Validating a UTAUT-Based Instrument for BIM Adoption in Construction Waste Management: A Pilot Study

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Abstract

The global adoption of Building Information Modelling (BIM) has revolutionised construction practices by improving collaboration, coordination, and project efficiency. However, its integration into Construction Waste Management (CWM) remains limited in developing contexts, particularly in the West Bank of Palestine, where rapid urbanisation, restricted landfill capacity, and institutional challenges exacerbate waste-related issues. This study presents a pilot validation of an extended Unified Theory of Acceptance and Use of Technology (UTAUT)-based framework to assess BIM adoption for CWM in the Palestinian Architecture, Engineering, and Construction (AEC) sector. The instrument comprised 26 items representing six constructs—Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC), Behavioural Intention (BI), and Actual Use (AU)—and was administered to 45 industry professionals. Data were analysed using SmartPLS 4 (SEM-PLS). Reliability analysis confirmed excellent internal consistency, with Cronbach's alpha values ranging from 0.905 to 0.970 and an overall alpha of 0.951. All outer loadings exceeded 0.75, and the Fornell–Larcker criterion verified discriminant validity (AVE values between 0.906 and 0.948). The model explained 61.3% of the variance in Behavioural Intention and 38.4% in Actual Use, indicating satisfactory explanatory power for a pilot study. These results confirm that the proposed instrument is psychometrically robust and contextually suitable for large-scale application. Findings also suggest that while professionals exhibit positive behavioural intentions toward BIM adoption, actual implementation remains constrained by limited training, non-mandatory policies, and fragmented organisational practices. The validated model provides a solid foundation for subsequent large-scale investigations and policy-oriented strategies to promote BIM-enabled waste minimisation in developing construction sectors.

Introduction

The Architecture, Engineering, and Construction (AEC) industry has undergone a profound digital transformation over the past two decades, with Building Information Modelling (BIM) emerging as a transformative technology that enhances collaboration, efficiency, and coordination across the entire project lifecycle (Chahrour et al., 2021; Waqar & Qureshi, 2023). Beyond its traditional role in project delivery, BIM is increasingly applied in sustainability assessment, lifecycle analysis, and construction waste management (CWM), making it pivotal for achieving global sustainability goals. This is especially critical as the construction sector is recognised as one of the largest generators of solid waste, accounting for 30–40% of the global total (Saad et al., 2022), with waste stemming from design inefficiencies, procurement challenges, material mismanagement, and demolition practices (Islam et al., 2019). The environmental, social, and economic implications of this waste are severe, encompassing greenhouse gas emissions, land degradation, public health risks, and depletion of natural resources (Siddiqua et al., 2022). Consequently, efficient CWM is now a central dimension of sustainable construction, with governments and industry stakeholders advocating for systematic frameworks to reduce, recycle, and valorise construction and demolition waste (C&DW). Within this global challenge, Palestine—particularly the West Bank—faces a heightened crisis due to constrained landfill capacity, resource scarcity, and weak waste management infrastructure, further exacerbated by rapid urbanisation and post-conflict reconstruction pressures (Hammad et al., 2021). Studies reveal that C&DW constitutes 30–50% of total solid waste in the West Bank, yet less than 5% is recycled (Al-Khatib et al., 2010; Ibrahim et al., 2025) , compared to recycling rates exceeding 70% in many European contexts (PNA, 2010; Elshaboury et al., 2024). Despite the global acceleration of BIM adoption, its penetration in Palestine's AEC sector remains minimal (Musleh, 2018; Saleh & Bakri, 2021), constrained by political instability, outdated digital infrastructure, insufficient training, cultural resistance to organisational change, and the absence of supportive institutional policies (Al-Khatib et al., 2010; I Mahamid, 2017).

Existing research has largely examined generic barriers to BIM uptake rather than its application to CWM, leaving a significant gap in knowledge. By contrast, evidence from other regions demonstrates that BIM can substantially enhance waste management by improving material estimation, enabling clash detection, optimising design to reduce waste, supporting selective demolition planning, and integrating lifecycle assessment (A. Eftekhari et al., 2017; D. Han et al., 2021; Kang et al., 2022) . When combined with advanced technologies such as artificial intelligence, predictive modelling, and the Internet of Things, BIM further enables proactive monitoring and facilitates circular economy practices in construction (Saka & Chan, 2020; Yang et al., 2024). Yet, successful BIM adoption depends not only on technological capabilities but also on the behavioural intentions, attitudes, and organisational readiness of practitioners (Abdulrahim, 2024; Tayeh et al., 2019). This human and institutional dimension is particularly decisive in developing and conflict-affected regions such as the West Bank, where systemic barriers are compounded by political instability and infrastructural fragility. Global evidence underscores that behavioural intention is the strongest predictor of technology adoption in such contexts (GUIMARAES et al., 2024; Nguyen et al., 2023). Against

this backdrop, the present study addresses the knowledge gap by pilot-testing a UTAUT-based framework to examine BIM adoption for CWM in the West Bank. By emphasising behavioural intention and actual use, it seeks not only to validate the research instrument but also to generate preliminary insights into the contextual drivers and constraints of BIM adoption. The findings of this pilot are expected to inform subsequent large-scale investigations and provide actionable recommendations for policymakers, industry leaders, and scholars concerned with advancing digital transformation and sustainable construction in fragile and resource-constrained environments.

Research Gap and Justification
While global scholarship has advanced substantially in demonstrating the role of BIM in enhancing construction efficiency and sustainability, the literature remains fragmented and limited in relation to BIM adoption for CWM, particularly in developing and conflict-affected regions. Several critical research gaps emerge from the review of prior work.

First, although BIM has been shown to reduce construction waste through material quantification, lifecycle assessment, and selective demolition planning (A. F. Eftekhari et al., 2024; D. C. Han et al., 2021, 2023; Yang et al., 2024), most existing studies are situated in developed economies with mature digital infrastructure, strong policy support, and relatively stable institutional environments . These conditions are markedly different from those in the West Bank, where resource scarcity, limited recycling infrastructure, and political instability hinder technological diffusion (Al-Khatib et al., 2020; Hammad et al., 2021). Consequently, global findings cannot be directly generalized to the Palestinian context without careful adaptation. Second, within Palestine itself, empirical research on BIM adoption is scarce. The few studies that exist (e.g., Musleh, 2018; Saleh & Bakri, 2021; Cheng et al., 2024) primarily investigate general barriers to BIM implementation such as cost, lack of training, or institutional weaknesses (Cheng et al., 2024). However, they do not explicitly address behavioral adoption dynamics—that is, how the perceptions, attitudes, and intentions of AEC professionals shape actual BIM uptake for specific applications like CWM. This omission leaves a significant gap in understanding the human and organizational factors that determine whether BIM is embraced in practice.

Third, theoretical framing has been underutilized in BIM research in Palestine. While many global studies apply robust models such as UTAUT to examine digital adoption, these frameworks have not yet been systematically applied in the Palestinian AEC sector. The absence of theory-driven inquiry makes it difficult to identify causal relationships among key adoption factors, such as performance expectancy, effort expectancy, social influence, and facilitating conditions. Without such analysis, policymakers and practitioners lack evidence-based strategies to overcome resistance and promote BIM adoption for CWM. Finally, there is a methodological gap. To date, no published study has conducted a pilot test of a BIM adoption framework in the Palestinian context. Pilot studies play a critical role in instrument validation, ensuring that survey items are reliable, culturally relevant, and contextually appropriate before broader-scale application (Neuman, 2006). In regions like the West Bank, where institutional fragility and stakeholder fragmentation pose unique challenges, piloting is particularly important to confirm the feasibility of proposed models and avoid misinterpretation or measurement errors.

The primary objective of this study is to identify and adapt appropriate measurement instruments for the specified variables, followed by their modification and rigorous evaluation through reliability and validity assessments within a pilot survey. This methodological approach aligns with established practices in prior research, where similar validation procedures have been employed to ensure the robustness of research instruments. Notable contributions in this regard include the works of Richins (1983), Mikkelsen and Grønhaug (1999), Paré and Sicotte (2001), and Garrison, Cleveland-Innes, and Fung (2004), among others, who have demonstrated the necessity of such procedures in achieving credible and generalisable findings.

By explicitly focusing on the intersection of BIM, CWM, and behavioral intention, and situating the analysis within the unique socio-political and economic realities of the West Bank, this study contributes novel insights to both the academic literature and practical policymaking. In doing so, it advances understanding of how digital transformation in construction can be enabled in fragile and resource-constrained environments, while also ensuring the methodological robustness of future large-scale investigations.

Theoretical Background

The adoption of the Unified Theory of Acceptance and Use of Technology (UTAUT) as the guiding framework for this study is grounded in its strong explanatory power and proven adaptability across diverse technology adoption contexts. UTAUT identifies four principal determinants of behavioural intention (BI)—performance expectancy, effort expectancy, social influence, and facilitating conditions—which together capture both individual and organisational dimensions of technology acceptance (Venkatesh et al., 2003). In the context of this research, these factors, alongside customer concerns as an additional construct, serve as the five independent variables influencing the actual use of BIM in CWM. Compared with eight preceding acceptance models, UTAUT has consistently demonstrated superior predictive capability (Van Biljon & Kotzé, 2007; Wu et al., 2007), rendering it highly suitable for examining the adoption of complex digital innovations such as BIM. Nevertheless, while the original model has been extensively validated, scholars have highlighted the need to extend UTAUT by incorporating contextual influences beyond the universal constructs initially proposed (Venkatesh, Thong, for, et al., 2016).

Within the West Bank, where the construction industry faces acute challenges of political instability, resource scarcity, infrastructural deficiencies, and limited BIM awareness, a more nuanced framework is necessary to capture the interplay between behavioural and contextual drivers. To this end, four moderating factors—gender, age, experience, and voluntarism—are integrated into the extended model, enabling analysis of how demographic and organisational characteristics shape the relationship between intention and use. Such extensions not only enhance the predictive power of the framework but also ensure greater contextual sensitivity, thereby providing more accurate forecasts of BIM adoption outcomes in fragile environments. Furthermore, this enriched perspective highlights the importance of stakeholder collaboration across architects, engineers, contractors, and policymakers, whose collective engagement is essential to overcoming barriers and embedding BIM-driven CWM practices. By foregrounding both the independent determinants of behavioural intention and the moderating influences of demographic and organisational factors, the extended UTAUT model offers a comprehensive theoretical foundation that advances academic understanding

while delivering actionable insights to support the transition of the West Bank's construction sector towards greater technological sophistication, efficiency, and sustainability.

Table 1
Definitions of Factors Included in the Research Model

Main Factor	Definition	Sources
Behavioural Intention	The willingness of the person to adopt BIM for CWM.	Nguyen et al. (2023); Adekunle et al. (2023)
Performance Expectancy	Users perceive BIM as enhancing project efficiency and reducing waste, which is crucial for effective CWM.	Sushandoyo (2023)
Effort Expectancy	The ease of use of BIM tools significantly impacts user acceptance; training and support can mitigate resistance.	Sushandoyo (2023); Eftekhari et al. (2024)
Social Influence	Peer pressure and organizational culture play a role in encouraging BIM adoption, as stakeholders follow industry leaders.	Sushandoyo (2023); Adekunle et al. (2023)
Facilitating Conditions	Availability of resources, such as training and technology infrastructure, is essential for successful implementation.	Sushandoyo (2023); Eftekhari et al. (2024)
Gender	Demographic factor influencing the perception and use of BIM.	Wang K. et al. (2024); Isa (2022); Ata (2024)
Age	Age-related variations in BIM adoption and its ease of use.	Wang K. et al. (2024); Isa (2022); Ata (2024)
Experience	The level of prior exposure and expertise in using BIM.	Wang K. et al. (2024); Isa (2022); Ata (2024)
Voluntarism	The extent to which BIM adoption is perceived as voluntary or mandatory.	Wang K. et al. (2024); Isa (2022); Ata (2024)
Actual Use of BIM in CWM	The actual implementation and utilisation of BIM in CWM.	Venkatesh et al. (2012); Wang (2023)

Literature Review and Hypotheses
Understanding how construction professionals adopt and utilize new technologies is essential to ensuring successful implementation, particularly in the context of BIM) for improving CWM and reducing construction waste. The behavioral aspect of technology acceptance plays a critical role in determining whether technological innovations are successfully integrated into practice , particularly in sectors like construction that are often resistant to change.

Core UTAUT Determinants
Performance Expectancy (PE)
Performance expectancy (PE) refers to the degree to which an individual believes that employing a particular technology will enhance their work performance and ensure better alignment with their work requirements. In the context of BIM adoption for CWM, PE captures the belief that BIM will enhance job performance, which demonstrably drives adoption. The capacity of BIM to identify design inefficiencies and material waste early in the construction phase, thereby reducing CW generation, provides a tangible performance advantage (Cheng et al., 2024; CN Ibe, 2024). Prior studies in the field of BIM adoption have repeatedly shown that behavioral intention and PE are positively correlated, as shown by studies by (Xue et al., 2021) and (Nguyen et al., 2023), among others. Therefore, it is expected

that when practitioners sense a larger degree of performance anticipation, their intentions to adopt BIM will be enhanced.

H1: Performance Expectancy (PE) has a significant positive effect on Behavioural Intention (BI) to use BIM in CWM in the West Bank.

Effort Expectancy (EE)

Effort expectancy (EE) is conceptualized as the perceived ease associated with using BIM technologies. It is an especially pertinent concern in the Palestinian AEC industry where variations in digital literacy may influence perceptions of complexity. The development of user-friendly BIM-based platforms (like visual planning systems) effectively lowers the barriers to adoption by simplifying complex waste management processes, thereby reducing the perceived effort required (Abdulrahim, 2024; D. C. Han et al., 2023; Yuan et al., 2019). Also, the intention to utilize BIM is more likely to increase when practitioners believe it requires less effort to use. This relationship suggests that the perceived benefits of a technology increase when it is easier to use.

H2: Effort Expectancy (EE) has a significant positive effect on Behavioural Intention (BI) to use BIM in CWM in the West Bank.

Social Influence (SI)

Social influence (SI) refers to the extent to which an individual perceives that important stakeholders (e.g., colleagues, managers, or regulatory authorities) believe they should employ the technology. Given the hierarchical nature of construction organizations, this dimension is particularly salient in shaping technology-related decisions. Social influence extends beyond mere peer pressure to encompass a strong organizational culture and leadership endorsement. The substantial impact of social influence on the propensity to use technology was acknowledged by earlier study (Dowelani et al., 2022; Wang et al., 2020), especially during the initial introduction phase. Therefore, the influence of social factors is expected to have a beneficial effect on practitioners' intention to utilize BIM.

H3: Social Influence (SI) has a significant positive effect on Behavioural Intention (BI) to use BIM in CWM in the West Bank.

Facilitating Conditions (FC)

Facilitating Conditions (FC) refer to an individual's perception of the extent to which organizational and technical infrastructures are available to support the use of a new system. FC includes the availability of training, IT support, and institutional policies conducive to BIM integration (Chen et al., 2022; Nguyen et al., 2023; Wang et al., 2020). FC is crucial for identifying whether the current resources and technical support systems enable or hinder the actual usage of BIM for CWM. Consequently, FC is proposed as a direct predictor of Actual Use.

H4: Facilitating Conditions (FC) have a significant positive effect on the Actual Use (AU) of BIM in CWM in the West Bank.

Behavioural Intention (BI) and Actual Use (AU)

Behavioural intention (BI), the willingness to adopt and use BIM technology, serves as a strong precursor to actual use behaviour in CWM. The perceived benefits of BIM, such as improved sustainability outcomes and significant cost savings, directly influence this intention (Dowelani & Ozumba, 2022; Abdulrahim, 2024). Examining this relationship is vital to

understanding whether strong behavioral intention translates into real-world implementation in the West Bank's construction sector. Building on (Venkatesh and Davis's, 2000) research, the willingness to use BIM is expected to translate into actual utilization.

H5: Behavioural Intention (BI) to use BIM in CWM has a significant positive effect on the Actual Use (AU) of BIM in CWM in the West Bank.

Moderating Effects

UTAUT posits that the relationships between the core factors (PE, EE, SI, FC) and the outcomes (BI, AU) are further moderated by demographic and experiential variables, including Gender, Age, Computer Experience, and Voluntariness of Use.

Gender as a Moderator

Gender is hypothesized to moderate the impact of PE, EE, and SI on BI (Venkatesh, Thong, & Xu, 2016). For example, in male-dominated industries, women often rely more on peer support (SI), and their effort expectancy (EE) may be more sensitive to perceived usability (Akbari et al., 2024).

> *H6: Gender moderates the relationship between Performance Expectancy (PE) and Behavioural Intention (BI).*
>
> *H7: Gender moderates the relationship between Effort Expectancy (EE) and Behavioural Intention (BI).*
>
> *H8: Gender moderates the relationship between Social Influence (SI) and Behavioural Intention (BI).*

Age as a Moderator

Age is hypothesized to moderate the impact of PE, EE, SI, and FC. Empirical evidence supports the assertion that younger individuals and males are generally more inclined to perceive technological innovations as performance-enhancing (Venkatesh et al., 2003; Venkatesh, Thong, & Xu, 2012). Older professionals may perceive higher risks or encounter more barriers to technology use, weakening this relationship (Arief et al., 2023; Hur et al., 2014).

> *H9: Age moderates the relationship between Performance Expectancy (PE) and Behavioural Intention (BI).*
>
> *H10: Age moderates the relationship between Effort Expectancy (EE) and Behavioural Intention (BI).*
>
> *H11: Age moderates the relationship between Social Influence (SI) and Behavioural Intention (BI).*
>
> *H12: Age moderates the relationship between Facilitating Conditions (FC) and Actual Use (AU) Behaviour.*

Computer Experience as a Moderator

Computer Experience is hypothesized to moderate the impact of EE, SI, and FC. Experienced users typically requiring less reassurance about ease of use, thereby diminishing the impact of EE on BI (Venkatesh & Davis, 2000, Sun & Zhang, 2006). For professionals with limited technological proficiency, social validation becomes a crucial lever (Baswara et al., 2021).

> *H13: Computer Experience moderates the relationship between Effort Expectancy (EE) and Behavioural Intention (BI).*
>
> *H14: Computer Experience moderates the relationship between Social Influence (SI) and Behavioural Intention (BI).*

H15: Computer Experience moderates the relationship between Facilitating Conditions (FC) and Actual Use (AU) Behaviour.

Voluntariness of Use as a Moderator

Voluntariness of Use (non-mandatory adoption) significantly affects behavioral intention, particularly amplifying the effect of Social Influence (SI) when adoption is a personal choice[36].

H16: Voluntariness of Use moderates the relationship between Social Influence (SI) and Behavioural Intention (BI).

The entire theoretical framework and the 16 hypotheses are summarized visually in figure 1 below.
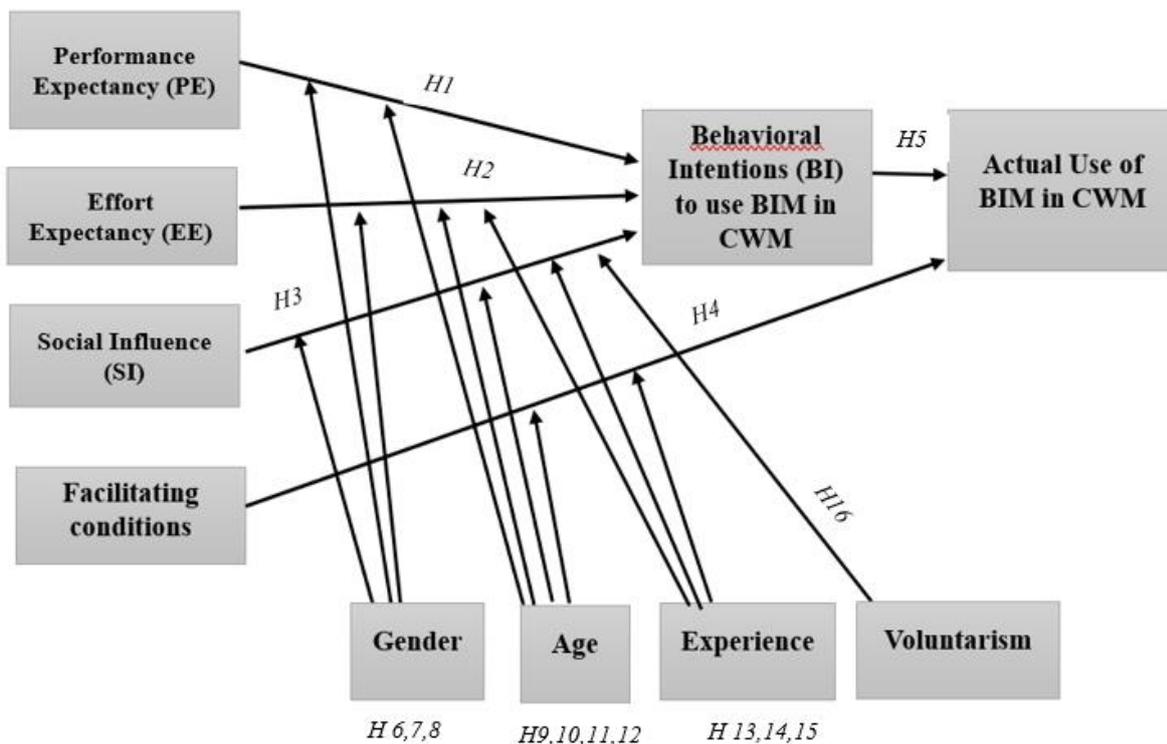

Figure 1 The Theoretical framework and proposed hypothesis of the present study.

Research Methodology

This study adopts an explanatory quantitative research design to investigate the behavioral intentions of AEC professionals in the West Bank, Palestine, toward adopting BIM for CWM. The design was selected as it enables systematic testing of relationships among latent constructs while providing empirical evidence to support theory-driven models (Creswell & Creswell, 2018).

The study is underpinned by the UTAUT, which provides a comprehensive framework for understanding technology adoption. Specifically, the model incorporates four core constructs—performance expectancy, effort expectancy, social influence, and facilitating conditions—as predictors of behavioral intention (BI). In alignment with UTAUT, the research further models the link between BI and actual use of BIM for CWM, as in Appendix 1. This framework ensures theoretical rigor and situates the study within a robust body of adoption research (Venkatesh et al., 2003).

Pilot Testing

Prior to full-scale implementation, it is essential to evaluate the robustness of the measurement instrument to ensure its appropriateness for the study context. Accordingly, this research employs a pilot study to examine both the reliability, defined as the internal consistency of the instrument in capturing the intended construct (Sekaran & Bougie, 2009), and the validity, which concerns the extent to which the instrument accurately reflects the concept under investigation (Creswell & Clark, 2017; Sekaran, 2009). Specifically, face, discriminant, and convergent validity are assessed through expert review and factor analysis, while internal consistency is tested to establish measurement reliability. This process not only enhances the instrument's conceptual soundness but also helps to identify ambiguities, confirm feasibility, and ensure contextual relevance prior to full deployment (Neuman WL, 2006).

The choice of a pilot design is also justified by precedent in construction management and technology adoption research. Small-scale pilots using 30–50 participants are widely recognized as appropriate for instrument validation and exploratory structural equation modeling (SEM) (Antwi-Afari et al., 2018; Li et al., 2016). In line with these recommendations, this study employs a sample of 45 respondents, ensuring sufficient data for reliability assessment while maintaining the pilot's exploratory nature.

Data Collection

The pilot survey targeted 45 professionals across the Palestinian AEC sector, including engineers, project managers, contractors, and government representatives. This purposive sampling approach was chosen to capture diverse perspectives from key stakeholders directly engaged in construction and waste management.

The questionnaire items were adapted from validated UTAUT measurement scales (Venkatesh et al., 2003; Venkatesh et al., 2012) and carefully modified to reflect the dual context of BIM adoption and construction waste management. The instrument was structured in three sections:

1. Demographic Information (e.g., gender, age, years of experience, BIM volinteerizm).
2. UTAUT Constructs (performance expectancy, effort expectancy, social influence, facilitating conditions, BI, and actual use).

The questionnaire was distributed electronically and through professional networks, with voluntary participation ensured via informed consent. Respondents were assured of confidentiality and anonymity, consistent with ethical research practice.

Data Analysis

Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) via SmartPLS 4 software, which is suitable for small sample sizes and exploratory research (Hair et al., 2019). The analysis followed a two-stage approach:

1. Measurement Model Assessment: Reliability and validity of the constructs were tested using Cronbach's alpha, composite reliability, average variance extracted (AVE), and discriminant validity measures.
2. Structural Model Assessment: Path coefficients, R^2 values, and significance levels were examined to assess the hypothesized relationships between UTAUT constructs, behavioral intention, and actual use of BIM for CWM.

This dual-stage analysis ensured both the adequacy of the measurement instrument and the preliminary validation of the conceptual framework. Findings from the pilot will serve as the basis for refining the instrument and guiding a full-scale investigation in subsequent research phases.

Reliability of Constructs

The reliability analysis was performed to assess the internal consistency of the constructs using Cronbach's alpha (Cronbach, 1951). According to (J. F. Hair et al., 2021), reliability reflects the degree to which an instrument consistently measures the intended construct, and a minimum value of 0.70 is considered acceptable (Cortina, 1993; Sekaran & Bougie, 2016). In this study, all constructs exceeded this threshold, with Cronbach's alpha values ranging from 0.905 to 0.970. These results indicate excellent internal consistency across the measurement items.

Similarly, the outer loadings of all items were above 0.75, confirming that each indicator strongly loaded on its respective construct (see Table 2). These results suggest that the questionnaire items adequately represent their intended constructs and are reliable for further statistical testing. As recommended by Hair et al. (2011), establishing reliability prior to validity assessment ensures the robustness of the instrument (J. Hair, 2014). Therefore, the measurement model in this pilot study demonstrates high reliability, supporting the use of the instrument in broader data collection and analysis.

Table 2

The Outer Loadings

	AU	BI	EE	FC	PE	SI
AU1	0.925					
AU2	0.955					
AU3	0.941					
AU4	0.959					
BI1		0.892				
BI2		0.927				
BI3		0.932				
BI4		0.878				
BI5		0.899				
EE1			0.875			
EE2			0.888			
EE3			0.892			
EE4			0.887			
FC1				0.894		
FC2				0.909		
FC3				0.918		
FC4				0.892		
FC5				0.918		
PE1					0.959	
PE2					0.959	
PE3					0.936	
PE4					0.937	
SI1						0.765
SI2						0.862
SI3						0.853
SI4						0.840

Results

Demographic Characteristics of Respondents

A total of 45 valid responses were obtained from professionals in the AEC sector in the West Bank. As shown in Figure 2, the majority of respondents were male (68.9%), with females comprising 31.1% of the sample. With regard to age distribution (Figure 3), one-third of respondents (33.3%) were aged between 31 and 40 years, while the 21–30, 41–50, and 51–60 age groups each represented 20% of the sample. A smaller proportion (6.7%) were aged 61 years or above. This profile suggests that most participants were early- to mid-career professionals with sufficient industry experience to provide meaningful insights. Gender and age, together with experience and voluntarism (examined later), represent the four moderating factors identified within the UTAUT framework, thereby providing a basis for interpreting variations in behavioural intention and technology adoption across different respondent groups.
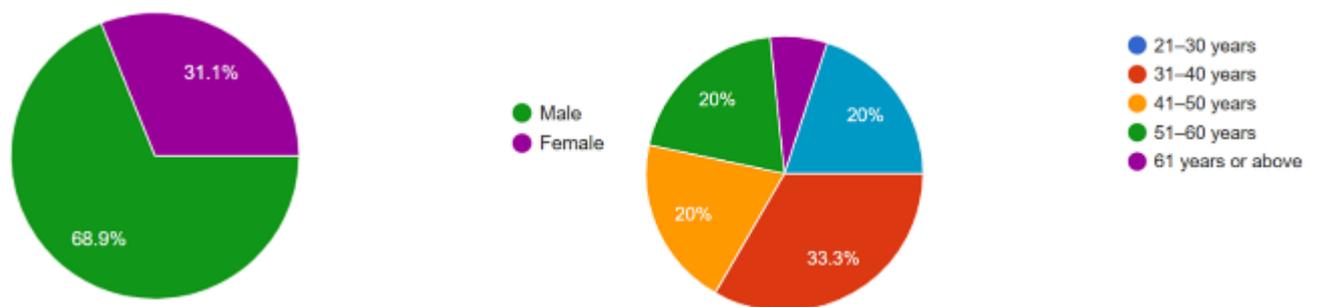

Figure 2- Gender and age distribution of respondents

Computer Proficiency and BIM Use in Organisations

The self-reported levels of computer proficiency are presented in Figure 4. The majority of respondents rated themselves as intermediate (55.6%) or advanced (28.9%). Only 11.1% reported a basic level of competence, and 4.4% described themselves as having a low level of digital skills. These findings indicate that the cohort was generally equipped with adequate digital literacy to engage with BIM tools effectively.

Concerning the integration of BIM within organisations (Figure 5), 60% of respondents stated that its use was encouraged but not obligatory, 24.4% indicated that it was entirely voluntary, and only 15.6% reported that BIM use was mandatory. This pattern reflects the transitional stage of BIM adoption within the West Bank, whereby awareness and promotion exist but institutionalisation and regulatory enforcement remain limited.
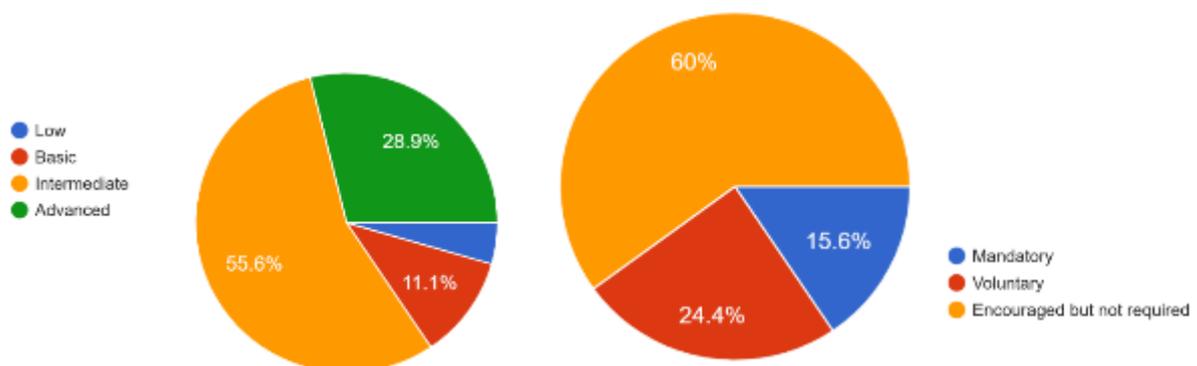

Figure 3: Computer proficiency and BIM use in organisations

Reliability and Validity of Constructs
The reliability of the constructs was evaluated using Cronbach's alpha, with the results presented in Figure 6. In line with the criteria proposed by Hair et al. (2010, 2011) and Taber (2018), a threshold of 0.70 was adopted. The Cronbach's alpha coefficients ranged from 0.905 to 0.970, thereby confirming excellent internal consistency across the six constructs: Behavioural Intention (BI), Actual Use (AU), Effort Expectancy (EE), Facilitating Conditions (FC), Performance Expectancy (PE), and Social Influence (SI). These results indicate that the measurement instrument was both reliable and suitable for subsequent analysis.
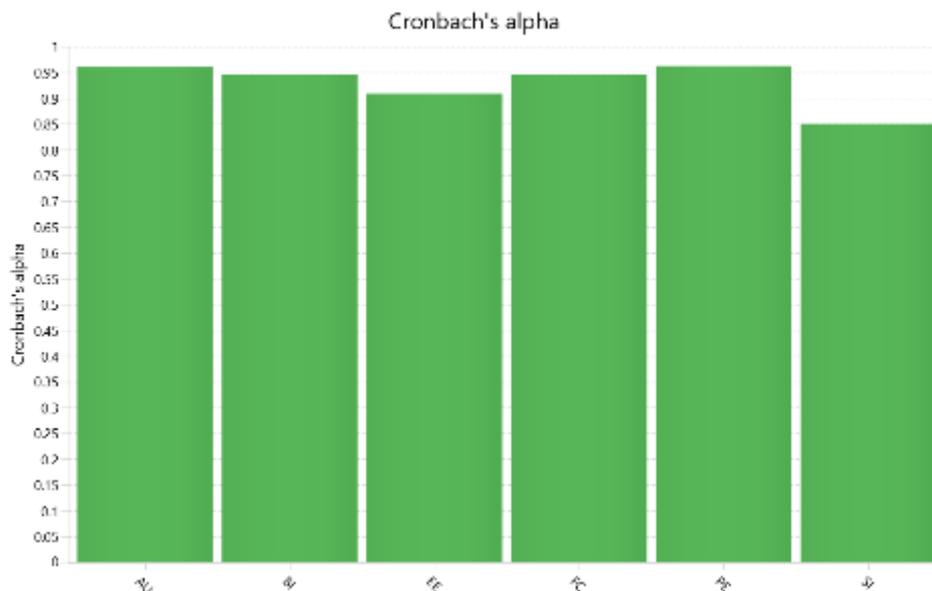

Figure 4- Reliability results (Cronbach's alpha)

Reliability Analysis
Reliability was assessed using Cronbach's alpha to evaluate the internal consistency of the measurement items. According to Hair et al. (2010), a Cronbach's alpha value greater than 0.70 is considered acceptable, while values above 0.90 indicate excellent reliability.

As shown in Table 3, the overall Cronbach's alpha for the 26 items in the model was 0.951, which demonstrates excellent reliability of the measurement scale. The corrected item–total correlations for all items ranged from 0.492 to 0.810, confirming that each item contributes meaningfully to its respective construct. Furthermore, Cronbach's alpha if item deleted remained consistently high across all items (between 0.948 and 0.951), indicating that no single item reduced the overall reliability of the scale.

Table 2
Reliability Analysis of Measurement Items (Cronbach's Alpha and Item-Total Statistics)

	SCALE MEAN IF ITEM DELETED	SCALE VARIANCE IF ITEM DELETED	CORRECTED ITEM-TOTAL CORRELATION	CRONBACH'S ALPHA IF ITEM DELETED
PE1	72.20	388.664	0.668	0.949
PE2	72.07	396.382	0.560	0.950
PE3	72.16	393.862	0.616	0.950
PE4	72.07	396.336	0.535	0.951
EE1	72.69	398.265	0.594	0.950
EE2	72.56	396.616	0.729	0.949
EE3	72.53	390.618	0.681	0.949
EE4	72.36	394.825	0.588	0.950
SI1	72.87	397.345	0.593	0.950
SI2	72.67	398.364	0.635	0.950
SI3	72.73	398.473	0.664	0.949
SI4	72.62	396.877	0.683	0.949
FC1	72.71	393.301	0.692	0.949
FC2	72.96	398.680	0.593	0.950
FC3	72.98	397.022	0.555	0.950
FC4	72.98	398.886	0.492	0.951
FC5	72.96	398.453	0.544	0.950
BI1	72.44	386.707	0.742	0.948
BI2	72.31	390.219	0.736	0.948
BI3	72.22	390.040	0.739	0.948
BI4	72.02	394.340	0.668	0.949
BI5	72.33	387.136	0.810	0.948
USE1	73.31	392.946	0.652	0.949
USE2	73.16	391.953	0.690	0.949
USE3	72.98	396.522	0.607	0.950
USR4	72.91	394.901	0.634	0.949

These results confirm that the instrument used in this study is internally consistent and highly reliable, making it suitable for further analysis such as validity testing and structural model evaluation.

Discriminant Validity Results
Discriminant validity was assessed using the Fornell–Larcker criterion, with results presented in Table X. The analysis confirmed that the square roots of the AVE values, shown on the diagonal, exceeded the corresponding inter-construct correlations, thereby indicating that each construct was empirically distinct. For instance, Actual Use (0.945), Facilitating Conditions (0.906), and Performance Expectancy (0.948) demonstrated strong discriminant validity by maintaining higher diagonal values relative to their shared correlations with other constructs. These findings provide assurance that the adapted measures captured

conceptually independent dimensions, thereby supporting their appropriateness for inclusion in the subsequent large-scale study.

Table 3
Discriminant validity results based on Fornell–Larcker criterion

Discriminant validity - Fornell-Larcker criter				
	AU	**BI**	**EE**	**FC**
AU	0.945			
BI	0.537	0.906		
EE	0.414	0.569	0.885	
FC	0.500	0.403	0.305	0.906

Discussion
This study developed and validated measurement instruments for assessing the constructs in an extended UTAUT model applied to BIM adoption for CWM in the West Bank. The measurement model underwent rigorous validation procedures, including assessments of face validity, convergent validity, discriminant validity, and reliability. Such validation was essential to ensure that the items measured their intended constructs (Sekaran, 2003), particularly given that instruments developed in one context may not always be directly transferable to another (Brett et al., 1997).
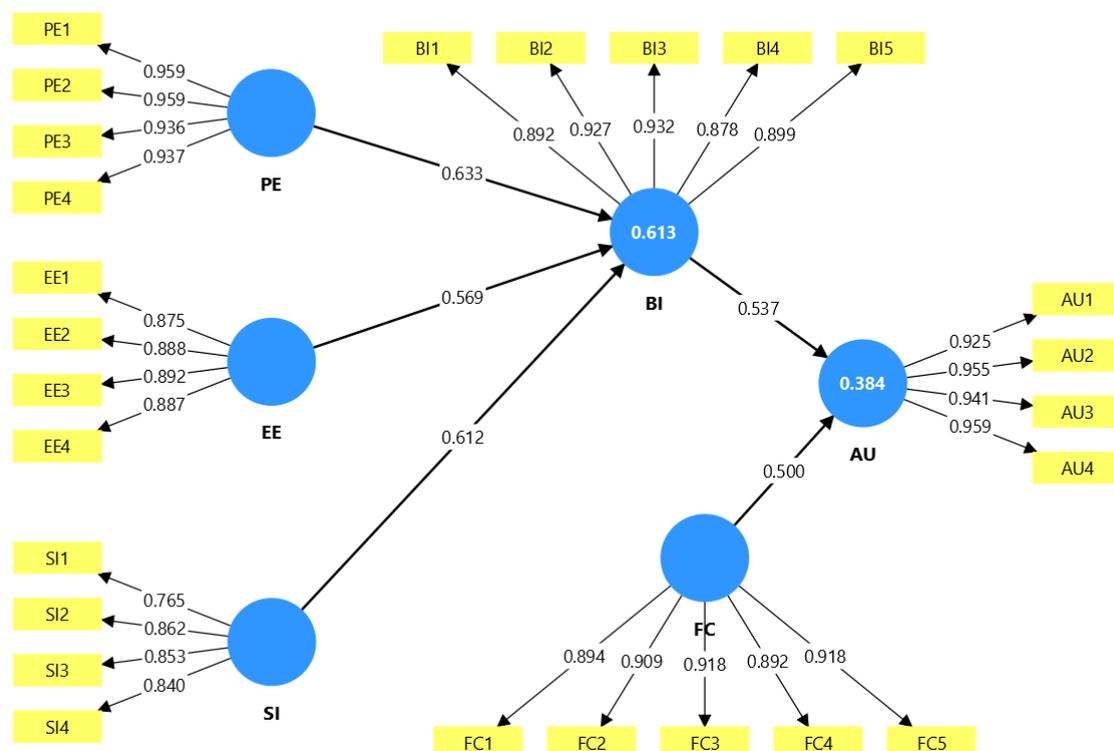

Figure 5 The measurement model

We adapted 26 measurement items from established UTAUT-related literature and modified them to align with the context of Building Information Modelling (BIM) adoption for Construction Waste Management (CWM) in the West Bank. Out of the 45 questionnaires distributed to professionals in the construction industry, 26 were returned as usable, which is considered adequate for a pilot study (Chiu, Chang, Cheng, & Fang, 2009; Ngai & Gunasekaran, 2004). Similarly, Chin and Newsted (1999) confirmed that the PLS-SEM technique tolerates relatively small sample sizes for exploratory analysis.

The measurement model was estimated, and the results provided sufficient statistical justification that the items adequately measured their intended constructs. However, the loadings for some items (e.g., SI1 and FC4) were comparatively lower. Despite this, the constructs' reliability and validity values, such as Composite Reliability (CR) and Average Variance Extracted (AVE), exceeded the recommended thresholds for acceptable measures (Compeau et al., 1999; Gefen et al., 2000; Hair et al., 2010). Accordingly, all items were retained for the full-scale study, as their removal would not significantly improve the AVE (Hair et al., 2014).

Although the primary objective of this pilot study was not to test the full structural model, the PLS algorithm indicated that the model explained 61.3% of the variance in behavioural intention and 38.4% of the variance in actual use, which reflects satisfactory explanatory power for a preliminary investigation (Chin, 1998). Finally, while the instrument performed well within the context of this study, caution must be exercised when applying it in different settings, as contextual modifications may render some items context-specific. Nonetheless, this approach offers a valuable framework for researchers seeking to adapt, refine, and validate measurement instruments for BIM adoption in specific construction management contexts.

Collectively, these findings suggest that while professionals recognise BIM's potential for enhancing CWM, actual utilisation remains partial and inconsistent, shaped by organisational policies and levels of digital adoption. This outcome reflects several barriers identified in the literature. First, although most respondents demonstrated intermediate to advanced computer proficiency, gaps in BIM-specific knowledge and awareness limit their ability to translate intention into practice. Similar barriers of poor awareness and inadequate training have been widely reported as inhibitors of BIM adoption for waste management (Akinade et al., 2018; Gerges et al., 2017). Second, the survey revealed that in 60% of organisations, BIM use is merely encouraged rather than mandated, meaning adoption depends heavily on individual initiative. Prior research confirms that top management support and organisational policy enforcement are critical enablers of BIM diffusion (Son et al., 2015; Won & Cheng, 2017). Third, the divergence between respondents' relatively positive behavioural intention and their inconsistent actual use reflects the well-documented intention–behaviour gap in technology adoption studies (Mahamadu et al., 2017; Marzouk & Azab, 2014). Finally, at an industry level, issues such as resistance to change, lack of standardisation, and fragmented practices have been shown to impede BIM integration into CWM workflows (Akinade et al., 2016; Lu et al., 2021).

Taken together, these findings indicate that while the potential of BIM for improving waste reduction and resource efficiency is well recognised, its real-world impact in the West Bank

construction sector remains constrained by awareness, organisational enforcement, and industry-wide challenges.

Implications

Implications for Research

As a pilot investigation, this study provides initial validation of the survey instrument and affirms the relevance of the UTAUT framework in examining BIM adoption for CWM within the West Bank. The divergence observed between behavioural intention and actual utilisation indicates that the proposed conceptual model is contextually appropriate but requires testing with a substantially larger and more representative sample. Furthermore, the variability in responses highlights the need to refine certain measurement items—particularly those addressing organisational support and policy enforcement—to better reflect the nuances of local industry practices. These insights will directly inform the design of the forthcoming large-scale study (n ≈ 300), thereby enabling more robust structural equation modelling and the generation of generalisable findings.

Implications for Practice

The pilot findings also bear practical significance for the Palestinian construction sector. Although respondents reported adequate levels of general digital proficiency, awareness and training in BIM-specific applications for waste management remain limited. Targeted professional development initiatives will therefore be essential in strengthening actual utilisation. Moreover, the current reliance on voluntary rather than mandatory BIM adoption policies suggests that stronger organisational and governmental support will be critical if BIM is to deliver consistent outcomes in waste minimisation. Finally, the fragmented and partial nature of current adoption points to the necessity of developing sector-wide guidelines and standardised protocols for integrating BIM into CWM practices.

Conclusion

This pilot study demonstrates the feasibility and robustness of applying an extended UTAUT model to assess BIM adoption for CWM in the West Bank. The developed instrument exhibited excellent internal consistency (Cronbach's α = 0.905–0.970; overall α = 0.951) and strong indicator reliability (outer loadings > 0.75), confirming its suitability for subsequent large-scale application. The measurement model achieved satisfactory explanatory power, accounting for 61.3% of the variance in Behavioural Intention and 38.4% in Actual Use, thereby validating the structural soundness of the framework.

Findings reveal that although construction professionals acknowledge BIM's potential to enhance waste reduction, resource efficiency, and project coordination, actual utilisation remains limited. Key inhibitors include insufficient BIM-specific training, low institutional enforcement, and non-mandatory adoption policies, compounded by broader industry fragmentation. These barriers contribute to the persistent gap between intention and practice in BIM-based waste management. To bridge this gap, the study highlights the need for stronger organisational and governmental mandates, targeted professional development initiatives, and the establishment of sector-wide standards to institutionalise BIM practices within CWM workflows. By confirming the statistical reliability and contextual relevance of the research instrument, this study provides a validated foundation for a forthcoming large-scale investigation (n ≈ 300). The results will enable the generation of generalisable evidence

to inform policy formulation, organisational strategy, and sustainable construction practices in developing economies.

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