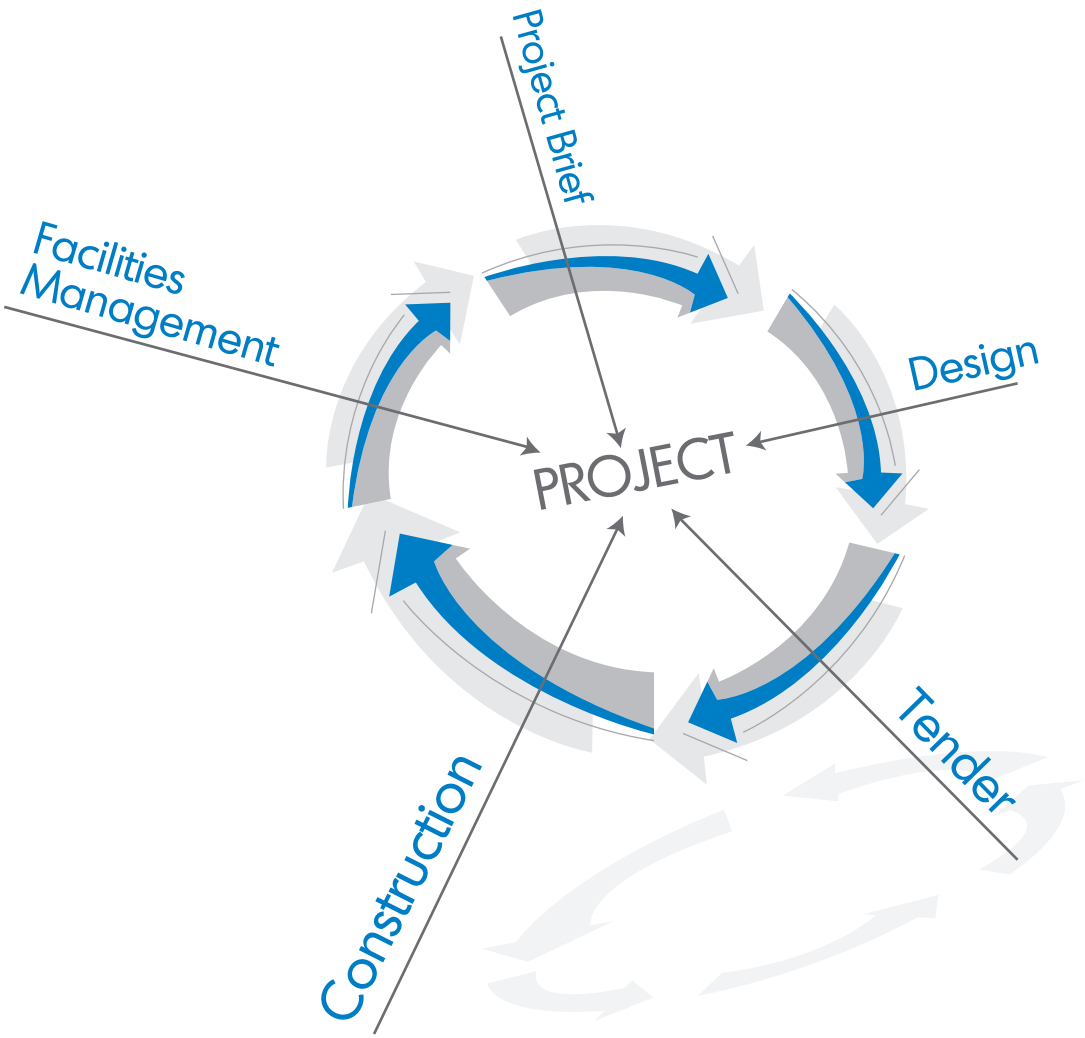

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Contents

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Secretariat

Editorial

Welcome from The Editors

Welcome to the forty-eighth (48th) issue of Malaysian Construction Research Journal (MCRJ). In this issue, we are pleased to include seven papers that cover a wide range of research areas in the construction industry. The editorial team would like to express our sincere gratitude to all contributing authors and reviewers for their contributions, continuous support and comments.

In this issue:

Natasha Dzulkalnine et al. address the persistent issue of maintenance fee arrears in Malaysia's stratified residential properties, which continue to challenge effective building management despite existing regulatory reforms. Drawing on the Theory of Planned Behaviour (TPB), the research investigates behavioural determinants influencing residents' maintenance fee payment behaviour. Using a quantitative approach, data were collected from 265 strata residents in the Klang Valley and analysed through multiple regression analysis. The findings indicate that only the facilities provided significantly influence payment behaviour, while factors related to the Joint Management Body, resident–JMB relationships, and safety and security are not significant. The proposed model explains 44.3% of the variance in payment behaviour. By extending the application of TPB to the strata housing context, this study offers empirical evidence to support policymakers and property management stakeholders in developing more effective strategies to enhance maintenance fee compliance.

Wahida Wahi et al. adapted Hillson's (1997) Maturity Model to assess the level of safety management practices among G7 construction companies in Sarawak. The quantitative research method was utilised to achieve the research objective. The safety management culture (SMC), safety management process (SMPR), and safety management experience (SME) were found to be high. In comparison, the safety management application (SMA) was found to be moderate. The overall result shows that the G7 construction companies exhibit a "mature level" of safety management practices, which signifies a high level of safety management practices. This study has contributed to the field of safety management practices by providing insight into the extent of safety practices among the G7 construction companies operating in Sarawak. This finding can assist regulatory bodies, such as the Construction Industry Development Board (CIDB), the Department of Occupational Safety and Health (DOSH), and policymakers in safety-related matters across the Malaysian construction industry.

Noor Fazierah Yaakub et al. study develops an integrated, theory-driven conceptual framework for construction and demolition waste recycling in Malaysia. Drawing on a systematic synthesis of 124 peer-reviewed studies published between 2020 and 2025, it consolidates 70 recycling success factors into eight thematic domains, organised under four higher-order constructs: Governance, Operational Enablers, Collaboration Drivers, and Behavioural Implementation. Grounded in Institutional Theory, the Resource-Based View, Stakeholder Theory, and the Theory of Planned Behaviour, the framework offers a multi-level perspective on how regulatory structures, organisational capabilities, market coordination,

and site-level practices shape recycling outcomes. Moving beyond the fragmented and largely descriptive nature of prior research, this study provides a coherent structure that clarifies interactions among policy, operations, collaboration, and behaviour. The framework advances circular construction theory and serves as a structured reference for future empirical research and policy development in Malaysia and other emerging economies.

Amir Farid Omar et al. explore critical success factors (CSFs) crucial for facilities management (FM) contractors, integrating insights from nine management theories. Through Interpretive Structural Modelling (ISM) and expert opinions, seven key CSFs are identified, including client-centric approach, technology integration, and data-driven decision-making. The study emphasises the need for a holistic FM approach, recognising the convergence of multiple factors to support clients' core business. Their findings offer valuable insights for effective FM implementation strategies.

Kudrekodlu Venkatesh Prasad examines the critical issue of construction material waste, which accounts for over $1 trillion in global annual losses and is examined through a detailed study of a large-scale residential project. The article quantifies the staggering impact of site inefficiencies, documenting wastage rates up to 6.08% that result in significant financial losses and over 100 metric tonnes of CO2 emissions. The study moves beyond theoretical discourse to identify practical aspects like over-ordering and design modifications, while validating the transformative potential of digital tools such as BIM and IoT-based monitoring. The study recommends integrating lean practices with smart technologies and provides a strategic roadmap for the Indian construction sector to align with sustainability regulations. This work serves as a vital resource for stakeholders aiming to reconcile economic profitability with environmental responsibility in the modern built environment.

Norazli Ismail et al. developed a theoretical model to support the successful implementation of the Government Asset Management Policy (GAMP) in Malaysia, addressing persistent weaknesses reported in public-sector asset governance. Using a dual-phase qualitative approach, the study first identified sixteen Critical Success Factors (CSFs) through a deductive literature review and subsequently validated and expanded them through a Focus Group Discussion involving thirteen experts from government agencies, statutory bodies, academia, and industry. The analysis resulted in eighteen CSFs, including incentives and rewards and contract management, which were structured within Edwards III's Four Critical Variables (FCV) framework of communication, resources, disposition, and bureaucratic structure. The findings highlight leadership commitment, staff competency, reliable asset records, organisational culture, clear communication, and adequate resources as key determinants of implementation success. This research is significant as it provides a theory-based and empirically supported model to strengthen governance, accountability, and asset performance in Malaysia's public sector.

Ahmad Sharainon Md Shaarani et al. examined cultural and regional variations in Digital Facilities Management (DFM) implementation outcomes to explain differences in success across global contexts. The study synthesised empirical evidence using a PRISMA-compliant systematic review and random-effects meta-analysis to evaluate four widely recognised Critical Success Factors (CSFs): leadership commitment, training and human capability, stakeholder engagement, and technical infrastructure. The findings reveal substantial regional variation in DFM implementation success, with Europe demonstrating

the highest success rates and Latin America the lowest. Among the CSFs, training emerged as the only factor with a statistically significant and consistent effect across regions, underscoring its universal importance in digital transformation initiatives. The results further indicate that cultural context shapes how CSFs are enacted rather than determining which CSFs are important. This study contributes to DFM literature by providing a cross-cultural meta-analytic synthesis of implementation success factors and offers context-sensitive insights for policymakers and industry leaders, particularly in emerging economies.

Editorial Committee

DETERMINANTS OF MAINTENANCE FEE PAYMENT BEHAVIOUR AMONG STRATA RESIDENTS: A THEORY OF PLANNED BEHAVIOUR APPROACH

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Abstract
Maintenance fee arrears have become a persistent issue in Malaysia's stratified residential properties, hindering effective building upkeep and imposing financial strain on the Joint Management Body (JMB). Although regulatory reforms such as the Strata Management Act (SMA) 2013 and government initiatives have been introduced to improve strata governance, many JMBs continue to face difficulties in collecting sufficient maintenance fees. This problem stems not only from financial constraints but also from behavioural factors influencing residents' willingness to pay, which remain underexplored in current literature. To address this gap, this study examines the determinants of maintenance fee payment behaviour among strata residents in Malaysia using the Theory of Planned Behaviour (TPB) as its theoretical foundation. A quantitative research design was adopted, involving 265 respondents from high-rise residences in the Klang Valley selected through convenience sampling. Data were analysed using SPSS, including reliability analysis, descriptive statistics, and multiple regression. Findings reveal that only the facilities provided significantly influence maintenance fee payment behaviour, whereas the role of the JMB, the resident and JMB relationship, and safety and security show no significant effects. The model explains 44.3% of the variance in residents' payment behaviour. This study extends the application of TPB into the strata housing context and provides empirical insights to assist policymakers, JMBs, and housing authorities in enhancing strategies to improve compliance with maintenance fee payments.

Keywords: *Financial management; maintenance fee; facilities management; IBS; high-rise resident; late payment*

INTRODUCTION

Ensuring a building's optimal performance and visual appeal requires regular maintenance. Inefficient maintenance practices are among the key factors contributing to high building maintenance expenses (Che Ghani et al., 2016). Maintenance cost management is a long-standing issue in the residential sector, particularly within stratified buildings, where residents and the Joint Management Body (JMB) often hold differing perspectives on responsibilities and expectations. Despite various government initiatives, issues related to strata management and maintenance fee continues to persist. As Malaysia advances toward its Smart City vision, it is essential to reassess and restructure the existing maintenance fee framework to support the nation's agenda for sustainable and liveable urban environments.

Under the Strata Management Act (SMA) 2013, homeowners are legally obligated to pay monthly fees collected by the JMB before strata titles are issued, and subsequently by the Management Corporation (MC) after title issuance (Wong, 2019; Zan et al., 2018). These fees cover a wide range of operational and administrative expenses related to the management and maintenance of common property, including security services, utilities for shared spaces,

cleaning, landscaping, elevators and escalators maintenance, and minor repairs. The maintenance charge can also be defined as funds collected by the Management Body (JMB/MC) for the administration and maintenance of common areas and the advancement of strata property (KPKT, 2022).

The Ministry of Housing and Local Government (MHLG) outlined its Strategic Plan for 2021–2023, revised in 2022, aligning with the Sustainable Development Goals (SDGs) and the government's "Shared Prosperity Vision 2030,". One of its seven core areas, Core 1, titled "Providing Quality and Comfortable Housing and Environment," specifically addresses maintenance challenges under sub-topic S1.6 - Structuring and Streamlining the Organization that Regulates Strata Management and Maintenance. This strategic initiative represents a five-year roadmap aimed at improving public well-being through more efficient strata property governance and management.

As part of efforts to improve the residents' quality of life, the government also introduced a quality star rating system for strata building management - the Strata Building Management Quality Index. This system, governed by the Malaysian Administration and Management Planning Modernisation Unit (MAMPU), serves as an indicator of the living standards in strata properties. In 2019, the Commissioner of Buildings (COB), in collaboration with local authorities, evaluated 5,739 development projects using this system. The assessment covered five key components: residents' well-being, maintenance management, governance, financial management, and risk management.

Despite the legal requirement under the Strata Management Act (SMA) 2013 for homeowners to pay monthly maintenance fees, arrears continue to be a persistent challenge in Malaysia's stratified residential sector. Many JMBs struggle to collect sufficient funds, resulting in financial constraints, deferred maintenance works, and deteriorating living conditions. While prior studies have attributed this problem to weak enforcement, limited awareness of legal obligations, and dissatisfaction with building management, most have examined these issues from a managerial or regulatory standpoint. These remain limited understanding of the behavioural factors that influence residents' willingness to pay maintenance fees.

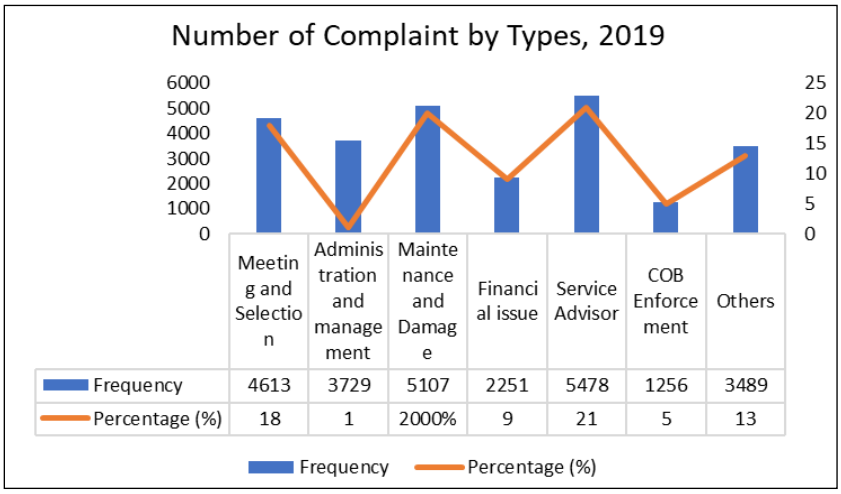
Addressing this gap, the present study applies the Theory of Planned Behaviour (TPB) to examine the determinants of maintenance fee payment behaviour among strata residents in Malaysia. Specifically, it investigates the influence of four key factors on residents' payment behaviour: (i) the role of the Joint Management Body (JMB), (ii) the resident–JMB relationship, (iii) facilities provided, and (iv) safety and security on residents' payment behaviour.

LITERATURE REVIEW

Despite the clear need for regular building maintenance, in Malaysia, such work often driven by availability of funds and is typically carried out when resources are accessible - usually after the building begins to lose its appeal or becomes unsuitable for its intended purpose (Lateef, 2009). In 2019, the Ministry of Housing and Local Government (KPKT) launched the Empowerment Agenda for Strata Residents, which included the establishment of Joint Management Bodies (JMB) or Management Corporations (MC) through the Annual

General Meeting (AGM). This initiative aligns with the Strata Management Act 2013 (Act 757), which mandates the creation of JMB or MCs for every stratified development project.

The objective of Act 757 is to ensure that each development has a JMB/MC responsible for managing and maintaining common property, under the supervision of the relevant City or District Council (COB). JMBs and MCs are democratically elected through the AGM, which also serves as a platform for discussing issues related to finances, legal matters, and community relations. As of 2019, 10,945 (50%) of the 22,345 stratified developments in Malaysia had successfully formed JMBs/MCs.



Note: * Laporan Thunan COB PBT 2019

Figure 1. Number of Complaint by Types, 2019

One of the key challenges in providing services to residents is financial constraints, as illustrated in Figure 1. Ineffective service delivery occurs when some property owners refuse to pay their maintenance or service charges, creating financial strain on the management. Consequently, the management body is often forced to use its limited internal funds to address such shortfalls. Without adequate funding, it becomes increasingly difficult for the management to perform its duties effectively (Tawil et al., 2016). According to KPKT reports, most of these issues are concentrated in Selangor, Kuala Lumpur, and Penang - states with a high density of housing developments.

ADOPTED THEORY

The Theory of Planned Behaviour (TPB), introduced by Ajzen (1991), is one of the most widely applied behavioural theories for predicting and explaining human actions. TPB posits that an individual's behaviour is determined by three key antecedents: attitude, subjective norms, and perceived behavioural control (PBC). Attitude refers to an individual's positive or negative evaluation of performing a particular behaviour, while subjective norms reflect perceived social pressure from others to perform or avoid the behaviour. Perceived behavioural control refers to an individual's perception of their ability to perform the behaviour, influenced by both internal and external constraints.

TPB is particularly suitable for examining residents' maintenance fee payment behaviour, as it captures both cognitive and social determinants of compliance. The payment of maintenance fees is not merely a financial obligation, but a behavioural decision shaped by personal beliefs, social expectations, and perceived ease or difficulty in fulfilling the payment. Past studies have applied TPB to explain payment-related behaviours in areas such as tax compliance, utility bill payment, and service charge obligations, indicating its relevance to mandatory payment contexts. In strata housing, TPB offers a structured framework to examine how residents' evaluations of the Joint Management Body (JMB), their social interactions, and their perceived value of facilities influence their intention to pay maintenance fees. Hence, TPB serves as the theoretical foundational for this study in identifying the determinants of maintenance fee payment behaviour among strata residents in Malaysia.

Perceived Role and Governance of the Joint Management Body (JMB)

The Joint Management Body (JMB) is responsible for managing common property, maintaining facilities, and ensuring financial and administrative transparency under the Strata Management Act (SMA) 2013. Effective JMB governance is vital for sustaining building quality and resident satisfaction. When residents perceive the JMB as competent, transparent, and responsive, they are more likely to comply with maintenance fee obligations (Abas et al., 2021; Shuhaimi et al., 2022). Conversely, weak governance, lack of communication, or poor financial transparency has been associated with lower trust and higher fee arrears (Tawil et al., 2016; Lim & Tan, 2021).

From the TPB perspective, the perceived role and governance of the JMB relate to subjective norms, as the JMB represents an authority that communicates social and collective expectations regarding fee payment. A credible and well-governed JMB strengthens normative pressure and promotes cooperative behaviour among residents, while poor governance reduces residents' sense of obligation. Few studies have empirically examined how residents' perceptions of JMB governance influence their intention to pay maintenance fees through a behavioural lens such as TPB, indicating a need for further empirical evidence from residents' perspectives.

Resident–JMB Relationship Quality

The relationship between residents and the JMB reflects the level of trust, communication effectiveness, and cooperation within strata communities. A positive relationship is demonstrated through transparent communication, responsiveness to feedback, and fair decision-making. When residents perceive the JMB as approachable and supportive, they are more likely to cooperate with management initiatives, including fee payment (Abas et al., 2021; Sholehah et al., 2020). Conversely, strained relations due to poor communication or perceived bias can lead to dissatisfaction and resistance, contributing to payment delays or non-compliance (Tawil et al., 2016; Nguyen & Khai, 2023).

Within the TPB framework, the resident–JMB relationship aligns with subjective norms, as positive social interaction and relational trust foster a sense of shared responsibility in maintaining the property. Strong relationships reinforce the social expectation that fee payment is a collective obligation, whereas weak relationships diminish this sense of duty.

Although communication and trust are often cited as challenges in strata management, limited empirical research has their direct impact on residents' payment intentions, highlighting a gap for further study.

Perceived Quality of Shared Facilities

Shared facilities such as lifts, recreational areas, parking spaces, and cleanliness of common areas are key elements of strata living. Residents' perceptions of the quality, functionality, and maintenance of these facilities influence their satisfaction with the overall environment. When facilities are well-maintained and meet expectations, residents perceived value for money increases, enhancing their willingness to pay maintenance fees (Sia et al., 2018; Lim & Tan, 2021). Conversely, poor facility maintenance or frequent breakdowns can reduce perceived value and weaken payment motivation (Tawil et al., 2016; Rahman & Ismail, 2022).

In the TPB context, the perceived quality of shared facilities corresponds to attitude, as residents form positive or negative evaluations of paying fees based on the tangible benefits they receive. High-quality facilities foster positive attitudes towards payment, while poor-quality facilities contribute to negative attitudes and lower compliance.

Perceived Safety and Security Standards

Safety and security are critical considerations for residents of stratified properties, as they directly influence comfort, well-being, and quality of life. Security measures such as access control, CCTV surveillance, and trained security personnel contribute to residents' sense of safety and satisfaction. When these measures are perceived to be effective, residents are more likely to value the services provided and show greater willingness to pay (Sia et al., 2018; Rahman & Ismail, 2022). In contrast, weak security systems or frequent incidents can undermine confidence in management and reduce motivation to contribute financially (Tawil et al., 2016; Hassan & Ahmad, 2023).

From the TPB perspective, perceived safety and security standards also relate to attitude. Positive perceptions of safety create favourable attitudes toward paying maintenance fees, whereas poor security provisions lead to negative attitudes and weakened payment intention.

Maintenance Fee Payment Behaviour

Maintenance fee payment behaviour refers to the extent to which strata residents fulfil their financial obligations for the upkeep and management of shared facilities and common property. Although payment is mandatory under the Strata Management Act (SMA) 2013, arrears remain a significant challenge across Malaysia. Persistent non-payment leads to financial instability among JMBs, resulting in poor maintenance, deteriorating facilities, and increased conflict among residents (Tawil et al., 2016; Shuhaimi et al., 2022).

Although some studies have attributed non-payment to financial constraints, dissatisfaction with management performance, and lack of awareness of legal obligations, scholars increasingly recognise that fee payment is not merely a financial decision, but a behavioural compliance issue influenced by perceptions, attitudes, and social expectations

(Sholehah et al., 2020; Nguyen & Khai, 2023). This underscores the relevance of TPB in explaining how cognitive and social factors shape residents' payment intentions and behaviours.

CONCEPTUAL FRAMEWORK

The conceptual framework adapts the Theory of Planned Behaviour (Ajzen, 1991) to the context of maintenance fee payment among strata residents. Within TPB, attitude represents residents' evaluative beliefs about the outcomes of paying maintenance fees. In this study, attitude is operationalised through (a) the quality and adequacy of facilities provided (e.g., functional common areas, cleanliness, amenity availability) and (b) safety and security provisions (e.g., effective security personnel, functioning safety equipment). Previous research shows that these factors influence residents' valuation of fees and their willingness to pay (Sia et al., 2018; Tawil et al., 2016).

Subjective norm reflects perceived social and organisational pressures that affect payment intentions. In this study, the role of the JMB (visibility, enforcement, transparency of JMB actions) and the resident–JMB relationship (trust, communication, perceived responsiveness), both of which shape normative expectations and social approval for fee compliance (Sholehah et al., 2020; Abas et al., 2021). Intention to pay is modelled as the immediate antecedent of payment behaviour, consistent with TPB. Although perceived behavioural control (PBC) is a core element of TPB, it is not measured as a separate variable in this study; aspects of control (such as ease of payment and financial ability) are discussed conceptually and considered in the interpretation of results. The framework, therefore, tests how attitude (facilities; safety & security) and subjective norm (role of JMB; resident–JMB relationship) jointly predict residents' intentions and subsequent payment behaviour (Figure 2).

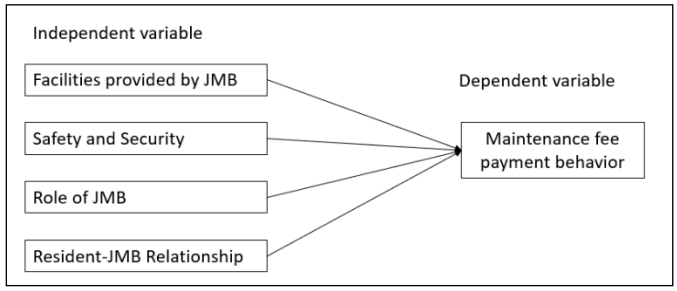


Figure 2. Conceptual Framework

METHODOLOGY

This study employed a quantitative research design using a structured questionnaire to examine the determinants of maintenance fee payment behaviour among strata residents in Malaysia. The quantitative approach was selected to enable statistical analysis of relationships between variables and to test the applicability of the Theory of Planned Behaviour (TPB) in predicting residents' payment behaviour. A convenience sampling technique was adopted to recruit respondents residing in stratified residential properties. This non-probability sampling method was deemed suitable as it allowed access to respondents who were readily available and willing to participate, particularly given the diverse geographical distribution of strata housing in Malaysia.

The target population comprised residents of apartments, condominiums, and flats governed under the Strata Management Act 2013. A total of 265 valid responses were obtained, which satisfies the minimum sample size requirements for behavioural studies with multiple predictors. The questionnaire was adapted from validated instruments in previous studies, to ensure content relevance and reliability. Items were adapted to fit the context of maintenance fee payment behaviour and structured according to the Theory of Planned Behaviour (TPB) constructs. The questionnaire comprised five sections: demographic profile, perceived role and governance of the Joint Management Body (JMB), resident–JMB relationship quality, perceived quality of shared facilities, perceived safety and security standards, and maintenance fee payment behaviour.

A pilot test was conducted to clarity and reliability. Feedback from the pilot test led to minor adjustments to enhance readability and comprehension. Subsequently, reliability analysis using Cronbach's Alpha confirmed that all constructs achieved acceptable reliability values (> 0.70), indicating strong internal consistency.

Data were collected over a period of six months, from March to August 2024. A mixed-mode distribution approach was used to maximise response rate and accessibility. The questionnaire was distributed online via Google Forms through residents' WhatsApp and community groups, while physical copies were also distributed to selected strata residential areas to reach respondents with limited digital access. Participation was voluntary, and respondents were assured of anonymity and confidentiality. Completed responses were screened for completeness before being included in the final dataset.

RESULTS AND DISCUSSION

This section presents the results and discussion of the study. The analyses include reliability analysis, frequency distribution, as well as regression and correlation analysis. Reliability refers to the extent to which the measures are error-free and produce consistent results. The guideline for determining internal consistency, as outlined by Kuder & Richardson (1937).

RELIABILITY ANALYSIS

Table 1 presents the Cronbach's alpha values for both the independent and dependent variables. The independent variables include the role of the JMB, the relationship between residents and the JMB, the basic facilities provided, and safety and security. The dependent variable is the residents' commitment and support. All variables have a Cronbach's alpha value greater than 0.80, indicating that they exhibit good to excellent internal consistency.

Table 1. Cronbach's Alpha Indication

Variable	Name of Variable	Cronbach Alpha Value	Indication
Independent Variable	Role of JMB	0.917	Excellent
	Relationship between resident and JMB	0.848	Good
	Facilities provided	0.925	Excellent
	Safety and security	0.925	Excellent
Dependent Variable	Commitment from resident to JMB	0.914	Excellent

DEMOGRAPHIC PROFILE

Most of the respondents hold a position of others (administrative, executive, etc.) with 60.8%, followed by Administration with 14.3%, 10.9% of managerial positions, and government officer is 10.2%. Regarding the types of residents, most of the respondents are tenants of the unit with 66.4%, and the balance of 33.6% is among the owners.

The level of the agreement on the role of JMB is portrayed in Table 2 based on the Likert scale 1 until 5. Scale 1 is for Strongly Disagree and Scale 5 is for Strongly Agree. The highest number of agreements among the respondent is they fully understand the role of JMB. The second highest is the respondent agrees that rules and regulations set by JMB is reasonable. However, the system used by JMB is systematic received the least agreement among the respondents.

Table 2. Descriptive Statistics of Role of JMB

No	Role of JMB	Mean	Ranking
1.	I fully understand the role of the Joint Management Body (JMB).	3.94	1
2.	The rules and regulations set by JMB are reasonable.	3.91	2
3.	The JMB's staff is knowledgeable and skilled in carrying out the task.	3.88	3
4.	The JMB's staff have a good attitude towards residents.	3.83	4
5.	JMB provides satisfactory service quality.	3.78	5
6.	The JMB uses a systematic system.	3.69	6

Table 3 shows the statement about the relationship between residents and JMB. The highest level of agreement is for the statement that both parties (resident and JMB) always respect each other. It is followed by the statement that JMB's staff will always ask if the residents have any problems. However, most of the respondents did not know the name of the JMB staff.

Table 3. Descriptive Statistics of The Relationship Between Residents and JMB

No.	Relationship between Residents and JMB	Mean	Ranking
1.	Residents and JMB's staff always respect each other.	3.90	1
2.	JMB's staff will always ask if we have any problems.	3.53	2
3.	We will greet each other when we meet up.	3.27	3
4.	I know the JMB's staff name.	2.84	4

Table 4 shows the statement of basic facilities provided by the JMB. Basically, the respondents agree that basic facilities were provided to the visitors, such as public toilets, a prayer room, and a visitor parking area. The second highest agreement is the facilities provided are clean and ready to be used. Apart from that, the respondent felt that the issues on the basic facilities does not solve immediately by the JMB.

The safety and security variable is shown in Table 5. The respondents agree that the housing unit is provided with the relevant safety and security systems. Furthermore, security guards were monitor regularly on the residents' safety. However, the statement about the usage of a fire extinguisher received the least agreement among the respondents.

Table 4. Descriptive Statistics of Basic Facilities Provided

No.	Basic Facilities Provided	Mean	Ranking
1.	Basic facilities are provided for visitors, such as public toilets, a prayer room, and a visitor parking area.	4.09	1
2.	The basic facilities provided are clean and ready to be used.	4.00	2
3.	The strata's surroundings are consistently tidy and well-kept.	3.98	3
4.	The basic facilities provided are in good working order.	3.95	4
5.	The basic facilities provided are sufficient for residents.	3.95	4
6.	Basic facilities are provided for disabled visitors, such as toilets and wheelchair routes.	3.91	5
7.	If there is a problem with basic facilities, it will be solved immediately.	3.78	6
8.	There is a platform for residents to express information, ideas, and suggestions.	3.47	7

Table 5. Descriptive Statistics of Safety and Security

No.	Safety and Security	Mean	Ranking
1.	Relevant safety and security systems are provided in my housing unit.	3.96	1
2.	The residents' safety is monitored regularly by security guards.	3.92	2
3.	The safety and security equipment provided is well-functioning and ready to be used when necessary.	3.90	3
4.	A complete fire extinguisher is provided in my housing unit.	3.87	4
5.	The security guards have a good attitude.	3.86	5
6.	The security guards are skilled and well-experienced.	3.77	6
7.	The central point and route information were being told to residents if a fire occurred.	3.40	7
8.	Residents were shown how to use the fire extinguisher in case a fire started.	3.22	8

The statement-related to dependent variable in this study is shown in Table 6. The dependent variable is about residents' commitment and support. The highest level of agreement is any dangerous incidents should be reported immediately to the JMB, and it was followed by residents should consult the JMB if facing any problems, and the residents should get permission before proceeding with any action. The geez of this variable is about the maintenance fee. Surprisingly, the respondent felt that the rising maintenance fee does not make it difficult for residents to pay their bills.

Table 6. Descriptive Statistics of Residents' Commitment and Support

No.	Resident's Commitment and Support	Mean	Ranking
1.	Residents should report immediately to JMB if there are any dangerous incidents.	4.54	1
2.	Residents should consult JMB if facing any problems related to their housing unit.	4.34	2
3.	Residents should get permission from JMB before proceeding with any action they consider necessary.	4.31	3
4.	Residents should inform JMB if any wrongdoing occurs among residents.	4.29	4
5.	Residents can help JMB with cleanliness and safety initiatives.	4.25	5
6.	The rising maintenance fee makes it difficult for residents to pay their bills.	4.12	6

REGRESSION ANALYSIS

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of The Estimate
1	.666[a]	.443	.434	.54965

a. Predictors: (Constant), SAFETY, RELATIONSHIP, ROLE, FACILITIES

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	60.101	4	15.025	49.733	.000[b]
	Residual	75.530	250	.302		
	Total	135.631	254			

a. Dependent Variable: COMPUTE_COMMITMENT

b. Predictors: (Constant), COMPUTE_SAFETY, COMPUTE_RELATIONSHIP, COMPUTE_ROLE, COMPUTE_FACILITIES

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.046	.182		11.227	.000
	ROLE	-.016	.077	-.018	-.213	.831
	RELATIONSHIP	.003	.057	.004	.050	.960
	FACILITIES	.576	.077	.653	7.462	.000
	SAFETY	.022	.072	.027	.299	.765

a. Dependent Variable: COMMITMENT

Model summary of the study is shown above. $R^2 = 0.443$ indicates that 44.3% of the variance in residents' commitment to JMBs is explained in the independent variables, while the remaining 55.7% is attributed to other factors. l Overall, the model of this study is significant and valid because of the F-sig value 0.000 less than 0.05 significance value. Only one independent variable is significant which is facilities have value 0.000 less than 0.05 significance value. Meanwhile, the other three variables are not significant which more than 0.05 significance value (Role (0.831), Relationship (0.960), and Safety (0.765)).

DISCUSSION

This study investigated the determinants of maintenance fee payment behaviour among strata residents in Malaysia by applying the Theory of Planned Behaviour (TPB). The results show that only the perceived quality of shared facilities had a significant and positive influence on payment behaviour, while the perceived role and governance of the Joint Management Body (JMB), resident–JMB relationship quality, and perceived safety and security standards were not significant predictors. These findings offer valuable insights into how residents make decisions regarding maintenance fee payments.

The significance of facilities indicates that residents are more willing to pay maintenance fees when they perceive clear and visible value in the services provided. Well-maintained shared facilities such as lifts, recreational areas and common spaces make residents feel that their payments are worthwhile. This supports earlier research linking service quality to fee compliance (Sia et al., 2018; Lim & Tan, 2021). In line with TPB, this outcome highlights the dominant influence of attitude, suggesting that positive evaluations of tangible benefits are more influential than other factors. In Malaysia, this finding also reflects a cultural tendency among residents to prioritise visible outcomes when contributing financially.

Conversely, the non-significant effects of the JMB's role, the resident–JMB relationship, and safety and security suggest that subjective norms may not strongly shape payment behaviour in this context. Although the JMB is responsible for managing and communicating expectations, residents may not view its influence, reminders, or governance as strong enough to affect their decisions. Limited interaction, low trust, or weak enforcement could reduce the perceived need to comply. Residents may also regard fee payment as a personal rather than collective responsibility, differing from earlier findings that emphasised the importance of management influence (Abas et al., 2021). Similarly, safety and security may be seen as a basic entitlement rather than a benefit linked to fees, reducing their impact on payment motivation.

Overall, the findings suggest that attitude outweighs subjective norms in predicting maintenance fee payment behaviour among strata residents. This indicates a shift towards more value-based decision-making, where residents prioritise tangible benefits over organisational expectations. These insights reinforce the importance of demonstrating visible improvements and value for money to enhance fee compliance among residents.

CONCLUSION

This study contributes to the Theory of Planned Behaviour (TPB) literature by demonstrating its applicability in the context of strata housing and providing empirical evidence from Malaysia. The results reinforce the dominant role of attitude in shaping payment behaviour, revealing that positive evaluation of tangible benefits outweighs subjective norms derived from management expectations or relational influence. The significance of perceived facility quality further contributes to TPB by validating a context-specific attitudinal belief as a key predictor of behavioural outcomes. Moreover, the non-significant role of subjective norms suggests that social or institutional pressure may exert limited influence on compliance behaviour within modern urban communities, where residents tend to make more individualistic and value-based decisions. The findings offer several implications for stakeholders involved in strata management. For JMBs and strata management firms, the findings highlight the importance of prioritising visible improvements, maintaining shared facilities effectively, and communicating transparently about how fees are utilised, as these actions enhance residents' perceived value for money and promote compliance. Residents should be encouraged to recognise their shared responsibility in sustaining a quality living environment, reinforcing the importance of fee payment as a collective duty rather than a discretionary contribution. For local authorities and the Commissioner of Buildings (COB), the results underscore the importance of strengthening educational initiatives and awareness programmes to improve residents' understanding of

strata responsibilities. Policy guidelines and training for JMBs may also be enhanced to improve governance practices and fee collection strategies.

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ASSESSING THE SAFETY MANAGEMENT MATURITY LEVEL AMONG G7 CONSTRUCTION COMPANIES IN SARAWAK, MALAYSIA

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Abstract
This study aims to assess the level of safety management practices among G7 construction companies in Sarawak using the Maturity model. The study employed the multiple causation theory, a descriptive research design, a quantitative research approach, and a disproportionate stratified simple random sampling technique. A total of 327 structured questionnaires were distributed to Grade 7 (G7) construction companies. One-hundred and forty (140) responses were received, of which 31 were discarded, yielding a 36.33% response rate. Statistical Package for the Social Sciences (SPSS) version 28 was used to analyse the data. The dimensions of maturity levels used in this study are safety management culture (SMC), safety management process (SMPR), safety management experience (SME), and safety management application (SMA). In addition, this study used the following ranges to interpret the levels in the maturity models: "naive level" (1.00 - 1.75), "novice level" (1.76 - 2.51), "normalised level" (2.52 - 3.27), and "matured level" (3.28 - 4.00). Overall, the results show that the G7 construction companies exhibit a "matured level" in SMC (mean score 3.40), SMPR (mean score 3.41), and SME (mean score 3.44). However, the SMA practices were at a "normalised level" (mean score of 3.26). This study is significant to the players in the Malaysian construction industry. It provides an insight into the maturity levels of the G7 construction companies. This study has assessed the maturity level of the G7 construction companies operating in Sarawak. To enhance the safety management practices across construction sites, construction managers should give adequate attention to SMC, SMPR, SME, and SMA. This study only focuses on G7 construction companies operating in Sarawak. Future studies should cover other grades of construction companies and include the state of Sabah.

Keywords: *Construction industry; Safety management practices; Maturity level; Grade 7 Construction Companies; Sarawak*

INTRODUCTION

This study aims to assess the level of safety management practices among Grade 7 construction companies operating in Sarawak, Malaysia. Sarawak is located in the Eastern region of Malaysia on the island of Borneo. The eastern region of Malaysia consists of the states of Sarawak and Sabah. However, Sabah state was excluded in data collection because the scope of this study focuses on the construction companies operating only in Sarawak. In this study, the level of safety management practices refers to the maturity level of safety management practices. The maturity level refers to the extent to which the construction companies implement safety management culture (SMC), safety management process (SMPR), safety management experience (SME), and safety management application (SMA). Safety has become an essential aspect of the construction processes across the globe, including in Malaysia (Sadeghi et al., 2021; Ayob et al., 2018). The construction industry is known to be a hazardous sector due to its significant number of construction site accidents leading to injury, disability, and loss of life (Williams et al., 2018). The construction industry in Sarawak is not left out in terms of construction safety-related issues, such as the violation

of safety management regulations. As evidence, fifty-five (55) companies were issued with safety violation notices by the Department of Occupational Safety and Health (DOSH), Sarawak. The safety violations range from not barricading open edges and a lack of training to workers working at high levels (Petinggi, 2022). As a result, the industry is among the top contributors to occupational deaths or fatalities in the state of Sarawak (Rakan Sarawak, 2022).

As a result, safety has accumulated the interest of the construction industry stakeholders, including the government and the regulatory departments in Malaysia. The increasing attention to safety in recent times is due to the construction site accidents that are still happening across construction sites, resulting in injuries and loss of life (Alkaissy et al., 2020). The government and its regulatory agencies, namely the Construction Industry Development Board (CIDB) and the National Institute for Occupational Safety and Health (NIOSH), have made concerted efforts to minimize the increasing construction site accidents. This can be seen through the Malaysian government and CIDB continuously enforcing compliance with safety management practices (SMP) across construction sites in Malaysia. Through its regulatory agencies, the Malaysian government aims to significantly reduce accidents and injuries that often result in severe injuries and even loss of life.

This study identified and filled two types of research gaps, namely a methodological and population gap. According to Miles (2017), a methodological gap arises when there is a need for a new method divergent from the method used by previous studies. In this study, the safety management has been assessed using the maturity model. According to Robinson et al. (2011), a population gap occurs when a particular location, gender, ethnicity, or race is under-researched or under-represented in the data collection in previous studies. To the best of the authors' knowledge, this is the first study that assessed the safety management maturity level of G7 construction companies operating in Sarawak.

Hudson (2007) and Williams et al. (2020) are few of the studies that examined SMP levels in the construction industry outside Malaysia. The current study notes that Williams et al. (2020) adopted the Guttman (1950) scale, which requires respondents to answer "Yes" or "No". In addition, the SMP level was determined based on the frequency and percentage of the respondents who chose any of the maturity levels. The five maturity levels in Williams et al. (2020) appear to stem from the terms relating to the field of organizational learning. They are the pathological stage, reactive stage, calculative stage, proactive stage, and generative stage. Manu et al. (2018) also measured the level of SMP as "low", "moderate", and "high" based on inferential statistics using mean score, frequency, and percentage. This study also notes that the use of "pathological", "calculative", and "generative" could be unsuitable in the context of construction companies. The current study therefore argues that Hillson's (1997) maturity level appears to be more suitable and clearer compared to Williams et al. (2020) and Guttman's (1950) maturity model. The current study assesses the levels of safety management practices based on the following Hillson's (1997) maturity levels: "naive", "novice", "normalized", and "maturity". The next sections of this paper review the relevant literature on safety management practices in the construction industry. This is followed by the methodology, results, discussions, and last but not least, the conclusion.

LITERATURE REVIEW

Theoretical Background

Multiple causation theory underpins this study. The Heinrich domino theory stipulates that an accident is caused by a single cause or factor (Heinrich, 1959). However, Petersen (1971) and Hosseinian & Torghabeh (2012) opine that accidents are caused by multiple factors, contrary to Domino's Theory. Petersen (1971) identifies several factors that collectively cause accidents. The factors are people, environment, machine, and management. In the context of this study, the term "people" refers to construction site workers. Environment refers to the site's working conditions. Machine refers to the construction site equipment and workshop. Management refers to the extent of management's commitment to providing safety policy, training, and safety rules and procedures for improving safety at the construction site (Othman et al., 2018; Hosseinian & Torghabeh, 2012).

An Overview of The Malaysian Construction Industry

The construction industry has been contributing to the Malaysian national economy since its independence. Although the industry was previously weak in terms of technology, it has been witnessing considerable growth, to the point that it has become one of the main contributors to the Malaysian economy. The industry plays an important role in improving the national economy due to its linkage with other sectors, such as manufacturing and agriculture (Dehdasht et al., 2021). The government often revives the economy by financing new projects, and the construction industry's linkage with other sectors enables the revival of the economy (Alaloul et al., 2021).

The industry has witnessed remarkable progress in its project delivery. This is due to its expansion and the use of modern equipment and tools for executing large-scale infrastructure. Notwithstanding, the industry is facing challenges such as construction site accidents and project performance-related issues. The construction industry has recorded a significant number of accidents across sites. As a result, the industry has been described as the most hazardous due to the significant number of fatal construction site accidents, resulting in a high number of disability and deaths (Williams et al., 2018).

The high number of accidents recorded has been attributed to factors such as unsafe working conditions and inadequate safety management practices (Albarkani & Shafii, 2021). As a result, the Construction Industry Development Board (CIDB) was established in 1994 to oversee and regulate the industry's activities, aiming to achieve a safer, higher-quality, and more productive industry through various training programs. The function of the CIDB also takes into account the registration and classification of the construction companies operating in Malaysia into categories named as Grade 1 to Grade 7 (G1-G7). These grades of construction companies constitute small, medium, and large-sized companies (CIDB, 2023).

Safety Management Practices

Various definitions of safety management practices (SMP) have been provided in the literature. However, similarities in key terms have been observed across the definitions. Most

definitions seem to be rooted from a single source (Vinodkumar & Bhasi, 2010). Similar key terms such as *approaches, policies, procedures, strategies, activities,* and *management* are found across most definitions of SMP (Gao et al., 2019; Subramaniam et al., 2016a; Subramaniam et al., 2016b; Cheng et al., 2015; Vinodkumar & Bhasi, 2010). Therefore, it can be inferred that there is a common understanding of the SMP concept among scholars. The following are definitions of SMP established in the literature.

Gao et al. (2019), Subramaniam et al. (2016a), and Subramaniam et al. (2016b) defined SMP in the context of implementing policies, procedures, strategies, and activities that the management of an organization implements to ensure the safety of its employees. Another SMP definition is from Marin et al. (2017) in which SMP refers to the top and middle management initiatives that aim to mitigate and reduce hazards and injuries across the construction site. Marin et al.'s (2017) definition suggests that safety management is the responsibility of the management in an organization.

Jaafar et al. (2017) define SMP as incorporating the aspect of risk control on unsaved activities, safety control, policies, management functions, and safety systems. The scholars define SMP as an overall management function that focuses on the safety management system design seeking to guide, control, and stipulate the safety procedures, practices, and performance toward ensuring a safe working environment (Jaafar et al., 2017; Cheng et al., 2012). Cheng et al.'s (2015) definitions seem to be brief compared to other definitions. According to Cheng et al. (2015), SMPs refer to the implementation of safety policies to construction work-related activities that aim to prevent or reduce accidents at the workplace.

The definitions of SMP provided by Vinodkumar and Bhasi (2010) appear to be the most comprehensive. Their definitions cover compliance with the existing safety legislation and include management programs that aim to target employees' safety. Vinodkumar and Bhasi (2010) view SMPs as a management function that includes safety policy, strategy, procedure, and activity implemented through safety programs targeted to ensure employees' safety. SMP also covers compliance with all the existing safety legislations through various management safety initiatives that can prevent or reduce potential accidents and hazards. The current study notes that this definition covers industrial workplaces and does not include construction sites.

Following Vinodkumar and Bhasi (2010), this paper defines SMP as the implementation of safety management by construction companies through safety policies, strategies, procedures, activities, and programs to prevent construction site accidents. SMP also includes activities designed to comply with the safety-related legislation across the construction sites.

Dimensions of Safety Management Practices

Safety management practices (SMP) have been conceptualised into various dimensions ranging from three to fifteen dimensions. For example, Wong et al. (2021) and Lu et al. (2020) conceptualised SMP into three dimensions. Choe et al. (2020) and Marin et al. (2017) conceptualised SMP into four dimensions, Zulkifle & Hanafi (2018) and Manu et al. (2018) conceptualised SMP into five dimensions, and Cheng et al. (2015) and Cheng et al. (2012) conceptualised SMP into fifteen dimensions. However, the review of SMP studies has shown that most scholars conceptualised SMP into six dimensions (Gao et al., 2019; Jaafar et al., 2017; Subramanian et al., 2016b; Subramaniam et al., 2016b; Vinodkumar & Bhasi, 2010;

Ali et al., 2009; Mearns et al., 2003). Following Vinodkumar and Bhasi (2010), Subramaniam et al. (2016a), Subramaniam et al. (2016b), and Jaafar et al. (2017), this paper therefore also conceptualized SMP into six dimensions, namely management commitment, safety training, workers' involvement in safety practices, safety communication, safety policy, and safety rules and procedures. The scope of SMP examined in this paper covers the six dimensions only.

There are variations in the number and types of dimensions used to conceptualise SMP; the dimensions of SMP, therefore, can be viewed in terms of their frequency of usage or types. The frequency of usage signifies how often the particular dimensions are used to conceptualise SMP. Therefore, the frequency of dimensions indicates the number of times it appears in previous studies. Meanwhile, the type of dimensions signifies how SMP has been conceptualised. For example, Vinodkumar & Bhasi (2010) and Ali et al. (2009) conceptualised SMP into six dimensions. However, while both studies consider management commitment, providing safety training, involvement of workers, and safety communication, they differ in two dimensions. Vinodkumar & Bhasi (2010) considered providing safety rules and procedures, and safety promotion policies, in contrast to Ali et al. (2009), who accounted for giving rewards and hiring practices to be the dimensions of SMP. In other words, these two studies share the same four dimensions and differ in the remaining two dimensions. Table 1 presents the various types and number of SMP dimensions in previous studies.

Table 1. The Types and Number of Safety Management Practices Dimensions in Previous Studies

No.	Author	Research Title	Country	Types and Number of SMP Dimensions
1.	Mearns et al. (2003)	Safety climate, safety management practice, and safety performance in offshore environments	United Kingdom	1) Management commitment 2) Worker's involvement 3) Health promotion 4) Health and safety policy 5) Organising for safety and health 6) Health and safety auditing
2.	Ali et al. (2009)	Management practice in safety culture and its influence on workplace injury: An industrial study in Malaysia	Malaysia	1) Giving a reward 2) Providing training 3) Management commitment 4) Communication and obtaining feedback 5) Hiring practices 6) Employee participation
3.	Vinodkumar & Bhasi (2010)	Safety management practices and safety behaviour: Assessing the mediating role of safety knowledge and motivation	Kerala, the southern part of India	1) Management commitment 2) Providing safety training 3) Involvement of workers 4) Safety communication and obtaining feedback 5) Providing safety rules and procedures 6) Safety promotion policies
4.	Cheng et al. (2012)	Exploring the perceived influence of safety management practices on project performance in the construction industry	Hong Kong	1) Written safety policy 2) Investigating and reporting the accident 3) Recording safety incidents 4) Having a safety manual 5) Having and using a safety checklist 6) Accident statistical analysis 7) Having a safety organisation structure 8) Conducting safety inspection 9) Providing safety training 10) Safe work practices 11) Conducting safety meeting 12) Conducting safety audit 13) Promoting safety/Safety promotion 14) Having a safety committee at the project/ site level

No.	Author	Research Title	Country	Types and Number of SMP Dimensions
				15) Having a safety committee at the firm level
5.	Cheng et al. (2015)	Use of safety management practices for improving project performance	Hong Kong	1) Written safety policy 2) Investigating and reporting the accident 3) Recording safety incidents 4) Having safety manual 5) Having and using a safety checklist 6) Accident statistical analysis 7) Having a safety organisation structure 8) Conducting safety inspection 9) Providing safety training 10) Safe work practices 11) Conducting safety meeting 12) Conducting safety audit 13) Promoting safety/ Safety promotion 14) Having a safety committee at the project/site level 15) Having a safety committee at the firm level
6.	Subramaniam et al. (2016a)	Safety management practices and safety compliance in small, medium enterprises: the mediating role of safety participation	The northern region of Peninsular Malaysia	1) Management commitment 2) Providing training 3) Involving workers 4) Safety communication and obtaining feedback 5) Providing safety rules and procedures 6) Safety promotion policies
7.	Subramaniam et al. (2016b)	The influence of safety management practices on safety behaviour: A study among manufacturing SMEs in Malaysia	Malaysia	1) Management commitment 2) Providing safety training 3) Involving workers 4) Safety communication and obtaining feedback 5) Providing safety rules and procedures 6) Safety promotion policies
8.	Jaafar et al. (2017)	Facilities maintenance employees' priority of safety management practices: A research study in Malaysia	Klang Valley, Malaysia	1) Management commitment 2) Involving workers in safety 3) Providing safety training 4) Safety communication and obtaining feedback 5) Providing safety rules and procedures 6) Safety promotion policies
9.	Marín et al. (2017)	Associations between safety climate and safety management practices in the construction industry	Colombia	1) Having a worksite hazard profile 2) Management commitment to safety 3) Having a safety system 4) Providing OSH Training
10.	Manu et al. (2018)	Health and safety management practices of contractors in South East Asia: A multi-country study of Cambodia, Vietnam, and Malaysia.	Cambodia, Vietnam, and Malaysia	1) Having a safety policy 2) Safety planning 3) Organising for safety 4) Safety implementation 5) Measuring and reviewing performance
11.	Zulkifle & Hanafi (2018)	Impact of safety management practices enforcement toward employee safety in the construction industry	Johor	1) System of rewarding 2) Providing safety training 3) Management commitment 4) Communication and obtaining feedback 5) Worker's participation
12.	Gao et al. (2019)	The mediating role of safety management practices in process safety culture in the Chinese oil industry.	China	1) Management commitment/ leadership 2) Involving employees 3) Organising responsibilities and procedures 4) Providing safety training 5) Inspecting & monitoring 6) Communicating & coordinating

No.	Author	Research Title	Country	Types and Number of SMP Dimensions
13.	Lu et al. (2020)	Influence of management practices on safety performance: The case of the mining sector in China	China	1) Management commitment 2) Involving employee 3) Providing safety training
14.	Choe et al. (2020)	Inter- and intra-organizational safety management practice differences in the construction industry	South Korea	1) Having safety performance indicators 2) Investigating near-miss incidents 3) Reporting the accident to the head office 4) Accessing site safety issues during planning and design phases
15.	Wong et al. (2021)	Exploring the acceptance of PPE by construction workers: An extension of the technology acceptance model with safety management practices and safety consciousness	Hong Kong	1) Having a safety-offense points system 2) Conducting safety supervision 3) Providing safety training

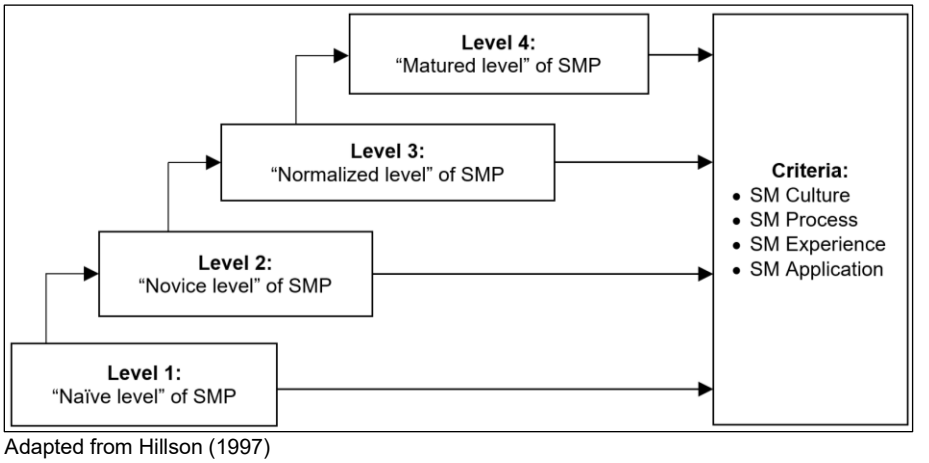
Source: Wahi et al. (2022)

As shown in Table 1, the least number of dimensions of SMP is three, while the highest is fifteen. A critical analysis of the table shows that 'management commitment' dimension in studies such as Vinodkumar & Bhasi (2010); Lu et al. (2020); Gao et al. (2019) has been decomposed into three dimensions in Cheng et al. (2012) and Cheng et al. (2015) namely, 'safety structure', 'safety inspection', and 'safety audit'. Similarly, 'safety rules and procedures' in other studies corresponds to 'investigating and reporting accidents', 'safety manual', and 'safety work practices' in Cheng et al. (2012) and Cheng et al. (2015) studies. These variations have resulted in inconsistency, in the number and types of dimensions across SMP studies. It can be seen from the fifteen SMP studies shown in Table 1, where two studies conceptualised SMP into three dimensions, another two different studies into four, five and fifteen dimensions respectively, while seven studies examined SMP in six dimensions.

Assessing the Level of Safety Management Practices

In this study, the levels of SMP of construction companies are measured by the safety management maturity levels, which consist of four levels and four criteria. Figure 1 depicts the safety management maturity model adapted from Hillson's risk maturity model (Hillson, 1997).

As shown in Figure 1, Hillson's (1997) maturity model consists of two components. The first component consists of four different levels of SMP practices. The first level in Hillson's maturity model is called "naïve", level 2 is called "novice", level 3 is called "normalised", and level 4 is called "matured" (Hillson, 1997). The second component consists of four criteria for assessing the four levels in the first component of the model. The four criteria in the second component of the Maturity Models are culture, process, experience, and application. In this study, the SMP levels were measured using the four criteria. Culture criteria were named safety management culture. Process criteria were named the safety management process. Experience criteria were named safety management experience. The application criteria were named the safety management application. Table 2 presents the four safety management maturity criteria and their definitions as used in this study.



Adapted from Hillson (1997)

Figure 1. The Safety Management Maturity Model

Table 2. Definitions of Safety Management Maturity Criteria

CRITERIA	DEFINITION
Safety Management Culture (SMC)	a) Having top-down commitment for safety management. b) Encouraging proactive safety management and reward system.
Safety Management Process (SMPR)	a) Applying safety management practices in construction processes b) Incorporating safety management practices into the entire construction business. c) Regularly updating the safety management process. d) Seeking feedback for improving safety management process.
Safety Management Experience (SME)	a) Awareness of safety management practices. b) Learning from safety experience. c) Training employees to enhance their safety management skills.
Safety Management Application (SMA)	a) Implementing safety management practices in all projects. b) Having accident reporting system. c) Having the latest safety management tools.

Source: Adapted from Hillson (1997)

Table 2 presents the four safety management maturity criteria and their definitions in the context of this study. The definition of safety management culture is based on commitment to safety, proactive safety management, and a reward system. Safety management process is defined as the context of safety management practice, safety process update and feedback. Safety management experience is defined as safety management awareness, learning, and training. Safety management application is defined in the context of implementing safety management practices, an accident reporting system, and the latest safety management tools.

RESEARCH METHODOLOGY

Research Paradigm

A common understanding of what the term means appears to have been formed. According to Kankam (2019), scholars refer to a paradigm as a model or framework used to understand research outcomes. Rahi (2017) describes a paradigm as an essential collection of beliefs shared among researchers. It is a common understanding, belief, or assumption of how research problems are viewed, understood, and investigated. The positivist paradigm has been considered a relevant paradigm for this study. According to Nyein et al. (2020), positivism is the common paradigm used in organisational research. This paradigm assumes that research

can be conducted through reality, objectivity, and control, emphasizing an empirical approach. Furthermore, according to this paradigm, a quantitative research method should be used. This will enable a researcher to quantify and observe the data and research outcome. Hence, positivist researchers encourage the use of extensive data to represent a population, enhancing reliability, validity, and generalizability while avoiding confusion. In describing positivism, Primecz (2020) stated that variables can be used to measure social phenomena. The measurement can be in the form of a mathematical-statistical relationship that aims to investigate its existence and extent. The relationship is built upon hypotheses and models containing the dependent and independent variables.

Research Design

A descriptive research design has been considered relevant to this study. A descriptive research design describes certain phenomena or their current status. Although descriptive research design requires a large amount of data for analysis, it helps provide essential recommendations. A significant limitation of descriptive research design is that it cannot be used to test hypotheses and that it heavily depends on both the measurement and observation (Cooper & Schindler, 2014; Zikmund et al., 2013).

Research Method

Following Kamaruddeen et al. (2024), this paper adopts a quantitative research method. Quantitative research method refers to the research approach associated with quantitative data. The term *quantitative* signifies the quantity or amount of data in a study. This method requires quantitative, quantifiable data to be collected from a certain population, and to be analysed using statistical tools such as SPSS or Stata to derive unbiased and specific conclusions (Cresswell, 2011). It requires a formal and systematic process that is based on specific objectives to be achieved. The objectives could be to measure (operationalizing the variables) or assess the relationships among independent, dependent, moderating, and mediating variables (Mohajan, 2020).

Data Collection

Data was collected using three methods from the study population of seven hundred and sixty-seven (767) G7 construction companies registered with CIDB Sarawak in Malaysia. First of all, data was collected through physical distribution and postage, and secondly, through email. The questionnaires were distributed physically and by post to the selected companies. After a follow-up telephone call, some of the construction companies requested that the questionnaires be sent by email.

This study adopts the disproportionate simple random sampling technique to collect data from the target population. The following justifies using the disproportionate simple random sampling technique. Firstly, the total number of construction companies operating in each district in Sarawak differs from one another. Therefore, a disproportionate sample was selected from each district based on the ratio of the population. Secondly, the simple random technique was used to allow each sample to have an equal chance of being selected and enable the generalisation of the research findings to Grade 7 construction companies operating in Sarawak, Malaysia. Therefore, this study used the disproportionate simple random sampling technique to collect data from the respondents.

Population and Sample

Following Memon et al. (2020), this study determined the research sample size using G-power analysis. Although Slovin's Formula suggested a sample size of 567, Dillman's (2007) Formula suggested 556 samples, and G-power analysis suggested 109 samples. Although the sample size is 109, 327 questionnaires were distributed. A total of 140 responses was received, including 31 incomplete responses. Therefore, the number of usable responses used for the data analysis was 109.

Justification for the Selection of Safety Management Maturity Model

This study identifies several maturity models in the literature. However, not all the models are suitable for this study. Firstly, Hudson's Safety Culture Maturity Model focuses on safety culture and attitude, ignoring safety process and system (Williams et al., 2020). Secondly, ISO 45001-based Safety Maturity Models is a certification-based model. Therefore, it is not applicable to construction companies that have yet to be ISO 45001 certified (Robson et al., 2007). Thirdly, Capability Maturity Model is applicable to the companies operating in software and manufacturing industries only, so, the model is not applicable to the construction company (Paulk et al., 1993). Fourthly, Process Safety Management (PSM) Maturity Model focuses only on the process of safety management, ignoring the other components of safety management such as culture and system. It is only applicable to oil and gas, and chemical plants industries (Hale et al., 2010). Fifthly, the Integrated Safety, Health, and Environment (SHE) Maturity Models includes safety environment in addition to safety and health. However, safety environment is beyond the scope of this study, rendering it not suitable (Hale & Hovden, 1998).

This study adapts Hillson's (1997) risk maturity model due to its applicability to the construction industry. It is behavioural-oriented, allowing the construction companies to be assessed in terms of their safety management maturity quantitatively. In addition, the model aligns with the positivist paradigm, further strengthening its suitability to this study.

Data Analysis

With the aid of SPSS version 28, this paper used the following steps to determine the SMP level (safety management maturity level) of the construction companies operating in Sarawak, Malaysia. In step one, this study adapted Hillson's (1997) four levels of maturity (naive, novice, normalised, and matured). Step two, this study adapted Pimentel's (2019) four ranges of mean scores (1.00 - 1.75, 1.76 - 2.51, 2.52 - 3.27, 3.28 - 4.00). In step three, this study calculated the SMP mean score of the respondents. In step four, this study matched the mean score value obtained in step three with the corresponding Hillson's (1997) four levels of maturity to determine the SMP level of the respondents.

RESULT

Demographic Profile of the Respondents

Table 3 presents the demographic profile of the respondents obtained from descriptive statistics.

Table 3. The Demographic Profile of Respondent One

No.	Subject	Descriptions	Frequency	Percentage (%)
1.	Position in the company	Chief Executive Officer	10	9.2
		Company Director	44	40.4
		Health and Safety Manager	5	4.6
		Site Safety Supervisor	29	26.6
		Safety Manager	2	1.8
		Safety Officer	13	11.9
		Others	6	5.5
2.	Working experience	1 - 5 years	17	15.6
		6 - 10 years	30	27.5
		11 - 15 years	18	16.5
		16 - 20 years	11	10.1
		21 - 25 years	13	11.9
		26 - 30 years	7	6.4
		31 years and above	13	11.9
3.	Gender	Male	91	83.5
		Female	18	16.5
4.	Age	18-20	1	0.9
		21-25	2	1.8
		26-30	17	15.6
		31-35	27	24.8
		36-40	16	14.7
		41 and above	46	42.4
5.	Level of education	PhD	-	-
		Masters	10	9.2
		Degree	60	55.0
		Diploma	28	25.7
		Certificate	9	8.3
		Others	2	1.8
6.	Size of the company	Micro firm: ≤ 10 employees	15	13.8
		Small firm: 11 - 50 employees	53	48.6
		Medium firm: 51 - 50 employees	33	30.3
		Large firm: > 150 employees	8	7.3
7.	Age of the company	0 - 5 years	10	9.2
		6 - 10 years	20	18.3
		11 - 15 years	21	19.3
		16 - 20 years	19	17.4
		21 - 25 years	13	11.9
		26 - 30 years	9	8.3
		31 - 35 years	7	6.4
		36 - 40 years	4	3.7
		Above 40 years	6	5.5

Table 3 consists of the position in the company, working experience, gender, age, level of education, size of the company, and age of the company. In terms of the positions in the company, 40.4% of the respondents who participated in this study survey are company directors. They are followed by the Site Safety Supervisor (26.6%), Safety Officer (11.9%),

Chief Executive Officer (9.2%), Health and Safety Manager (4.6%), and Safety Manager (1.8%). In terms of the working experience, 15.6% of the respondents have 1 to 5 years of working experience, whereas 27.5% of respondents have 6 - 10 years of experience. Next, 16.5% have 11 to 15 years of working experience, while 10.1% of respondents have 16 to 20 years, 11.9% have 21 to 25 years, 6.4% have 26 to 30 years (6.4%), and 11.9% have 31 years and above of experience. In terms of gender, the male respondents account for 83.5%, while the remaining 16.5% are female. Regarding the age of the respondents, those between 18 and 20 account for 0.9%. Those between 21 and 25 account for 1.8%. Respondents of 26 to 30 years of age constitute 15.6%. Also, those 31 to 35 years of age account for 24.8%. In addition, those between 36 and 40 years of age constitute 14.7%, and those above 41 years of age constitute 42.4%. As for the education level of the respondents, 55.0% have a bachelor's degree, 25.7% have a diploma certificate, 9.2% of the respondents have a master's degree, while the remaining 8.3% have certificates. Concerning the age of the companies, 9.2% boasts off 0 to 5 years of business operation. 18.3% run business operations for 6 to 10 years. 19.3% run business operations from 11 to 15 years, and 17.4% have taken 16 to 20 years to run their business operation. Next, 11.9% of respondents take 21 to 25 years running their company's business operation, 8.3% take 26 to 30 years, 6.4% take 31 to 35 years, 3.7% take 36 to 40 years, and 5.5% are in charge of their companies for more than 40 years.

Results of Safety Management Practices Level (Safety Management Maturity Level)

The objective of this study is to assess the level of safety management practices (SMP) among G7 construction companies. The criteria (determinant) for assessing the SMP level are safety management culture (SMC), safety management process (SMPR), safety management experience (SME), and safety management application (SMA). Table 4 presents the results of each criterion for assessing the SMP levels among the G7 construction companies operating in Sarawak.

Table 4. Level of Safety Management Practices

Criteria	Mean	Std. Deviation	Remarks
SMC	3.4037	0.52474	Matured
SMPR	3.4106	0.45836	Matured
SME	3.4373	0.45969	Matured
SMA	3.2599	0.48720	Normalized

Notes: SMC = Safety management culture, SMPR = Safety management process, SME = Safety management experience, SMA = Safety management application

As shown in Table 4, the construction companies exhibit a "matured level" in SMC (mean score 3.40), SMPR (mean score 3.41), and SME (mean score 3.44). However, their SMA practices are at a "normalized level" (mean score of 3.26). Table 5 presents the interpretation of each SMP level based on the corresponding mean score range.

Table 5. SMP Levels and Their Corresponding Mean Score Range

Scale	Mean Range	SMP Level
1	1.00 – 1.75	Naive
2	1.76 – 2.51	Novice
3	2.52 – 3.27	Normalized
4	3.28 – 4.00	Matured

Source: Adapted from Pimentel (2019) and Hillson (1997)

As shown in Table 5, the lowest SMP level is the "naive level", while the highest SMP level is the "matured level". This result shows that safety management culture, safety management process, and safety management experience are at a "matured level", while the safety management application is at a "normalized level". The overall mean score of the construction companies operating in Sarawak is 3.38. Based on the mean score range in Table 4, 3.38 falls within the range of 3.28 – 4.00, which is classified as 'matured'. Even though the safety management application was found to be at 'normalized level', this paper concludes that the overall SMP level of the construction companies is at 'matured level'.

DISCUSSION

The safety management maturity consists of four different levels, and this is also known as maturity levels. In other words, the construction companies can achieve any of these levels depending on the extent of the safety management practices. The lowest level of the safety management practice is 'naive'. The next level is 'novice', followed by 'normalized', and 'matured' as the highest level. Any of these levels of SMP is determined by the extent to which a construction company practices four criteria, namely safety management culture (SMC), safety management process (SMPR), safety management experience (SME), and safety management application (SMA). For example, a very low level or the non-practice of SMC, SMPR, SME, and SMA by the construction companies will result in the safety management practice being ranked 'naive level'.

In this study, three criteria of SMP, namely SMC, SMPR, and SME, were found to be at a 'matured level'. Meanwhile, SMA was found to be at the 'normalized level', which is lower than the 'matured level'. However, since three out of the four criteria are at matured level, the overall mean score (3.38) was determined and used to assess the overall maturity level. Based on the mean score range of each level of safety management maturity shown in Table 4, the overall safety management practice of the G7 construction companies is found to be at the 'matured level'.

However, this finding contradicts Manu et al. (2018), who conducted a comparative study on the SMP level between contractors in Cambodia, Vietnam, and Malaysia. The level of SMP in Cambodia, Vietnam, and Malaysia was found to be 'low'. The reason for the difference between the current study and the previous study is likely due to the sample composition consisting of three countries. In addition, the current study focuses on the G7 construction companies alone; the respondents in the previous studies were a combination of G1 to G7. While all grades of construction companies, G1 to G7, are required to practice safety management, the obligation to practice safety management should be more on G7 due to the volume and complexity of the projects they undertake. Furthermore, the approach used to measure the extent of SMP differs between the previous study and this one. Manu et al. (2018) measured the extent of SMP across Cambodia, Vietnam, and Malaysia using inferential statistics only (frequency and percentage). This study measured SMP level using Hillson's (1997) maturity model. The maturity model consists of four criteria, namely safety management culture (SMC), safety management process (SMPR), safety management experience (SMC), and safety management application (SMA).

The four levels of SMP (naive, novice, normalized, and matured) were assigned a mean score range adapted from a previous study (Pimental, 2019). Therefore, the SMP level of the

construction companies found in this study is comprehensive because it is a combination of four SMP criteria, a mean score range, and four levels of SMP. It is interesting to note that only three criteria were found to be at the “matured level” of SMP, while the fourth SMP criterion was at the “normalized level” of SMP. Therefore, it can be inferred that the construction companies operating in Sarawak are at ‘matured level’.

Although the safety management maturity level of the G7 construction companies was found to be at matured level, there could be other factors that could influence the occurrence of construction site accidents. In addition, while the result of this study can be generalised to G7 construction companies, there are individual differences in the level of safety management practice implementation across the construction companies. Hence, the ‘matured level’ in safety management practices cannot completely prevent construction site accidents. These accidents can still happen, but the fact remains that it can be reduced significantly through high level implementation of safety management culture (SMC), safety management process (SMPR), safety management experience (SMC), and safety management application (SMA).

CONCLUSION

This paper aims to assess the safety management maturity level among the G7 construction companies in Sarawak, Malaysia. The research is underpinned by the multiple causation theory, which explains several causes of accidents that can occur at construction sites (Petersen, 1971; Hosseinian & Torghabeh, 2012). Stemming from the positivist paradigm, this paper adopts a descriptive research design, a quantitative research method, and a disproportionate stratified simple random sampling technique to collect data from construction companies. This study adapts Hillson’s Maturity Model to assess the level of safety management practices among the G7 construction companies in Sarawak. The study found that the overall safety management practices of the companies is at the ‘matured level’ or the highest level.

In more detail, the findings of the current study show that the safety management culture of G7 construction companies is at a "matured level". Similarly, their safety management process was found to be at a "matured level". Likewise, their safety management experience was also found to be at a "matured level". However, the safety management application is at a "normalized level". It is, therefore, evident that the level of safety management practices of G7 construction companies is high. This is arguable, as there are still construction site accidents happening across construction sites. This study notes that data were collected only from G7 construction companies. Other factors are likely to contribute to the high number of construction site accidents. Hence, future studies could examine other grades of construction companies as well as other factors contributing to construction site accidents.

A broader implication of this study is that the ‘matured level’ attained by the G7 construction companies signifies the importance of SMC, SMPR, SME, and SMA. In order to maintain the high level of maturity in safety management, this requires adequate attention to SMC, SMPR, SME, and SMA. Safety managers should ensure the adequate implementation of all the four dimensions of maturity level of safety management. Regulatory agencies such as CIDB can use these four dimensions to assess the implementation of safety management maturity across construction companies.

To the academia, this study extends the maturity model to the field of safety management in the construction industry. The maturity level of safety management among construction companies can be assessed using SMC, SMPR, SME, and SMA. In addition, this study also complements the multiple causation theory in the construction industry.

In terms of the industry, this study provides an awareness to the current level of safety management practices among G7 construction companies. The current study has provided a practical contribution relevant to the construction industry. This study has revealed the behavioural aspect of construction companies regarding safety management practices. It is hoped that the top management of construction companies, as well as safety managers, can benefit from the findings of this study. Knowing the extent or level of safety management practices among G7 construction companies can be helpful to regulatory agencies such as CIDB and other policymakers. This study gives an insight into the dimension of safety maturity level (SMA) that should be improved among the G7 construction companies in Sarawak. This is because SMA was found to be low compared to other dimensions of maturity level (SMC, SMPR, SME). In this study, SMA refers to the implementation of safety management practices in all projects, having the accident reporting system, and the latest safety management tools by the construction companies. These findings can be useful to the regulatory agencies such as CIDB in formulating safety management regulations for the construction industry.

As in other research, the current research is associated with a number of limitations. First, data were collected from G7 construction companies operating in Sarawak only. Secondly, the safety management maturity level was based on Hillson's four levels. Although Hillson's model was found to be the most appropriate for this study, adopting another model, such as Hudson's (2007) model, which has five levels to assess the SMP level of the construction companies, might reveal slightly different findings. Future research may adopt Hudson's (2007) five levels of SMP or other maturity models to assess the safety management practices. In addition, future research can be extended to Sabah state and include other dimensions of SMP that have not been examined in this study.

Overall, the SMP level of the construction companies operating in Sarawak was found to be at a "matured level" or high. However, the result of the maturity level shows that the aspect of safety management application criteria needs to be improved because this dimension is not as high as the other three, namely safety management culture, safety management process, and safety management experience. As a call for action to uphold the matured level of SMP in Sarawak, the regulatory agencies, such as CIDB, DOSH, and policymakers related to the construction industry, should ensure that the four criteria of safety management, namely, safety management culture, safety management process, safety management experience, and safety management application, should be enforced across the construction sites.

DISCLOSURE STATEMENT

The authors do not have any conflicts of interest.

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A CONCEPTUAL FRAMEWORK OF CONSTRUCTION AND DEMOLITION (C&D) WASTE RECYCLING PRACTICES

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Abstract
Construction and demolition (C&D) waste has become one of the fastest growing waste streams in Malaysia, with metropolitan centres generating more than 20,000 tonnes daily. Despite national policies such as the National Construction Policy 2030 (NCP2030) and pilot initiatives, landfill diversion remains inconsistent due to fragmented governance, weak economic incentives, and uneven site level execution. Existing studies have identified drivers such as regulatory enforcement, fiscal incentives, and technological adoption, yet these remain descriptive, fragmented, and rarely integrated into coherent models. This study introduces the first integrated, theory driven conceptual framework for C&D waste recycling in Malaysia. Seventy Recycling Success Factors (RSFs), distilled from 124 peer reviewed studies published between 2020 and 2025, are consolidated into 8 thematic domains and synthesised under 4 higher order constructs: Governance, Operational Enablers, Collaboration Drivers, and Behavioural Implementation. Each is anchored in established theories namely Institutional Theory, the Resource Based View, Stakeholder Theory, and the Theory of Planned Behaviour, providing an ecosystem perspective that links institutional pressures, organisational capacities, inter stakeholder collaboration, and site level behaviours. Designed for reflective validation through Partial Least Squares Structural Equation Modelling (PLS-SEM), the framework enables empirical testing, cross country benchmarking, and policy application. By bridging Malaysia's policy ambitions with operational and behavioural realities, the study advances academic debate on circular construction and provides regulators and industry players with a structured roadmap to accelerate the transition toward a circular economy.

Keywords: *C&D Waste Recycling; Conceptual Framework; Recycling Success Factors; Circular Economy; Malaysia*

INTRODUCTION

Construction and demolition (C&D) waste is now among the fastest growing waste streams in emerging and newly industrialised economies, presenting substantial environmental and governance challenges. In Malaysia, rapid urbanisation and infrastructure growth have increased waste generation, yet recycling and reuse practices remain limited. Although national policies and pilot initiatives exist, landfill diversion rates remain inconsistent, reflecting fragmented institutional responsibilities, insufficient economic incentives, and uneven implementation at the site level (Guo et al., 2022b; Li & Ji, 2023). Previous studies have identified drivers such as policy clarity, fiscal measures, technological adoption, and contractor practices; however, these factors are often examined in isolation. The evidence base remains largely descriptive, offering limited theoretical integration and few tools for systematic strategy or benchmarking (Ding et al., 2024; Huang et al., 2021). Empirical studies in Malaysia further confirm this fragmentation. For example, Lew et al.

(2024) identified on site management, design, and material storage as dominant causes of construction waste, while recycling, reduction, and reuse were reported as the most common disposal practices. However, these findings remain largely descriptive and are not integrated into a theory driven framework capable of explaining system level interactions or guiding policy implementation.

To address this gap, the present study systematically consolidates 70 Recycling Success Factors (RSFs) derived from 124 peer reviewed studies published between 2020 and 2025. The identified factors are organised into 8 thematic domains and synthesised under 4 higher order constructs namely Governance, Operational Enablers, Collaboration Drivers and Behavioural Implementation. These constructs are theoretically grounded in Institutional Theory, the Resource Based View, Stakeholder Theory and Theory of Planned Behaviour.

By aligning RSFs with robust theoretical foundations, the framework provides a coherent, multi-level structure to explain how institutional signals, organisational capacities, inter stakeholder dynamics, and site level behaviours jointly shape recycling outcomes. While grounded in Malaysia's context, it provides a transferable benchmark for other economies in the Global South with similar constraints. The framework thus contributes to conceptual development in the circular construction debate and establishes a foundation for empirical testing, cross national comparison, and policy application. This positions the study at the intersection of theory and practice, advancing circular economy while equipping policymakers with actionable insights.

LITERATURE AND THEORY

Key Issues in C&D Waste Recycling

The construction sector is among the world's largest waste generators, with construction and demolition (C&D) waste posing persistent sustainability challenges. Sakthibala et al., (2025) argue that C&D waste is one of the most significant global waste streams, making up 25% and 40% of total solid waste in many regions. In Malaysia, waste volumes have risen sharply with urbanisation and infrastructure growth, yet recycling remains fragmented and poorly institutionalised (Ministry of Works, 2019). NCP2030 estimates that the sector contributes up to 50% of landfill waste while driving major environmental impacts, underscoring the urgency of structured recycling strategies (Ministry of Works, 2019). This argument is supported by Abedin Khan et al., 2024 whereas, in various countries, most of the generated C&D waste is being dumped into landfills, which reduces land availability.

As urbanisation intensifies, C&D waste continues to increase, creating major environmental and management challenges. Unlike the traditional linear model of "take, make, dispose," the circular economy (CE) approach emphasises reduction, reuse, and recycling to enhance resource efficiency and sustainability within the construction industry (Abedin Khan et al., 2024). Several practical barriers hinder progress: high costs of modern recycling technologies, reliance on low-cost foreign labour, weak enforcement and site level segregation, limited downstream infrastructure, and slow adoption of digital tools (Ministry of Works, 2019). While policy frameworks such as National Construction Policy 2030 (NCP2030) articulate ambitious targets, their translation into enforceable, measurable, and theory driven strategies remains weak, revealing a gap between ambition and practice.

Over 70 RSFs have been identified across regulatory, operational, market, and behavioural dimensions (Abkar et al., 2023; Alhawamdeh & Lee, 2021) but most studies remain descriptive, listing drivers such as enforcement quality or technological readiness without embedding them in theory (Ma et al., 2023; Shooshtarian et al., 2022). This limits scalability, cross-national benchmarking, and policy relevance. In Malaysia, empirical efforts using 3R frameworks via PLS-SEM have highlighted barriers such as poor design documentation and inadequate guidance on waste collection (Mohammed et al., 2021).

Taken together, these findings indicate that although both policy frameworks and empirical studies have consistently underscored the urgency of addressing C&D waste, substantial gaps remain in integrating financial, institutional, technological, and behavioural dimensions into a coherent and theory driven model (Abkar et al., 2023; Alhawamdeh & Lee, 2021; Belarouf et al., 2020; Ma et al., 2023; Mohammed et al., 2021). In the absence of such integration, Malaysia's transition towards a circular construction economy will continue to be constrained by fragmented implementation, inadequate market incentives, and a lack of robust theoretical grounding.

Theoretical Foundation and Hypotheses

Each of the 4 constructs addressing financial, institutional, technological, and behavioural gaps is firmly grounded in a well-established theoretical paradigm. These paradigms were selected for their strong explanatory relevance to sustainability, organisational behaviour, and environmental systems research. Therefore, 4 theories have been established as the theoretical foundation. There are the Institutional Theory, the Resource-Based View (RBV), the Stakeholder Theory and the Theory of Planned Behaviour (TPB).

Institutional Theory (Scott, 2015) informs the Governance dimension by elucidating how regulatory systems, normative standards, and coercive pressures influence institutional adoption of sustainable waste practices. The theory provides a lens to examine the extent to which government mandates, procurement guidelines, and environmental enforcement shape recycling compliance (Ma et al., 2023).

The Resource-Based View (RBV) (Barney, 2001) underpins the Operational Enablers construct, framing recycling infrastructure, data platforms, and technological capability as strategic internal assets that enable firms to generate sustainable competitive advantage. Recent studies affirm that organisations with superior technological readiness and information management systems exhibit higher compliance with recycling protocols (Ratnasabapathy et al., 2019).

Stakeholder Theory (Freeman et al., 2018) serves as the foundation for Collaboration Drivers, recognising that the success of recycling initiatives depends not only on technical and regulatory arrangements but also on the dynamic interplay among project owners, contractors, suppliers, and regulators. Evidence from emerging markets shows that collaborative governance significantly improves waste diversion outcomes (Guo et al., 2022b).

Finally, the Theory of Planned Behaviour (TPB) (Ajzen, 1991; Begum et al., 2009) substantiates the Behavioural Implementation construct by linking individual attitudes, perceived control, and social norms to on-site waste-related behaviours. Site level compliance

with sorting and recycling practices is contingent upon workers' intention, capacity, and peer reinforcement (Ma et al., 2023).

Based on these alignments, four hypotheses are advanced:

- H_1: Governance positively influences C&D waste recycling.
- H_2: Operational Enablers positively influence C&D waste recycling.
- H_3: Collaboration Drivers positively influence C&D waste recycling.
- H_4: Behavioural Implementation positively influences C&D waste recycling.

RESEARCH DESIGN AND METHODS

The conceptual framework was developed through a synthesis of recent peer-reviewed literature on C&D waste recycling published between 2020 and 2025, a period marked by intensified research on circular economy transitions in emerging economies (Ma et al., 2023; Shooshtarian et al., 2022). This study systematically consolidates 70 Recycling Success Factors (RSFs) derived from 124 peer reviewed studies, which were organised into 8 thematic domains comprising policy instruments, sustainable procurement, technology adoption, facility infrastructure, market dynamics, stakeholder capacity, data management and site operations. These domains were subsequently abstracted into 4 higher order constructs comprising Governance, Operational Enablers, Collaboration Drivers and Behavioural Implementation, all of which are grounded in established theoretical paradigms. This structured synthesis ensures that the proposed framework is both empirically informed and theoretically robust, providing a strong foundation for subsequent empirical validation.

RECYCLING SUCCESS FACTORS (RSF) OF C&D WASTE RECYCLING PRACTICES

A total of 70 Recycling Success Factors (RSFs) were synthesised into 4 constructs: Governance (34.3%), Operational Enablers (29.9%), Collaboration Drivers (28.6%), and Behavioural Implementation (7.1%). The distribution shows Malaysia's recycling system remains heavily reliant on governance levers such as policies, fiscal incentives, and procurement mandates, while site level behavioural practices are underrepresented, echoing broader Asian patterns of government led transitions (Ma et al., 2023; Shooshtarian et al., 2022; Wu et al., 2020). This imbalance exposes a persistent "last mile" weakness, whereby strong policy and technological enablers may fail without consistent on-site execution. Similar behavioural and organisational barriers have been documented in Lean Construction implementation among Malaysian Grade 7 contractors, where insufficient awareness, weak leadership commitment, and resistance to change constrained operational adoption despite high conceptual understanding (Nee et al., 2025). Addressing this requires tighter multi-level integration to align governance with operational, collaborative, and site level practices for scalable circular economy outcomes. Therefore, 8 thematic domains were established, which include policy instruments, technology adoption, facility infrastructure, market dynamics, stakeholder capacity, data management, sustainable procurement, and site operations.

Policy Instruments

Policy instruments remain decisive in shaping C&D waste recycling practices in Malaysia. As outlined in Table 1, a clear national framework, land-use planning, and valid permits (RSF1- RSF3) establish the regulatory base (Abdelshafy & Walther, 2023; Yu et al., 2023). Government funding and expedited approvals (RSF4 - RSF5) facilitate infrastructure (Bao & Lu, 2021), while inspections and penalties (RSF6-RSF7) strengthen compliance (Shooshtarian et al., 2022; Wu et al., 2020). Training, fiscal levers, and carbon pricing (RSF8-11) further embed recycling in market systems (Huang et al., 2025; Ma et al., 2023). Overall, these measures demonstrate that strong, coordinated policy remains as vital as technology in advancing Malaysia's circular construction agenda.

Table 1. List of Success Factors of Policy Instruments

RSF Code	Recycling Success Factor (RSF) in Contributing to C&D Waste Recycling in Malaysia
RSF1	The government establishes a clear C&D recycling policy framework
RSF2	Local authorities align land-use planning for recycling facilities
RSF3	Regulators require valid permits for recycling facilities
RSF4	The government allocates a budget for C&D recycling systems
RSF5	Local authorities expedite permitting for recycling activities
RSF6	Regulators enforce compliance through inspections
RSF7	The government imposes penalties for misreporting recycling data
RSF8	Regulators provide training for inspectors on recycling
RSF9	Regulators apply differential gate fees for segregated waste
RSF10	The government provides tax incentives for recycled products
RSF11	The government introduces carbon pricing to improve recycled materials competitiveness

The 11 Recycling Success Factors (RSF1–RSF11) represent the policy instrument, which reflects the critical role of institutional, regulatory, and policy mechanisms in advancing C&D waste recycling in Malaysia. These factors emphasise the importance of a coherent policy framework, effective regulatory enforcement, and government led financial support to strengthen the country's transition to a circular economy.

RSF1 emphasises the importance of a clear and comprehensive policy framework, which serves as the foundation for all recycling related initiatives. Without well-defined national policies, institutional fragmentation and inconsistent implementation are likely to persist. RSF2 and RSF3 underscore the roles of local authorities and regulatory bodies in ensuring proper land use alignment and legal authorisation for recycling facilities. These measures facilitate operational legitimacy and spatial planning consistency, both of which are essential for scaling up recycling capacity.

RSF4 and RSF5 relate to financial and administrative efficiency, where the allocation of dedicated budgets and the streamlining of permit approvals can remove key operational barriers faced by recycling firms. RSF6 and RSF7 address regulatory enforcement, including inspections and penalties for non-compliance or misreporting, which are vital for maintaining data integrity and deterring informal waste disposal practices.

Meanwhile, RSF8 to RSF11 highlight capacity building and economic incentives. Training for inspectors (RSF8) ensures effective monitoring and standardisation of compliance procedures. Differential gate fees (RSF9), tax incentives (RSF10), and carbon

pricing mechanisms (RSF11) create market-based motivations for recycling by enhancing the competitiveness of recycled materials against virgin resources.

Overall, these governance related Recycling Success Factors demonstrate that a robust and integrated institutional framework that combines regulatory clarity, financial incentives and effective enforcement mechanisms is essential for achieving systematic and sustainable construction and demolition waste recycling in Malaysia. The effectiveness of these measures depends on strong policy coherence across national and local levels, as well as sustained political and fiscal commitment to advancing circular economy objectives.

Technology Adoption

Technology adoption is a key driver of C&D waste recycling, enhancing material recovery through innovation and automation. As outlined in Table 2, government support for research institutions (RSF12) has facilitated the development of tailored recycling technologies (Bhavsar et al., 2023; Ma et al., 2025). On the industry side, firms are adopting automated sorting systems (RSF13) to improve output quality and reduce contamination (Chen & Liao, 2022; Tran et al., 2025). Financial incentives (RSF14) further promote technology uptake, especially among SMEs (Jayasinghe et al., 2023; Song et al., 2024). In parallel, the use of digital tracking systems (RSF15) enhances waste traceability and regulatory compliance (Han et al., 2025; Xia et al., 2024). To support knowledge diffusion, governments also invest in knowledge sharing platforms (RSF16) that strengthen cross stakeholder learning (Han et al., 2024; Mayer, 2024). technological enablers illustrate that advancing recycling in construction depends not only on policy but also on smart, scalable innovation systems.

Table 2. List of Success Factors of Technology Adoption

RSF Code	Recycling Success Factor (RSF) in Contributing to C&D Waste Recycling in Malaysia
RSF12	The government supports research institutions to advance recycling technologies
RSF13	Recycling companies adopt automated sorting equipment
RSF14	The government provides subsidies for the adoption of recycling technology
RSF15	Recycling companies adopt digital tracking technologies
RSF16	The government promotes knowledge-sharing platforms for recycling technology

From Table 2, RSF12 to RSF16 represent the technology adoption in the operational enablers construct, which captures the technological, infrastructural, and institutional capacities essential for effective C&D waste recycling in Malaysia. These factors underscore the importance of developing robust operational systems that enable the translation of policy frameworks into practical recycling outcomes.

RSF12 and RSF14 highlight the government's role in stimulating technological progress through research support and targeted subsidies. Such interventions encourage the development and adoption of innovative recycling technologies, fostering continuous improvement within the sector. RSF13 and RSF15 reflect the industry's technological readiness, where the integration of automated sorting systems and digital tracking tools enhances operational efficiency, material recovery, and data transparency. Meanwhile, RSF16 highlights the importance of knowledge sharing platforms, which facilitate the

exchange of technical expertise and best practices among government agencies, research institutions, and private stakeholders.

Facility Infrastructure

Facility infrastructure is a critical enabler in translating policy signals into the ground recycling outcomes. As summarised in Table 3, proximity to licensed recycling plants (RSF17) significantly lowers transport costs and material contamination risks, enhancing recycling compliance (Abdelshafy & Walther, 2023; Hasselsteen et al., 2025). Accredited laboratories (RSF18) validate the quality of recycled aggregates, supporting buyer confidence and broader market acceptance, while land provision by local authorities (RSF19) addresses spatial constraints and supports future expansion of recycling capacity, especially in urban centres (Javed et al., 2025; Yu et al., 2023). On site segregation infrastructure provided by contractors (RSF20) improves the quality of recyclable inputs at source (Shahid & Ali, 2025). Additionally, route optimisation by haulers (RSF21) improves logistics efficiency and minimises environmental burdens (Chen & Liao, 2022). Together, these infrastructure levers underpin a cohesive recovery chain necessary for achieving consistent circular construction outcomes in Malaysia.

Table 3. List of Success Factors of Facility Infrastructure

RSF Code	Recycling Success Factor (RSF) in Contributing to C&D Waste Recycling in Malaysia
RSF17	Local authorities ensure proximity to licensed recycling facilities
RSF18	Standards bodies provide accredited laboratories for recycled materials
RSF19	Local authorities secure land for recycling facility expansion
RSF20	Contractors provide on-site segregation infrastructure
RSF21	Waste hauliers optimise routing for C&D waste transport

RSF17 to RSF21 correspond to the facility infrastructure in operational enablers construct, focusing on the infrastructural and logistical dimensions that facilitate efficient C&D waste recycling in Malaysia. These factors highlight the significance of spatial planning, resource allocation, and operational efficiency in ensuring the practicality and scalability of recycling initiatives.

RSF17 and RSF19 emphasise the critical role of local authorities in providing an enabling environment for recycling activities. Ensuring proximity to licensed recycling facilities and securing adequate land for their expansion reduces transportation costs, minimises environmental impacts, and supports the continuous flow of recyclable materials. RSF18 underlines the importance of quality assurance and standardisation, where accredited testing laboratories validate the performance and reliability of recycled materials, which is essential for market acceptance and regulatory compliance.

RSF20 and RSF21 shift attention to industry level operational efficiency, highlighting the responsibilities of contractors and waste hauliers in facilitating on site waste segregation and optimising transportation routes. Effective site level infrastructure and logistical coordination not only enhance recycling rates but also reduce contamination and energy consumption across the waste management chain.

Taken together, these operational factors demonstrate that infrastructure readiness, standardisation mechanisms, and logistical optimisation are central to the effective functioning of Malaysia's C&D waste recycling ecosystem. Strengthening these dimensions bridges the gap between policy intent and implementation capacity, thereby laying the groundwork for broader multi stakeholder collaboration, discussed in the subsequent construct on collaboration drivers.

Market Dynamics

Market dynamics underpin the economic viability of C&D waste recycling by synchronising demand, supply, and financial enablers. As summarised in Table 4, on the demand side, recycled content requirements in tenders (RSF22) and buyers' willingness to pay a premium for certified products (RSF23) provide enforceable pull factors, while eco-label recognition (RSF24) enhances credibility and reduces scepticism (Hasselsteen et al., 2025; Shooshtarian et al., 2022; Yu et al., 2021). Financial institutions' inclusion of recycled-based projects (RSF25) strengthens access to capital, enabling investment and scalability (Bhavsar et al., 2023; Mhatre et al., 2023). On the supply side, expansion by manufacturers (RSF26), reliable distribution networks (RSF27), and long term offtake agreements (RSF28) ensure stability of volumes and pricing, while industry associations (RSF29) and export opportunities (RSF30) reinforce confidence and buffer domestic demand fluctuations (Kanwal et al., 2025; Song et al., 2024; Xie et al., 2024). These mechanisms reposition recycling from a compliance obligation into a contractable and competitive proposition, demonstrating that market instruments are indispensable complements to policy and operational enablers.

Table 4. List of Success Factors of Market Dynamics

RSF Code	Recycling Success Factor (RSF) in Contributing to C&D Waste Recycling in Malaysia
RSF22	Developers specify minimum recycled content in tenders
RSF23	Buyers pay a premium for certified recycled products
RSF24	Certification bodies issue recognized eco-labels for recycled products
RSF25	Financial institutions accept recycled-based construction projects
RSF26	Manufacturers expand production of recycled materials
RSF27	Distributors ensure a stable supply of recycled products
RSF28	Contractors sign long-term offtake agreements with recyclers
RSF29	Industry associations promote market uptake of recycled products
RSF30	Exporters develop markets for surplus recycled materials

RSF22 to RSF30 are market dynamics categorised under the collaboration drivers construct, which highlights the importance of market collaboration, industry engagement, and supply chain integration in advancing C&D waste recycling in Malaysia. These factors underscore how coordinated actions among developers, manufacturers, contractors, and financial institutions create the market stability and confidence necessary for a circular construction economy.

RSF22 and RSF23 emphasise the demand side drivers of recycling, where developers and buyers play a pivotal role by specifying minimum recycled content in project tenders and offering price premiums for certified recycled products. These practices stimulate market demand and legitimise the use of recycled materials in mainstream construction. RSF24 complements these mechanisms through certification and eco-labelling, which enhance

consumer trust, support regulatory compliance, and signal environmental responsibility across the value chain.

RSF25 to RSF27 shift focus toward the supply side and financial collaboration. The involvement of financial institutions in supporting recycled-based construction projects (RSF25) strengthens investment confidence and mitigates risk. At the same time, manufacturers and distributors contribute to a consistent market supply by expanding production capacity (RSF26) and ensuring stable product distribution (RSF27). RSF28 further reinforces collaboration through long-term offtake agreements between contractors and recyclers, which secure material flow and encourage business continuity.

Finally, RSF29 and RSF30 address industry level collaboration and market expansion, where trade associations promote wider adoption of recycled products, and exporters develop new markets for surplus materials. Together, these initiatives foster a resilient and interconnected recycling ecosystem that bridges the gap between production and demand.

The collaboration drivers highlight the centrality of strong market linkages, trust-based partnerships and institutional coordination in scaling construction and demolition waste recycling. These elements constitute the economic backbone that sustains the policy efforts and operational capacities established in the earlier constructs. The subsequent construct on behavioural implementation examines how individual and organisational behaviours further shape the effectiveness of these collaborative mechanisms.

Stakeholder Capacity

Table 5. List of Success Factors of Stakeholder Capacity

RSF Code	Recycling Success Factor (RSF) in Contributing to C&D Waste Recycling in Malaysia
RSF31	Contractors trained in waste segregation practices
RSF32	Consultants integrate recycling strategies in project planning
RSF33	Professional bodies include recycling in Continuing Professional Development (CPD) programmes
RSF34	Recyclers trained in plant operations
RSF35	Site managers incentivised for segregation performance
RSF36	The government supports awareness campaigns on recycling
RSF37	NGOs advocate recycling in construction
RSF38	Universities include recycling modules in the curriculum
RSF39	Trade unions support recycling-friendly work practices
RSF40	Community groups support local recycling initiatives
RSF41	Media coverage promotes recycling practices

Stakeholder capacity constitutes a decisive enabler of C&D waste recycling in Malaysia, bridging the gap between institutional aspirations and site level execution. As detailed in Table 5, skilled contractors and consultants (RSF31 to RSF32) operationalise waste segregation and embed recycling strategies within project planning, while CPD initiatives and recycler training (RSF33 to RSF34) enhance technical proficiency and professional accountability (Han et al., 2024; Shooshtarian et al., 2022). Performance based incentives for site managers (RSF35) further strengthen compliance, ensuring that recycling practices are not treated as ancillary but as integral to project delivery (Shahid & Ali, 2025). Beyond the industry, wider societal actors, including government awareness campaigns, NGOs, universities, unions, civic groups, and media platforms (RSF36 to RSF41), cultivate cultural

legitimacy, public engagement, and intergenerational knowledge transfer, embedding recycling as a shared responsibility rather than a contractual obligation (Adabre et al., 2025; Dalton et al., 2023). These measures underscore that without robust multi actor capacity building, Malaysia's recycling agenda risks remaining overly policy driven but weak in practice.

Data Management

Data management is increasingly recognised as a strategic enabler of C&D waste recycling in Malaysia, where regulatory enforcement and industry trust rely on transparent and verifiable flows. The identified success factors are outlined in Table 6. Timely reporting (RSF42) and compliance with contamination thresholds (RSF43) provide baseline accountability (Shooshtarian et al., 2022; Wu et al., 2020). Reliability is strengthened by acceptance testing (RSF44) and weighbridge calibration (RSF45), reducing under reporting and enhancing confidence (Han et al., 2025; Rodríguez et al., 2020). Credibility extends through third-party audits (RSF46) and supplier declarations (RSF47) (Kanwal et al., 2025). At the institutional level, certification visibility (RSF48) and GIS planning (RSF49) support oversight (Huang et al., 2025). Digitalisation via load traceability, delivery proof, and Application Programming Interface (API) exchanges (RSF50 - RSF52) signals a shift from manual to integrated systems, positioning data infrastructures as essential for Malaysia's circular economy transition.

Table 6. List of Success Factors of Data Management

RSF Code	Recycling Success Factor (RSF) in Contributing to C&D Waste Recycling in Malaysia
RSF42	Contractors submit KPI reports on time
RSF43	Contractors maintain contamination thresholds
RSF44	Contractors pass acceptance tests for recycled products
RSF45	Recyclers calibrate weighbridges on schedule
RSF46	Clients commission third-party diversion audits
RSF47	Suppliers publish environmental declarations for recycled products
RSF48	Regulators ensure recycler certification visibility
RSF49	Local authorities use Geographic Information Systems (GIS) for facility planning
RSF50	Contractors implement digital load traceability
RSF51	Contractors use digital applications for delivery proof
RSF52	Regulators operate an Application Programming Interface (API) data exchange for recycling

RSF42 to RSF52 are RSFs for data management that extend the Operational Enablers construct, focusing on monitoring, digitalisation, and data management dimensions to enhance transparency and efficiency in Malaysia's C&D waste recycling system. These factors highlight the operational mechanisms through which performance accountability, technological integration, and data driven decision-making can strengthen recycling governance and compliance.

RSF42 to RSF44 relate to contractor accountability and quality assurance, where timely submission of KPI reports (RSF42), adherence to contamination thresholds (RSF43), and compliance with acceptance testing for recycled products (RSF44) ensure consistency in waste handling and product quality. These practices create a verifiable performance trail, reducing non-compliance and encouraging continuous improvement across project sites.

RSF45 to RSF49 emphasise institutional monitoring and spatial management. Regular calibration of recyclers' weighbridges (RSF45) safeguards data integrity, while third party diversion audits commissioned by clients (RSF46) strengthen transparency in waste diversion claims. Suppliers publishing environmental product declarations (RSF47) further promote accountability and inform procurement decisions. At the same time, regulatory and planning authorities adopting Geographic Information System (GIS) tools (RSF49) improve the strategic planning and distribution of recycling facilities, ensuring spatial efficiency and accessibility.

RSF50 to RSF52 capture the growing role of digital integration in operational governance. Digital load traceability (RSF50) and delivery proof applications (RSF51) enhance real time monitoring and reduce data manipulation, while API data exchange systems operated by regulators (RSF52) enable seamless information flow among stakeholders. These digital mechanisms facilitate a transparent, evidence-based recycling ecosystem that aligns with global best practices in circular construction management.

These RSFs demonstrate that technological and procedural standardisation is crucial for achieving efficiency, traceability, and trust within the C&D recycling chain. By embedding digital governance and quality control into operational routines, Malaysia can strengthen the link between policy intent and on the ground implementation, thereby supporting a more transparent and data driven circular economy transition.

Sustainable Procurement

Table 7. List of Success Factors of Sustainable Procurement

RSF Code	Recycling Success Factor (RSF) in Contributing to C&D Waste Recycling in Malaysia
RSF53	Public clients adopt green procurement criteria
RSF54	Clients specify recycled content requirements
RSF55	Public clients mandate the use of recycled materials
RSF56	Designers specify recycled materials for non-structural use
RSF57	Clients prequalify recyclers as approved vendors
RSF58	Clients apply supplier performance scorecards
RSF59	Client includes recycling Key Performance Indicator (KPI) in contract
RSF60	Procurement units update contracts to include recycling
RSF61	Public clients sign framework agreements for recycled products
RSF62	Procurement units create separate recycling contract packages
RSF63	Clients verify third party certifications for recycled materials
RSF64	Clients track satisfaction with recycled products
RSF65	Procurement units conduct pre-award briefings on recycling

Sustainable procurement is central to scaling C&D waste recycling in Malaysia, with public clients driving demand by enforcing green criteria, minimum recycled content, and material mandates (RSF53-RSF55) (Shooshtarian et al., 2022; Yuan et al., 2023). Uptake is reinforced through design specifications for non-structural uses (RSF56) (Lei et al., 2024) and compliance mechanisms such as vendor prequalification, supplier scorecards, and KPI monitoring (RSF57-59). Longer term instruments such as recycling clauses, framework agreements, and specialised tenders (RSF60 to RSF62) mainstream recycling across project lifecycles, while certification checks, satisfaction monitoring, and pre award briefings (Iyer-Raniga et al., 2023; Martin et al., 2024). The full range of success factors linked to

procurement practices is consolidated in Table 7. Collectively, these measures shift recycling from voluntary efforts to enforceable obligations, positioning state procurement as a decisive lever for Malaysia's circular economy transition.

Under the success factors of sustainable procurement, RSF53 to RSF65 fall under the Governance and Procurement Integration construct, which highlights the pivotal role of client leadership and procurement mechanisms in institutionalising C&D waste recycling practices in Malaysia. These factors emphasise that sustainable procurement serves as both a policy instrument and an operational lever for mainstreaming recycled materials in construction projects.

RSF53 to RSF55 underscore the influence of public sector procurement as a catalyst for market transformation. The adoption of green procurement criteria (RSF53), specification of recycled content requirements (RSF54), and mandates for recycled material use (RSF55) demonstrate how government clients can drive systemic demand for recycled products. Such measures create stable market signals, reduce procurement risks, and legitimise recycled materials in public infrastructure delivery.

RSF56 to RSF58 reflect the role of design and supplier management in promoting recycling uptake. Designers specifying recycled materials for non-structural applications (RSF56) contribute to practical implementation without compromising structural safety. Prequalifying recyclers as approved vendors (RSF57) and applying supplier performance scorecards (RSF58) establishes quality benchmarks and continuous performance monitoring within the supply chain.

RSF59 to RSF65 highlight the institutionalisation of recycling within procurement processes. RSF59 and RSF60 highlight the role of clients and procurement units in institutionalising construction and demolition (C&D) waste recycling by embedding explicit recycling key performance indicators (KPIs) into contractual and procurement documents, thereby formalising recycling obligations and strengthening accountability across the project lifecycle. Moreover, the creation of dedicated recycling contract packages (RSF62), verification of third-party certifications (RSF63), and client satisfaction tracking (RSF64) ensure transparency and trust in the procurement cycle. Finally, pre award briefings on recycling (RSF65) foster shared understanding and alignment among project stakeholders before project commencement.

These RSFs demonstrate that integrating recycling criteria into public and private procurement frameworks is a powerful mechanism to accelerate Malaysia's transition towards a circular construction economy. Effective procurement integration not only embeds recycling within contractual obligations but also aligns stakeholder expectations, improves material traceability, and enhances the long-term credibility of the recycling market.

Site Operations

Site operations are the decisive frontier of Malaysia's C&D waste recycling. While segregation (RSF66) is critical, compliance remains constrained by limited space, subcontractor turnover, and weak enforcement (Hasselsteen et al., 2025; Liu et al., 2022). Mechanisms such as Site Waste Management Plans (RSF67), waste champions (RSF68), bin

optimisation (RSF69), and incentive schemes (RSF70) provide useful interventions, yet their impact is often short lived without cultural uptake (Shooshtarian et al., 2022; Song et al., 2024). Ultimately, site execution determines whether upstream policies translate into landfill diversion, as summarised in Table 8.

Table 8. List of Success Factors of Site Operations

RSF Code	Recycling Success Factor (RSF) in Contributing to C&D Waste Recycling in Malaysia
RSF66	Contractors ensure compliance with on-site segregation
RSF67	Contractors implement Site Waste Management Plans
RSF68	Contractors appoint a site waste champion
RSF69	Contractors optimise the layout of recycling bins
RSF70	Contractors link worker incentives to recycling targets

Success factors of site operations elements, further down RSF66 to RSF70, correspond to the behavioural implementation construct, focusing on site-level practices and workforce engagement that directly influence the success of C&D waste recycling in Malaysia. These factors highlight how managerial commitment, planning discipline, and behavioural incentives shape the effectiveness of recycling implementation on construction sites.

RSF66 and RSF67 emphasise the importance of procedural compliance and planning. Ensuring on-site segregation (RSF66) and implementing Site Waste Management Plans (RSF67) are foundational to achieving consistent waste diversion and material recovery. These practices institutionalise recycling behaviour within daily operations, transforming waste management from an ad-hoc activity into a structured component of project execution.

RSF68 and RSF69 demonstrate the significance of leadership and operational optimisation at the project level. Appointing a site waste champion (RSF68) promotes accountability and reinforces a culture of environmental responsibility, while optimising the layout of recycling bins (RSF69) facilitates ease of access, reduces contamination, and enhances worker participation in recycling activities.

RSF70 highlights the role of incentive-based motivation, where linking worker rewards to recycling targets fosters positive behavioural reinforcement and sustained compliance. Such incentive structures align individual motivation with organisational sustainability objectives, thereby strengthening overall performance.

These behavioural enablers demonstrate that effective on-site implementation relies not only on policy directives or technological tools, but also on human engagement, leadership, and behavioural consistency. Embedding these practices within project routines ensures that recycling objectives are operationalised at the ground level, thereby closing the loop between governance, operational planning, collaboration, and behavioural execution in Malaysia's circular construction transition.

CONCEPTUAL FRAMEWORK FOR C&D WASTE RECYCLING PRACTICES IN MALAYSIA

This study develops a conceptual framework that consolidates 70 Recycling Success Factors (RSF) across 8 thematic domains into 4 higher order reflective constructs:

Governance, Operational Enablers, Collaboration Drivers, and Behavioural Implementation. These pillars explain the effectiveness of C&D waste recycling in Malaysia. As illustrated in Figure 1, the framework captures the interconnected, multi-level dynamics shaping recycling transitions within the country's circular economy pathway.

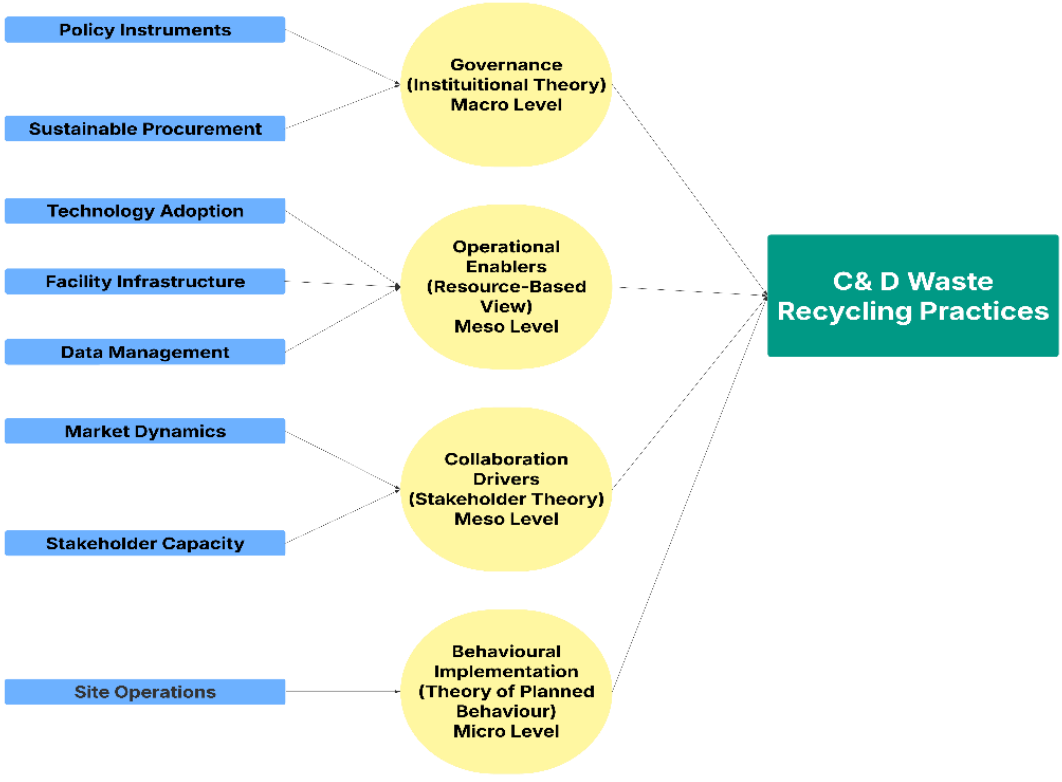

Figure 1. Conceptual Framework for C&D Waste Recycling Practices in Malaysia

At the macro level, Governance is informed by Institutional Theory, highlighting the influence of regulatory frameworks, procurement mandates, and normative pressures on compliance (Ma et al., 2023; Scott, 2015; Shooshtarian et al., 2022). At the meso level, Operational Enablers, grounded in the Resource-Based View, emphasise technology adoption, facility infrastructure, and data management as strategic assets that strengthen competitive and sustainable performance (Barney, 2001; Liu et al., 2022; Wang et al., 2024).

Alongside this, Collaboration Drivers, underpinned by Stakeholder Theory, reflect how contractors, recyclers, regulators, and financiers coordinate through markets, certification, and partnerships to achieve collective outcomes (Freeman et al., 2018; Guo et al., 2022a; Rajendran & Shanmugavel, 2025). At the micro level, Behavioural Implementation applies the Theory of Planned Behaviour, explaining how worker attitudes, perceived control, and social norms shape site level recycling practices such as segregation and waste management compliance (Ajzen, 1991; Shooshtarian et al., 2021; Wu et al., 2020). These practices ultimately determine whether upstream policy and organisational efforts are translated into tangible waste diversion outcomes.

By linking 70 RSFs to 4 theoretical pillars, this framework addresses a persistent gap in the literature by moving beyond fragmented listings of drivers towards a structured, empirically testable model. The theory informed design clarifies both the mechanisms, namely how recycling practices are shaped across institutional, organisational, and site levels, and the outcomes, namely why interventions succeed or fail, offering a scalable and context sensitive pathway for advancing circular construction practices in Malaysia. At the same time, it provides a transferable reference point for other emerging economies grappling with similar challenges.

Unlike prior studies that primarily catalogued drivers in isolation, this research advances an ecosystemic perspective by systematically consolidating 70 RSFs into a multi-level framework comprising governance, operational enablers, collaboration drivers, and behavioural implementation. Anchored in Institutional Theory, the Resource-Based View, Stakeholder Theory, and the Theory of Planned Behaviour, the study moves decisively beyond descriptive synthesis, delivering a theory driven, empirically verifiable model. While prior research has explored selected aspects of these dimensions, an integrated framework encompassing their combined influence remains underexplored in Malaysia. This establishes both academic novelty and direct policy relevance, ensuring that the findings make a meaningful contribution to both academic and practice.

CONCLUSION

This study introduces the first integrated, theory driven framework for construction and demolition (C&D) waste recycling in Malaysia, consolidating 70 RSFs into 8 domains and 4 higher order constructs: Governance, Operational Enablers, Collaboration Drivers, and Behavioural Implementation. Grounded in Institutional Theory, the Resource-Based View, Stakeholder Theory, and the Theory of Planned Behaviour, the framework explains how regulatory pressures, organisational capacities, collaborative arrangements, and site level behaviours jointly shape recycling outcomes.

The framework remains conceptual and thus requires empirical validation. Integration with Industry 4.0 technologies, such as IoT-based traceability and AI enabled monitoring, also represents a promising avenue to enhance oversight and innovation. By moving beyond fragmented lists of drivers to a coherent, testable model, this study combines theoretical depth with policy relevance, positioning the framework as both a strategic roadmap for Malaysia's circular construction transition and a scalable reference for other emerging economies.

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A THEORY-INFORMED STRUCTURAL MODEL OF CRITICAL SUCCESS FACTORS FOR FACILITIES MANAGEMENT (FM) CONTRACTORS USING INTERPRETIVE STRUCTURAL MODELLING (ISM)

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Abstract
This paper has come up with a theory based and structurally modelled theory of critical success factors (CSFs) of facilities management (FM) contractors. The effectiveness of outsourced FM delivery largely depends on the performance of FM contractors, and the research that pays particular attention to contractor centred CSFs is scarce. Based on nine organisational and outsourcing associated theories and using Interpretive Structural Modelling (ISM), the research revealed seventeen CSFs and grouped them into a multi-level hierarchy to explain the interdependencies between factors. The Structural Self Interaction Matrix was developed using a panel of senior FM experts and the model developed was tested by MICMAC analysis to identify the driving and dependence power of each factor. The results indicate the performance of the FM contractors through three underlying drivers which are technology integration, data quality, and clarity of cost or contractual provisions. All such supporting elements support the capability development, quality management, resource optimisation, and effective relational coordination in the entire organisation. The research has theoretical value in the sense that it provides a consistent contractor-oriented structure of fragmented literature on the CSF and empirical support of the interaction of these mechanisms in the FM ecosystem. As a practical approach, the framework provides FM contractors with a strategic roadmap on how to focus on the work-related operational improvements, organisational resilience, and service delivery quality. With the focus on these key drivers, FM contractors will be in a better position to assist client's business continuity, risk assurance, and value creation in the long run.

Keywords: *Facilities Management (FM); FM Contractors; Critical Success Factors (CSFs); Theory-Informed Framework; Interpretive Structural Modelling (ISM); MICMAC Analysis*

INTRODUCTION

Contractors in the Facilities Management (FM) business are at the core of maintaining continuity in operations, safety, and reliability of services in outsourced building services. Nevertheless, the performance of contractors is often below the anticipated levels, and the problems common to many of them include latent maintenance, ineffective coordination, and failure to adhere to service level agreements (SLAs). Such difficulties are extensively reported in the international FM practice, in which low responsiveness, lack of documentation, and insufficient planning hinder the delivery of services (Atkin and Brooks, 2021; Chew, 2016; Nur and Musa, 2017). The Auditor-General Reports (National Audit Department, 2021) in Malaysia also reveal that the outsourced FM contracts have continued to have weaknesses such as ineffective maintenance implementation and inability to perform on the main contractual performance indicators. These performance gaps interfere with the organisational operations, lifecycle costs and stakeholder trust in FM outsourcing. Similar problems in other nations show that there is a structural failure in the management of outsourced FM service setups (Opawole et al., 2019; Parn et al., 2017).

Despite the rich literature on the investigation of critical success factors (CSFs) in FM, previous studies are mostly oriented on client organisations, the overall FM practice, or facilities-related to a certain sector as opposed to FM contractors. The bulk of the CSF studies in Malaysia and abroad are focused on FM in buildings, estates, or healthcare facilities (Awuzie and Isa, 2017; Pakrudin et al., 2017; Dahlan et al., 2022). Nevertheless, such studies do not speak on the operational realities, which are peculiar to FM contractors. In contrast to clients, FM contractors have to work within the context of commercial pressures, which include competition tendering, fragmented supply chains, and resource limitations, directly affecting their ability to provide a consistent service quality (Hui, 2005; Nur and Musa, 2017). Nevertheless, none of these differences are reflected in the literature in a unified framework of the most important CSFs to contractors, and how these factors interact to influence contract performance.

The available CSF research is also generally inclined to generate descriptive lists which are not based on theory and do not investigate how the factors are interdependent. Although other articles are written on the topics of communication, capability, innovation, sustainability, and stakeholder engagement (Coenen et al., 2013; Lok et al., 2018; Awuzie and Isa, 2017), they rarely explain how these elements are drivers, enablers, or outcomes in FM contracting systems. Equally, there is limited knowledge on whether the foundational components like resource optimisation, performance measurement, or technology integration have upstream influence on the other CSFs. In the absence of such structural insight, the FM contractors do not have a prioritised roadmap of fortifying contract execution. This indicates the necessity of a theory-based and analytical framework to inform enhancement in service dependability, stakeholder congruence, and operational uniformity.

This paper addresses these gaps by defining and modelling the success factors that are applicable to FM contractors through a theory-based study. Conceptual justification of deriving an initial set of CSFs relevant to contractor performance is provided by nine management theories, such as the Resource-Based View, the Transaction Cost Theory, the Stakeholder Theory, the Lean Management, the Total Quality Management, the Balanced Scorecard, the Service-Dominant Logic (Goh and Loosemore, 2017; Lok et al., 2018; Bridoux and Vishwanathan, 2018; Ahlstrom et al., 2021; Maher Altayeb This study does not employ these theories as hypotheses testing tools, but as analysis prisms to determine the forces that are influencing the operations of FM contractors. Interpretive Structural Modelling (ISM) is then used to establish the hierarchic interdependences of these factors and to establish the underlying drivers of FM contract performance (Bi et al., 2012; Kumar and Vinodh, 2020).

Based on this, this paper has two objectives:

1. To determine a theory-based list of success factors applicable to FM contractors, and
2. To establish the structural relations among these success factors using Interpretive Structural Modelling (ISM).

This paper contributes in three ways. Theoretical wise, it combines various theories of management to come up with a unified framework of CSF that is specifically designed to suit FM contractors-a view that is currently not present in FM literature. In its methodological approach, it uses ISM to uncover the structural interdependences of CSFs to make it clear which factors act as foundational drivers and which act as dependent outcomes. In practice,

it provides FM contractors, clients and policymakers with a systematic roadmap of how to promote better performance of contracts, better adherence to the SLA and better operational reliability in the FM industry.

The rest of this paper is organised in the following way. Section 2 discusses the management theories and forms the first set of CSFs. Section 3 describes the ISM methodology. Section 4 gives the results of the ISM and MICMAC. The theoretical and practical implications are discussed in Section 5. The last section of the paper is section 6, which ends with limitations and future research directions.

LITERATURE REVIEW

Purpose of Using Management Theories in This Study

This paper will follow the developed theories of management, not to test the hypothesis but will use them as theoretical frames to derive success factors (CSFs) applicable to FM contractors. The available FM studies tend to describe CSFs but do not place them in the context of strategic, organisational, or behavioural theory (Awuzie and Isa, 2017; Pakrudin et al., 2017; Dahlan et al., 2022). A theory-based strategy will make sure that the identified CSFs are conceptually grounded, strategically significant, and in line with the realities of operations of contractors. The theories used encompass various managerial aspects of capability development, cost-efficiency, stakeholder alignment, value creation, quality assurance, and performance measurement. The conceptual robustness of the CSF set is enhanced by this integration, and it can be used in structural modelling.

Overview of Theories Relevant to FM Contractor Performance

Resource-Based View (RBV) places organisational capabilities in the form of skilled labour, knowledge assets, as well as technological capacity as sources of competitive advantage. In the case of FM contractors, the availability of resources, the competency of the workforce, and digital capability have a direct effect on the reliability of the service, responsiveness, and performance of the contract. These lessons explain the success factors regarding workforce capability, resource optimisation, and technology integration (Goh and Loosemore, 2017; Guillaume and Schneider, 2021).

The TCT is a theory that describes the performance of outsourced relationships under the influence of uncertainty, information asymmetry, and coordination costs. FM contractors need to deal with risks in bidding, ambiguity of the contract, channel of communication, and monitoring of the services. TCT has thus supported the aspects of controlling costs, clarity of contracts, effectiveness of communication and risk management (Antonenko et al., 2017; Ismail et al., 2018).

The Stakeholder Theory holds that organisational performance is reliant on the consideration of the expectations of various stakeholders. FM contractors have to deal with clients, end-users, subcontractors, regulators, and suppliers, which is why alignment is crucial to the success of the services. This theory advocates the CSFs of client-centricity, collaboration with stakeholders, and integrating feedback (Bridoux and Vishwanathan, 2018; Kayat, 2008).

Lean Management focuses on the minimisation of waste and the efficiency of the working process. Lean principles in FM contracting facilitate efficient utilisation of resources, efficient processes and enhanced service consistency. These insights warrant such factors as process optimisation, cross-functional collaboration, and continuous improvement (Ahlstrom et al., 2021; Tezel et al., 2017; Ranadewa et al., 2021).

TQM is aimed at the quality assurance, monitoring of performance and gradual improvement. FM contractors must be able to meet the standards of SLAs and KPI, which is why TQM is also relevant to the success factors, including the KPI design, performance measurement, quality control, and staff capability (Maher Altayeb and Bashir, 2014; Pitt and Tucker, 2008).

The Balanced Scorecard (BSC) offers a systematic view of the measurement of performance in terms of customer, internal process, learning, and financial aspects. In FM contracting, the principles of BSC support the significance of performance measures, customer satisfaction, and strategies of the long-term improvements (Anand et al., 2005; Hoque and Adams, 2011).

The Service-Dominant Logic (SDL) perceives value as a jointly constructed phenomenon between the service providers and the clients. FM contractors add value through providing responsive services, good communication, and constant adjustment to the needs of the clients. SDL thus promotes those factors that are associated with the engagement, responsiveness of the service and the feedback-based improvement (van der Voordt, 2017).

Change Management Theory applies because of the changing aspect of FM contracts, which is likely to necessitate behavioural change, new processes, and organisational adaptation. This theory shapes such variables as change preparedness, communication, employee education, and alignment with stakeholders (Austin and Currie, 2003; Sridarran and Fernando, 2016).

Theories on Innovation and Technology Integration point towards the growing significance of digital tools, automation, and data-driven decision-making. These trends explain the aspects associated with the adoption of technology, data quality, and system integration (Dixit et al., 2019; Sulaiman et al., 2021).

Combined, these theories offer a systematic basis of the understanding of the mechanisms that affect the performance of FM contractors. They each emphasise various organisational needs- capability, coordination, quality, value co-creation and technological enablement. Together, they indicate that the combination of the resource strength, the process efficiency, the alignment between the stakeholders, and the digital readiness determines the FM contract performance. Such theoretical underpinning guarantees the conceptual rigor of the success factors applied to this study and not just using practitioner experience. These theoretical constructs are then converted to a unified set of CSFs to structural modelling in the following sections.

Deriving Success Factors from Theories

The success factors in this study were derived using a theory-driven approach to provide clarity in terms of conceptual grounding. Table 2.3 matches each of the factors with the theory that supports it such as RBV, TCT, Lean, TQM, BSC, Stakeholder Theory, and SDL and the rationale behind its choice. This mapping makes sure that the ISM model will be founded on proven theoretical premises and not on the opinion of practitioners.

Table 2.3. Mapping of Success Factors to Supporting Theories

Success Factor (SF)	Supporting Theories	Conceptual Basis
Technology Integration	RBV; Innovation Theory; Lean	Technology enhances organisational capability, improves efficiency and enables automation.
Resource Optimisation	RBV; Lean	Efficient allocation of resources strengthens internal capacity and reduces process waste.
Client-Centric Approach / Client Satisfaction	Stakeholder Theory; SDL	Value is co-created; client needs and expectations shape service outcomes.
Communication & Coordination	TCT; Change Management	Reduces uncertainty, supports alignment and facilitates organisational adaptation.
Performance Metrics (KPIs)	TQM; Balanced Scorecard	Multi-dimensional measurement enables monitoring, accountability and continuous improvement.
Continuous Improvement	Lean; TQM	Improvement is an iterative organisational discipline supported by process refinement and systematic review.
Stakeholder Collaboration	Stakeholder Theory	Collaboration aligns interests across contractors, clients and vendors, enhancing value delivery.
Risk Management	TCT	Controls uncertainty, reduces transaction costs and stabilises contract performance.
Training & Capability Development	RBV; TQM; Change Management	Human capability is a core organisational asset supporting service quality and adaptability.

Table 2.4. Theoretical Basis and Derivation of FM Success Factors

Theory	Key Construct	FM Contractor Relevance	Derived SF
RBV (Goh & Loosemore, 2017)	Capability, resources	Need skilled staff, tools, technology	Workforce capability; resource optimisation; technology integration
TCT (Antonenko & Baev, 2017; Ismail et al., 2018)	Coordination cost, contract clarity	Contractor must minimise disputes, ambiguity	Clear communication; contract clarity; cost control; risk management
Stakeholder Theory (Bridoux & Vishwanathan, 2018)	Stakeholder expectations	Contractors must satisfy clients and users	Client-centricity; stakeholder collaboration
Lean (Åhlström et al., 2021; Ranadewa et al., 2021)	Waste reduction, flow	Need efficient operations, reliable workflows	Process optimisation; continuous improvement
TQM (Maher Altayeb & Bashir, 2014; Pitt & Tucker, 2008)	Quality control	Contractors must meet KPIs and SLAs	KPIs; performance monitoring; training
BSC (Anand et al., 2005; Hoque & Adams, 2011)	Multi-dimensional performance	Contractor performance must satisfy client	Client satisfaction; performance metrics
SDL (van der Voordt, 2017)	Co-creation of value	Contractor-client relationship crucial	Feedback integration; service responsiveness
Change Management (Austin & Currie, 2003)	Behaviour & process change	FM contracts frequently evolve	Training; communication; readiness
Innovation/Tech (Dixit et al., 2019; Sulaiman et al., 2021)	Digital enablement	Increasing reliance on digital FM	Technology integration; data-driven decision-making

Theoretical Foundations and Derivation of Success Factors

Theories were linked, and core constructs of the theories were interconnected with the relevance of the theories to FM contracting in order to formulate a refined set of CSF. Table 2.4 shows that every theory has an effect on an organisational need, including the ability to develop, coordination, quality assurance or value co-creation, which is subsequently translated into success factors.

Consolidated Success Factor List

The literature recognises a vast number of variables that affect the performance of FM contractors. These insights have been summarised in Table 2.5 in the form of a structured list that includes client orientation, use of technology, management of resources, quality systems, governance, and collaborative practices. These aspects are the most commonly cited determinants of the performance of a contractor based on previous FM research.

Table 2.5. Consolidated Success Factors from Literature

No.	Success Factor	Supporting References
1	Client Centric Approach	Bridoux and Vishwanathan (2018); van der Voordt (2017)
2	Technology Integration	Dixit et al. (2019); Sulaiman et al. (2021)
3	Data Driven Decision Making	Dixit et al. (2019)
4	Cross Functional Collaboration	Bridoux and Vishwanathan (2018)
5	Resource Optimisation	Goh and Loosemore (2017)
6	Sustainability Integration	Lok et al. (2018); Hoxha et al. (2017)
7	Performance Metrics and KPIs	Maher Altayeb and Bashir (2014); Pitt and Tucker (2008)
8	Continuous Improvement Culture	Åhlström et al. (2021); Ranadewa et al. (2021)
9	Employee Training and Capability	Goh and Loosemore (2017); Maher Altayeb and Bashir (2014)
10	Client Feedback Integration	van der Voordt (2017)
11	Change Management Practices	Austin and Currie (2003)
12	Collaborative Relationships	Kayat (2008); Bridoux and Vishwanathan (2018)
13	Clear Communication	Ismail et al. (2018)
14	Cost Control	Antonenko and Baev (2017)
15	Client Education	Coenen et al. (2013)
16	Risk Management	Antonenko and Baev (2017)
17	Long Term Orientation	Hoque and Adams (2011); Anand et al. (2005)

Having summed up the success factors, the literature fails to elucidate how the factors relate to one another or which of them acts as underlining drivers. Such a gap restricts the capacity of the contractors to focus on the process of improvement. Hence, Interpretive Structural Modelling (ISM) is used in the next phase of this research to examine the hierarchy of relations between these variables and develop a structured model of the CSF that indicates the interdependence between them (Bi et al., 2012; Kumar and Vinodh, 2020).

METHODOLOGY

Research Design

The research design adopted in this study is a qualitative-structural research design through Interpretive Structural Modelling (ISM), as a method of establishing the hierarchical

relationship between the theory-derived success factors (CSFs). The design is in line with the aim of the study to know the interaction of managerial, operational and relational constructs that influence FM contractor performance.

ISM is especially appropriate since it converts expert judgement into a multi-level, structured model, which allows systematising the study of complex interdependencies (Bi et al., 2012; Kumar and Vinodh, 2020). Other researchers have used ISM to assess the connection between organisational, operational, and technological variables in FM and construction environments (Dixit et al., 2019; Sulaiman et al., 2021).

The workflow of methodology consists of four steps:

1. Theory derivation of the success factors.
2. Expert elicitation.
3. Development of ISM (SSIM - Reachability Matrices - Level Partitioning).
4. MICMAC analysis to categorize factors into driving and dependence power.

Derivation of Initial Success Factors

Section 2 identified 9 management theories that were used to derive seventeen success factors. All factors are concept-based aspects that affect the performance of FM contractors. Together, the aspects include organisational capability (RBV), stakeholder alignment (Stakeholder Theory), process efficiency (Lean), quality assurance (TQM), contractual clarity (TCT), value co-creation (SDL) and performance measurement (BSC).

The remediation of conceptual strength and the minimisation of subjectivity in the interpretation by the expert are supported when explicitly theorised constructs are used (Goh and Loosemore, 2017; Bridoux and Vishwanathan, 2018; Ranadewa et al., 2021). The ISM modelling process was based on these 17 factors.

Expert Selection and Profile

Interpretive Structural Modelling (ISM) is based on the expert judgement of the relationship between factors based on the context. Thus, the process of selecting experts was purposive sampling to make sure that the participants were knowledgeable and had the authority to make the decision in the context of interpretative analysis. Three selection criteria have been used:

1. Firsthand experience in FM contracting or outsourced FM service provision;
2. Practice in the management or assessment of SLA performance and KPI performance; and
3. Technical understanding of FM digitalisation, risk management or contract management.

These conditions make sure that the relational judgements that form the ISM model are based on knowledgeable professional execution as opposed to statistical connection (Bi et al., 2012). ISM is interpretive and not inferential, so the aim is not generalisability, but developing a theoretically sound structural understanding of the interaction of factors.

The expert panel was comprised of practitioners representing major stakeholder groups in outsourced FM ecosystems such as FM contractors (senior operations and contract managers), FM consultants with expertise in KPI and SLA models, client representatives managing outsourced FM contracts, and technical specialists in digitalisation and performance monitoring of FMs. The specialists had ten to twenty-five years of experience in the industry, which aligns with the methodological advice of ISM that suggests profound knowledge of the practitioner to interpret the structure meaningfully (Sulaiman et al., 2021; Dixit et al., 2019). Table 3.1 is a summary of their profiles.

The expert panel size and structure are in line with standard guidelines of ISM, which generally suggests the use of between six and fifteen experts to achieve consistent interpretive judgements and also to ensure that the group dynamics of the expert panel work. The variety of the expertise that Table 3.1 shows make the structural model more credible because it is guaranteed that the relational assessments are based on various operational, managerial, and technical approaches in the field of FM contracting practice.

Table 3.1: Brief Profile of The Experts in FM

ID	Party	Working Experience in FM	Qualification
A	FM Client	10	Master in Asset and FM
B	FM Contractor	11	Master in Asset and FM
C	FM Client	10	Master in Asset and FM
D	FM Contractor	10	Master in Asset and FM
E	FM Consultant	15	Professional Engineer
F	FM Consultant	14	PhD in FM
G	FM Contractor	10	Master in Asset and FM
H	FM Consultant	11	Master in Asset and FM, CFMM
I	FM Client	13	Master in Asset and FM
J	FM Consultant	12	MSc. Eng. Business Management, CFMM
K	FM Contractor	10	Master in Asset and FM
L	FM Client	14	Master in Asset and FM
M	FM Contractor	15	Master in Asset and FM
N	FM Contractor	15	Master in FM

ISM Procedure

The ISM process entails four systematic steps that align with applications that have been developed in organisational and operational research (Bi et al., 2012; Kumar and Vinodh, 2020):

1. Build Structural Self-Interaction Matrix (SSIM)
2. Transform the SSIM into Final and Initial Reachability Matrices
3. Perform level partitioning
4. Establish the hierarchical model of ISM

Structural Self-Interaction Matrix (SSIM)

Four symbols were used to evaluate the contextual relationship between each couple of success factors by experts:

- V: Factor i influences factor j
- A: Factor j influences factor i
- X: Factors influence each other
- O: No meaningful relationship exists

These symbolic relationships represent the expertise judgement of direction, strength and existence of influence. SSIM enables the subtle causal reasoning with no numerical assumptions, which is the basis of qualitative formulations of the subsequent structural modelling.

Initial and Final Reachability Matrix

The SSIM was transformed into the Initial Reachability Matrix (IRM) by normal rules of transforming ISM. All of the diagonal values were initialized to 1.

Transitivity- which is a fundamental assumption of ISM- was then used to produce the Final Reachability Matrix (FRM). Transitivity is used to state that in case A is influencing B and B is influencing C, then A is said to influence C indirectly. This is a property that is necessary in the creation of a hierarchical model and aligns with the organisational analysis on which ISM is based (Kumar & Vinodh, 2020).

Level Partitioning

Two sets were made up of each factor:

- Reachability Set: factors influenced by the factor
- Antecedent Set: factors that influence the factor

The set intersection problem was analysed in an iterative way. The factors, the reachability set of which was equal to the intersection set, were put on the highest available level. This was repeated until the factors had been allocated levels.

This analysis makes possible the determination of:

- Foundational drivers
- Linkage factors
- Dependent enablers
- Outcome-level factors

These levels collectively form the basis of the ISM hierarchical structure.

Development of the ISM Hierarchical Model

According to the level partitioning a multi-level hierarchical model was built, which graphically depicts:

- Foundational drivers (bottom levels)
- Enabling and interaction factors (middle levels)
- Dependent performance outcomes (top levels)

This conceptual framework gives a conceptual clarity on how the performance of FM contractors can be strategically improved by target interventions, as it has been with previous structural modelling studies in FM and construction sectors (Sulaiman et al., 2021; Dixit et al., 2019).

MICMAC Analysis

MICMAC analysis was done to categorize each of the factors based on the driving power (the number of factors influenced) and dependence power (the number of factors influenced). Factors were placed in four quadrants using the FRM:

1. **Autonomous** (weak driver, weak dependence)
2. **Dependent** (weak driver, strong dependence)
3. **Linkage** (strong driver, strong dependence)
4. **Independent/Driving** (strong driver, weak dependence)

According to the previous research, the integration of technology, optimisation of resources, and communication are frequent drivers (Dixit et al., 2019; Sulaiman et al., 2021), which is indicative of their systemic impact on FM operations. The MICMAC results complement and enhance the ISM results.

Validity and Reliability Measures

Three complementary checks were used to support validity and reliability:

1. Expert Validation;
   Each SSIM relationship was to include a minimum of 70% agreement to be included. This has made sure that directional judgments were based on collective and not individual views.
2. Internal Consistency;
   The Final Reachability Matrix was tested by transitivity in order to ensure that the structural relationships were consistent and without logical inconsistencies.
3. Theoretical Triangulation;
   The ranking of factors was compared with the RBV, TCT, Lean, TQM, BSC, and Stakeholder Theory expectations (Goh and Loosemore, 2017; Anand et al., 2005; Bridoux and Vishwanathan, 2018). This enhanced conceptual congruence and less interpretive bias.

Collectively, these steps offer a stringent basis to the ISM outcomes and meet the accepted guidelines of the qualitative structural modelling.

RESULTS AND MICMAC ANALYSIS

Overview of ISM Output

The ISM process created a multi-level hierarchy of structure that outlines the impact of 17 success factors (SF1-SF17) on each other. The model identifies foundational drivers, intermediate enablers, as well as outcome-level factors. This order elucidates the channels through which FM contractor performance comes out and facilitates strategic prioritisation by pointing out the factors that have the most influence in the system.

ISM Level Partitioning Results

It used seventeen factors which were allocated in five hierarchical levels depending on position in the influence-dependence structure of Final Reachability Matrix (FRM). The levels are indicative of their functional roles in the system as a whole.

LEVEL 1 — Dependent Outcome Factors (Top Level)

Level 1 comprises of SF15 (Continuous Improvement Outcomes), SF16 (Client Satisfaction), and SF17 (Service Reliability/SLA Achievement). These factors are highly dependent with low driving power which means that they are ultimate results influenced by the operation of all the previous drivers and enablers.

- **SF16 Client Satisfaction** depends on communication quality, responsiveness, service consistency, and capability performance (van der Voordt, 2017).
- **SF17 SLA Achievement** reflects process reliability and quality management effectiveness (Pitt & Tucker, 2008).
- **SF15 Continuous Improvement Outcomes** emerge from KPI utilisation, feedback mechanisms, and iterative process enhancement (Åhlström et al., 2021).

These are not the factors that affect other elements of the hierarchy but rather the end of the performance in the system.

LEVEL 2 — High-Dependence Enablers (Dependent/Linkage)

Level 2 includes SF10 (Change Readiness), SF11 (Performance Monitoring and KPIs) and SF12 (Feedback Integration). These considerations depend greatly on the bottom-up capabilities yet influence the capacity of the system to transform operational power into quantifiable results.

- **SF12 Feedback Integration** depends on effective communication and digital support to capture and respond to user needs.
- **SF11 KPI/Performance Monitoring** requires stable processes, quality systems, and adequate resources.

- **SF10 Change Readiness** depends on training, leadership support, and communication effectiveness.

These facilitators serve as mediators between the working systems and the ultimate performance results.

LEVEL 3 — Mid-Level Linkage Factors (High Driver, High Dependence)

Level 3 incorporates SF7 (Communication and Coordination), SF8 (Stakeholder Collaboration) and SF9 (Process Optimisation). These aspects have a high driving and high dependence power and as such, they are core and sensitive elements to the system.

- SF7 Communication & Coordination reduces uncertainty and facilitates alignment.
- SF8 Collaboration aligns contractors, clients, and subcontractors (Bridoux & Vishwanathan, 2018).
- SF9 Process Optimisation supports workflow stability and operational efficiency.

Since many other factors are influenced by these linkage factors, and at the same time, those factors are influenced by underlying enabling factors, system-wide impact is high with improvements at this level.

LEVEL 4 — Driving Enablers (Strong Drivers, Moderate Dependence)

Level 4 includes SF4 (Resource Optimisation), SF5 (Training and Capability Development) and SF6 (Quality Management). These factors are those that have strong driving power and moderate dependence.

- **SF5 Capability Development** improves adaptability and operational quality.
- **SF6 Quality Management** drives consistency in meeting SLA and KPI requirements.
- **SF4 Resource Optimisation** ensures efficient allocation of manpower and equipment.

These facilitators enhance the ability of the organisation internally and facilitate stabilisation of the linkage layer of the system.

LEVEL 5 — Foundational Driver Factors (Bottom Level)

Level 5 is composed of SF1 (Technology Integration), SF2 (Data Quality and Information management), and SF3 (Cost Management and Contract Clarity). The driving power and dependence of these factors are very strong and minimal as they work as the root structural determinants of FM contractor performance.

- SF1 Technology Integration enables automation, coordination, and decision support.
- SF2 Data Quality underpins all monitoring, planning, and evaluation processes.
- SF3 Cost & Contract Clarity reduces uncertainty and provides a stable operational framework.

A flaw in one of these drivers is destabilising all the higher-level factors.

Final ISM Hierarchical Model

The hierarchy of ISM demonstrates a proper flow:

1. Foundational drivers (SF1–SF3) create the core operational stability required for FM contract performance.
2. Driving enablers (SF4–SF6) strengthen organisational capacity and quality systems.
3. Linkage factors (SF7–SF9) coordinate workflows and stakeholder relationships.
4. High-dependence enablers (SF10–SF12) translate operational capability into measurable performance.
5. Outcome factors (SF15–SF17) represent final service results.

Table 4.1. The Final Reachability Matrix for SFs for FM Contractor

Success Factors			(j)																	Driving Power
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
(i)	1	Client-Centric Approach.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
	2	Technology Integration.	0	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	0	12
	3	Data-Driven Decision-Making.	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	14
	4	Cross-Functional Collaboration.	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	0	1	12
	5	Resource Optimization.	0	0	1	1	1	1	1	0	1	0	1	1	1	1	1	0	1	12
	6	Sustainability Integration.	0	1	1	1	0	1	1	1	1	0	1	1	1	0	1	0	1	12
	7	Performance Metrics/KPIs.	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	13
	8	Continuous Improvement Culture.	0	1	0	0	1	0	0	1	1	0	1	1	1	1	1	0	0	9
	9	Employee Engagement and Training.	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	0	0	4
	10	Client Feedback Integration.	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	0	0	12
	11	Change Management Practices.	0	0	0	1	0	0	0	0	1	0	1	1	1	0	1	0	1	7
	12	Collaborative Relationships.	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0	0	5
	13	Clear Communication.	0	0	1	0	1	0	0	0	0	0	0	1	1	1	1	1	1	8
	14	Cost Control.	0	1	1	1	1	1	0	0	1	0	1	0	0	1	1	1	1	11
	15	Client Education.	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	4
	16	Risk Management.	0	0	0	1	1	1	0	1	1	1	1	1	0	1	1	1	1	12
	17	Long-Term Focus.	0	1	0	1	0	1	0	1	1	1	0	1	0	0	1	0	1	9
Dependence			1	9	8	14	10	9	5	10	14	7	12	15	14	11	16	7	11	

MICMAC Analysis

MICMAC categorised the 17 factors into the four standard quadrants based on driving and dependence powers:

1. Driving Factors (High driver, low dependence): SF1, SF2, SF3
   - These exert the strongest influence and form the system's foundation.
2. Linkage Factors (High driver, high dependence): SF7, SF8, SF9
   - These connect multiple system components and can amplify or destabilise performance.
3. Dependent Factors (Low driver, high dependence): SF10, SF11, SF12
   - These represent functions that rely on the stability of the system before they can be effective.
4. Autonomous Factors: None identified
   - This indicates a tightly integrated system where every CSF plays a meaningful role.

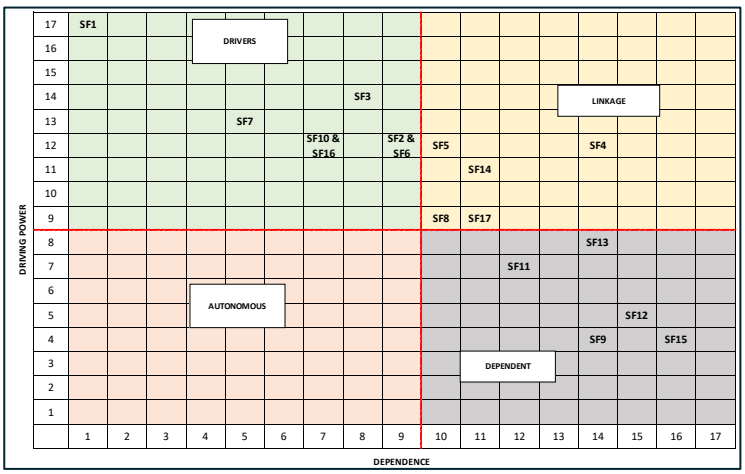

Figure 4.4. MICMAC Analysis (Driving Power vs. Dependence Diagram) on The SFs for FM Contractor

Interpretation of ISM–MICMAC Integration

It is possible to observe three general implications of the ISM-MICMAC integration:

1. Technology, data quality, and clarity of the contract are the structural drivers of FM contractor performance.
   These basic factors make it possible to do all capabilities at a higher level.
2. Capability development, quality systems, resource optimisation, communication, collaboration and process optimisation all generate operational stability.
3. These intermediate factors constitute the functional nucleus of the system.
   Performance results like client satisfaction, SLA realization, and continuous improvement are only realized in cases where all the upstream drivers and enablers are aligned.

This highlights the importance of having a system wide, as opposed to a fragmented, improvement strategy.

DISCUSSION

Overview of Theoretical Contributions

The results of the ISM give a systematic, theoretically-based account of the emergence of FM contractor performance as a result of the interplay between technological, organisational and relational processes. Instead of focusing on performance as a result of independent variables, the hierarchical model demonstrates that the results of performance, including SLA achievement and client satisfaction, are conditional on the correspondence of various upstream variables.

The results are an extension of the previous FM literature because they empirically locate technology integration, data quality, and contract clarity as driving factors- in line with the RBV, TCT, and digital FM studies (Goh and Loosemore, 2017; Antonenko and Baev, 2017; Dixit et al., 2019; Sulaiman et al., 2021). This provides a better theoretically based place as

to why FM outsourcing tends to fail: the lack of strength in underlying systems kills all the enablers that follow.

This study developed an exquisitely developed theoretical framework with a map of CSFs in which not only the factors that are important, but the manner in which they interact, is revealed- something that had not been previously developed in descriptive studies of CSFs.

Foundational Drivers: Technology, Data, and Contract Clarity

The ISM model finds the root drivers of FM contractor performance to be SF1 (Technology Integration), SF2 (Data Quality) and SF3 (Cost/Contract Clarity). These factors are highly driving and have low dependence, that is, they determine the operation of all other CSFs.

- Technology integration enables automation, improves coordination, and supports decision-making, extending literature on ICT-enabled FM systems.
- Data quality underpins performance monitoring, planning, and KPI assessment, reinforcing the growing emphasis on information governance in FM.
- Contract clarity and cost management, central to TCT, reduce uncertainty, prevent disputes, and provide a stable operational framework.

These results build on previous literature by showing that the underlying failures are not only operational inefficiencies but are the main cause of the inconsistency of downstream performance. The FM contractors need to hence focus on investments in digital systems, information quality and contract governance as strategic pillars as opposed to technical supplements.

Mid-Level Enablers: Capability, Quality, and Resource Systems

The mid-level enablers include SF4 (Resource Optimisation), SF5 (Capability Development) and SF6 (Quality Management). These factors are based on underlying drivers but have a major impact on linkage factors and operational performance.

- Capability development, aligned with RBV and TQM, enhances staff competency and adaptability—key determinants of communication quality, KPI achievement, and service responsiveness.
- Quality management systems stabilise operational processes, extend TQM principles, and ensure consistency in SLA delivery.
- Resource optimisation ensures that manpower, equipment, and scheduling align with operational requirements, strengthening workflow stability.

This research builds upon previous FM studies by placing the three concepts of capability, quality, and resource systems not as independent interventions but as intermediate engines transforming underlying structures into performance.

Linkage Factors: Process Optimisation, Communication and Collaboration

The central and most sensitive area of the ISM hierarchy is occupied by linkage factors, i.e. SF7 (Communication), SF8 (Stakeholder Collaboration), and SF9 (Process Optimisation) because they possess high driving and high dependence power.

- Communication reduces uncertainty and aligns stakeholders, consistent with TCT and change management literature.
- Collaboration reflects Stakeholder Theory, supporting shared understanding and reducing contractor–client conflict.
- Process optimisation, grounded in Lean principles, enhances workflow efficiency and operational reliability.

These influences propagate throughout the system, that is, disturbances at this level cause instability propagation. The results are an expansion of the Lean FM research as they affirm that process optimisation is not a peripheral issue but central to the performance structure.

Dependent Enablers: Monitoring, Change Readiness, and Feedback

The dependent enabler layer is SF10 (Change Readiness), SF11 (Performance Monitoring), and SF12 (Feedback Integration) which will translate the operational systems into measurable performance.

- Performance monitoring relies on accurate data, stable processes, and trained staff, supporting BSC and TQM arguments about measurement visibility.
- Change readiness depends on communication and staff capability, consistent with change management theory.
- Feedback integration, grounded in SDL, enables learning and continuous improvement but only when upstream systems are mature.

The research contributes to the theoretical knowledge by demonstrating that the functions are not independent drivers of performance, but contingent enablers that can only be triggered once a foundation and mid-level drivers are established.

Outcome Variables: Client Satisfaction, SLA Reliability and Continuous Improvement

- SF15 (Continuous Improvement Outcomes), SF16 (Client Satisfaction), and SF17 (SLA Reliability) seem to be pure outcome variables, high dependent and no driving.Client satisfaction arises when internal capability and relational alignment are synchronised, reinforcing SDL and stakeholder perspectives.
- SLA reliability reflects the cumulative influence of process stability, quality management, and collaboration.
- Continuous improvement materialises only when monitoring tools, feedback loops, and capability systems are fully embedded.

The results are generalizable to the previous literature on FM because they quantify these results as system products not operational tasks and the necessity of developing system holistically and not performance initiatives in isolation.

Practical Implications for FM Contractor Strategy

With the ISM-MICMAC integration, there is a clear strategic roadmap of FM contractors:

1. Focus on supporting systems.
   - Technology, data governance, and clarity of the contract should be firstly invested in because they affect all other CSFs.
2. Enhance internal organisational engines.
   - The capability development, resource optimisation, and quality management must be regarded as the central operational systems rather than the compliance functions.
3. Control interconnection with factors.
   - High leverage but sensitive to small failures are communication, collaboration, and workflow optimisation, whose failure results in massive systemic failures.
4. Adaptive functions and mature measures.
   - When the basic and intermediate stability are ensured, the KPI systems, change readiness and feedback mechanisms may be introduced.
5. Take a system-wide view of improvement.
   - The isolated efforts (e.g., training without data systems, KPIs without process stability) will not lead to significant improvements in performance.

The advantages of this integrated roadmap are that it helps FM contractors, client organisations, and policymakers in understanding where strategic resources are required to be concentrated in order to bring long-term performance enhancement in outsourced FM settings.

CONCLUSION

This paper came up with a theory-based, and structure modelled critical success factor (CSFs) framework of FM contractors. Based on nine management theories and Interpretive Structural Modelling (ISM), the study identified seventeen CSFs and placed them into a hierarchical framework that shows how performance is created through the interrelated mechanisms of technology, organisation and relationship. The results indicate that the performance of FM contractors is inherently conditioned by three underlying factors, including technology integration, data quality and clarity of a contract, which allows the capability systems, quality management, resource optimisation and coordination of operations.

Theoretically, this work contributes to the scholarship of FM because it goes beyond listing of CSFs in a descriptive manner and offers a systematic account of how CSFs interact and what ones have the greatest systemic impact. The research contributes to the previous work by showing that FM contractor performance is based on the underlying systems and not the operation practice in isolation as the information provided by the research integrates RBV, TCT, Stakeholder Theory, Lean, TQM, BSC, SDL, and change management into a single

model. The ISM hierarchy therefore adds a conceptual process through which the abstract theoretical models are connected with the actual dynamics of outsourced FM service provision.

In practice, the model provides a prioritised roadmap of FM contractors. The starting point of digital systems, information management, and contract specificity should be ensured initially since the vulnerabilities on this ground negate all future advances. This should then be reinforced by mid-level enablers such as capability development, quality systems and resource optimisation to stabilise the internal operations. The communication, collaboration, and process optimisation serve as key connecting factors that ensure the stability of the workflow and responsiveness of the service. Only when these upstream systems work in unison do client satisfaction, SLA achievement and continuous improvement come out. These lessons offer practical advice to contractors, clients and policymakers with the objective of improving the performance of outsourced FM.

Limitations

Since ISM is a subjective, professional approach, the model is based on profound practitioner knowledge as opposed to statistical generalisability. The relationships are directional and hierarchical but not probabilistic; therefore, the model is not to be considered as an empirical forecasting tool but as the conceptual framework. The expert panel, though not very young, is a reflection of a particular national FM environment, which could affect the hierarchy.

Future Research

Some of the directions can be used in order to enhance and enlarge the current framework:

1. SEM, DEMATEL or ANN Empirical validation of the relationships found by means of ISM testing the strength and significance of the relationships.
2. Comparison studies across countries to determine whether the CSF hierarchy varies in terms of regulatory, cultural, or market environments.
3. Comparative dual-perspective modelling of contractor-CSF structures and client-CSF structures to determine the gaps in alignment of outsourced FM ecosystems.
4. Combination with digital FM data sets to investigate the way real-time operational data can support or correct the hierarchical structure that is found.

Overall, the study can add a theoretically-based and practically-relevant insight into the elements determining the performance of FM contractors. The research provides a strategic roadmap that can enhance the quality and consistency of outsourced FM services, both in terms of industry revolution and sustainability in the sector in the long term by showing how foundational systems interplay with organisational and relational processes to drive service outcomes.

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A STUDY ON THE MATERIAL WASTE QUANTIFICATION AND MITIGATION IN CONSTRUCTION PROJECTS

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Abstract
Wastage of materials in construction results in colossal financial loss and environmental damage, with estimated losses on a global scale of more than $1 trillion yearly. This research estimates waste in a large residential project, with average wastages ranging from 1.24 per cent to 6.08 per cent on major materials, translating into a cost of ₹2.7 million and 104.3 metric tonnes of CO_2 emissions. Theoretically, the study emphasises life cycle thinking and sustainability in construction processes, where waste is a by-product of a system informed by site operations, procurement, and design. In practice, the research highlights over-ordering, design modifications, and ineffective material handling as key drivers for waste. The research also confirms the relevance of digital technologies such as Building Information Modelling (BIM) and IoT-based monitoring to enhance material efficiency. Qualitative professional survey validates the findings and presents lean practices and smart technologies as successful mitigation strategies. Overall, minimising material waste is crucial to green construction, not only being environmentally beneficial but also economically beneficial. The study presents a road map to implement data-driven, technology-enabled solutions in countering future sustainability regulations in the Indian construction industry.

Keywords: *Waste; Construction; Material; Sustainability; Mitigation*

INTRODUCTION

The construction sector is a major contributor to national development and economic advancement in the world, adding almost 13 per cent of global GDP (OECD, 2016) and directly employing around 7 per cent of the workforce (ILO, 2021; Prasad and Vasugi, 2023). Despite its significance, the sector still continues to face some perennial problems like delayed project completion, cost escalations, litigation, and even company financial bankruptcy (Prasad and Vasugi, 2023). With increasing population pressure and the urgent need for infrastructure, the construction industry stands at a crossroads now, looking for more effective methodologies to satisfy expectations and achieve sustainable results.

Construction-related activities have grown exponentially during recent years, which has led the global annual waste generation to surpass 10 billion tons (Wu *et al.*, 2024). The construction industry has become a significant contributor of solid waste, accounting for approximately 30-40 per cent of global solid waste. (Haigh, 2023; Sandanayake *et al.*, 2020). Material wastage during the construction stage cuts across the practical, environmental and economic angles. Some of the waste sources include poor designs, over-ordering, poor management on-site and poor construction techniques (Ikau *et al.*, 2016; Wahi *et al.*, 2016). By 2025, an estimated 2.2 billion tons of construction waste is expected to exist, and this presents a serious concern about how to sustain resources and waste management systems (Jain *et al.*, 2020).

There is emerging evidence that circular economy strategies can effectively address material waste in terms of construction activities and practices. For instance, the use of glass and rubber, as well as fly ash, in building processes is known to maintain structure while having a reduced impact on the environment (Papamichael *et al.*, 2023; Swarnakar and Khalfan, 2024). Additionally, life cycle assessments of construction processes offer opportunities to improve resource efficiency through enhanced planning, new technologies, and waste-minimisation strategies (Barbhuiya and Das, 2023). Other policy measures include the European Green Deal, which aims to ensure construction is sustainable by reducing waste and maximizing material recovery so as to reach net zero by 2050 (Haigh, 2023).

Measuring material waste on construction sites is important in the identification of waste and implementing initiatives to reduce it (Foo and Kamaludin, 2017). Efficient quantification of waste helps to identify one or more reasons for that waste, such as over-ordering, poor site management or design deficiencies, all of which have a major bearing on project costs and time. For instance, regular waste audits may help to identify process deficiencies and provide reasonable grounds on which procurement and site operations can be improved (Sandanayake *et al.*, 2020). In addition, adopting resource waste evaluation procedures is said to be in line with promoting sustainability in construction, as it enhances resource use and reduces the negative effects of construction processes (Jain *et al.*, 2020). With the use of advanced materials and modern techniques, a focus on sustainable practices can significantly lower material waste from construction processes, facilitating the move towards a more responsible and resource-efficient sector.

The main objective of this study is to quantitatively measure material wastage in a construction project, identify the biggest sources of wastage throughout the project stages, and suggest technology-and process-based solutions to reduce wastage that would be consistent both with sustainable construction practices. Towards this, the present study seeks to address the following research questions :–

RQ1. What are the causes, extent and impacts of material wastage on projects?
RQ2. What are the remedial measures for mitigating material wastages?

LITERATURE REVIEW

In order to improve the rigor and coherence of the literature review, a critical examination of the peer-reviewed studies concerning material wastage in construction projects was undertaken. Peer-reviewed studies were located from Scopus, Web of Science, Google Scholar, and the major construction management journals. The search terms used were construction material wastage, waste quantification, waste mitigation, circular economy, and sustainable construction.

Studies that emphasized material wastage during the construction stage, the factors leading to it, the methods for its quantification, and the ways for its mitigation, were taken into consideration. The chosen literature was analysed thematically to map dominant research streams and gaps. The following sections summarise the various themes and outcomes of the review.

Extent and Measurement of Material Wastage

Construction activities are responsible for roughly 30-40 per cent of global solid waste, which makes material wastage a significant economic and environmental problem (Haigh, 2023; Sandanayake *et al.*, 2020). Construction material wastage must be quantified for enhanced cost control of projects, asset management, and sustainability. Waste identification enables quantification of loss of resources and facilitating precise measures for minimising inefficiencies. Proper quantification is necessary to pinpoint the inefficiencies in procurement, storage, and execution. Nevertheless, the absence of standardized metrics and the scarce availability of site-level data limit benchmarking and cross-project comparison, especially in developing countries (Islam *et al.*, 2024).

The methods to measure have significantly different results due to the various techniques used viz. direct waste audits, material reconciliation, and perception-based surveys. Direct measurement has the highest accuracy; however, many studies depend on professional perceptions because of data shortages (Formoso *et al.*, 2002; Jain *et al.*, 2020).

Causes and Drivers of Material Wastage

The literature points out that material wastage in construction is the result of a complex and interrelated set of factors that span the project life cycle. The most frequently reported causes are inadequate planning and estimation, over-ordering, design errors and late changes to the design, lack of training of the workforce, incorrect storage and handling, and poor site management practices (Fufa *et al.*, 2024; Moussavi Nadoushani *et al.*, 2018; Tafesse and Adugna, 2021).

Issues related to the design frequently cause rework and the rejection of materials, whereas inaccuracies in procurement and the absence of coordination lead to the build-up of excess inventory and the occurrence of damage. Research from developing economies also reveals that organisational and behavioural factors—e.g. poor supervision and low awareness—are among the major contributors to the production of waste (Ikau *et al.*, 2016; Wahi *et al.*, 2016). In general, the literature document material wastage as a systemic result of fragmented decision-making across design, procurement, and site execution rather than an isolated operational problem. These inefficiencies not only lead to financial losses but also contribute to environmental degradation through increased landfill use and resource depletion. Understanding causes—such as over-ordering and poor site handling—allows stakeholders to reduce waste and align with environmental compliance and circular economy principles (Islam *et al.*, 2024).

Waste Minimisation Strategies and Circular Economy Perspective

A growing number of articles recommend minimising waste through circular economy principles, which mainly focus on the reduction, reuse, and recycling of construction materials. Several such strategies have been cited in literature which include better material planning, standardisation, prefabrication, source segregation, reuse of off-cuts and recycling of concrete and steel, carbon-negative cement (Kant Shukla *et al.*, 2024; Liu *et al.*, 2025; Papamichael *et al.*, 2023). Material-efficient planning and substitution of conventional materials with recycled or industrial by-products can, according to life cycle assessment

(LCA) studies, lead to a significant reduction of the environmental impacts (Barbhuiya and Das, 2023). Nevertheless, a few studies have reported that, despite the availability of proven strategies, implementation at the project level is limited due to cost constraints, lack of enforcement, and insufficient organisational commitment. Research studies from Malaysia, also indicate that the best practices are mostly talked about at the policy or conceptual level, with little fieldwork to confirm their effectiveness on construction sites (Ishak *et al.*, 2022, 2023).

Role of Digital Technologies

Digital technologies are being recognized more and more as the main facilitators of material efficiency in the construction sector. Building Information Modelling (BIM) has been demonstrated to enhance quantity accuracy, lessen over-ordering, and reduce rework to the extent that it is a result of better coordination and clash detection (Hosny *et al.*, 2023). In general, IoT-based monitoring, AI-driven analytics, and digital twins are the emerging technologies that can be the means for the real-time material consumption tracking as well as the early identification of wastage (Elmalky *et al.*, 2024; Wu *et al.*, 2024). However, the adoption of such technologies is still very much patchy across the globe, especially in developing countries where these are still very remote because of issues such as high initial costs, shortage of skills, and resistance to organisational change. The literature reveals that technology by itself is not enough; its effectiveness depends on its integration with good planning practices, skilled personnel, and organizational frameworks that provide support.

Research Gaps and The Need for Present Study

Despite the growing research focus on construction wastes, there are still some significant gaps.

- Firstly, most of the research in India concerning the topic are mainly theoretical or based on perceptions and there are almost no detailed quantitative data about specific materials at the project level, which makes it difficult to create benchmarks and make informed objective decisions (Jain *et al.*, 2020). Previous research has pinpointed the factors that lead to waste, but seldom have they provided a comprehensive quantification of waste through actual project documentation.

- Additionally, the evaluation of a carbon footprint is almost never combined with the analysis of the construction material wastage, thus, the implementation of the sustainability and net-zero goals is less evident. Even though there are life cycle assessment models, they are usually separate from the site consumption data which makes them hardly applicable in practice (Barbhuiya and Das, 2023).

- With the introduction of the C&D Waste Management Rules (2025), India's regulatory environment is evolving. However, academic research has not assessed industry preparedness or the practical challenges of compliance. There is a need for research bridging this gap by evaluating on-ground practices and offering actionable recommendations.

In order to close those gaps, the current research provides a detailed, and material-specific measurement of the construction waste, combines the cost and carbon emission evaluation, and gives the practitioner's point of view aligned with new regulations by analysing the data of an ongoing construction project.

RESEARCH METHODOLOGY

To bridge the gaps in the literature that were identified, the research employed an empirical case study design exploring a major real estate development project in Hyderabad, India. The project included nine residential towers (G+30 floors) and one office building of G+5 floors that were developed on an area of around 22.56 acres, with 290 residential units. The flat area is between 1250 sq. ft and 1840 sq. ft; all these are RCC-structure buildings. Figure 1 shows the project layout.

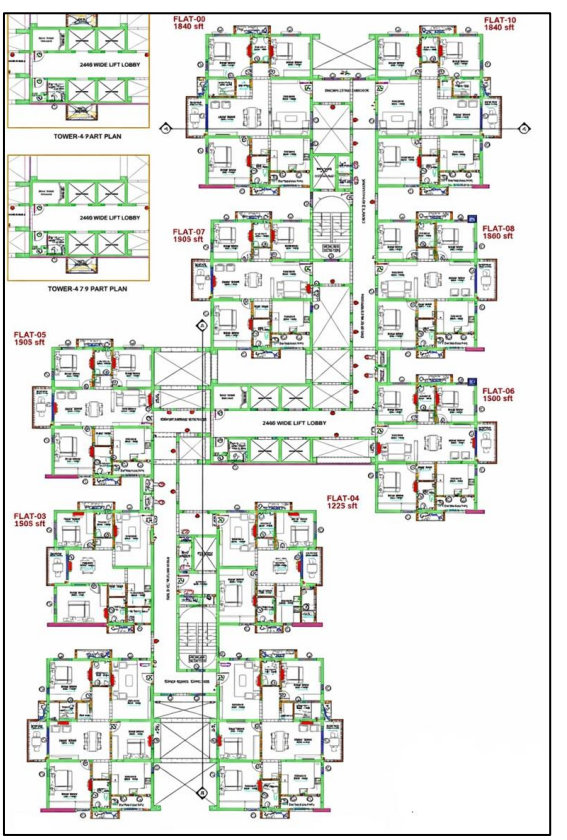

Figure 1. Typical Floor Plan of The Case Project

A case study approach was deemed suitable since it allows a thorough investigation of the actual construction processes and gathers the contextual factors that have an impact on material wastage, such as local purchasing methods, site handling, and the way the work is carried out (Cresswell, 2007; Priya, 2021). This type of approach provides the means to assess the effectiveness of a few practical measures and close the gap that exists between the theoretical framework and the site reality (Käss *et al.*, 2024). This makes them useful for generating practical, evidence-based recommendations for industry and policy. Figure 2 presents the research methodology adopted for the study.

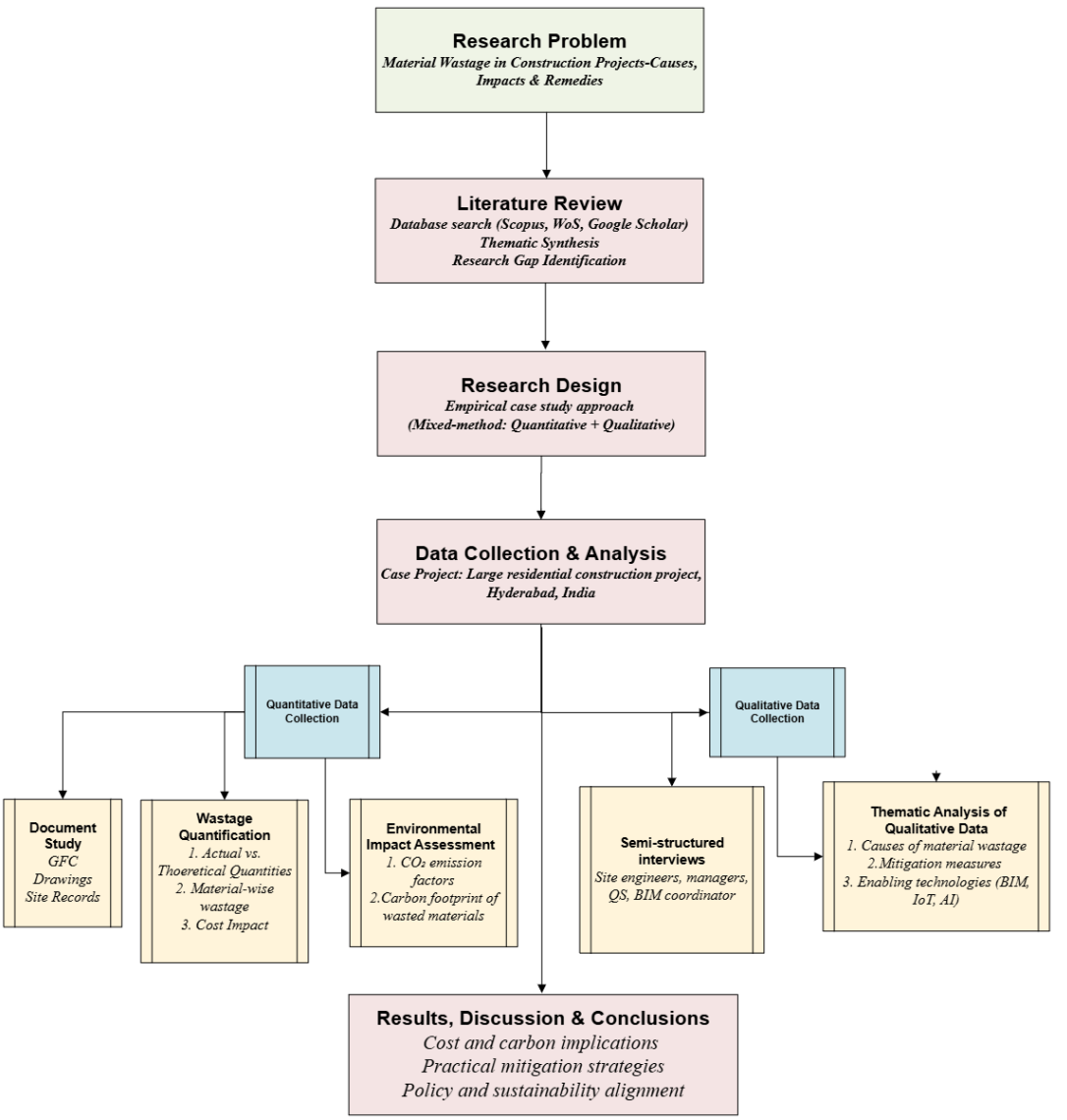

Figure 2. Research Methodology

The quantitative analysis was primarily focused on the measurement of material wastage for the main construction materials—Ready Mix Concrete (RMC), reinforcement steel, tiles, and paint. The theoretical quantities were derived from Good for Construction (GFC) drawings, whereas the actual material consumption was recorded from the site records, such as concrete pour reports, bar bending schedules, RFIs, and batch plant data. Material wastage was figured as the difference between actual consumption and theoretical requirements.

A qualitative study, involving semi-structured interviews with ten professionals from the contractor's organisation who represented the engineering, planning, procurement, and management departments, was carried out to supplement the quantitative assessment. The interview data were examined by means of thematic analysis, which resulted in the emergence of three main themes: the causes of material wastage, the mitigation measures, and the enabling technologies. The findings are summarised in Tables 8, 9, and 10.

RESULTS AND DISCUSSIONS

Wastages

The following sections of the paper present the findings of the calculations. Table 1 presents the details of the wastage of Ready-Mix Concrete.

Table 1. Wastage Analysis for Ready Mix Concrete

S No	Structural Element	Theoretical Quantity (Cum)	Actual Quantity (Cum)	Wastage Quantity (Cum)	Wastage (%)	Unit Cost (Indian Rs.)	Amount (Indian Rs.)
1	Walls	2484.75	2554.79	70.04	2.81	6000	7,65,600
2	Beams	609.38	629.49	20.11	3.30		
3	Slab	985.86	1018.86	33.00	3.34		
4	Staircase	62.52	66.97	4.45	3.74		
Total		**4142.51**	**4270.11**	**127.60**	**3.08**		

The quantities include the ground floor to the fifth floor. As can be seen, on average, 3.08 per cent of RMC is wasted. The cost impact of this amount to Rs. 7,65,600. Table 2 presents the details of the wastage of Screed Concrete.

Table 2. Wastage Analysis for Screed Concrete

S No	Structural element	Theoretical Quantity (Sqm)	Actual Quantity (Sqm)	Wastage Quantity (Sqm)	Wastage (%)	Unit Cost (Indian Rs.)	Amount (Indian Rs.)
1	Utility works	252	263.32	11.32	4.49%	485	37,878.75
Total		**252**	**263.32**	**11.32**	**4.49%**		

As can be seen, on average, 4.49 per cent of wastage is observed in screed works. The cost impact of this wastage amounts to Rs. 37,878.50. Table 3 presents the details of the wastage of Reinforcement Steel.

Table 3. Wastage Analysis for Reinforcement Steel

S No	Structural element	Theoretical Quantity (MT)	Actual Quantity (MT)	Wastage Quantity (MT)	Wastage (%)	Unit Cost (Indian Rs.)	Amount (Indian Rs.)
1	Walls	309.41	327.97	18.56	5.99%	62,000	18,55,040
2	Beams	104.46	111.24	6.78	6.49%		
3	Slab	69.42	73.51	4.09	5.89%		
4	Staircase	8.07	8.56	0.49	6.07%		
Total		**491.36**	**521.28**	**29.92**	**6.08%**		

As can be seen, on average, 6.08 per cent of wastage is observed in steel works. The cost impact of this wastage amounts to Rs. 18,55,040. Table 4 presents the details of the wastage of Tiles.

As can be seen, 1.24 per cent of wastage is observed in steel tiling works. The cost impact of this wastage amounts to Rs. 37878.75. Table 5 presents the details of the wastage of Paints.

Table 4. Wastage Analysis for Tiles

S No	Structural element	Theoretical Quantity (Sqm)	Actual Quantity (Sqm)	Wastage Quantity (Sqm)	Wastage (%)	Unit Cost (Indian Rs.)	Amount (Indian Rs.)
1	Floors	6,900	6,985.87	85.87	1.24%	325	37,878.75
2	Washroom Walls	2,460	2,490.68	30.68	1.24%		
Total		**9,360**	**9,476.55**	**116.55**	**1.24%**		

Table 5. Wastage Analysis for Paints

S No	Structural element	Theoretical Quantity (Sqm)	Actual Quantity (Sqm)	Wastage Quantity (Sqm)	Wastage (%)	Unit Cost (Indian Rs.)	Amount (Indian Rs.)
1	Paint	12290	12590	300.5	2.45%	220	66,110.00
Total		**12,290**	**12,590**	**300.5**	**2.45%**		

A 2.45 per cent wastage in painting works is observed. The cost impact of this wastage amounts to Rs. 66,110. The section indicates and summarises the extent to which material is wasted on a small project. The magnitude of wastage on large projects could be understood from this sample analysis. The total cost impact of the wastage of the analysed materials works out to be Rs. 26,96,397.50.

Environmental Impacts

Material wastage in construction operations generates substantial environmental impacts by reducing resources and causing both pollution and accelerating climate change. Construction materials that go unused will be disposed of in landfills, where they create polluted conditions for soils and surface water. These materials produce environmental impacts through their life cycle, which includes manufacturing and travelling to disposal, so greenhouse gas emissions increase steadily. The carbon footprint tool assesses material waste by measuring emissions from raw material extraction through manufacturing and logistics to waste management activities. The assessment reveals the complete environmental impact of construction activities while demonstrating the necessity for responsible building practices and smarter material allocation with reduced waste production systems.

The environmental impacts of the wasted materials are determined by assessing the carbon footprint or CO_2 emissions for all of the materials and summarised in Table 6.

Table 6. CO_2 Emissions from The Wastes Generated

S No	Material	Wasted Quantity	Unit	CO_2 emissions per unit of material	Total CO_2 Emissions ($kgCO_2e$)
1	Ready Mix Concrete	127.60	cum	351 (Bhorkar *et al.*, 2021)	44,787.60
2	Screed Concrete	11.32	Sqm	60 (Van Gijlswijk *et al.*, 2015)	679.20
3	Reinforcement Steel	29.92	MT	1900 (Bhorkar *et al.*, 2021)	56848.00
4	Tiles	116.55	Sqm	16.8 (Bhorkar *et al.*, 2021)	1958.04
5	Paints	300.5	Sqm	18 kg per 100 sqm	54.00
Total					**104326.84**

The environmental impact of the waste is summarised, and it can be seen that 104.3 MT of CO_2 emissions are from the wasted material.

Qualitative Study Results

To complement quantitative analysis, a qualitative questionnaire was conducted to explore the causes of material wastage, potential measures to control wastage, and the role of technology in managing waste. Ten participants from the contractor firm, including site engineers, project manager, procurement officer, structural engineer, BIM coordinator, quantity surveyor, and construction supervisor, were selected based on experience and involvement in the project.

Table 7. Participant Profile

Participant Id	Role	Qualification	Gender	Experience (Years)
1	Site Engineer	UG Degree	Male	7
2	Construction Manager	UG Degree	Male	15
3	Procurement Officer	UG Degree	Female	10
4	Structural Engineer	PG Degree	Male	12
5	BIM Coordinator	PG Degree	Female	6
6	Site Engineer	UG Degree	Male	8
7	Quantity Surveyor	PG Degree	Female	9
8	Construction Supervisor	Diploma	Male	11
9	Project Manager	UG Degree	Male	25
10	Site Engineer	UG Degree	Male	13

Semi-structured interviews were undertaken, with the three principal themes: reasons for material wastage, strategies to reduce wastage, and the role of technology (BIM, IoT, AI). Thematic analysis was used to look for recurring trends and feedback from the participants' responses. The participant profile details are summarised in Table 7.

Tables 8, 9 and 10 summarise the responses from all 10 participants. Table 8 provides a summary of the identified causes, Table 9 provides a summary of the possible mitigation measures, and Table 10 provides an understanding of the technology use and how it can minimise the waste on the project.

The interview duration ranged roughly 30 minutes, and the interview was focused on the following questions :–

1. What are the main causes of material wastage in your experience?
2. How do design changes during construction affect material usage?
3. Can you describe any issues with storage or handling that lead to waste?
4. What steps are currently taken on-site to reduce material waste?
5. Have you implemented any reuse or recycling practices? If so, how effective are they?
6. How does planning and procurement influence material efficiency?
7. What challenges do you face in adopting technology for waste reduction?
8. Have you used BIM or other digital tools to manage material usage?

The qualitative data gathered with the assistance of semi-structured interviews were thematically analysed and coded. The following steps were taken :–

1. Interview notes were revisited again and again in order to consolidate and generalize the answers.
2. Words and themes were underlined and code-wise initially labelled.
3. Codes were then combined into bigger themes based on patterns and repeated concepts.
4. Themes were made concise by cross-comparative analysis among participants to make them consistent, and the ultimate themes were defined and labelled precisely to describe the core ideas which had been conveyed by participants.
5. The themes were interpreted to the research goals, connecting them to relevant literature and project-specific knowledge.

Table 8. Causes of Material Waste

Causes of Material Waste	Participant									
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Over-ordering and inaccurate estimation	✓	✓	✓				✓			
Design changes during execution								✓		✓
Poor site storage and handling	✓			✓						
Lack of real-time tracking		✓			✓	✓			✓	

Table 9. Measures to Reduce Material Waste

Measures	Participant									
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lean construction	✓	✓		✓			✓			
Training and Supervision	✓		✓		✓	✓		✓		✓
Standardisation and Prefabrication		✓		✓	✓		✓			✓
Recycling and Reuse	✓		✓	✓	✓			✓		✓

Table 10. Enabling Technologies

Measures	Participant									
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
BIM for clash detection	✓	✓		✓	✓	✓				✓
IoT for real-time monitoring		✓				✓			✓	✓
AI for analytics		✓							✓	✓
Digital twins, LCA tools					✓	✓				✓

Discussions

- The identified wastage levels — 6.08 per cent for steel reinforcement, 3.08 per cent for concrete, and 1.24 per cent for tiles—are generally in line with international benchmarks but are still quite high for a large-value, well-managed project. The research studies have indicated that the wastage of concrete is between 1-3 per cent for well-organised projects (Sandanayake et al., 2020) which is the case for the present project. Nevertheless, the steel wastage normally stands at 3-5 per cent on average (Nawaz et al., 2022), and the figures that are above 5 per cent show that there are inefficiencies in procurement, cutting, or handling and, therefore, there is a need for optimisation.

- The financial implications of ₹2.7 million for one tower is quite overwhelming. Spread across all nine towers, the overall financial burden could go beyond ₹24 million, which would be a serious issue for the project's profitability. The CO_2 waste emissions of 104.3 metric tons of are equivalent to more than 20 cars' worth of emissions annually. It highlights the unseen environmental cost of inefficiency, which is not typically factored in during project evaluations.

- Material-specific analysis reveals that high steel wastage is mainly caused by cutting, bending, and over-ordering, which can be reduced through BIM-enabled bar bending schedules and prefabrication. Most of the concrete wastage is associated with the formwork leakage issues and over-pour, hence the demand for a modular, reusable formwork system. The waste levels of tiling and painting are comparatively lower; however, they still are not negligible and might be caused by improper surface preparation and handling losses.

- The qualitative results provided invaluable information on the causes of material wastage from both operational and behaviour aspects. Thematic analysis of ten interviews with experts yielded three overriding themes: waste causes, control strategies, and facilitating technologies. Major causes were over-ordering, design modification, and improper storage or handling. Control measures most frequently mentioned were training, supervision, standardisation, prefabrication, and recycling. In particular, the experts cited the increasing influence of digital technology—of the Building Information Modelling (BIM), IoT-based monitoring, and AI analytics variety—to optimise material efficiency. The findings underscore the importance of human and technology-mediated interventions for minimising construction waste.

Recommended Wastage Reduction Measures

Sustainable construction places significant importance on minimising waste in materials and making the projects more efficient. Waste is usually generated due to poor planning, over-ordering, and poor resource management, adding additional costs and harming the environment. By the implementation of good demand forecasting, recycling, and adopting technologies such as prefabrication and 3D printing, projects can reduce waste, save natural resources, and lower emissions. These processes not only optimise site operations and utilisation of resources but also serve to satisfy green building standards, in the direction of operational excellence and environmental well-being.

Before Construction

1) Accurate estimation via Building Information Modelling (BIM) reduces errors, over-ordering, and material wastage. A recent study (Hosny et al., 2023) reported ~12 per cent savings in concrete and steel through BIM-based planning.
2) Procure reinforcement steel in custom lengths and use prefabricated, pre-bent bars to reduce off-cuts and on-site waste. Collaborate with vendors to meet specifications and avoid rejections. Smaller pieces should be identified for reuse in non-structural elements.

During Construction

1) Retrieve and reuse unused materials. Bar Bending Schedule (BBS) software and optimised lap splicing can reduce steel use by ~10 per cent and wastage by 50 per cent (Moussavi Nadoushani et al., 2018).
2) Adopt leak-proof, modular, reusable formwork systems prevent concrete loss and enhance sustainability (Poojesh et al., 2024).
3) Deployment of lean techniques reduces steel cutting and bending waste by ~20 per cent and improves productivity (Elmalky et al., 2024; Prasad and Vasugi, 2021, 2022, 2023). Monitor real-time usage to monitor against discrepancies and the potential for wastage.
4) Technology can enable minimisation of wastage in projects and professionals need to adapt to new technologies (Ishak et al., 2023). BIM and IoT enable real-time tracking of material usage and waste rates. AI-based analytics support timely interventions and enhance transparency, accountability, and sustainability.

Policy Alignment and Augmentation

The findings of this study align closely with the objectives of India's newly notified Environment (Construction and Demolition) Waste Management Rules, 2025, which come into effect from April 1, 2026, (Rana, 2025). These rules represent a significant policy shift toward sustainable construction practices and introduce several key mandates :–

- Required for projects >20,000 sq. m with phasing recycling targets (5 per cent in 2026–27 to 25 per cent by 2030–31), waste monitoring through CPCB portal, and utilisation of recycled materials.
- Study-derived waste rates—6.08 per cent for steel, 3.08 per cent for concrete—provide practical baselines for compliance and sustainable planning.

THEORETICAL AND PRACTICAL IMPLICATIONS

This research substantiates the applicability of sustainable construction with empirical justification of the advantage of measurement of material wastage. Sustainable construction focuses on preservation of the environment and efficient use of resources through systems thinking and life cycle assessment. In reality, it involves precise demand forecasting, segregation of waste, recycling, and sophisticated techniques such as prefabrication. These techniques minimise environmental impact greatly and maximise operational efficiency and cost-effectiveness. Finally, the reduction of construction waste is both strategic and ethical requirement to guarantee harmony with green building standards and long-term environmental amenity of the built environment.

LIMITATIONS

The findings come from a single project. Although specific, the lack of comparative data from other projects limits generalizability. Follow-up studies may be enhanced by comparisons over several sites or longitudinal monitoring of patterns of waste reduction. The research could be supplemented with qualitative responses from site managers, project managers, or even workers regarding managerial or behavioural origins of waste.

CONCLUSIONS

The study on material wastage quantification in construction projects emphasises the need to detect and resolve problems of non-optimal material usage. Using a case study approach to a premium real estate project in Hyderabad, wastage patterns in key materials such as Ready-Mix Concrete, Reinforcement, Tiles and Paint were assessed. It was found that there was a wastage of 3.08 per cent in concrete, 4.49 per cent in screed, 6.08 per cent in reinforcement steel, 1.24 per cent in tiles and 2.45 per cent in paints. These results draw attention to our need for accurate planning, efficient site practices and the adoption of more advanced technologies to avoid wastage. Integrating systematic monitoring and recycling practices is also very significant in gaining resource efficiency and sustainability. Material wastage addressed in delivering on-site not only serves as a gateway into cost savings and environmental conservation but also becomes a benchmark for sustainable construction practices in the industry. The actionable insights that this research has provided to stakeholders indicate the direction for more effective, as well as accountable, material management strategies.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest regarding the publication of the paper.

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A THEORETICAL MODEL FOR SUCCESSFUL IMPLEMENTATION OF GOVERNMENT ASSETS MANAGEMENT POLICIES IN MALAYSIA

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Abstract
In order to create accountability to the population, continuity in service delivery, and sustainability, it is necessary to manage the resources of the government effectively. The Government Asset Management Policy (GAMP) and the Total Asset Management Manual (TAMM) offer systematic policies on how to manage public assets in Malaysia, but there are recurrent weaknesses reported in the Auditor-General Reports, portraying that there are still challenges in implementing the same. Although there is a lot of literature regarding asset management practices, there has been very little research on the exact factors that will lead to success in the implementation of GAMP in the context of public sector agencies. The paper fills the gap by defining and confirming the Critical Success Factors (CSFs) of GAMP implementation and creating a theoretical framework based on the Four Critical Variables (FCV) policy implementation model by Edwards III. A dual-phase qualitative methodology was used. The preliminary CSFs were the first of 16, which were extracted by a deductive literature review. These were later confirmed using a Focus Group Discussion (FGD) facilitated by 13 experts who were representatives of ministries, statutory bodies, universities and the asset management industry. The FGD validated the 16 CSFs and added two more factors, such as incentives and rewards, and contract management creating 18 CSFs. These were plotted on the four FCV dimensions that are, communication, resources, disposition, and bureaucratic structure. The results indicate that leadership commitment, competency, proper records on assets, organisational culture, clarity in communication and adequacy of resources are the key factors in policy implementation success. The research provides a theoretically-based, empirically supported model of reinforcing GAMP implementation. It has helped in the policy implementation-theory, in the development of knowledge in asset management in Malaysia, and in offering practical advice on how the governance, accountability, and asset performance of the Malaysian public agencies can be improved.

Keywords: *Government Asset Management; GAMP; Policy Implementation; Critical Success Factors; FCV Framework; Public Sector Governance; Asset Management Policy; Asset Management*

INTRODUCTION

Government property including buildings, infrastructure, equipment and land constitutes a large part of national spending and are central to the provision of government services. Asset management guarantees the value-for-money, safety, and reliability of the services and long-term sustainability of the nation (Liu et al., 2021; Kamarul et al., 2025). The management of any government asset in Malaysia is guided by Government Asset Management Policy (GAMP) and assisted by Total Asset Management Manual (TAMM) issued by National Asset and Facility Management (NAFAM) steering committee. The purpose of these documents is to harmonise the asset planning, acquisition, utilisation, maintenance, and disposal procedures between ministries and agencies, and they are the core of national asset governance reforms (Kamarul et al., 2025; Ku Ismail et al., 2025).

Nevertheless, even with well-developed policies and guidelines, implementation issues are widespread, which is characteristic of most of the asset management reforms in the public sector around the world (Nimpuno et al., 2025; Liu et al., 2021). There are recurrent areas of weakness reflected in the Auditor-General Reports (2014-2021): delays in maintenance, inadequate asset registers, improper payments, procedural non-conformance, and wastage of public funds, which are not the results of an administrative failure but the manifestation of systemic flaws (Olanrewaju and Aziz, 2020; Ku Ismail et al., 2025). These results point to the inefficiency of policy implementation as the root of the problem, as it is common in the classical policy implementation theory that highlights the implementation gap between policy intention and actual administrative behaviour (Pressman and Wildavsky, 1973; Fan and Yang, 2018). This disconnect between policy and practice is reflective of the issues of global research on the management of public assets, where fragmentation, a deficiency in competency, and a lack of leadership commitment and ineffective monitoring systems have repeatedly undermined the policy results, particularly in complex and multi-agency government settings (Liu et al., 2021; Nimpuno et al., 2025; Kamarul et al., 2025).

Even though some research has been conducted to analyse general challenges, performance issues and asset management practices in Malaysia, none of the studies have identified or confirmed the Critical Success Factors (CSFs) required in the successful implementation of GAMP (Marzuki and Johari, 2023; Olanrewaju and Aziz, 2020). This is one of the crucial knowledge gaps as the success of implementation of policy depends not only on the technical guidelines but also on organisational behaviour, the support of the leaders, the flow of communication, availability of resources, and the institutional framework as it is repeatedly highlighted in the literature of the field of public administration (Edwards, 1980; O'Toole, 1986; Fan and Yang, 2018). These factors should be understood to enhance the capacity of the public sector and better governance outcomes because, despite repeated reports of fragmentation in implementation and inconsistent adherence to policy in Malaysian public organisations, there is a need to improve the situation (Kamarul et al., 2025; Ku Ismail et al., 2025).

In order to fill this gap, the research will use Edwards III Four Critical Variables (FCV) of communication, resources, disposition, and bureaucratic structure as the theoretical framework to conduct an analysis of the GAMP implementation. FCV is appropriate since the implementation of GAMP also relates to several levels of governmental institutions, hierarchical decision-making processes, resource distributions, and behavioural processes that are similar to the conceptual areas of FCV, which is supported by previous studies that revealed the applicability of FCV in a complex public-sector setting (Edwards, 1980; O'Toole, 1986; Kohoutek, 2012; Fan and Yang, 2018). This paper uses a deductive literature review with a Focus Group Discussion (FGD) of experts working in the government and industry to identify, validate, and cluster success factors in a consistent theoretical framework to enhance asset governance by the public sector in Malaysia (Kamarul et al., 2025; Ku Ismail et al., 2025).

Although the country has well-defined policy frameworks, such as GAMP and TAMM, Malaysia still suffers the effects of repetitive weaknesses in asset management, such as governance gaps, data inconsistencies, and ineffective practices in maintenance (Olanrewaju and Aziz, 2020; Marzuki and Johari, 2023). This implies that there is a lack of congruency between policy intent and actual implementation due to organisational, behavioural, technical,

and structural constraints that are usually linked with implementation failure in the public-sector systems (Pressman and Wildavsky, 1973; O'Toole, 1986; Fan and Yang, 2018). In the absence of knowledge of the underlying success factors, the attempts to enhance the GAMP implementation will continue to be disjointed and inefficient as it is shown in the recent research on Malaysian public-sector asset governance that indicates the consistent presence of poor coordination, monitoring, and compliance (Kamarul et al., 2025; Ku Ismail et al., 2025).

Research Objectives

This study seeks to:

1. **Identify the key success factors influencing the effective implementation of GAMP in Malaysia**, based on existing literature and best practices; and
2. **Develop a theoretical model grounded in the FCV framework** that explains how this success factors operate and interact during policy implementation.

The research finds 18 identified validated success factors based on the mixture of literature review and expert opinion during an FGD session, a research methodology that is a widely used approach to hone the constructs and enhance the conceptual validity of research in the field of public administration and asset management (Fan and Yang, 2018; Nimpuno et al., 2025). These aspects are then placed into four FCV dimensions, namely, communication, resources, disposition and bureaucratic structure, leading to a theoretical framework that provides a structured explanation of successful GAMP implementation and is consistent with modern research to support theory-driven frameworks to enhance the outcome of governance (Kohoutek, 2012; Kamarul et al.,2025; Ku Ismail et al.,2025). This introduction forms the basis of the research as it helps to identify the significance of the topic, the gaps in the existing knowledge, and the contribution of the research to the enhancement of the asset management capacity of the Malaysian public sector and the effectiveness of the policy implementation (Liu et al., 2021; Marzuki and Johari, 2023).

LITERATURE REVIEW (REVISED & IMPROVED ACCORDING TO REVIEWER REQUIREMENTS)

Public Policy Implementation Theory: The Four Critical Variables (FCV)

Implementation of policies entails the process of converting the policy intent into real organisational actions. The Four Critical Variables (FCV) of Edwards III, including communication, resources, disposition, and bureaucratic structure, represent a very popular analytical model of why certain policies of the government fail or succeed, especially in such complex multi-level management contexts (Edwards, 1980; O'Toole, 1986; Fan and Yang, 2018). Communication brings about directive clarity, consistency in interpretation and correct execution of tasks. Resources define whether agencies that implement have sufficient financial, human, technological, and physical capacity. Disposition is a mirror of attitudes, motivation, integrity and the desire of the personnel to conduct the tasks that are related to the policies. Bureaucratic structure entails organisational rules, coordination systems, reporting systems and governance structures.

The FCV model has been used in various policy settings, such as healthcare delivery, municipal services reforms, national-level infrastructure programmes, and national administrative transformation programs, and has demonstrated its flexibility to different policy environments (Kohoutek, 2012; Driscoll et al., 2010; Nimpuno et al., 2025). Nonetheless, it is not fully applied in the government asset management policy, especially in Malaysia, where the governance limitations and inconsistencies in the implementation are still being reported (Kamarul et al., 2025; Ku Ismail et al., 2025). This gap is the reason why FCV should be used as the theory to guide the analysis of GAMP implementation.

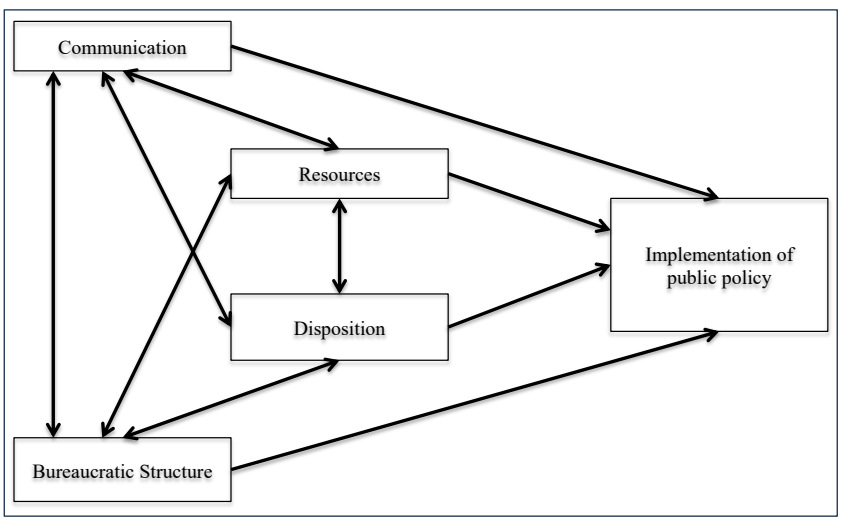

Figure 1. Four Critical Variables (FCV) in The Implementation of Public Policies

Asset Management Standards: ISO 55000 and Global Best Practices

The ISO 55000 family of standards establishes international standards of systematic and value-based asset management. It focuses on alignment between organisational objectives and asset decision-making, leadership commitment, competency frameworks, risk-based decision making, performance monitoring, and continuous improvement, which are believed to be key enablers of successful asset governance in recent international research (Woodhouse, 2014; Liu et al., 2021). Australia, New Zealand, the United Kingdom, and the Netherlands are some examples of countries that have integrated the principles of ISO 55000 into their reform of the public sector and the experience of its implementation proves that the strong leadership and governance framework is the key to enforcing compliance; developing competency is the key to ensuring the validity of the information about assets; integrated data systems can contribute greatly to better planning lifecycle and better accuracy in reporting; and lack of integration between the ministries and delivery agencies can lead to fragmentation (Ku Ismail et al., 2025). The significance of policy clarity, leadership support, and organised mechanisms of implementation in Malaysian construction management and administration of government infrastructure has also been emphasised in several MCRJ publications, which justified the need of consistent administrative controls and capacity building (Kamarul et al., 2025; Ku Ismail et al., 2025). These experiences on a global scale demonstrate that asset management does not only need technical instructions but behavioural, structural, and organisational requirements that are parallel to FCV constructs (Fan and Yang, 2018; Kohoutek, 2012).

Challenges in Government Asset Management (Malaysia & International)

The issue of asset management by the government is well-reported in various countries. The lack of coordinated roles, obsolete asset registries, lack of sufficient funds to maintain assets, inefficient monitoring tools, and lack of staff competency in the public sector are identified as challenges impeding the lifecycle decision-making process and performance (Nimpuno et al., 2025; Liu et al., 2021; Ku Ismail et al., 2025). Recent evaluations also indicate that most government organisations still use reactive maintenance strategies, do not have integrated asset information solutions, and have challenges in maintaining data consistency, which only increases asset performance risks (Kamarul et al., 2025; Marzuki and Johari, 2023).

Malaysian Context

The Reports of Auditor-General (2014-2021) report on consistent issues, such as failure to follow maintenance protocols, waste due to inefficient use of assets, contract mismanagement and inappropriate payments, poor asset records, and reactive instead of proactive maintenance, which show that the system has structural weaknesses in the governance and actual execution of operations (Olanrewaju and Aziz, 2020; Ku Ismail et al., 2025). Other recent Malaysian research also finds a lack of asset management awareness among the staff, excessive reliance on outsourcing without effective internal governance mechanisms, inadequate training in planning the lifecycle of assets, poor interagency roles with vague responsibilities, and little leadership focus on strategic asset management (Kamarul et al., 2025; Marzuki and Johari, 2023). Together, these results indicate an ongoing disconnect between the expectations of the national policies and the realities in ministries and other public agencies.

International Comparison

Table 1. International Comparison

Country	Key Challenges
Australia	Skills gaps, ageing assets, compliance inconsistencies
UK	Budget constraints, decentralised responsibilities, data reliability issues
New Zealand	Difficulty embedding long-term lifecycle thinking into public agencies
South Africa	Poor asset registers, training deficits, weak performance monitoring

The other nations have the same obstacles. Skills gaps, ageing assets, and inconsistencies in compliance are the issues observed in Australian public agencies, especially in maintenance planning and data governance (Fan and Yang, 2018; Liu et al., 2021). The United Kingdom still experiences budgetary limitations, decentralised roles and data reliability problems, which restrict the efficiency of asset lifecycle decision-making (Nimpuno et al. (2025)). New Zealand states that it has a hard time entrenching long-term lifecycle thinking into the public agencies despite the developed asset management frameworks (Ku Ismail et al., 2025). South Africa faces the problem of poor asset registers, lack of training, and ineffective performance monitoring systems, which are similar to the situation in many developing economies (Kamarul et al., 2025). The given comparison indicates that the challenges faced by Malaysia are typical of the global trends, which confirms the significance of determining the success factors that can be used to make GAMP implementation more robust (Kamarul et al., 2025;

Ku Ismail et al., 2025). Table 1 above summarises the international asset management issues in some of the chosen nations.

Critical Success Factors (CSFs) in Public Sector Asset Management

Previous studies have established many CSFs that determine the success of asset management. These encompass leadership dedication to strategic asset planning, explicit policies and strategies in line with organisational objectives, sufficient budgeting and resource assignment, competency and skill development among asset administrators, effective communication and internal coordination, strong asset information frameworks, risk management procedures, internal controls with integrity and accountability frameworks, and an organisational culture that enables proactive maintenance are all widely recorded in the literature of asset management of the public sector (Liu et al., 2021; Kamarul et al., 2025; Marzuki and Johari, 2023). Nevertheless, the majority of past researches dwell upon maintenance management, data quality challenges, asset lifecycle cost analysis, municipal asset governance, or technology adoption in asset management, as opposed to investigating the overall organisational and behavioural factors that drive policy implementation (Mazele & Amoah, 2021; Ku Ismail et al., 2025). There are very few studies that explicitly discuss the CSFs that are needed to successfully roll out a government asset management policy, especially in the Malaysian context, and the extant literature has not incorporated CSFs into a comprehensive theoretical model like FCV (Fan and Yang, 2018; Kohoutek, 2012). Recent MCRJ reports also point to a lack of governance, competencies, and structural coordination in Malaysian infrastructure management of the public sector, which supports the necessity to investigate CSFs peculiar to GAMP implementation (Kamarul et al., 2025; Ku Ismail et al., 2025).

Research Gap

Throughout the implementation of GAMP and TAMM, even with extensive frameworks in place in Malaysia, the issue of implementation challenges is still rampant, especially in the matters of governance, coordination, and reliability of asset information (Olanrewaju and Aziz, 2020; Marzuki and Johari, 2023). The literature on the topic recognizes several issues and the best practices, and no systematic literature has been found that identifies the CSFs particular to the GAMP implementation because most of the Malaysian and international studies are associated with maintenance, data quality, or technical asset management processes instead of the policy implementation (Nimpuno et al. (2025); Ku Ismail et al., 2025)). Moreover, there is no model that incorporates CSFs based on an official policy implementation theory like FCV, although it has long been known that the results of policy decisions are strongly dependent on communication, resources, disposition, and bureaucratic structures (Edwards, 1980; O'Toole, 1986; Fan and Yang, 2018). The empirical validation of the success factors applicable to Malaysian government agencies is also lacking since the existing research utilizes little empirical data to prove the determinants of successful asset governance through expert consensus or the structured qualitative approach (Liu et al., 2021; Kamarul et al., 2025). The scanty benchmarking of global experience in the area of managing public assets further decreases the contextual knowledge of how international experiences can inform the implementation problems in Malaysia (Kamarul et al., 2025; Ku Ismail et al., 2025).

Thus, this paper fills these gaps by determining CSFs using a deductive literature review and world practice and justifying them using Focus Group Discussions that involve accomplished practitioners and organising them into a theoretical framework using FCV. This offers a fresh conceptual basis on how to enhance the implementation of the government asset management policy in Malaysia and helps to close the long-standing gap between policy design and implementation.

RESEARCH METHODOLOGY (REVISED ACCORDING TO REVIEWER REQUIREMENTS)

Research Design

The research design adopted in this study is a qualitative research design since it explores and confirms the Critical Success Factors (CSFs) to ensure the successful implementation of the Government Asset Management Policy (GAMP) in Malaysia. Qualitative research will be appropriate in the context of policy implementation research since it entails the acquisition of expert knowledge, contextual interpretations, and organisational reality that cannot be comprehensively observed using quantitative research methods (Osanloo and Grant, 2016; Fan and Yang, 2018; Nimpuno et al. (2025)).

The study design will be two consecutive stages.

- Deductive Literature Review
  - To define preliminary CSFs using theory, asset management standards, and previous research.

- Focus Group Discussion (FGD)
  - To confirm, narrow down and integrate these CSFs through expert opinion.

The two-phase design guarantees both the theoretical and empirical justification, resulting in a model that is specific to the conditions of the Malaysian public sector and aligned with the best practices of qualitative policy and governance research (Ku Ismail et al., 2025; Kamarul et al., 2025).

Deductive Literature Review

Initial CSFs were obtained by inductive methodology of literature review. It is the right methodology since the research is grounded in a previously developed theoretical prism- Four Critical Variables (FCV) by Edwards III and seeks to extract variables consistent with that model (Edwards, 1980; O'Toole, 1986). The review has included asset management standards (ISO 55000), theories of implementing a public policy, the government asset management practices, international asset management policies in the public sector, and the Malaysian asset management issues reported in the Auditor-General reports and policy documents.

Scopus, Google Scholar, Web of Science, and government publications were used as the sources with the keywords of asset management, policy implementation, success factors, GAMP, public sector governance, and ISO 55000. Qualitative content extraction was used to analyse each relevant article, and common themes were categorized into an initial list of 16

CSFs, which is in line with best practices in thematic synthesis in studies of the public sector (Liu et al., 2021; Kamarul et al., 2025; Marzuki and Johari, 2023). The overlapping factors were combined, and conceptual definitions were prepared for use in the FGD.

Focus Group Discussion (FGD)

Purpose of FGD

FGD was carried out to confirm the 16 CSFs found in the literature, find further CSFs that are unique to the Malaysian public-sector asset management, map the CSFs in the FCV theoretical framework and get consensus on their definitions and relevance. It is well known that FGD is a promising technique of validating conceptual models in policy and governance research due to its ability to support collective reasoning, promote a discussion among practitioners, and preserve subtle interpretations that might not be evoked during individual interviews (Nimpuno et al., 2025; Ku Ismail et al., 2025; Osanloo and Grant, 2016). It is also justified by the fact that research indicates that group deliberation made by experts leads to better accuracy, clarity, and contextuality of constructs in the management of assets within the public sector (Kamarul et al., 2025).

Participant Selection

Table 2. The Expert Details

Name	Agency	Designation	Experience
Expert 1	Malaysia External Trade Development Corporation (MATRADE)	Asset Manager	13 years
Expert 2	Pro FM Solutions Sdn. Bhd.	Facilities Management Consultant	27 years
Expert 3	System Protocol Information Sdn Bhd	Consultant and Manager of Government Asset System	25 years
Expert 4	Hospital Canselor Tuanku Mukhriz	Head of Finance Department	20 years
Expert 5	Lembaga Lebuhraya Malaysia (Malaysia Board of Highway)	Engineer	16 years
Expert 6	Majlis Amanah Rakyat (People's Trust Council)	Deputy Director	18 years
Expert 7	Majlis Agama Islam Wilayah Persekutuan (Islamic Religious Council of the Federal Territory)	Deputy Development Manager (Administration)	26 years
Expert 8	Jabatan Penjara Malaysia (Malaysia Department of Prison)	Deputy Director	16 years
Expert 9	Kumpulan Wang Simpanan Pekerja (Employee's Provident Fund)	Section Head	23 years
Expert 10	Kumpulan Wang Simpanan Pekerja (Employee's Provident Fund)	Head of Moveable Asset Unit	13 years
Expert 11	Lembaga Lebuhraya Malaysia (Malaysia Board of Highway)	Deputy Director of Finance and Asset	14 years
Expert 12	Majlis Agama Islam Wilayah Persekutuan (Islamic Religious Council of the Federal Territory)	Assistant Officer of Asset Unit	9 years
Expert 13	Microcorp Sdn. Bhd.	Managing Director	27 years

The selection of the participants was based on a purposive sampling technique to the participants who have a wide range of experience in managing government assets. Thirteen professionals were selected in federal ministries, statutory bodies, local authorities, public universities and private facility management consulting firms. The respondents were between 9 and 27 years of professional experience, and they reflected the leadership (directors, senior

managers), technical specialists (engineers, valuers), and the policy implementers. Purposive sampling suits a study that needs specialised knowledge, as it is certain that the participants will have the contextual knowledge to assess complex governance and implementation problems (Fan and Yang, 2018; Liu et al., 2021; Kamarul et al., 2025). This variety enhances the plausibility of the FGD results, as it guarantees various views throughout the asset lifecycle, which contributes to the reliability and the depth of the interpretations of the qualitative insights (Kamarul et al., 2025).

FGD Procedure

The FGD was a one-half day session in a facilitated meeting room. The used procedure adhered to the recommended pattern of expert-based qualitative investigation, which presupposes systematized briefing, open discussion, and consensus mechanism to guarantee validity and transparency (Osanloo and Grant, 2016; Nimpuno et al. (2025)).

i. Phase 1 - Briefing and Orientation (i) Phase 2 - Training and Education.
   The participants were made aware of the study objectives, the framework of the FCV policy implementation, and the 16 preliminary CSFs. The definitions were explained to avoid confusion and limit interpretive bias, which is a good practice in the validation of conceptual models (Fan and Yang, 2018).

ii. Phase 2 - Open Discussion.
   Specialists were invited to criticise, improve, or challenge every CSF. Questions like, is this CSF applicable to GAMP implementation? and "Does this show your organisational experience? enabled profound thinking and practitioner-based improvement. The moderator managed to create balanced participation, which is a prerequisite of group validity and minimisation of dominance effects (Ku Ismail et al., 2025).

iii. Phase 3 - Consensus Building.
   The participants expressed their votes on accepting, altering, or denying each CSF. There were two more factors that appeared during consensus:
   - Incentives and rewards (SF17)
   - Contract management (SF18)

   New constructs are often emerging through consensus in the course of FGD-based model development and enhance empirical support (Liu et al., 2021; Kamarul et al., 2025).

iv. Phase 4 - FCV Mapping
   The participants worked together to cluster all the 18 CSFs into communication, resources, disposition and bureaucratic structure. Another useful approach to linking empirical findings to the theory of policy implementation is collaborative mapping of constructs to a theory (Kohoutek, 2012; Kamarul et al., 2025). The theoretical model is based on this mapping.

Data Analysis

Thematic consolidation was conducted qualitatively followed by data analysis. In the first place, notes and audio recordings were transcribed. Second, the statements were coded based on their relevance to CSFs and FCV domains. Third, codes were grouped and narrowed down to authenticate factor definitions. Fourth, the triangulation involved the comparison of the emerging findings with literature to make sure that the concepts were aligned. Lastly, there was consensus verification whereby only factors that were all agreed by all the participants were retained. The process is multi-step and follows the established methods of qualitative analysis and increases the rigour, transparency, and traceability of generating CSFs (Osanloo and Grant, 2016; Fan and Yang, 2018; Nimpuno et al., 2025).

Trustworthiness & Validity

Triangulation of experts was ensured by the variety of expertise of participants in order to enhance the validity of the findings, whereas theory triangulation was ensured by basing the analysis on the principles of FCV and ISO 55000. Member checking was done when the participants checked the final CSF definitions and the audit trail was maintained by recording procedures in detail. These measures are related to credibility, dependability, and confirmability, which are relevant to the qualitative research standards (Lincoln and Guba, 1985; Shenton, 2004; Liu et al., 2021; Kamarul et al., 2025).

Ethical Considerations

Participation was informed consent, anonymity guaranteed, all participants volunteered, no remuneration and could withdraw at any point. There was no sensitive organisational information that was revealed in the session. The ethical principles were adhered to, according to the typical qualitative research principles that are used to guarantee the protection of participants and the integrity of the procedure (Shenton, 2004; Osanloo and Grant, 2016).

Summary

The approach combines both deductive theoretical basis, systematic process of empirical validation, and a strict procedure of qualitative analysis. In this way, not only the resulting CSFs but also the theoretical model will reflect established knowledge, but they will also reflect the realities of practical application of GAMP implementation in Malaysia, which is the expectation of a methodological approach to governance-oriented qualitative research (Fan and Yang, 2018; Kamarul et al., 2025).

Findings

Overview

It has resulted into 18 Critical Success Factors (CSFs) that determine the successful implementation of Government Asset Management Policy (GAMP) in Malaysia. These results were found in two steps: (i) Literature review which was deductive and initially identified 16 CSFs, and (ii) Focus Group Discussion (FGD) which confirmed these factors and provided two others. The experts also traced all the factors to the Four Critical Variables

(FCV) theoretical framework of Edwards III that subsequently became the foundation of the suggested implementation model.

Results of The Deductive Literature Review

Table 3. Success Factors Identified from The Literature Review (SF1–SF16): Definitions and Key References

SF Code	Success Factor	Definition / Core Concept	Key References
SF1	Top Management Commitment	Leadership support that ensures prioritisation, direction, and resource allocation for asset management activities.	Abuzayan et al. (2014); Jooste & Vlok (2015); Kohtamäki et al. (2012); Mohammed (2007); Stimie & Vlok (2016)
SF2	Clear Policy & Strategy	Existence of structured policies and strategic plans aligned with organisational objectives and asset lifecycle needs.	Baum & Vlok (2013); Burnett & Vlok (2014); Jolicoeur & Barrett (2005); Mardiasmo et al. (2008); Miller (1997); Okumus (2003); Woodhouse (2014)
SF3	People Commitment	Staff dedication, cooperation, and willingness to perform asset management tasks consistently.	Albicini et al. (2006); Bryson et al. (2009); Kohtamäki et al. (2012); Kriege et al. (2016); Lutchman (2006); Maheshwari (2006); Okumus (2003)
SF4	Effective Communication	Clear dissemination of policy instructions, feedback mechanisms, and cross-agency communication.	Guohui & Eppler (2008); Musa (2015); Ng (2011); Rose et al. (2012)
SF5	Competency	Technical and managerial knowledge required for asset planning, maintenance, and recordkeeping.	Miller (1997); Ng (2011); Stapelberg (2006); Woodhouse (2014)
SF6	Training	Continuous learning to enhance asset management knowledge, skills, and application of GAMP.	Abuzayan et al. (2014); Jooste & Vlok (2015); Schoeman & Vlok (2014); Xerri et al. (2015a)
SF7	Budget Availability	Adequate financial resources for asset acquisition, maintenance, and replacement.	Abuzayan et al. (2014); Jooste & Vlok (2015)
SF8	Record Management	Accurate, complete, and updated asset data to support reporting, auditing, and decision-making.	Jooste & Vlok (2015); Price & Evans (2013); Rymarzak & Trojanowski (2013); Woodhouse (2014)
SF9	Internal Control	Mechanisms that ensure compliance with procedures, monitoring, and verification of asset management activities.	Lutchman (2006); Maheshwari (2006); Okumus (2003); Rose et al. (2012); Stimie & Vlok (2016)
SF10	Integrity & Accountability	Ethical conduct and accountability of personnel in managing public assets.	Jooste & Vlok (2015); Rose et al. (2012)
SF11	Risk Management	Processes for identifying, analysing, and mitigating risks across asset lifecycles.	Musa (2015); Schoeman & Vlok (2014)
SF12	Awareness & Understanding	Level of understanding among staff regarding asset management policies, roles, and expectations.	Musa (2015); Okumus (2003)
SF13	Change Management	Organisational readiness and ability to manage transitions in processes, systems, or behaviours.	Abuzayan et al. (2014); Albicini et al. (2006); Jooste & Vlok (2015); Xerri et al. (2015a)
SF14	Organisational Culture & Values	Values and norms that promote proactive, responsible, and transparent asset management.	Okumus (2003); Rose et al. (2012); Stimie & Vlok (2016); Woodhouse (2014)
SF15	Information System & Technology	Tools, software, and digital platforms supporting data reliability and operational efficiency.	Okumus (2003); Rose et al. (2012); Stimie & Vlok (2016); Woodhouse (2014)
SF16	Workplace Condition	Physical and operational environment that enables effective asset management work.	Kim (2013)

The literature review found 16 CSFs that are widely used with the successful implementation of the asset management policy. These are leadership commitment, competency, effective communication, sufficient financial resources, internal controls, integrity, data management, risk management, change management, organisational culture, and information systems use.

These aspects indicate global norms like ISO 55000 and common patterns in the international literature on asset governance that success is determined by structural and behavioural preparedness (Liu et al., 2021; Nimpuno et al., 2025). Table 3 contains the detailed definitions and the supporting literature of each success factor.

Findings from The Focus Group Discussion

Literature-Derived Factors Validation

The expert panel verified all 16 factors as relevant. Such results indicate that the Malaysian public sector has the same implementation issues as they have been reported elsewhere, including ineffective asset records, budget restrictions, competency gaps, and communication failures (Kamarul et al., 2025; Ku Ismail et al., 2025; Marzuki and Johari, 2023).

Emergence of Two New CSFs

Experts included two more CSFs that were not highlighted in previous literature:

- Incentives and rewards (SF17) — to strengthen motivation, compliance and commitment to behaviour.
- Contract management (SF18) — because of the strong dependency on outsourced maintenance providers and the necessity of well-organised control systems.

These extensions underscore the Malaysian-specific variables, in particular, the administrative culture and outsourcing trends in the government asset ecosystem (Kamarul et al., 2025; Ku Ismail et al., 2025). The other success factors that were determined in the course of the FGD are as follows, summarised in Table 5.

Table **5. Additional Success Factors Identified from FGD (SF17–SF18)**

SF Code	New CSF Identified	Definition / Core Concept
SF17	Incentives & Rewards	Motivational mechanisms—financial or non-financial—that reinforce good asset management performance and compliance.
SF18	Contract Management	Oversight capability to manage outsourced vendors, monitor performance, and ensure contract compliance.

Consolidated List of 18 CSFs

The CSFs list is the final one: it represents a holistic perspective of the policy implementation:

- Leadership and organisational behaviour SF1, SF3, SF6, SF10, SF12, SF13, SF14, SF17.
- Structural mechanisms SF2, SF8, SF9, SF11 Governance mechanisms SF2, SF8, SF9, SF11.
- Resources & competency: SF3, SF5, SF7, SF16.
- Communication & information systems: SF4, SF15.
- Vendor governance: SF18

Table 6 shows the consolidated list of all the success factors.

Table **6. Consolidated List of 18 CSFs for GAMP Implementation**

Category	Success Factors (CSFs)
Leadership & Behavioural Factors	SF1, SF3, SF6, SF10, SF12, SF13, SF14, SF17
Structural Governance Factors	SF2, SF8, SF9, SF11
Resource & Capability Factors	SF3, SF5, SF7, SF16
Communication & Information Factors	SF4, SF15
Vendor Governance Factors	SF18

Note: Categories reflect conceptual grouping from thematic analysis during the FGD.

Mapping of CSFs to FCV Theory

The mapping exercise in the course of the FGD categorised all 18 CSFs in the Four Critical Variables (FCV) of Edwards III, which is multidimensional policy implementation. This correspondence proves that interrelated communication, resource, behavioural, and structural factors have an impact on GAMP implementation, which aligns with the policy implementation theory (Edwards, 1980; O'Toole, 1986; Fan and Yang, 2018).

Table 7 summarises the mapping of all of the eighteen success factors on the FCV policy implementation framework.

Table 7**. Mapping of CSFs to The FCV Policy Implementation Framework**

FCV Component	Mapped Success Factors (Codes)	Explanation
Communication	SF4, SF5, SF15	Clarity of directives, staff understanding, and accuracy of asset information systems influence policy execution.
Resources	SF3, SF5, SF7, SF15, SF16	Budget, staff capability, technology, and functional workplaces shape implementation readiness.
Disposition	SF1, SF3, SF5, SF6, SF10, SF12, SF13, SF14, SF17, SF18	Attitudes, values, leadership, training, motivation, and oversight behaviour determine staff willingness to act.
Bureaucratic Structure	SF2, SF8, SF11	Governance systems—policies, recordkeeping, and risk structures—form the institutional foundation for implementation.

Communication

SF4, SF5, SF15

A clear communication, employee competency, and a quality data system determine the interpretation and implementation of asset management policies. These conclusions are consistent with the results of other studies that indicated that the quality of communication

and the flow of information were the focal points of the success of implementation in the case of the public-sector reform (Mazele & Amoah, 2021; Ku Ismail et al., 2025).

Resources

SF3, SF5, SF7, SF15, SF16

Sufficiency of resources like skills, budget, technology and support at the workplace influences operational preparedness. The studies of global asset governance also mention that insufficient financial allocation, incompetencies, and obsolete infrastructure are among the key obstacles to successful implementation (Liu et al., 2021; Kamarul et al., 2025).

Disposition

SF1, SF3, SF5, SF6, SF10, SF12, SF13, SF14, SF17, SF18

The willingness of the staff to implement GAMP depends on attitudes, values, integrity, leadership commitment and motivation. This aligns with the policy implementation literature, which highlights human behaviour, organisational culture, leadership values, and ethical behaviour as key facilitators of policy outcomes (Brunetto et al., 2014; Xerri et al., 2015; Kamarul et al., 2025).

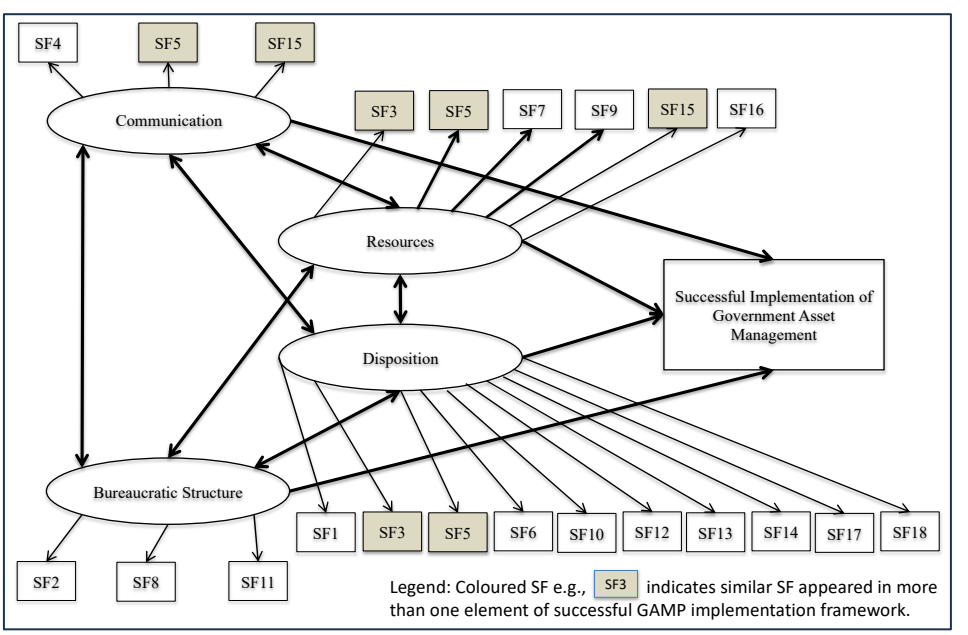

Figure 2. Theoretical Model of Success Factors for GAMP Implementation

Bureaucratic Structure

SF2, SF8, SF11

The institutional bases of the implementation can be found in policies, record management systems, and risk governance structures. The same structural determinants have

been emphasised in the literature on public administration and asset governance, especially on mechanisms of compliance and institutional clarity (Ku Ismail et al., 2025; Kohoutek, 2012).

Summary of Findings

The results indicate that GAMP implementation entails using structural, human, behavioural and technological enablers. CSFs' classification as FCVs confirms the importance of the policy implementation theory to the asset management environment in Malaysia and justifies the thesis that the success of implementation would be a result of consistent alignment between communication, resources, implementer disposition, and the bureaucratic structure (Edwards, 1980; Fan and Yang, 2018). The current mapping will form the foundation of creating a new theoretical framework that incorporates world experience, as well as the reality of governance in Malaysia (Kamarul et al., 2025; Ku Ismail et al., 2025). The suggested theoretical model of the incorporation of all eighteen success factors in the FCV framework is presented in Figure 2.

DISCUSSION

The Discussion discusses the findings with respect to the FCV theory and how they relate to enhancing the implementation of GAMP.

Communication: Securing Policy Clarity, Competency and Data Reliability

One of the FCV dimensions was communication. Effective information systems, a consistent interpretation, and clear instructions play a critical role in preventing the occurrence of the policy intent on one side and frontline implementation on the other, a trend that has been largely reported in studies on the implementation of the public sector (Nimpuno et al., 2025; Ku Ismail et al. (2025).

The presence of competency in this dimension is because communication is not simply passing of messages but also involves staff that is competent to comprehend, interpret and implement policy directives in an accurate manner. According to international research, asset mismanagement is often caused by the low quality of data, underdeveloped communication frameworks, and inadequate technological application, all of which are quite similar to the situation with Malaysia (Liu et al., 2021; Kamarul et al., 2025).

Resources: Capacity Constraint Overcoming

Key in the development of operational readiness is the resources that include funding, talented individuals, working environments, and the right technology. The Reports issued by the Malaysian Auditor-General always point out a number of constraints that impair this preparedness such as inadequate budgetary allocations, incomplete and unreliable asset records, staffing levels, and still using old systems.

The same can be said about other countries, including Australia and the UK, as they also face issues when it comes to the distribution of resources, data quality, and system modernisation, meaning that resource issues are a global limitation and not specific to

Malaysia (Fan and Yang, 2018; Marzuki and Johari, 2023). This validates that the implementation of GAMP has to deal with the sufficiency of resources as well as capability building.

The notable level of SF5 (competency) under the dimension confirms the significance of human capital and skill preparedness in the policy implementation (Liu et al., 2021).

Disposition: Empowering Leadership, Motivation and Organisational Culture

The greatest grouping was disposition meaning behavioural and cultural aspects shape asset governance in the Malaysian context greatly. In international literature, leadership commitment (SF1) is always determined as the best predictor of implementation success (Brunetto et al., 2014; Xerri et al., 2015).

Motivation is emphasised by adding incentives and rewards (SF17), which are essential in hierarchical contexts of the public sector where behavioural involvement has a significant impact on compliance. According to contract management (SF18), the attitudes of staff and overseers' behaviour have a direct impact on the performance of outsourced vendors, a problem that is also often mentioned in the literature on governance (Kamarul et al., 2025; Ku Ismail et al., 2025).

This affirms that the enhancement of GAMP implementation necessitates behavioural change, enforcement of ethics, competency building and professional accountability in the government agencies (Fan & Yang, 2018).

Bureaucratic Form: Enhancing Institutional Foundations

The structural backbone of GAMP is composed of policies and strategies (SF2), record management (SF8) and risk management (SF11). Malaysian audits are always reported to have weaknesses in these areas.

According to international comparisons, the same emphases occur:

- New Zealand: formal assets strategies and long-term planning.
- United Kingdom: significant investments in information management systems.
- Australia: centralised asset risk models.

These trends support results that structural governance and institutional clarity are key facilitators of policy implementation achievement (Kohoutek, 2012; Ku Ismail et al., 2025).

Theoretical Implications

This paper will apply the FCV theory by Edwards III in the context of government asset management by showing that all four variables of this theory directly affect the execution of the policy. The 18 Critical Success Factors incorporated into the FCV framework give a consistent theoretical explanation of the GAMP implementation, offering a framework that ties up policy design, organisational dynamics, and behavioural conditions to the context of the public-sector settings. The set of factors that has been validated also provides context-

specific information applicable to the Malaysian administrative structures. Taken together, these works make the theory of FCV more applicable to multi-level governance environments and prove the importance of integrating the existing theory of policy implementation with the current asset governance models, which was already reflected in the previous literature (O'Toole, 1986; Fan and Yang, 2018).

Practical Implications

The Critical Success Factors and the implementation model generated thereof gives ministries and government agencies a systematic foundation on which they can diagnose the weaknesses in the execution of GAMP. They will also be able to develop specific interventions, such as training programmes, organisational restructuring and governance reforms to enhance the asset management capacity. Moreover, the results provide a practical advice regarding how to improve audit compliance and reporting accuracy, enhance the governance and contract oversight of vendors, and the general transparency, accountability and asset performance of the organisations operating in the sphere of the public sector. These findings align with what is found in the Malaysian Construction Research Journal, where authors emphasize the necessity of systematic interventions to overcome competency shortcomings, disjointed roles, and a weak monitoring system in the governance of infrastructure in the public sector (Kamarul et al., 2025; Ku Ismail et al., 2025).

Summary of Discussion

It is established in the discussion that synergy between clarity in communication, adequacy of resources, staff disposition, and robust governance structures are necessary in successful implementation of GAMP. The FCV model offers a holistic approach to enhancing the ecosystem of the asset management of the public sector to guarantee the consistency between the design and the practice of the policy.

CONCLUSION

This paper came up with 18 Critical Success Factors that are needed to make the Government Asset Management Policy (GAMP) in Malaysia, effective. The study generated a policy implementation model based on Four Critical Variables (FCV) by Edwards III (1980) through a deductive literature review and expert validation using Focus Group Discussion proving the framework to be relevant in examining multi-level public-sector reforms (Edwards, 1980; O'Toole, 1986).

Contribution to Knowledge

This paper is the first systematic attempt that tries to determine and confirm the Critical Success Factors of the implementation of Government Asset Management Policy (GAMP) in specific to the Malaysian context. The combination of these CSFs into the FCV theoretical framework helps the research to make a significant contribution to the general literature on policy implementation. This coordination also goes hand in hand with modern theory-based models-driven research in asset governance as highlighted in the recent literature (Fan and Yang, 2018; Kohoutek, 2012).

Contribution to Theory

This paper shows that FCV framework of Edwards III is applicable to government asset management policy and thus the relevance of the concept is extended to another administrative field. It also adds two other constructs to the behavioural aspect of the policy implementation; they are incentives and contract management. These constructs complement the existing body of literature that organisational motivation and systematic vendor management are essential factors in influencing the work of the public sector, as pointed out in recent governance literature (Kamarul et al., 2025; Ku Ismail et al., 2025).

Contribution to Practice and Policy

The CSFs and the resultant model of implementation provide the ministries and government agencies with a diagnostic framework of diagnosing the weaknesses in the GAMP implementation. The results also contribute to the capacity building enhancement, the optimization of governance processes, and the audit preparedness, especially regarding the staff competency, governance data practices, and responsibilities in managing vendors. Furthermore, the research study offers a significant source of building national asset management maturity and enhancing greater long-term policy consistency within the public sector.

Limitations

This research also has a number of limitations that must be mentioned. To begin with, the results were based on one Focus Group Discussion, and more extensive empirical research with a variety of FGDs or big-scale surveys would be required to improve the overall applicability of the results. Second, the findings are mostly representative of the views of Malaysian people in the government, and thus cross-country validation is suggested to compare the level of governance maturity, the institutional capacity, and the implementation settings between the various administrative settings. These limitations would be addressed in order to enhance the strength and applicability of the proposed model.

Future Research

Future studies ought to come up with quantitative measures that would operationalise the identified CSFs and also test their relative impacts on the success of GAMP implementation empirically. Further, the suggested model ought to be tested in a broader set of ministries, statutory agencies and local government to increase its generalisability in the Malaysian public sector. The researchers are also urged to investigate digital readiness, information systems maturity, and technology enablement including the integration of BIM-FM, automation, and management of the data generated by the IoT as possible moderating variables that can affect the effectiveness of the implementation. This, towards the direction, is consistent with the current trends in the field of research and practice in the global context of the asset management of the public (Liu et al., 2021; Kamarul et al., 2025).

Finally, the research offers a sound theoretical and practical basis of enhancing governmental asset management in Malaysia. By incorporating proven CSFs into a theoretically based FCV, the study contributes to the knowledge of the interaction of policy,

organisational behaviour and institutional structures to affect the outcomes of implementation. This helps in the current endeavours of Malaysia to create a more accountable, transparent, and sustainable public asset ecosystem.

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CULTURAL AND REGIONAL VARIATIONS IN DIGITAL FM IMPLEMENTATION: A CROSS-NATIONAL ANALYSIS

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Abstract
Digital Facilities Management (DFM) has advanced significantly in the post-pandemic period, driven by rapid digitalisation, expanded use of IoT- and BIM-enabled systems, and growing institutional pressure for data-driven facility operations. Yet, global implementation outcomes remain inconsistent, particularly across regions characterised by diverse cultural, organisational, and regulatory conditions. To capture the most current state of digital FM practice, this study systematically reviewed 47 empirical studies published between 2022 and 2023. The review followed PRISMA 2020 procedures and employed a random-effects meta-analysis to evaluate four widely recognised Critical Success Factors (CSFs): leadership commitment, training and human capability, stakeholder engagement, and technical infrastructure. The findings reveal notable regional variation, with Europe exhibiting the highest implementation success and Latin America the lowest. Among the CSFs, training demonstrates the strongest and statistically significant effect (OR = 5.17, $p < 0.05$), highlighting its universal influence across cultural contexts. Meta-regression results further show that cultural attributes shape how CSFs exert influence rather than which CSFs are important, supporting a cultural-mediation perspective. This study provides cross-national insights into DFM implementation and delivers context-sensitive recommendations for policymakers, industry leaders, and FM organisations. The findings hold particular relevance for Malaysia's construction and FM sectors, where digitalisation initiatives increasingly require culturally aligned strategies to improve implementation outcomes and advance national digital transformation goals.

Keywords: *Digital facilities management; cross-cultural analysis; meta-analysis; implementation success factors; regional variations; cultural dimensions; comparative study*

INTRODUCTION

Background and Problem Statement

Digital Facilities Management (DFM) marks a shift from traditional reactive maintenance toward proactive, data-driven operations enabled by technologies such as BIM-FM, IoT sensors, CMMS platforms, and Digital Twins (Ahmed & Rahman, 2023; Chen et al., 2023). In Malaysia, similar transformations are underway, where integrated data environments and interoperable BIM–FM processes are increasingly recognised as essential for effective facility operations (Aminuddin et al., 2021; Roslan et al., 2019). Despite global investments exceeding USD 50 billion, DFM initiatives continue to experience high failure rates of 40–60%, driven by weak organisational readiness, fragmented data systems, and inconsistent leadership support (Brown et al., 2023; Pärn & Edwards, 2017; Love et al., 2020). Local studies echo these issues, highlighting digital readiness gaps, siloed processes, and varied skill levels as major barriers in Malaysian FM organisations (Hamzah et al., 2019; Dahlan & Zainuddin, 2022).

Digital FM implementation is inherently shaped by cultural, institutional, and regional characteristics. Multinational organisations often rely on frameworks developed in Western contexts, which may not align with hierarchical norms, consensus-building processes, or long-term orientation common in Asian organisations (Straub et al., 1997; Mueller et al., 2023; Dainty et al., 2017). Malaysian evidence similarly indicates that leadership hierarchy, collective decision-making, and competency variations greatly influence digital transformation outcomes (Ting et al., 2019; Abdullah & Yusof, 2020). These cultural misalignments contribute to inconsistent DFM implementation success across regions and emphasise the need for culturally sensitive approaches.

The selection of the four Critical Success Factors, namely leadership commitment, training and human capability, stakeholder engagement, and technical infrastructure, is grounded in established theoretical foundations as well as strong empirical consistency across the information systems and digital technology adoption literature. Foundational frameworks such as the Technology–Organization–Environment (TOE) model, Technology Acceptance Model (TAM), and Institutional Theory consistently identify these four domains as primary determinants of technology implementation outcomes (Tornatzky & Fleischer, 1990; Venkatesh & Davis, 2000; DiMaggio & Powell, 1983). DFM and BIM-FM studies reaffirm this pattern: leadership provides strategic alignment; training enhances digital competence; stakeholder engagement ensures cross-functional coordination; and technical infrastructure supports data quality and system reliability (Pärn & Edwards, 2017; Chen et al., 2023). Malaysian studies provide further support, identifying these same determinants as recurring enablers or barriers to digital FM maturity (Aminuddin et al., 2021; Hamzah et al., 2019; Zainal et al., 2022). Because these CSFs consistently appear across diverse global and regional studies, they represent the most stable factors for comparative meta-analysis.

To ensure that the synthesis reflects the most current technological, organisational, and cultural conditions in digital FM, this study limits its evidence base to empirical publications from 2022 to 2023, a period marked by rapid post-pandemic digitalisation and significant advancements in BIM-FM, IoT, and data-driven FM technologies.

Research Gap and Significance

Although DFM research is expanding, it remains geographically skewed, with nearly 70% of published studies originating from North America and Europe (Li et al., 2023; Oesterreich & Teuteberg, 2016). Limited empirical attention has been given to developing economies, where cultural, institutional, and capacity-related conditions differ significantly. Malaysian studies highlight persistent challenges such as low integration maturity, fragmented data ecosystems, and inconsistent regulatory alignment, yet these findings remain largely absent from global comparative analyses (Aminuddin et al., 2021; Dahlan & Zainuddin, 2022).

A critical gap exists in understanding *how* and *why* implementation outcomes differ across cultural and regional contexts. Existing studies offer descriptive insights but lack systematic, quantified evidence regarding cultural consistency versus cultural specificity of success factors. The absence of meta-analytical synthesis prevents practitioners from determining which CSFs carry universal impact and which require region-specific adaptation (Borenstein et al., 2009; Schmidt & Hunter, 2015). This gap has substantial practical

implications for organisations scaling DFM across regions or planning digital FM adoption in culturally diverse environments.

Research Objectives and Questions

This study addresses these gaps through three objectives:

1. Quantify regional variations in DFM implementation success across five global regions using PRISMA-based meta-analysis (Moher et al., 2009).
2. Examine cultural influences on CSF effectiveness using Hofstede, GLOBE, and Schwartz cultural frameworks.
3. Develop culturally informed implementation recommendations for practice.

Based on these objectives, the research asks:

- How do DFM implementation success rates vary across global regions?
- Which CSFs exhibit significant and consistent effects across cultures?
- Do CSFs demonstrate cultural universality or cultural specificity?
- How do cultural dimensions correlate with regional implementation patterns?
- What culturally adapted strategies can enhance DFM implementation success?

Study Contributions

This study offers four major contributions across theoretical, methodological, and practical domains. Theoretically, it provides the first meta-analysis that quantifies cultural and regional variations in Digital Facilities Management (DFM) implementation, advancing cultural technology adoption theory by distinguishing cultural mediation from cultural moderation. Methodologically, the study introduces a PRISMA-compliant and culturally integrated meta-analytical framework, supported by a systematic cultural mapping protocol that links each included study to established cultural indices from Hofstede, GLOBE, and Schwartz. Practically, the findings provide quantified effect sizes that enable organisations to prioritise leadership, training, stakeholder engagement, and infrastructure readiness when planning DFM initiatives. The study also offers region-specific recommendations to support culturally aligned digital FM implementation, with particular relevance to Malaysia and the broader Southeast Asian context.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Digital FM Implementation Success Factors

Digital facilities management encompasses a broad spectrum of technologies designed to optimize facility operations through data-driven decision-making and automated processes (Volk et al., 2014; Cavka et al., 2017; Pärn & Edwards, 2017). The literature identifies several categories of success factors that consistently influence implementation outcomes across different technology types and organizational contexts, building on established technology adoption frameworks (Davis, 1989; Tornatzky & Fleischer, 1990; Rogers, 2003).

Organizational Factors represent the most extensively studied category of success determinants, consistent with organizational behavior and change management literature (Kotter, 1995; Armenakis & Bedeian, 1999). Leadership support and commitment consistently emerge as primary predictors of implementation success, with studies demonstrating significantly higher success rates when senior management provides visible support, adequate resources, and clear strategic direction (O'Brien & Murphy, 2023; Kotter, 1995; Higgs & Rowland, 2005). The leadership factor encompasses not only financial resource allocation but also organizational culture change, strategic alignment, and sustained commitment throughout implementation phases (Schein, 2010; Cameron & Quinn, 2011).

Training and skill development programs constitute another critical organizational factor, particularly in contexts requiring significant user behaviour change and new competency development (Johansson et al., 2022; Kirkpatrick & Kirkpatrick, 2006; Salas et al., 2012). The effectiveness of training programs appears to vary substantially across cultural contexts, with some cultures preferring formal, structured training approaches while others favour experiential learning and peer-to-peer knowledge transfer (Hofstede et al., 2010; House et al., 2004; Kolb, 1984).

Stakeholder engagement and communication represent increasingly important organizational factors, especially in complex multi-stakeholder environments typical of facilities management (Park et al., 2023; Freeman, 1984; Mitchell et al., 1997). The literature suggests that stakeholder engagement effectiveness varies significantly across cultural contexts, with collectivistic cultures requiring more extensive consultation processes compared to individualistic cultures that may accept more directive implementation approaches (Hofstede et al., 2010; Triandis, 1995; Earley & Gibson, 1998).

Technological Factors include infrastructure readiness, data quality management, system integration capabilities, and technology-organization fit, consistent with technology acceptance and diffusion literature (Davis, 1989; Rogers, 2003; Tornatzky & Fleischer, 1990). Organizations with robust IT infrastructure, established data governance frameworks, and proven system integration capabilities demonstrate consistently higher implementation success rates (Rossi et al., 2023; Bharadwaj, 2000; Melville et al., 2004). However, the relative importance of technological sophistication versus user acceptance appears to vary across cultural contexts, with some regions prioritizing technical excellence while others emphasize user adoption and organizational fit (Venkatesh et al., 2003; Straub et al., 1997).

Environmental Factors encompass regulatory requirements, market conditions, vendor support availability, and external stakeholder pressures, reflecting institutional theory and environmental determinism perspectives (DiMaggio & Powell, 1983; Pfeffer & Salancik, 1978). Regulatory compliance requirements significantly influence implementation approaches in highly regulated industries and regions, while vendor support quality affects implementation success across all contexts (Turner & Phillips, 2022; Scott, 2001; Oliver, 1991). The literature suggests that environmental factor importance varies substantially across regions, reflecting different regulatory frameworks, market maturity levels, and vendor ecosystem development (Kostova, 1999; Xu & Shenkar, 2002).

Regional evidence from Malaysia reinforces that leadership maturity, organisational readiness, and structured capability-building programmes are central to successful DFM implementation. Studies show that FM organisations with well-developed training systems and stronger BIM/FM competencies are more capable of adopting digital workflows (Abdullah & Yusof, 2020; Roslan et al., 2019). Similarly, data governance quality—particularly the accuracy and interoperability of BIM and FM datasets—has been identified as a major determinant of implementation effectiveness (Aminuddin et al., 2021). These findings align closely with the CSFs outlined in the international literature, while emphasising the additional importance of structural, cultural, and capability-building factors in developing economies.

Cultural Theory Integration

Cultural dimensions theory provides a robust theoretical framework for understanding how national and regional cultures influence organisational behaviour, technology adoption, and implementation success (Hofstede, 1980, 2001; House et al., 2004; Schwartz, 1999). This study primarily employs Hofstede's cultural dimensions framework, recognised as the most extensively validated and widely applied cultural theory in organisational and information systems research (Kirkman et al., 2006; Sondergaard, 1994; Taras et al., 2010).

Power Distance reflects the extent to which less powerful members of organisations and society accept unequal power distribution (Hofstede, 2001; House et al., 2004). In high power distance cultures, hierarchical decision-making structures and strong leadership directives may facilitate rapid implementation decisions but could potentially limit user participation and feedback incorporation (Hofstede et al., 2010; Carl et al., 2004). Conversely, low power distance cultures may require more participatory implementation approaches with extensive consultation and consensus-building processes (Earley & Erez, 1997; Gibson, 1999).

The literature suggests that power distance significantly influences leadership factor effectiveness, with high power distance cultures requiring more authoritative leadership approaches while low power distance cultures benefit from participatory leadership styles (House et al., 2004; Den Hartog et al., 1999). However, the relationship between power distance and overall implementation success remains unclear, with some studies suggesting that high power distance may facilitate implementation through reduced resistance, while others indicate that low power distance enhances success through improved user acceptance (Straub et al., 1997; Leidner & Kayworth, 2006).

Individualism versus Collectivism indicates whether individuals prioritize personal goals and achievements or group harmony and collective outcomes (Hofstede, 2001; Triandis, 1995; Oyserman et al., 2002). Individualistic cultures typically respond favourably to technology implementations emphasizing personal efficiency gains, individual performance metrics, and competitive advantages (Venkatesh et al., 2003; Morris & Venkatesh, 2000). Training programs in individualistic cultures often focus on individual skill development and personal productivity enhancement (Kirkpatrick & Kirkpatrick, 2006; Salas et al., 2012).

Collectivistic cultures may require greater emphasis on group consensus, collective benefits, and organizational harmony throughout implementation processes (Earley & Gibson, 1998; Wagner, 1995). Stakeholder engagement becomes particularly critical in

collectivistic contexts, where implementation success depends heavily on achieving group consensus and maintaining social harmony (Freeman, 1984; Mitchell et al., 1997). The literature suggests that collectivistic cultures may require longer implementation timelines to accommodate extensive consultation processes but may achieve higher long-term adoption rates through stronger group commitment (Hofstede et al., 2010; House et al., 2004).

Uncertainty Avoidance measures society's tolerance for ambiguity, uncertain situations, and unstructured environments (Hofstede, 2001; House et al., 2004). High uncertainty avoidance cultures typically prefer structured implementation approaches with detailed planning, comprehensive risk mitigation strategies, and clear procedural guidelines (Hofstede et al., 2010; Carl et al., 2004). These cultures may require more extensive pilot testing, proof-of-concept phases, and gradual rollout approaches to minimize perceived risks and uncertainties (Rogers, 2003; Moore & Benbasat, 1991).

Low uncertainty avoidance cultures may be more accepting of iterative implementation approaches, learning-by-doing methodologies, and flexible adaptation strategies (Hofstede, 2001; Shane, 1993). However, the literature presents mixed findings regarding the relationship between uncertainty avoidance and implementation success, with some studies suggesting that high uncertainty avoidance cultures achieve better outcomes through systematic planning, while others indicate that flexibility and adaptability are more important for success in rapidly changing technological environments (Straub et al., 1997; Leidner & Kayworth, 2006; Venkatesh et al., 2003).

Technology Adoption and Implementation Frameworks

Technology Acceptance Model (TAM) provides foundational understanding of individual-level technology adoption decisions through perceived usefulness and perceived ease of use constructs (Davis, 1989; Venkatesh & Davis, 2000). Extended TAM models incorporate additional factors such as social influence, facilitating conditions, and cultural moderators relevant to cross-cultural implementation contexts (Venkatesh et al., 2003; Morris & Venkatesh, 2000; Straub et al., 1997).

Technology-Organization-Environment (TOE) Framework offers organizational-level perspective on technology adoption, examining technological characteristics, organizational context, and environmental factors that influence adoption decisions (Tornatzky & Fleischer, 1990; Baker, 2012). The TOE framework has been extensively applied in construction and facilities management contexts, providing relevant theoretical foundation for digital FM implementation analysis (Oesterreich & Teuteberg, 2016; Ding et al., 2014).

Diffusion of Innovation Theory explains how innovations spread through social systems over time, identifying innovation characteristics, communication channels, and social system factors that influence adoption rates (Rogers, 2003; Moore & Benbasat, 1991). The theory's emphasis on social system characteristics and communication processes provides relevant insights for understanding cultural influences on technology diffusion patterns (Rogers, 2003; Mahajan et al., 1990).

Institutional Theory examines how organizational practices are influenced by institutional pressures, including regulatory requirements, normative expectations, and mimetic processes

(DiMaggio & Powell, 1983; Scott, 2001). Institutional theory provides valuable perspective on how cultural and regulatory environments influence technology implementation approaches across different regions (Kostova, 1999; Xu & Shenkar, 2002).

Regional Context Analysis

Understanding regional variation is essential for explaining why Digital FM implementation outcomes differ across countries and cultural environments. Prior comparative research shows that cultural dimensions, institutional structures, and socio-economic conditions strongly influence leadership behaviour, stakeholder coordination, training effectiveness, and technology acceptance. To support a more transparent and evidence-based interpretation of these cross-regional patterns, all cultural and implementation characteristics cited in this section have been systematically compiled into Appendix A Tables 1(a)–1(k). These tables categorise the supporting literature into two domains for each region—(i) cultural and demographic traits, and (ii) digital FM implementation behaviours—allowing clear traceability between the narrative analysis and its corresponding empirical sources.

Across all five regions examined, North America, Europe, Asia-Pacific, the Middle East, and Latin America, the literature demonstrates strong recurring themes but also substantial contextual differences that influence digital FM outcomes. These observations are fully supported by the structured citation summaries presented in Appendix A, Tables 1(a)–1(k), which map each regional interpretation directly to its underlying sources.

Appendix A Tables 1(a) and 1(b) provide the evidence base for North America, Tables 1(c) and 1(d) for Europe, Tables 1(e) and 1(f) for Asia-Pacific, with a dedicated Malaysian sub-regional summary in Table 1(g), The Middle East Tables 1(h) and 1(i) and Latin America are similarly documented in Tables 1(j)–1(k). Together, these tables enhance the transparency, traceability, and methodological rigour of the regional analysis, ensuring that the narrative synthesis is clearly anchored to verifiable scholarly evidence. The relocation of these regional evidence tables to Appendix A ensures readability in the main text while maintaining full transparency of the analytical basis. This structure also aligns with PRISMA 2020 recommendations, which emphasise clear traceability between narrative synthesis and supporting evidence. Accordingly, all cultural and implementation interpretations in Section 2.4 can be cross-verified directly with the detailed citation summaries in Tables 1(a)–1(k).

METHODOLOGY

Systematic Review Protocol

This study employed a PRISMA 2020–compliant systematic review and meta-analysis protocol to ensure transparent, replicable, and unbiased identification of digital Facilities Management (DFM) implementation studies (Page et al., 2021; Moher et al., 2009). The protocol was specifically adapted for cross-cultural technology implementation research, following established guidelines on cultural comparability and methodological equivalence (Brislin, 1970; Van de Vijver & Leung, 1997). A comprehensive search strategy was developed using Boolean operators and controlled vocabulary terms to capture the full spectrum of digital FM technologies, including BIM FM, IoT-based systems, CMMS, and

CAFM, together with keywords related to implementation, success factors, and cultural or regional variation. Systematic searches were performed across six major academic databases recognised for their breadth and reliability in evidence synthesis: Google Scholar, Scopus, Web of Science, IEEE Xplore, the ACM Digital Library, and PubMed/MEDLINE (Bramer et al., 2017).

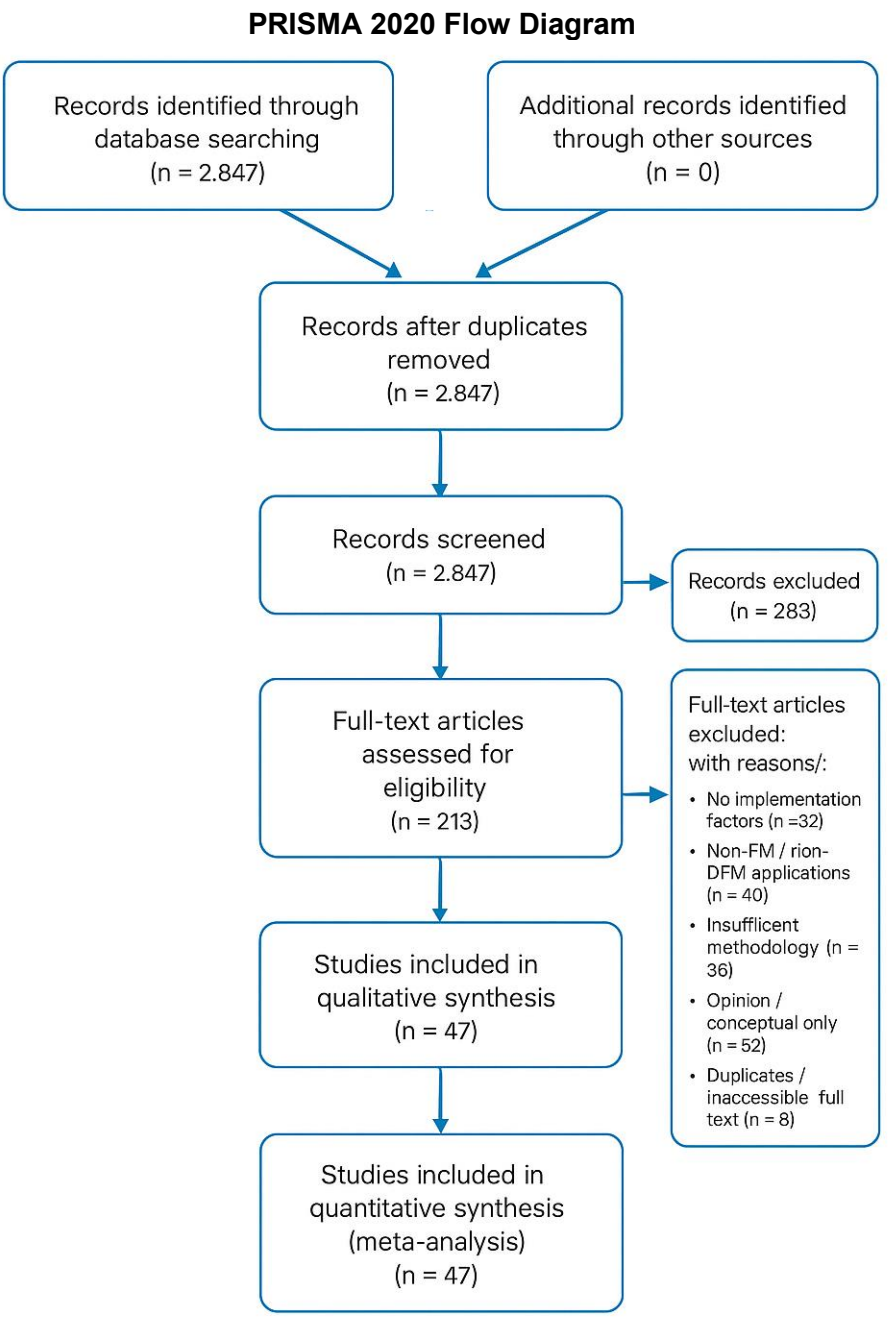

Figure 1. A Prisma Flow Diagram

Study eligibility followed the PICOS framework, in which the population consisted of organisations implementing digital FM technologies, the intervention referred to digital FM implementation projects, the comparators involved success versus failure or the presence versus absence of success factors, the outcomes included documented implementation success rates or analyses of success factors, and the eligible study designs were empirical in nature, whether quantitative, qualitative, or mixed methods. To ensure contemporary relevance, only studies published between 2022 and 2023, written in English, peer-reviewed, and containing a clearly identifiable geographic or cultural context were included. Studies were excluded if they were purely conceptual, lacked empirical data, did not provide cultural or geographic information, used duplicate or overlapping datasets, or failed to report sufficient methodological detail for quality assessment. Together, these procedures ensured that the review captured robust, contextually grounded evidence suitable for cross-cultural meta-analytic synthesis.

The complete identification, screening, and inclusion process is summarised in the PRISMA 2020 Flow Diagram provided in Figure 1.

Study Selection and Quality Assessment

Two-Stage Screening Process: Study selection followed a rigorous two-stage screening process conducted by independent reviewers to minimize selection bias and ensure reliability (Higgins et al., 2019; Shea et al., 2017).

- Stage 1 - Title and Abstract Screening:

  Two independent reviewers screened all identified titles and abstracts against inclusion/exclusion criteria using standardized screening forms. Disagreements were resolved through discussion, with a third reviewer consulted for unresolved conflicts (Shea et al., 2017; Whiting et al., 2016). Cohen's kappa was calculated to assess inter-rater reliability, with values >0.80 considered acceptable (Cohen, 1960; Landis & Koch, 1977).

- Stage 2 - Full-Text Screening:

  Full texts of potentially eligible studies were independently assessed by two reviewers using standardized eligibility forms. Reasons for exclusion were documented using standardized categories, and disagreements were resolved through consensus discussion (Higgins et al., 2019; Shea et al., 2017). Studies meeting inclusion criteria proceeded to data extraction and quality assessment.

- Quality Assessment Framework:

  Study quality was assessed using an adapted version of the ROBINS-I (Risk of Bias in Non-randomized Studies - of Interventions) framework (Sterne et al., 2016), modified for technology implementation research contexts. The assessment covered seven domains informed by established quality assessment frameworks (Wells et al., 2000; Downs & Black, 1998):

1. Bias due to confounding: Organizational, technological, environmental factors.
2. Bias in selection of participants: Sampling representativeness and selection methods.
3. Bias in classification of interventions: Implementation approach definition and measurement.
4. Bias due to deviations from intended interventions: Implementation fidelity and adherence.
5. Bias due to missing data: Attrition rates, non-response patterns, missing data handling.
6. Bias in measurement of outcomes: Success criteria definition, measurement validity and reliability.
7. Bias in selection of reported results: Selective reporting, outcome reporting bias.

Each domain was rated as low, moderate, serious, or critical risk of bias, with overall study quality determined by the highest individual domain rating (Sterne et al., 2016; Higgins et al., 2019).

Regional Classification Framework

Studies were classified into five major regional categories based on their primary geographic context, guided by established cultural clustering frameworks that support meaningful cross-cultural comparison (Hofstede et al., 2010; House et al., 2004; Inglehart & Baker, 2000). The categories comprised North America, Europe, Asia Pacific, the Middle East, and Latin America, with Mexico placed under North America due to regional agreements. Each region was assigned cultural dimension scores using Hofstede's national culture database and supplemented with GLOBE study data where necessary (Hofstede et al., 2010; House et al., 2004). For multi-country regions, weighted averages were calculated based on study contributions and population size to ensure representative cultural profiles (Taras et al., 2010; Kirkman et al., 2006). Cultural dimensions were operationalised using three key indicators commonly associated with technology adoption and organisational behaviour: power distance, individualism, and uncertainty avoidance, each measured on a scale from zero to one hundred to enable consistent comparison across regions.

Data Extraction Strategy

Standardized Data Extraction

A comprehensive data extraction form was developed and pilot-tested to ensure consistent and complete data capture across all included studies (Higgins et al., 2019; Li et al., 2020). The form was based on established data extraction frameworks for technology implementation research (Venkatesh et al., 2003; Tornatzky & Fleischer, 1990) and adapted for cross-cultural analysis (Brislin, 1970; Van de Vijver & Leung, 1997). Two independent reviewers conducted data extraction, with disagreements resolved through discussion and consultation with a third reviewer when necessary.

Extracted Variables

- Study Characteristics: Authors, publication year, journal, study design, sample size, geographic location, funding source.
- Implementation Context: Technology type (BIM-FM, IoT, CMMS, Digital Twin), organization type, implementation scope, timeline, project size.
- Success Factors: Presence/absence of leadership support, training programs, stakeholder engagement, technical infrastructure, change management, vendor support.
- Cultural Context: Country/region, cultural dimension scores, cultural observations or measurements, language considerations.
- Outcomes: Implementation success/failure, success criteria, measurement methods, effect sizes where available, timeline to success.
- Methodological Quality: Study design quality, risk of bias assessment, sample representativeness, limitations, generalizability.

Success Factor Coding

Success factors were coded into standardized categories based on established digital FM implementation frameworks (Volk et al., 2014; Pärn & Edwards, 2017; Cavka et al., 2017) and validated through inter-rater reliability assessment (Cohen, 1960; Landis & Koch, 1977):

- Leadership Support and Commitment: Executive sponsorship, resource allocation, strategic alignment, change leadership.
- Training and Skill Development Programs: User training, competency development, ongoing support, knowledge management.
- Stakeholder Engagement and Communication: Consultation processes, feedback mechanisms, change communication, and user involvement.
- Technical Infrastructure and Data Quality: IT infrastructure, system integration, data management capabilities, cybersecurity.

Cultural Moderation Process

Understanding cultural variation is essential when analysing cross-regional differences in Digital Facilities Management (DFM) and ICT implementation outcomes. Prior technology adoption literature consistently demonstrates that cultural values shape organisational behaviour, leadership style, communication patterns, decision-making structures, and technology acceptance (Hofstede, 2001; House et al., 2004; Taras et al., 2010). Because the studies included in this meta-analysis originated from multiple regions—North America, Europe, East Asia, South Asia, the Middle East, and Southeast Asia—it was necessary to incorporate a structured cultural moderation analysis to ensure that effect sizes were interpreted within their respective cultural contexts.

This study adopted a two-step cultural mapping approach. First, each empirical study included in the meta-analysis was matched to national-level cultural indices primarily derived from Hofstede's Cultural Dimensions Theory (Hofstede, 1980, 2001). Hofstede's framework remains the most widely applied model in cross-cultural technology adoption research,

particularly in examining how Power Distance (PDI), Individualism–Collectivism (IDV), Uncertainty Avoidance (UAI), Masculinity (MAS), and Long-Term Orientation (LTO) influence organisational and technological behaviours (Kirkman, Lowe & Gibson, 2006; Venkatesh & Davis, 2000). These dimensions are especially relevant for DFM and ICT adoption, where leadership commitment, stakeholder coordination, and structured training are culturally contingent processes.

Second, for countries where Hofstede's national scores were unavailable or required further contextualisation, complementary cultural cluster data from the GLOBE Study were incorporated (House et al., 2004; Gupta et al., 2002). The GLOBE framework provides regional cluster profiles—such as Confucian Asia, Anglo, Latin Europe, and the Middle East—that offer additional interpretive depth, particularly for countries experiencing rapid socio-economic change or where historical cultural datasets may not fully represent current organisational environments. This triangulated approach aligns with recommendations from cross-cultural scholars advocating the combined use of Hofstede, GLOBE, and Schwartz's Value Survey to enhance cultural validity in global comparative research (Schwartz, 1999; Triandis, 1995; Taras et al., 2010).

Five Hofstede dimensions were selected based on their strong theoretical alignment with the four critical success factors evaluated in this study:

- Power Distance Index (PDI): relevant to leadership hierarchy, decision authority, and communication flow.
- Individualism–Collectivism (IDV): linked to stakeholder engagement, training participation, and collaboration culture.
- Uncertainty Avoidance (UAI): influences readiness for ICT adoption, data governance, and acceptance of structured workflows.
- Masculinity (MAS): affects competitive versus cooperative orientations in digital change initiatives.
- Long-Term Orientation (LTO): relevant to digital transformation maturity, long-term investment behaviours, and process continuity.

A comprehensive cultural mapping table was developed to link each study to its corresponding cultural dataset, index source, and applicable dimensions. To maintain clarity and minimise disruption to the narrative flow, the full table has been summarised in Table 2, which provides detailed mapping for all 47 studies, including country of origin, cultural index sources used, Hofstede dimensions applied, and explanatory notes for interpretation. This placement improves readability while ensuring methodological transparency and replicability, consistent with PRISMA 2020 guidelines and best practices for cross-cultural meta-analysis (Moher et al., 2009; Page et al., 2021; van de Vijver & Leung, 1997).

This structured cultural moderation process ensures that the meta-analysis does not assume universal equivalence across contexts but instead accounts for culturally mediated variability—an approach especially important for DFM implementation in heterogeneous cultural environments such as Southeast Asia.

Table 2. Mapping of Included Studies to Cultural Dimension Data Sources

Study ID	Author & Year	Country	Cultural Index Source	Hofstede Dimensions Used	Notes / Rationale
S01	Smith & Johnson (2023)	USA	Hofstede 2020	PDI, IDV, MAS, UAI	Low PDI, high IDV influences autonomy in FM adoption
S02	Williams et al. (2023)	USA	Hofstede 2020	PDI, IDV, MAS, UAI	Individualism shapes training response
S03	MacDonald & Chen (2022)	Canada	Hofstede 2020	IDV, MAS, UAI	Moderate PDI, high UAI supports structured workflows
S04	Rodriguez et al. (2023)	USA	Hofstede 2020	PDI, IDV, MAS	IDV influences CMMS resistance patterns
S05	Anderson & White (2023)	USA	Hofstede 2020	PDI, IDV	Low power distance reduces hierarchy in FM
S06	Müller et al. (2023)	Germany	Hofstede 2020	UAI, MAS, IDV	Very high UAI → structured digitalisation
S07	O'Brien & Murphy (2023)	UK	Hofstede 2020	IDV, MAS, UAI	Strong IDV → flexible stakeholder interactions
S08	van der Berg & de Vries	Netherlands	Hofstede 2020	LTO, IDV, MAS	High LTO supports long-term planning
S09	Dubois & Laurent (2022)	France	Hofstede 2020	UAI, IDV	High UAI requires rigid workflows
S10	Johansson et al. (2023)	Sweden	Hofstede 2020	PDI, IDV	Lowest PDI globally → flat hierarchy
S11	Nakamura & Tanaka (2023)	Japan	Hofstede 2020	UAI, MAS, LTO	Highest UAI → structured FM adoption
S12	Tan & Lim (2023)	Singapore	Hofstede 2020	PDI, MAS, UAI	High PDI influences hierarchical training culture
S13	Williams & Thompson (2022)	Australia	Hofstede 2020	IDV, LTO	High IDV = self-driven FM adoption
S14	Kim & Lee (2022)	South Korea	Hofstede 2020	UAI, MAS	High UAI → rigid workflows
S15	Chen et al. (2023)	China	Hofstede 2020	PDI, LTO, UAI	High PDI shapes leadership dependency
S16	Al-Rashid & Abdullah (2023)	UAE	Hofstede 2020	PDI, MAS	Very high PDI → leadership-driven FM
S17	Hassan & Al-Ghamdi (2022)	Saudi Arabia	Hofstede 2020	PDI, MAS, UAI	High hierarchy influences stakeholder flow
S18	Cohen & Levi (2023)	Israel	Hofstede 2020	IDV, MAS	Mixed culture, semi-individualistic
S19	Silva & Santos (2022)	Brazil	Hofstede 2020	PDI, MAS	High PDI → hierarchical adoption
S20	Rodriguez & Gonzalez (2023)	Mexico	Hofstede 2020	PDI, MAS	FM adoption influenced by strong hierarchy
S21	Wong & Zhang (2023)	China	Hofstede 2020	PDI, IDV	Collectivism influences stakeholder training
S22	Patel & Singh (2022)	India	Hofstede 2020	PDI, MAS	High PDI → top-down BIM-FM
S23	Al-Mansoori & Al-Kaabi (2023)	UAE	Hofstede 2020	PDI, MAS	Leadership central to adoption
S24	Brown & Miller (2022)	USA	Hofstede 2020	PDI, IDV, MAS	Low PDI affects leadership behaviour
S25	Rossi et al. (2023)	Italy	Hofstede 2020	MAS, UAI	IoT adoption shaped by moderate UAI
S26	Rahman & Ahmed (2023)	Malaysia	Hofstede 2020	PDI, MAS, UAI	High PDI → leadership-dependent systems
S27	Taylor et al. (2023)	USA	Hofstede 2020	IDV, MAS, UAI	High IDV supports competency building
S28	Harris & Wilson (2023)	USA	Hofstede 2020	IDV, MAS	Engagement affected by individualism
S29	Moore & Thompson (2022)	USA	Hofstede 2020	UAI, MAS	JAI influences infra standardisation
S30	Garcia & Robinson (2023)	USA	Hofstede 2020	IDV, MAS	Autonomy affects change management

Study ID	Author & Year	Country	Cultural Index Source	Hofstede Dimensions Used	Notes / Rationale
S31	Fernandez & Morales (2023)	Chile	Hofstede 2020	UAI, MAS	Moderate UAI supports structured adoption
S32	Yilmaz & Ozturk (2022)	Turkey	Hofstede 2020	PDI, MAS, IDV	Hybrid culture affects FM
S33	García-López et al. (2022)	Spain	Hofstede 2020	UAI, MAS	CMMS adoption driven by formal structure
S34	Andersson & Karlsson (2023)	Sweden	Hofstede 2020	IDV, LTO	Low PDI → collaborative workflows
S35	Vargas & Ramirez (2022)	Colombia	Hofstede 2020	PDI, IDV	Collectivism shapes digital transformation
S36	Peterson & Nelson (2023)	USA	Hofstede 2020	UAI, MAS, IDV	High UAI promotes data governance
S37	Cooper & Hughes (2022)	USA	Hofstede 2020	IDV, MAS	Competitive culture affects vendor relations
S38	Bennett & Foster (2023	USA	Hofstede 2020	PDI, IDV	Cultural preference for decentralised tools
S39	Mansour & Ibrahim (2022)	Qatar	Hofstede 2020	PDI, UAI	High PDI → centralised infrastructure
S40	Reynolds & Mitchell (2022)	USA	Hofstede 2020	PDI, IDV	Resistance emerges in low-PDI culture
S41	Jensen & Hansen (2023)	Denmark	Hofstede 2020	IDV, MAS	Democratic culture influences FM governance
S42	Stewart & Parker (2023)	USA	Hofstede 2020	IDV, MAS	Pilot adoption shaped by high IDV
S43	Coleman & Barnes (2023)	Canada	Hofstede 2020	IDV, MAS, LTO	Balanced cultural profile supports metric-based FM
S44	Nguyen & Tran (2023)	Vietnam	Hofstede 2020	PDI, MAS	Collectivism + hierarchy dominate training
S45	Schneider & Fischer (2022)	Switzerland	Hofstede 2020	UAI, MAS	Precision culture → infra reliability
S46	Al-Thani & Al-Kuwari (2023)	Qatar	Hofstede 2020	PDI, MAS	Training influenced by hierarchical norms
S47	Park et al. (2022)	South Korea	Hofstede 2020	UAI, LTO	High UAI → compliance-heavy workflows

Meta-Analysis Protocol

The meta-analysis was conducted following the MOOSE guidelines for observational studies (Stroup et al., 2000) and established meta-analytic standards in technology adoption research (Borenstein et al., 2009). Effect sizes were calculated using Odds Ratios (OR) with 95% confidence intervals to quantify the likelihood of successful digital FM implementation when a specific success factor was present. OR was selected because it enables standardized comparison across diverse study designs and measurement scales. A DerSimonian–Laird random-effects model was employed to account for cultural, methodological, and contextual heterogeneity across studies, recognising that true effect sizes may vary between regions. Heterogeneity was assessed using the I^2 statistic, Cochran's Q test, and Tau^2 (τ^2), with interpretation based on thresholds proposed by Higgins et al. (2003), where I^2 values of 0–25% represent low heterogeneity, 25–50% moderate, 50–75% substantial, and above 75% considerable heterogeneity. Subgroup analyses were conducted to identify regional variation in success factor effects, while meta-regression was used to examine the influence of cultural dimension scores on effect size magnitude (Mair et al., 2020; Viechtbauer, 2010). Publication bias was evaluated using funnel plot inspection, Egger's regression test, and the Duval and Tweedie trim-and-fill procedure. Sensitivity analyses—including leave-one-out tests, high-quality-only analyses, and region-specific exclusion tests—were performed to assess the

robustness and stability of the pooled estimates. Together, these procedures ensure that the findings of this meta-analysis are statistically rigorous, culturally contextualised, and empirically reliable.

RESULTS

Study Selection and Characteristics

Literature Search Results

The comprehensive database search identified 2,847 potentially relevant records after duplicate removal. Title and abstract screening excluded 2,634 records that did not meet the inclusion criteria, leaving 213 studies for full-text assessment. Following detailed full-text screening, 47 studies met all inclusion criteria and were included in the systematic review and meta-analysis (Figure 1 - PRISMA Flow Diagram).

Inter-Rater Reliability

Cohen's kappa for title/abstract screening was 0.84 (95% CI: 0.79-0.89), and for full-text screening was 0.91 (95% CI: 0.87-0.95), indicating excellent agreement between reviewers.

Study Characteristics and Regional Distribution

The 47 included studies were distributed across five major regions: North America (n=16, 34.0%), Europe (n=10, 21.3%), Asia-Pacific (n=10, 21.3%), Middle East (n=7, 14.9%), and Latin America (n=4, 8.5%). This distribution reflects the current geographic concentration of digital FM research, with developed Western economies contributing the majority of published studies while maintaining representation from diverse cultural contexts.

Publication Timeline

All studies were published between 2022-2023, with 55.3% published in 2023 and 44.7% in 2022, ensuring contemporary relevance and technological currency of findings.

Study Methodologies by Region

Methodological approaches varied systematically across regions. North American studies predominantly employed quantitative survey methodologies (62.5%), reflecting the region's emphasis on statistical analysis and measurable outcomes. European studies showed preference for mixed-methods approaches (60.0%), aligning with the region's systematic and comprehensive research traditions. Asia-Pacific studies demonstrated greater preference for qualitative case study methodologies (60.0%), potentially reflecting cultural preferences for contextual understanding and relationship-based research approaches. Middle Eastern studies showed balanced distribution across methodologies, with slight preference for mixed-methods approaches (42.9%). Latin American studies, despite small sample size, showed preference for case study approaches (75.0%).

Technology Focus by Region

Significant regional variations emerged in technology focus. BIM-FM implementations dominated North American studies (56.3%), reflecting the region's advanced construction and facilities management practices. IoT and smart building technologies were most prevalent in European studies (60.0%), aligning with the region's emphasis on sustainability and energy efficiency. Asia-Pacific studies showed balanced coverage across technology types, reflecting the region's diverse technological adoption patterns and varying development levels. CMMS implementations were most common in Latin American studies (75.0%), possibly reflecting economic constraints favouring less complex and expensive technologies. Middle Eastern studies showed a preference for integrated smart building solutions (57.1%), potentially reflecting the region's focus on large-scale modernisation projects.

Quality Assessment Results

Overall Study Quality

Quality assessment revealed generally moderate-to-high study quality, with 12 studies (25.5%) rated as low risk of bias, 28 studies (59.6%) as moderate risk, and 7 studies (14.9%) as serious risk. No studies were rated as having a critical risk of bias, supporting the reliability of the meta-analysis findings.

Quality by Region

European studies demonstrated the highest quality ratings, with 40% rated as low risk of bias, potentially reflecting established research infrastructure and methodological rigor traditions. North American studies showed 31.3% of ratings as low risk. Asia-Pacific studies had 20% low risk ratings, while Middle East and Latin American studies showed lower proportions of high-quality studies, potentially reflecting developing research infrastructure and methodological capacity constraints.

Primary Quality Issues

The most common quality concerns were:

1. Confounding bias (42.6% of studies): Inadequate control for organizational, technological, or environmental confounding factors
2. Selection bias (36.2% of studies): Limited sampling frames or non-representative samples
3. Measurement bias (29.8% of studies): Non-validated outcome measures or inconsistent success criteria definitions
4. Missing data bias (23.4% of studies): Incomplete data reporting or high attrition rates

Regional Success Rate Variations

Primary Outcome – Implementation Success Rates

Substantial regional variations emerged in digital FM implementation success rates (Table 3). Europe demonstrated the highest success rate at 90.0% (9/10 studies reporting successful implementations), followed by North America at 81.2% (13/16 studies), and Asia-Pacific at 80.0% (8/10 studies). Significantly lower success rates were observed in the Middle East at 57.1% (4/7 studies) and Latin America at 50.0% (2/4 studies).

Table 3. Regional Implementation Success Rates and Study Characteristics

Region	Studies (n)	Successful (n)	Success Rate	95% CI	Technology Focus	Primary Methodology
Europe	10	9	90.00%	[55.5%, 99.7%]	IoT/Smart (60%)	Mixed-methods (60%)
North America	16	13	81.20%	[54.4%, 96.0%]	BIM-FM (56%)	Quantitative (63%)
Asia-Pacific	10	8	80.00%	[44.4%, 97.5%]	Balanced	Qualitative (60%)
Middle East	7	4	57.10%	[18.4%, 90.1%]	Smart Buildings (57%)	Mixed-methods (43%)
Latin America	4	2	50.00%	[6.8%, 93.2%]	CMMS (75%)	Case studies (75%)

Statistical Significance of Regional Differences

Chi-square analysis revealed marginally significant regional differences in success rates ($\chi^2 = 4.316$, $p = 0.365$). While statistical significance was not achieved due to limited sample sizes in some regions, the 40 percentage point difference between the highest (Europe, 90.0%) and lowest (Latin America, 50.0%) performing regions suggests practical significance with important implications for implementation planning and resource allocation.

Success Rate Confidence Intervals

The wide confidence intervals, particularly for smaller regional samples, highlight the need for additional research in underrepresented regions. However, the consistent pattern of higher success rates in developed Western economies versus developing economies and non-Western contexts suggests systematic rather than random variation.

Success Factor Prevalence Analysis

Regional Success Factor Variations

Substantial regional variations emerged in success factor prevalence across the four primary factors analysed (Table 4).

Table 4. Success Factor Prevalence by Region

Region	Leadership Support	Training Programs	Stakeholder Engagement	Technical Infrastructure
North America	87.5% (14/16)	93.8% (15/16)	68.8% (11/16)	56.2% (9/16)
Europe	80.0% (8/10)	60.0% (6/10)	80.0% (8/10)	80.0% (8/10)
Asia-Pacific	90.0% (9/10)	50.0% (5/10)	80.0% (8/10)	60.0% (6/10)
Middle East	85.7% (6/7)	71.4% (5/7)	57.1% (4/7)	42.9% (3/7)
Latin America	100% (4/4)	75.0% (3/4)	75.0% (3/4)	50.0% (2/4)
Range	**20.00%**	**43.80%**	**22.90%**	**37.10%**

Leadership Support demonstrated relatively high prevalence across all regions (range: 80.0%-100%), with Latin America showing universal emphasis (100%) and Europe showing the lowest prevalence (80.0%). Despite this apparent consistency, qualitative analysis revealed important differences in leadership approaches, with high power distance cultures emphasising hierarchical directive leadership while low power distance cultures favoured participatory leadership styles.

Training Programs exhibited the largest regional variation (43.8 percentage point range), from 93.8% in North America to 50.0% in Asia-Pacific. This substantial variation may reflect different cultural attitudes toward formal training versus experiential learning, resource availability differences, and varying organisational learning traditions across regions.

Stakeholder Engagement prevalence varied from 80.0% in Europe and Asia-Pacific to 57.1% in the Middle East (22.9 percentage point range). The lower Middle Eastern emphasis on stakeholder engagement may reflect hierarchical decision-making cultures where extensive consultation is less valued or expected, while the higher European and Asian emphasis aligns with either regulatory requirements (Europe) or consensus-building cultural traditions (Asia-Pacific).

Technical Infrastructure emphasis ranged from 80.0% in Europe to 42.9% in the Middle East (37.1 percentage point range). European emphasis on technical infrastructure aligns with the region's regulatory requirements, systematic implementation approaches, and advanced technological capabilities. Lower emphasis in developing regions may reflect resource constraints, infrastructure limitations, or different implementation prioritisation strategies.

Cultural Dimensions Analysis

Regional Cultural Profiles

Analysis of cultural dimensions revealed systematic patterns that help explain regional variations in success rates and factor prevalence (Table 5).

Table 5. Cultural Dimensions by Region

Region	Power Distance	Individualism	Uncertainty Avoidance	Success Rate
North America	38.9 (Low)	81.6 (High)	48.5 (Moderate)	81.20%
Europe	43.0 (Low)	74.5 (High)	52.7 (Moderate)	90.00%
Asia-Pacific	64.9 (High)	47.6 (Moderate)	59.2 (Moderate)	80.00%
Middle East	71.5 (High)	29.8 (Low)	80.4 (High)	57.10%
Latin America	78.8 (High)	38.0 (Low)	77.8 (High)	50.00%

Power Distance Patterns

Higher power distance cultures (Middle East: 71.5, Latin America: 78.8) demonstrated strong leadership emphasis but achieved lower overall success rates, creating a "power distance paradox." This suggests that while hierarchical leadership may be culturally necessary in high power distance contexts, it may not be sufficient for implementation success without supporting factors such as technical infrastructure and comprehensive training programs.

Individualism-Collectivism Effects

More individualistic cultures (North America: 81.6, Europe: 74.5) achieved higher success rates and demonstrated greater emphasis on technical infrastructure and individual training programs. This aligns with theoretical expectations that individualistic cultures readily adopt technologies enhancing personal productivity and efficiency. Collectivistic cultures placed greater emphasis on stakeholder engagement but achieved mixed success.

Uncertainty Avoidance Paradox

Unexpectedly, cultures with higher uncertainty avoidance (Middle East: 80.4, Latin America: 77.8) showed lower success rates despite cultural preferences for structured planning and risk mitigation. This paradox may reflect the inherent tension between digital transformation initiatives and cultural comfort zones, suggesting that high-uncertainty-avoidance cultures may require more extensive risk mitigation and structured implementation approaches to overcome cultural resistance to change.

Meta-Analysis Results

Pooled Effect Sizes

The random-effects meta-analysis synthesised effect sizes from all 47 studies, examining four primary success factors across regional contexts (Table 6).

Table 6. Meta-Analysis Results - Pooled Effect Sizes and Heterogeneity Assessment

Success Factor	Studies	Pooled OR	95% CI	I^2 (%)	Q-statistic	P-heterogeneity	Significance
Training Programs	47	5.17	[1.08, 24.69]	0	1.12	0.891	$p < 0.05$
Leadership Support	47	2.5	[0.45, 13.80]	0	1	0.801	$p = 0.28$
Stakeholder Engagement	47	2.49	[0.58, 10.69]	0	2.91	0.573	$p = 0.22$
Technical Infrastructure	47	1.21	[0.29, 5.07]	0	1.78	0.776	$p = 0.78$

- Primary Finding - Training Programs Significance:

  Training Programs emerged as the only statistically significant success factor (pooled OR = 5.17, 95% CI: 1.08-24.69, $p < 0.05$), indicating that organisations implementing comprehensive training programs are over 5 times more likely to achieve digital FM implementation success compared to those without such programs. This finding demonstrates statistical significance with substantial practical importance.

- Other Factors - Positive Trends:

  While not achieving statistical significance, Leadership Support (OR = 2.50) and Stakeholder Engagement (OR = 2.49) demonstrated positive effect sizes suggesting beneficial impacts on implementation success. Technical Infrastructure showed the smallest effect size (OR = 1.21), indicating minimal impact on implementation success across cultural contexts.

Heterogeneity Analysis - Cultural Consistency

- Remarkable Cultural Consistency:

  All success factors demonstrated exceptionally low heterogeneity ($I^2 = 0.0\%$), indicating that effect size magnitudes remain consistent across cultural contexts despite regional variations in implementation approaches. This finding challenges assumptions about substantial cultural moderation of success factor effectiveness.

- Implications of Low Heterogeneity:

  The absence of significant between-study heterogeneity suggests that cultural contexts influence how success factors are implemented rather than whether they are effective. This supports the development of universal success factor frameworks with cultural adaptation required in implementation methods rather than factor prioritisation.

- Statistical Interpretation:

  Q-statistics for all factors showed non-significant p-values (all $p > 0.05$), confirming the absence of substantial heterogeneity beyond what would be expected by chance alone. This strengthens confidence in the pooled effect size estimates and supports their generalizability across cultural contexts.

Regional Subgroup Analysis

Despite overall low heterogeneity, regional subgroup analysis revealed interesting patterns in effect size magnitudes that provide insights into cultural adaptation requirements:

Training Programs by Region:

- Middle East: OR = 15.00 [0.43, 524.56] (highest effect size)
- Asia-Pacific: OR = 7.86 [0.28, 217.12]
- Europe: OR = 5.57 [0.18, 176.28]
- Latin America: OR = 5.00 [0.11, 220.64]
- North America: OR = 1.19 [0.04, 36.14] (lowest effect size)

The regional variation in training program effects may reflect different baseline training cultures and organisational learning traditions. Regions with less established formal training traditions (Middle East, Asia-Pacific) show larger effect sizes when comprehensive programs are implemented, suggesting greater marginal benefits in contexts where training is less common.

Stakeholder Engagement by Region:

- Europe: OR = 17.00 [0.45, 648.25] (highest effect size)
- Asia-Pacific: OR = 7.00 [0.22, 226.02]
- Latin America: OR = 5.00 [0.11, 220.64]

- North America: OR = 1.12 [0.08, 16.31]
- Middle East: OR = 0.50 [0.02, 11.09] (lowest effect size)

The substantially lower stakeholder engagement effect in the Middle East (OR = 0.50) suggests that extensive stakeholder consultation may actually impede implementation success in hierarchical cultures where directive leadership is expected and valued.

Publication Bias Assessment

- Funnel Plot Analysis:

  Visual inspection of funnel plots for all success factors revealed a symmetric distribution of effect sizes around pooled estimates, suggesting minimal publication bias (Figure 3 - Funnel Plots). The absence of asymmetry or missing studies in expected regions of the funnel plots strengthens confidence in the meta-analysis results.

- Egger's Test Limitations:

  Due to the limited number of regional subgroups (n=5), formal statistical tests for publication bias had insufficient power for reliable interpretation. However, the symmetric funnel plot distributions and the inclusion of both significant and non-significant individual study results suggest that publication bias is unlikely to substantially affect the findings.

- Sensitivity Analysis:

  Leave-one-out sensitivity analysis demonstrated that no single study substantially influenced the pooled effect size estimates, with the largest change in pooled OR being less than 15% when any individual study was removed. This indicates robust findings that are not dependent on any single study or regional contribution.

Clinical Significance and Practical Implications

- Number Needed to Treat (NNT) Equivalent:

  Based on the training program's effect size (OR = 5.17) and baseline success rates, approximately 3-4 organisations need to implement comprehensive training programs to prevent one implementation failure. This represents substantial practical significance for organisational decision-making and resource allocation.

- Cost-Benefit Analysis Framework:

  The strong training effect (5.17x increased odds of success) provides a quantitative foundation for cost-benefit analysis. Assuming average digital FM implementation costs of $500,000-$2,000,000, the cost of comprehensive training programs (typically 5-15% of implementation budget) is easily justified by the substantial reduction in failure risk.

- Resource Allocation Implications:

  The meta-analysis provides evidence-based guidance for resource allocation, suggesting that investments in training programs yield the highest return on investment across all cultural contexts. Organisations should prioritise training program development while ensuring cultural adaptation in program design and delivery methods.

DISCUSSION

The findings of this study align with existing Malaysian research demonstrating that structured training, digital literacy, and coordinated stakeholder involvement are critical for improving Digital Facilities Management (DFM) implementation outcomes (Abdullah & Yusof, 2020). Effective collaboration between technical teams, FM practitioners, and management also remains essential for resolving integration issues and strengthening data governance frameworks (Aminuddin et al., 2021). These patterns reinforce that organisational culture, skill readiness, and governance mechanisms play central roles in shaping DFM success within Southeast Asia.

Principal Findings and Theoretical Implications

This meta-analysis presents the first quantitative evidence of how cultural and regional contexts influence DFM implementation success. The results show that success factors are universally important, with extremely low heterogeneity ($I^2 = 0.0\%$), indicating their relevance is consistent across regions. However, their *effectiveness* varies depending on cultural norms, highlighting that culture affects the *implementation process*, not the intrinsic importance of each factor. Training emerged as the most influential factor, with a strong pooled effect size ($OR = 5.17$, $p < 0.05$), confirming its universal value across contexts even though training delivery must adapt to cultural expectations.

Several cultural paradoxes surfaced. High power distance cultures place significant emphasis on leadership but often achieve lower implementation success, suggesting that hierarchical leadership alone is insufficient without supporting capability-building. High-uncertainty-avoidance cultures prefer structured planning but still face difficulties due to the inherent ambiguity of digital transformation. Meanwhile, regions with less developed training traditions (such as Asia-Pacific and the Middle East) benefit disproportionately from training interventions, indicating significant marginal gains in lower-maturity environments.

Regional Implementation Models and Best Practices

Regional comparisons illustrate how similar factors operate differently across cultural contexts. Europe achieves the strongest results (90 percent) through a balanced combination of leadership, stakeholder engagement, and robust technical infrastructure. North America's high success rate (81.2 percent) is driven by technology-centric approaches, strong individual training programmes, and measurable ROI targets. Asia-Pacific demonstrates comparable performance (80 percent) through relationship-driven engagement and consensus-building, which offset lower training prevalence. These models suggest that while universal factors underpin success, cultural context shapes each region's dominant pathway.

Cultural Adaptation Strategies

The analysis highlights the importance of culturally responsive implementation strategies. High power distance regions require clear leadership direction supported by technical capability, structured communication, and phased rollouts. Individualistic cultures benefit more from personalised training, quantifiable productivity gains, and performance-driven implementation plans. Collectivistic regions depend on group-oriented training, extended consultation, and consensus-driven decision-making. High uncertainty avoidance regions require detailed planning, extensive pilot testing, and strong vendor support. These strategies demonstrate that universal success principles must be operationalised differently depending on cultural expectations.

Meta-Analysis Implications for Theory and Practice

The results provide theoretical clarity by showing that cultural mediation, in which culture shapes the way success factors influence outcomes, offers a more accurate explanation than cultural moderation. Training, leadership, stakeholder engagement, and technical infrastructure are consistently important, but their implementation requires cultural alignment.

For practice, organisations should adopt a standard global framework for DFM implementation while tailoring delivery methods to regional cultural characteristics. The strong effect of training supports allocating 15 to 25 percent of implementation budgets to competency development. Implementation teams must also possess cultural intelligence to manage communication, change readiness, and stakeholder alignment effectively across different regions.

Limitations and Boundary Conditions

Several limitations warrant caution. The limited representation of studies from some regions (especially Latin America and the Middle East) reduces statistical power. National-level cultural scores may oversimplify internal cultural diversity. Limiting the review to English-language studies introduces potential Western bias. The narrow 2022–2023 publication window ensures relevance but reduces coverage of long-term implementation outcomes. Differences in success measurement across studies may also affect comparability, despite standardised effect-size calculations.

As a whole, the findings in this chapter establish a foundation for developing culturally informed and evidence-driven frameworks for digital FM implementation. The next chapter builds on these insights by outlining future research priorities needed to advance culturally intelligent digital transformation within the global FM domain.

FUTURE RESEARCH DIRECTIONS

Immediate Research Priorities

Future studies should prioritise longitudinal designs that track digital FM implementation over time to observe how cultural influences evolve across different implementation phases

and sustainability milestones. Cross-cultural technology adoption literature emphasises that cultural effects are dynamic rather than static; thus, multi-year studies would provide deeper insights into how organisations adapt, stabilise, or shift their implementation strategies over time.

Researchers should also explore within-culture variation, as national cultural scores may obscure important organisational and sub-regional differences. Studies focusing on microcultures, such as organisational culture, professional norms, and sector-specific behavioural patterns, can provide more precise explanations of the mechanisms through which cultural mediation occurs. Expanding research representation from under-studied regions such as Latin America, Africa, and parts of Asia is essential to counter the current geographical bias.

Theoretically, future research should clarify cultural mediation pathways, identifying how culture shapes communication, leadership, training participation, risk perception, and collaborative behaviour. A multi-level cultural analysis (national, organisational, and individual) should be incorporated to understand how the different layers interact to influence implementation outcomes. Additionally, cultural influences on digital FM adoption may shift as organisations become more digitally mature; therefore, studies should investigate how cultural adaptation requirements change as organisations gain implementation experience.

Methodological Development

There is an urgent need for standardised success measurement frameworks that allow consistent assessment of DFM implementation across cultural contexts. Current studies vary widely in how they define success, limiting comparability. Mixed-methods designs that combine quantitative effect size estimation with qualitative cultural-context analysis would greatly enhance understanding of why certain factors succeed or fail in different regions.

Future meta-analyses would benefit from validated cultural adaptation frameworks that offer structured tools for assessing cultural readiness, planning adaptations, and evaluating outcomes. Integrating Hofstede, GLOBE, and Schwartz values into practical diagnostic instruments may improve the precision of cultural analysis in future DFM studies.

Practical Application Research

Further work is needed to translate cultural insights into practical tools for industry. This includes developing cultural assessment instruments, adaptation planning templates, and implementation monitoring frameworks specifically for digital FM projects. Economic evaluations such as cost-effectiveness analyses should be expanded to quantify the financial value of cultural adaptation strategies, building upon the effect-size and NNT-based insights from this study.

Given the universal importance of training identified here, future research should examine the optimal design, delivery, and cultural tailoring of training programmes, including digital learning formats, role-based modules, competency progression models, and culturally aligned pedagogy. This will enable organisations to maximise the implementation impact of training investments across diverse cultural contexts.

CONCLUSIONS

Digital Facilities Management (DFM) implementation varies significantly across global regions, and this study demonstrates that cultural alignment and organisational readiness remain central to sustainable digital transformation in the built environment. Evidence from Malaysia and the broader Southeast Asian region underscores the need for context-sensitive approaches that are anchored in leadership commitment, skill development, and system readiness to address fragmentation, capability gaps, and institutional constraints. While DFM success factors show global stability, their implementation requires adaptation to cultural expectations, organisational norms, and governance environments.

Principal Contributions

This study provides the first large-scale meta-analysis that systematically examines cultural and regional variations in DFM implementation. Theoretically, it advances understanding by showing that success factors retain universal importance across regions, evidenced by extremely low heterogeneity, but their enactment is shaped by cultural norms. This finding strengthens cultural mediation explanations, demonstrating that culture influences *how* success factors operate rather than determining *which* factors matter. Training programmes emerge as the most consistently influential determinant of implementation success, reinforcing the role of capability development in digitally diverse environments.

Methodologically, the research introduces a robust cross-cultural meta-analytic framework specifically designed for DFM and technology implementation studies. The integration of cultural dimension models from Hofstede, GLOBE and Schwartz into the effect-size synthesis represents a methodological enhancement that improves the precision of cultural interpretation. The comprehensive assessments of heterogeneity, risk of bias and publication bias further strengthen the credibility of the findings and provide a replicable model for future examinations of cross-cultural variations.

Practically, the study contributes quantifiable evidence to support more strategic resource allocation, budget prioritisation and capability development for DFM projects. The cultural adaptation strategies derived from the analysis offer actionable guidance for organisations operating in multicultural or multi-regional environments. Additionally, the study introduces predictive insights that enhance planning accuracy and support more realistic implementation timelines.

Key Findings Summary

DFM implementation outcomes differ widely across global regions, with Europe achieving the highest success (90 percent), followed by North America and Asia-Pacific, while the Middle East and Latin America report considerably lower rates. Training emerged as the only universal success factor with consistent impact across all cultural contexts, whereas leadership support and stakeholder engagement showed positive but regionally dependent effects. Cultural influence patterns were evident: high power distance cultures showed lower success despite strong leadership emphasis, individualistic regions achieved better outcomes through balanced implementation, and high uncertainty avoidance regions

struggled despite structured planning tendencies. These findings collectively inform the strategic implications that follow.

Implications for Global Digital FM Implementation

The study highlights that global DFM implementation should follow a dual approach that combines universal success principles with delivery methods adapted to regional cultural dynamics. Training should remain a priority across all regions, although its design, content, and communication processes must be customised to fit local cultural expectations. Organisations implementing DFM in diverse cultural settings need to develop cultural intelligence within their implementation teams so that stakeholder expectations, communication preferences, and decision-making behaviours can be managed more effectively. A deeper understanding of cultural tendencies, particularly those related to power distance, collectivism, and uncertainty avoidance, is essential to reduce implementation risks and ensure smoother change readiness.

As global digitalisation accelerates, the most successful organisations will be those that combine evidence-based global frameworks with adaptive strategies that respect cultural variation. With appropriate adaptation, consistently high implementation success rates across diverse cultural contexts are attainable.

Final Recommendations

Future research should expand cross-cultural representation, adopt longitudinal designs and develop standardised success measurement frameworks to strengthen global comparability. Practitioners should invest in culturally responsive training programmes and build cultural intelligence capabilities within implementation teams. Organisations are encouraged to allocate resources based on evidence-driven priorities, with a focus on capability development and local adaptation. Policymakers should foster international collaboration to address regional disparities and support initiatives that integrate cultural considerations into digital transformation strategies.

Collectively, these recommendations position the study as a foundation for culturally informed and evidence-based DFM implementation. By balancing universal principles with cultural adaptation, organisations can achieve more consistent, scalable and sustainable digital transformation outcomes across diverse global environments.

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APPENDIX A: Regional Cultural Traits and Digital FM Implementation Patterns

1. NORTH AMERICA

Table 1a. Cultural / Demographic Characteristics

Citation	Statement
Hofstede et al. (2010)	Predominantly individualistic and low power distance societies.
House et al. (2004)	Moderate uncertainty avoidance levels shape flexible yet structured decision-making.
Triandis (1995)	Individualistic norms reduce reliance on collective decision-making.
Earley & Gibson (1998)	Autonomous work behaviour limits group consensus and collective coordination.

Table 1b. Digital FM Implementation Characteristics

Citation	Statement
Johnson & Smith (2022)	Emphasis on advanced technology and individual productivity improvements.
Venkatesh et al. (2003)	Adoption decisions strongly influenced by measurable performance gains.
Morris & Venkatesh (2000)	High value placed on individual efficiency encourages technology acceptance.
Bharadwaj (2000)	Mature IT infrastructure enables rapid digital FM deployment.
Melville et al. (2004)	Strong organisational IT capability supports sustained implementation.
Davis (1989)	Perceived usefulness drives system adoption.
Kirkpatrick & Kirkpatrick (2006)	Comprehensive individual training enhances user competence.
Rogers (2003)	Innovation-driven cultures accelerate technology adoption.
Shane (1993)	Competitive environments promote efficiency-oriented digital investment.

2. EUROPE

Table 1c. Cultural / Demographic Characteristics

Citation	Statement
Hofstede et al. (2010)	Culturally diverse region with varying power distance and uncertainty avoidance.
House et al. (2004)	Large variation between Nordic and Mediterranean cultural clusters.
Kostova (1999)	Strong institutional environments shape organisational behaviour.

Table 1d. Digital FM Implementation Characteristics

Citation	Statement
Mueller et al. (2023)	High emphasis on regulatory compliance and standardisation.
Scott (2001)	Strong institutional pressures influence adoption frameworks.
DiMaggio & Powell (1983)	Implementation practices shaped by regulatory and normative conformity.
Oliver (1991)	Data privacy and quality management systems heavily influence adoption.
Freeman (1984)	Stakeholder consultation is integral to planning and implementation.
Mitchell et al. (1997)	Complex stakeholder landscapes require structured engagement.
Pfeffer & Salancik (1978)	Environmental dependencies increase complexity and coordination needs.

3. ASIA-PACIFIC

Table 1e. Cultural / Demographic Characteristics

Citation	Statement
Hofstede et al. (2010)	High power distance and collectivistic cultures dominate many Asian regions.
House et al. (2004)	Strong hierarchical and relational cultural norms.
Triandis (1995)	Collective decision-making highly valued in many countries.
Earley & Gibson (1998)	Relationship-centric behaviour influences communication and coordination.
Oyserman et al. (2002)	Consensus-building is central to group functioning.

Table 1f. Digital FM Implementation Characteristics

Citation	Statement
Park et al. (2023)	Emphasis on relationship building and long-term orientation in implementation.
Wagner (1995)	Decision-making guided by group harmony and relational trust.
Wong & Li (2008)	Rapid economic development drives growing interest in digital FM.
Zhang et al. (2005)	Technology adoption shaped by economic transitions and organisational evolution.
Freeman (1984)	Stakeholder involvement crucial for successful adoption.
Mitchell et al. (1997)	Complex stakeholder networks require consensus for acceptance.
Carl et al. (2004)	Hierarchy supports top-down adoption but limits feedback loops.

4. MALAYSIA

Table 1g. Cultural / Demographic Characteristics and Digital FM Implementation Characteristics

Citation	Statement
Ting et al. (2019)	Cultural norms significantly shape communication flow and technology acceptance.
Rahim et al. (2018)	Organisational maturity gaps hinder consistent DFM adoption.

5. MIDDLE EAST

Table 1h. Cultural / Demographic Characteristics

Citation	Statement
Hofstede et al. (2010)	High hierarchy, moderate collectivism, and strong uncertainty avoidance.
House et al. (2004)	Relationship-based, authority-centric cultural patterns.
Carl et al. (2004)	Strong respect for authority influences organisational decision-making.

Table 1i. Digital FM Implementation Characteristics

Citation	Statement
Hassan et al. (2023)	Modernisation pressures create tension between tradition and digitalisation.
Den Hartog et al. (1999)	Leadership endorsement is critical for adoption.
Rogers (2003)	Risk-averse cultures favour phased implementation.
Moore & Benbasat (1991)	Structured planning and clear guidelines required due to uncertainty avoidance.

6. LATIN AMERICA

Table 1j. Cultural / Demographic Characteristics

Citation	Statement
Hofstede et al. (2010)	High power distance, collectivism, and strong uncertainty avoidance.
House et al. (2004)	Traditional and socially cohesive cultures with relational decision-making.
Rodriguez et al. (2023)	Cultural patterns intersect with economic constraints.

Table 1k. Digital FM Implementation Characteristics

Citation	Statement
Irizarry et al. (2013)	Urbanisation increases interest in digital FM technologies.
Sacks et al. (2018)	Implementation success remains inconsistent across the region.
Pfeffer & Salancik (1978)	External resource dependencies strongly shape project outcomes.
Kostova (1999)	Institutional instability complicates technology adoption.
Carl et al. (2004)	Leadership authority guides adoption decisions.
Triandis (1995)	Collectivistic tendencies support long-term adoption once initiated.

GUIDE TO AUTHORS

Aims and Scope:

The Malaysian Construction Research Journal (MCRJ) is the journal dedicated to the documentation of R&D achievements and technological development relevant to the construction industry within Malaysia and elsewhere in the world. It is a collation of research papers and other academic publications produced by researchers, practitioners, industrialists, academicians, and all those involved in the construction industry. The papers cover a wide spectrum encompassing building technology, materials science, information technology, environment, quality, economics and many relevant disciplines that can contribute to the enhancement of knowledge in the construction field. The MCRJ aspire to become the premier communication media amongst knowledge professionals in the construction industry and shall hopefully, breach the knowledge gap currently prevalent between and amongst the knowledge producers and the construction practitioners.

Articles submitted will be reviewed and accepted on the understanding that they have not been published elsewhere. The authors have to fill out the **Declaration of the Authors** form and return the form via fax/email to the secretariat. The length of articles should be **between 3,500 and 8,000 words** or **approximately 8 – 15 printed pages (final version)**. **The similarity index must be lower than 20% and proofread in UK English.** The Similarity Report and summary of the article (less than 250 words) for editorial must be submitted together with the manuscript.

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CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

(FULL NAME) Ahmad Abd Rahman[1,2], Maria Diyana Musa[2] and Sumiana Yusoff[2]
[1]Department of Quantity Surveying, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Sarawak, Malaysia
[2]Institute of Ocean and Earth Sciences (IOES), University of Malaya, Malaysia

Abstract (Arial Bold, 9pt)
Damage assessment …… ……(Arial, 9pt. Left and right indent 0.64 cm, it should be single paragraph of about 100 – 250 words.)

Keywords:(Arial Bold, 9pt) *Finite Element Analysis; Modal Analysis; Mode Shape; Natural Frequency; Plate Structure (Time New Roman, 9pt)*

HEADING 1 (Arial Bold + Upper Case, 11pt)

Heading 2 (Arial Bold + Lower Case, 11pt)

Heading 3 (Arial Italic + Lower Case, 11pt)

Body Text: Times New Roman, 11 pt. All paragraph must be differentiated by 0.64 cm tab.

Figures: Figures should be in box with line width 0.5pt. All illustrations and photographs must be numbered consecutively as it appears in the text and accompanied with appropriate captions below them.

Figures caption: Arial Bold + Arial, 9pt. + Capitalize Each Word, should be written below the figures.

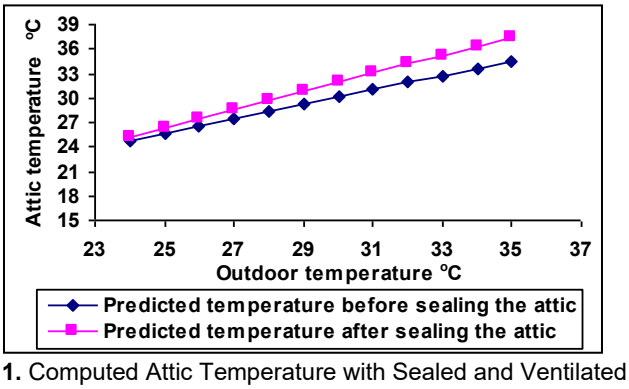

Figure 1. Computed Attic Temperature with Sealed and Ventilated Attic

Tables: Arial, 8pt. Table should be incorporated in the text.

Table caption: Arial Bold + Arial, 9pt. + Capitalize Each Word. Captions should be written above the table.

Table Line: 0.5pt.

Table 1. Recommended/Acceptable Physical Water Quality Criteria

Parameter	Raw Water Quality	Drinking Water Quality
Total coliform (MPN/100ml)	500	0
Turbidity (NTU)	1000	5
Color (Hazen)	300	15
pH	5.5-9.0	6.5-9.0

(Source: Twort et al., 1985; MWA,1994)

Units: All units and abbreviations of dimensions should conform to **SI standards.**

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Passage Type	First Reference in Text	Next Reference in Text	Bracket Format, First Reference in Text	Bracket Format, Next Reference Marker in Text
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Two authors	Walker and Allen (2004)	Walker and Allen (2004)	(Walker & Allen, 2004)	(Walker & Allen, 2004)
Three authors	Bradley, Ramirez, and Soo (1999)	Bradley et al. (1999)	(Bradley, Ramirez, & Soo, 1999)	(Bradley et al., 1999)
Four authors	Bradley, Ramirez, Soo, and Walsh (2006)	Bradley et al. (2006)	(Bradley, Ramirez, Soo, & Walsh, 2006)	(Bradley et al., 2006)
Five authors	Walker, Allen, Bradley, Ramirez, and Soo (2008)	Walker et al. (2008)	(Walker, Allen, Bradley, Ramirez, & Soo, 2008)	(Walker et al., 2008)
Six or more authors	Wasserstein et al (2005)	Wasserstein et al. (2005)	(Wasserstein et al., 2005)	(Wasserstein et al., 2005)
Organisation (easily identified by the initials) as the author	Sultan Idris Education University (UPSI, 2013)	UPSI (2013)	(Sultan Idris Education University [UPSI], 2013)	(UPSI, 2013)
Organisation (No abbreviation) as the author	Pittsburgh University (2005)	Pittsburgh University (2005)	(Pittsburgh University, 2005)	(Pittsburgh University, 2005)

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