TYPE Original Research
PUBLISHED 08 October 2024
DOI 10.3389/fbuil.2024.1442184

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RECEIVED 01 June 2024
ACCEPTED 23 September 2024
PUBLISHED 08 October 2024

CITATION
Kineber AF, Oke AE, Elshaboury N, Abunada Z, Elseknidy M, Zamil A, Alhusban M and Ilori SA (2024) Agile project management for sustainable residential construction: A study of critical success factors.
Front. Built Environ. 10:1442184.
doi: 10.3389/fbuil.2024.1442184

Agile project management for sustainable residential construction: A study of critical success factors

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Sustainability principles should be incorporated into all decision-making stages for residential construction projects to ensure maximum revenue while maintaining essential residential building services. This study identifies and analyzes the critical success factors (CSFs) necessary for implementing agile project management (APM) in residential construction projects. Data were collected from 120 professionals in the Nigerian construction industry through questionnaire surveys to understand the implementation of APM. The CSFs were obtained from previous research and analyzed within the specific context of the Nigerian construction industry through questionnaire surveys. The CSFs were grouped into two main categories using exploratory factor analysis: dynamic project optimization and agile project foundations. The model for the CSFs was developed using partial least squares structural equation modeling. The study found that the dynamic project optimization element had the most significant impact on the model, highlighting its importance as a key CSF in APM implementation. These results support the adoption of APM within Nigeria's construction industry as stakeholders and professionals seek effective strategies to reduce costs and improve sustainability.

KEYWORDS

agile project management, critical success factors, residential construction, sustainability, sustainable buildings

1 Introduction

The construction industry significantly affects the global economy, driving development and infrastructure projects across both developed and developing countries. However, this industry is heavily influenced by cultural, economic, and environmental factors. For instance, construction activities account for more than 40% of the world's electricity usage and approximately 30% of global greenhouse gas emissions (Min et al., 2022). In Europe and the United States, the construction industry accounts for approximately 40% of the total energy used (Shoemaker, 2023). In developing nations, the construction industry provides essential benefits and services that contribute to the growth and improvement of the quality of life in these regions. Policymakers in African countries seek to diversify their resources through infrastructure and manufacturing investments (Bwanali and Rwelamila, 2017; Lu et al., 2015). Thus, the requirements for construction in African developing nations differ from those in industrialized countries, particularly regarding climate and environmental factors. Consequently, the construction sector in these countries still requires significant improvement to meet international quality benchmarks (Kineber et al., 2021). Although the construction industry is a major energy consumer and has a considerable impact on the environment, research has shown that sustainability can be achieved in this sector (Kineber et al., 2020).

Incorporating sustainable practices in the construction industry is essential as it encompasses a range of environmental, social, and economic considerations (Moshood et al., 2024). The sector's substantial resource consumption and environmental effects necessitate prompt action (Lima et al., 2021). However, the conventional waterfall project management methodology, with its linear and sequential approach, poses several obstacles to integrating sustainability principles into construction projects. According to Fathalizadeh et al. (2019), one of the primary hindrances to achieving sustainability is a lack of understanding of its potential advantages and the high economic risks involved. Furthermore, practitioners frequently adopt a silo-based approach and fail to cooperate adequately. This absence of cooperation can lead to resistance to change from conventional working practices as well as a lack of understanding of the processes and workflows necessary for sustainability, as noted by Olawumi et al. (2018). Additionally, the Waterfall model does not provide a systematic approach to planning and acting to fulfill sustainability objectives, nor does it consider sustainability in construction project portfolio management, as emphasized by Siew (2016). Furthermore, the model's constraints in accommodating iterative improvements, engaging with community and stakeholder feedback, and prioritizing social aspects such as worker safety and community wellbeing underscore the need for more adaptive and flexible project management approaches to attain sustainability in construction, as highlighted by Lalmi et al. (2021).

Agile project management (APM), a flexible and collaborative approach that emphasizes continuous improvement, has gained popularity in software development and is now being explored for other project types (Dong et al., 2024). This methodology is characterized by its focus on self-managing teams and its four key principles: minimum critical specification, autonomous teams, redundancy, and feedback and learning (Dybå et al., 2014). The incorporation of agile practices in construction projects can lead to more sustainable outcomes by improving adaptability to changing requirements, enhancing client satisfaction, increasing project transparency, and improving risk management and project delivery timelines (Pinto et al., 2023). The AgiLean project management framework, which combines lean and agile principles, can further enhance flexibility and eliminate waste in construction projects (Demir et al., 2012). Its value-driven prioritization and early risk identification contribute to economic sustainability by ensuring cost efficiency and maximizing return on investment (Sertyesilisik, 2014a). Agile emphasis on collaboration and regular feedback fosters social sustainability, addresses community needs, and improves worker satisfaction (Arefazar et al., 2022). A comprehensive view of the methodology encourages thorough consideration of sustainability factors across all project phases. Agile principles align closely with the objectives of sustainable construction, offering a dynamic framework that can lead to more environmentally friendly, economically viable, and socially responsible construction projects (Ershadi et al., 2021).

The integration of agile methodologies with sustainability in the construction industry, particularly in developing countries, presents several research gaps. According to Fathalizadeh et al. (2019) and Freitag et al. (2019), there is an insufficient understanding and awareness of sustainability practices, as well as a need for the dissemination of knowledge in this area. Interest in sustainability has increased in Nigeria's construction industry (Daniel et al., 2018; Esezobor, 2016; Toriola-Coker et al., 2018; Zuofa and Ochieng, 2021). However, the adoption of sustainable construction practices faces challenges such as a lack of expertise, strategy, and demand (Daniel et al., 2018; Dania, 2017). Despite the potential significance of APM in construction project delivery (Esangbedo and Ealefoh, 2021), its integration with sustainability has not been thoroughly explored. The need for a value shift towards sustainability (Esezobor, 2016) and the importance of social sustainability and procurement (Okeke et al., 2023) further highlight the research gap in the integration of agile methodologies and sustainability in the Nigerian construction industry.

The primary purpose of this study is to investigate how APM methodologies can be effectively integrated with sustainability practices to enhance residential construction projects in Nigeria. This research aims to bridge the gap between agile methodologies and sustainable construction practices by addressing the following aspects.

1. Identify the critical success factors (CSFs) necessary for implementing APM in sustainable residential construction projects within the Nigerian context.
2. Develop a model using partial least squares structural equation modeling (PLS-SEM) to understand the relationships between the identified CSFs and the successful implementation of APM in sustainable residential construction.
3. Provide practical recommendations for stakeholders in the Nigerian construction industry to enhance project management practices and achieve sustainability objectives.

2 Literature review

APM operates as a transformative approach to managing complex projects, particularly in environments where requirements are fluid and difficult to define from the outset. This methodology, which has gained widespread acceptance in the software industry, is increasingly being incorporated into the construction sector due to its adaptability, emphasis on collaboration, and iterative development processes. The integration of APM into the construction and other sectors is driven by several key factors that align with the unique challenges and demands of managing projects in today's fast-paced and uncertain business environments.

A core principle of APM is its ability to adapt to changing requirements, which is crucial in a dynamic and evolving business world. Conventional project management techniques often fall short when it comes to navigating intricate organizational structures and fluctuating business demands. This shortcoming highlights the need for a more flexible and responsive methodology like APM (Augustine et al., 2005; Macheridis, 2009a; Salameh, 2014; Shenhar, 2004; Weinstein, 2009). Enhanced collaboration within project teams is another fundamental principle of APM, which promotes continuous feedback and iterative learning. This approach extends to interactions with customers, facilitating direct and frequent communication that is essential for managing changes and ensuring that project evolution aligns with customer expectations (Hidalgo, 2019).

Improving stakeholder involvement is a critical aspect of APM. This methodology focuses on customer feedback, continuous improvement, and cooperative development to ensure that projects deliver value and meet stakeholders' priorities (Hidalgo, 2019; Salameh, 2014). As projects become increasingly complex and involve a wide range of stakeholders and politically sensitive environments, APM's effective management of such intricacies proves beneficial (Harvett, 2013; Hillson and Simon, 2007; van Marrewijk et al., 2008). Agile methodologies are well-known for improving project quality and efficiency, with continuous collaboration and adaptive processes resulting in better project outcomes and higher customer satisfaction (Salameh, 2014; Sharma et al., 2012).

APM's focus on short-term scope, planning, and design facilitates efficient resource utilization and faster project delivery, allowing for rapid adjustments in response to changes and saving time and resources (Cervone, 2011; Sharma et al., 2012). Additionally, agile principles promote employee empowerment and engaged teams, which encourages decision-making, ownership, and innovative problem-solving within project teams (Beck et al., 2013; Nerur et al., 2005; Stare, 2013). Agile practices contribute to reduced waste and rework, rapid changes and innovation, early issue identification, environmental sustainability, and the ability to adapt quickly to new technologies and stakeholder priorities (Arefazar et al., 2022; Leybourne, 2009; Sertyesilisik, 2014b). Incorporating APM into construction is increasingly vital for sustainability and green building practices, aligning well with sustainable construction objectives and environmental stewardship (Franks and Vanclay, 2013). APM enhances transparency through direct communication, customer collaboration, and iterative feedback loops, in contrast to traditional methods where transparency may be less of a priority (Betta and Boronina, 2018; Betta and Jastrzębska, 2017).

APM can significantly support sustainability practices in construction by fostering adaptability, collaboration, and efficient resource management. The Agile Building Adaptation (AgiBuild) framework, for instance, emphasizes user-centric approaches and adaptability, which can drive innovation and enhance productivity in building adaptation projects, ultimately leading to more sustainable outcomes (Ng et al., 2023). Agile methodologies encourage a culture of continuous improvement and responsiveness to change, which aligns well with the dynamic nature of sustainability requirements in construction projects (Silva et al., 2022). By integrating agile practices, construction teams can better manage the economic, environmental, and social aspects of sustainability, ensuring that projects are not only completed efficiently but also meet high sustainability standards (Moshood et al., 2024). Furthermore, APM can facilitate the implementation of sustainability interventions by providing a structured yet flexible approach to project management, which is crucial for addressing the fragmented and diverse data typical in construction projects (Rodrigues et al., 2022).

In summary, the widespread adoption of APM across various sectors, including construction, can be attributed to its versatility, collaborative approach, and ability to manage complex and unforeseeable circumstances. Additionally, its focus on stakeholder participation, risk minimization, and sustainability further enhances its use as a solution for current project management challenges. Table 1 displays a compilation of 13 CSFs, which have been identified in the existing literature and are essential for the successful implementation of APM.

3 Research method and model development

Figure 1 illustrates the conceptual framework for this study, including the relationships between the identified CSFs and the successful implementation of APM. In this study, the drivers of integrating APM with sustainability practices in Nigerian construction projects are considered as the CSFs. As illustrated in Figure 2, this study utilized a quantitative research methodology, distributing a comprehensive questionnaire to residential building experts with substantial industry experience. The data obtained were analyzed by exploratory factor analysis (EFA) using the Statistical Package for the Social Sciences (SPSS).

PLS-SEM has become widely used in various fields, including social sciences, owing to its robustness in handling non-normal data and its effectiveness in modeling latent variables with smaller sample sizes (Henseler et al., 2016). Furthermore, studies that use PLS-SEM have been prominently featured in leading journals listed on the Social Sciences Citation Index (Banihashemi et al., 2017; Hult et al., 2018; Lee and Hallak, 2018). The most current version of the software, SMART-PLS 3.3.9, was used to perform the inferential analysis of the collected data. This inferential analysis aimed to explore the causal relationships between independent (exogenous) and dependent (endogenous) variables in relation to CSFs (Hair et al., 2017; Hair et al., 2011). The statistical analysis approach in this study included the evaluation of both measurement and structural models using appropriate techniques.

3.1 Data collection and case study

This study investigates the CSFs of APM within Nigeria's residential construction industry. To ensure the representativeness and relevance of our findings, we conducted a comprehensive demographic analysis of the survey participants. As detailed in Table 2, the respondents comprise a diverse mix of professionals, including contractors, consultants, clients,

TABLE 1 CSFs of APM in the construction industry.

Code	CSFs	Studies
CSF1	Adaptability to changing requirements	Macheridis (2009a), Salameh, 2014; Shenhar (2004)
CSF2	Improved collaboration among project teams	Hidalgo, 2019; Salameh (2014)
CSF3	Risk management, mitigation, and adaptation to uncertainties	Ahimbisibwe et al. (2015), Elkhatib et al. (2022)
CSF4	Enhanced stakeholder engagement	Rico et al. (2009), Salameh (2014)
CSF5	Managing complex projects	Harvett (2013), Hillson and Simon (2007), van Marrewijk et al. (2008)
CSF6	Efficient resource utilization	Cervone (2011), Masood and Farooq (2017)
CSF7	Faster delivery of projects	Masood and Farooq (2017), Sharma et al. (2012)
CSF8	Employee empowerment and engaged teams	Beck et al. (2013), Nerur et al., 2005; Stare (2013)
CSF9	Reduced waste and rework	Leybourne (2009), Sertyesilisik (2014a)
CSF10	Rapid changes and innovation	Arefazar et al. (2022), Hoda et al. (2008)
CSF11	Enhanced project quality and efficiency	Salameh (2014), Sharma et al. (2012)
CSF12	Sustainability and green building	Betta and Boronina (2018)
CSF13	Transparency	Betta and Boronina (2018)
CSF14	Empowered and engaged teams	Harvett (2013), Hillson and Simon (2007), van Marrewijk et al. (2008)
CSF15	Adjustment of scope in response to changing needs	Macheridis (2009b), Salameh, 2014; Shenhar (2004)

architects, engineers, and quantity surveyors. This varied demographic profile is crucial for capturing a broad spectrum of insights and experiences pertinent to APM implementation. To collect this data, we employed two non-probability sampling methods: purposive (judgment) sampling and snowball sampling. Purposive sampling was particularly efficient and cost-effective, enabling the selection of participants directly involved in or knowledgeable about APM in the construction sector. Conversely, snowball sampling expanded our coverage by leveraging the networks of initial respondents, who recommended additional professionals. This method effectively broadened the diversity of viewpoints by creating a referral network that enriched the study's data set.

The survey was structured into three sections: (1) respondents' demographic information; (2) inquiries about the APM CSFs listed in Table 1; and (3) open-ended questions to identify any CSFs deemed crucial by the respondents. The APM CSFs were evaluated using a 5-point Likert scale, with 5 indicating "extremely high", 4 signifying "high", 3 meaning "moderate", 2 signifying "low", and 1 indicating "none or very low". To determine the appropriate sample size, the methodological analysis recommended by Badewi (2016) suggested that a sample size exceeding 100 was suitable for survey studies. A total of 109 responses were obtained from 120 individuals, resulting in a response rate of 90%. This response rate was considered satisfactory based on the findings of previous studies (Kothari, 2004; Wahyuni, 2012).

3.2 Common method variance

The emergence of common method variance (CMV) can lead to common method bias (CMB), which can cause discrepancies in the results of analysis because of the measurement method rather than the constructs the measurements aim to represent. Conversely, the CMV is defined as an overlap in the variance attributed to the constructs and measurement instruments used (Podsakoff et al., 2003). CMV becomes particularly problematic when data are collected from a single source, such as a self-administered questionnaire (Glick et al., 1986; Strandholm et al., 2004). In these situations, self-reported data may introduce issues either by inflating or diminishing observed relationships (Strandholm et al., 2004; Williams et al., 1989). Given that this study relied on subjective, self-reported data from a single source, addressing these potential concerns to mitigate the impact of CMV is critical. To this end, a formal systematic one-factor test, as outlined in Harman's 1976 experiment, was implemented (Podsakoff et al., 2003). Factor analysis revealed that the dominant factor accounted for most of the variance, as noted by Strandholm et al. (2004).

3.3 Construct validity analysis

Assessing the measurement model, commonly known as confirmatory factor analysis, typically serves as the initial step in examining the PLS-SEM outcomes. Conversely, EFA was used to verify the statistical significance of the constructs before their aggregation into clusters (Williams et al., 2010). The EFA applies to data that possess either interval or ordinal properties, demonstrating that variables can exhibit varying degrees or no interconnectedness, as depicted in a scatterplot. The objective of EFA is to simplify factors into grouped categories that subsequently encompass a range of variables. The procedure is shown in Equation 1.

$$X_i = a_{i1}F_1 + a_{i2}F_2 + \ldots + a_{im}F_m + e_i \quad (1)$$

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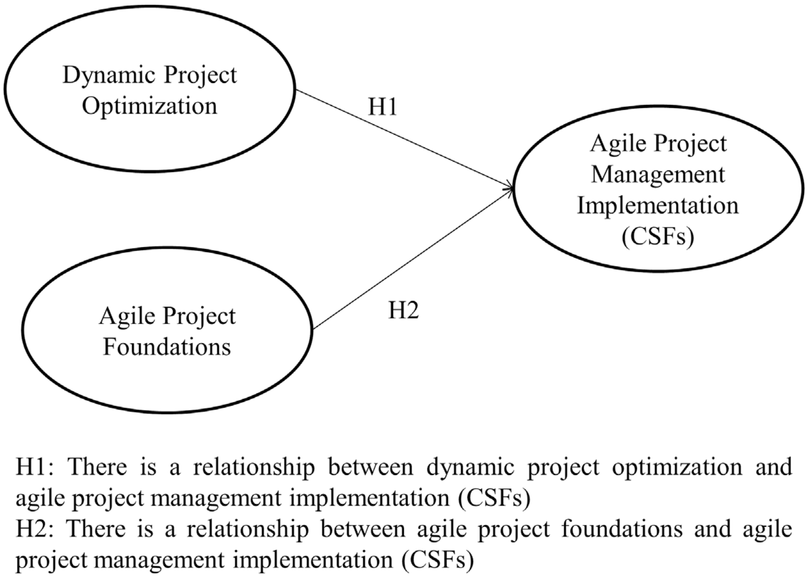

FIGURE 1
Research hypotheses.

Where, X_i represents the i^{th} standardized variable to be measured, a_i denotes the factor loading (or score) for the i^{th} variable, F is the factor under investigation, and e_i refers to the portion of the variable that remains unexplained by the factors.

For this research, EFA was used to uncover the foundational constructs central to the APM CSFs and to assess the measurement items of each construct for validity verification. Principal component analysis (PCA) is favored for its higher precision and simpler conceptual basis compared to alternatives such as alpha factoring, image factoring, maximum likelihood, and principal axis factoring (Field, 2009). As indicated by Williams et al. (2010), PCA is particularly effective in situations devoid of pre-established theories or models and when seeking initial solutions through EFA, making it the default option in numerous statistical software and a prevalent choice for EFA applications. The varimax rotation method was selected over direct oblimin or promax rotation because of its superior capability to optimize the distribution of loadings among variables. This advantage positions varimax as the preferred method for straightforward EFAs, offering an efficient method to facilitate the clustering of variables (factors) (Costello and Osborne, 2005). The analysis included 18 variables, all of which fit EFA (Olanrewaju et al., 2021).

3.4 Measurement model

To analyze the outcomes of PLS-SEM, the initial step involves evaluating the measurement (outer) model, also referred to as confirmatory factor analysis. This procedure elucidates the associations between observed variables and their underlying latent constructs (Al-Ashmori et al., 2020). Subsequently, the convergent and discriminant validity of the measurement model were assessed.

3.4.1 Convergent validity

Convergent validity is a measure of the extent to which various measures of the same construct cluster agree and is a subset of construct validity (Hulland, 1999). Multiple tests are typically conducted to evaluate convergent validity, including average variance extracted (AVE), Cronbach's alpha, and composite reliability (CR) (Fornell and Larcker, 1981). A CR value of 0.70 or higher is typically considered acceptable, while higher values for AVE, Cronbach's alpha, and CR indicate greater reliability (Wong and bulletin, 2013). AVE is a critical measure for assessing convergent validity and a value of 0.50 or higher, is required (Wong and bulletin, 2013).

3.4.2 Discriminant validity

This highlights the unique empirical nature of the phenomena under investigation, and the extent to which the model factors are distinct and not highly interconnected (Hair et al., 2010). To establish discriminant validity, the similarity between the measures designed to be disparate must remain insignificant.

3.5 Structural model

The primary objective of this study is to investigate the effect of CSFs of APM on the construction industry. This entails determining the causal relationship between the CSFs of APM constructs (£) and the implementation of APM CSFs (µ) in a unidirectional manner. Equation 2 illustrates the structural relationship between £, µ, and €1 within the structural model (inner relationship), as detailed by Zaid Alkilani (2018).

$$\mu = \beta £ + €1 \qquad (2)$$

Where (β) is the path route coefficient that links the CSFs of the APM construct, and the residual variance at this structural level is

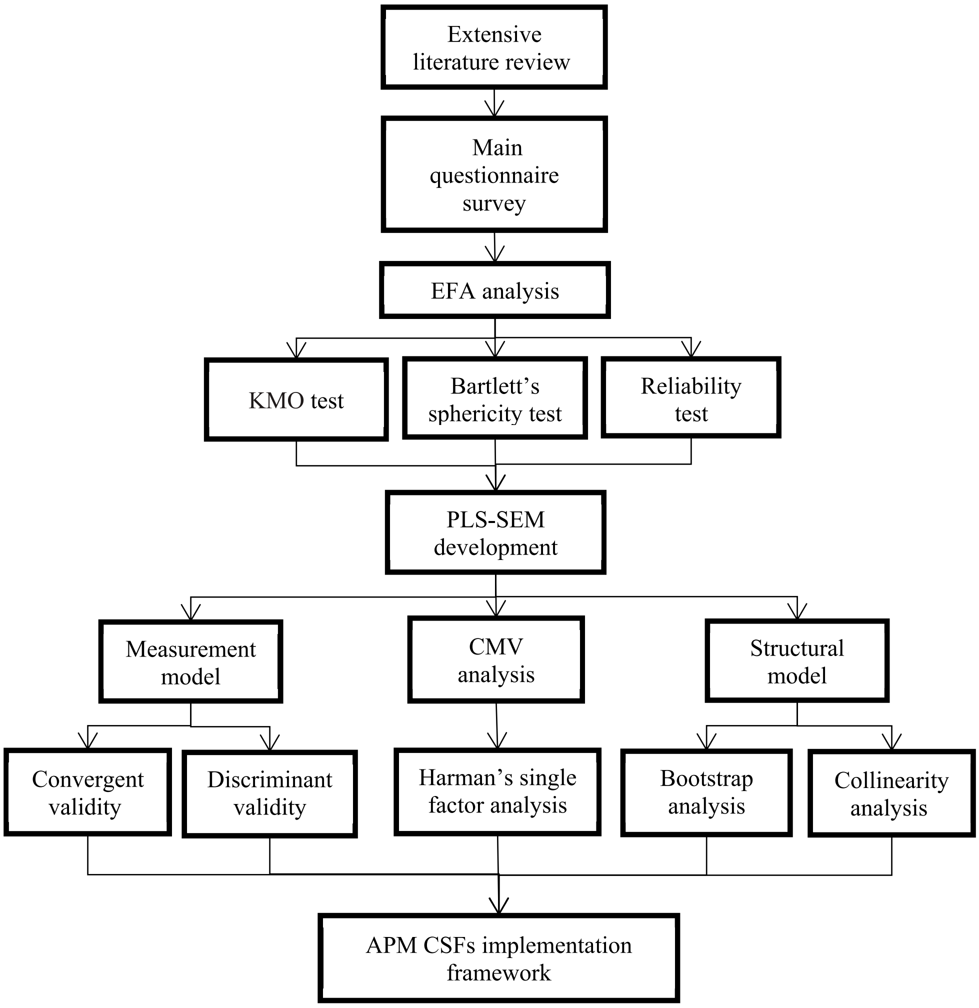

FIGURE 2
Research design.

predicted to reside in Equation 1. This equation can be found here: In addition, the weight of the standardized regression is denoted by the symbol, which is the same as the weight of the multiple regression model. To determine whether the path coefficient, denoted by, was statistically significant, a bootstrapping method included in the Smart PLS program was utilized to calculate the standard deviations of the path coefficients. In accordance with the study by (Henseler et al., 2016), the bootstrap was carried out with 5,000 subsamples which defined the t-statistics for the model. For the PLS Model, four structural equations for the APM CSFs constructs were formulated, which represented the inner relationship between the constructs and Equation 2.

4 Data analysis and results

4.1 Common method bias

CMB is a type of inconsistency or measurement error that can compromise the validity of research findings. Costello and Osborne (2005) defined the systematic error variance connected with both estimated and measured variables. One commonly used method to assess this bias is Harman's single-factor test, which evaluates various structural dimensions (Demirkesen and Tezel, 2022). In this study, we employed a single-factor test to gauge the variance attributed to the standard method (Olanrewaju et al., 2021). When the total variance accounted for by the factors was less than 50%, CMB did not significantly influence the results. The results indicated that the primary group of factors contributed 21.75% of the total variance, suggesting that CMB did not notably impact the findings, as it was well below the 50% criterion (Demirkesen and Tezel, 2022).

4.2 Exploratory factor analysis

Table 3 presents the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, which confirms that the collected data are appropriate for factor analysis. Furthermore, Bartlett's test of Sphericity demonstrated a significant correlation between the

TABLE 2 Demographic profile of survey respondents.

Demographic feature	Categories	Number of respondents	Percentage (%)
Professional role	Contractors	30	28
	Consultants	35	32
	Clients	25	23
	Others (Architects, Engineers, Quantity Surveyors)	19	17
Experience	Less than 5 years	40	37
	5–10 years	35	32
	More than 10 years	34	31
Educational background	High school diploma	10	9
	Bachelor's degree	55	50
	Master's degree or higher	39	36
	Other certifications	5	5
Age group	Under 25	15	14
	25–34	50	46
	35–44	25	23
	45–54	10	9
	55 and above	9	8

variables. This test evaluates the feasibility of conducting factor analysis on the data or samples in question.

The KMO measure, set at 0.964, indicated that 96.4% of the collected data were suitable for factor analysis. As shown in Table 3, the *p*-value is less than 0.05, indicating that the data are ready for factor analysis, with a degree of freedom of 120 and an approximate chi-square of 1548.535. Additionally, Bartlett's test yielded a highly significant result (*p*-value = 0.000), suggesting that the correlation constitutes an identity matrix. This indicates a significant correlation at the 5% level among all items listed, making EFA appropriate.

In PCA, loadings are used to indicate the correlation between a factor and an original variable, serving as a measure of the factor's ability to explain the variable. The loadings are used to classify the variables into three distinct levels of contribution to Factor 1, namely, high, medium, and low. These classifications are then used to group the CSFs into two categories: dynamic project optimization

TABLE 3 Drivers for integration of KMO and Barlett's test.

KMO and Bartlett's test		
Kaiser-Meyer-Olkin measure of sampling adequacy		0.964
Bartlett's test of sphericity	Approx. Chi-Square	1548.525
	Df	120
	Sig	0

and agile project foundations. The categorization is based on the contribution of each CSF to Factor 1 and serves as a useful tool for analyzing the relative importance of each factor in the context of a project. Table 4 shows the rotated component matrix of the problems associated with APM and it is grouped into four factors, namely, agile project foundation and dynamic project optimization.

4.3 Structural equation modeling

4.3.1 Convergent validity

Evaluating reflective measurement models using PLS-SEM requires an assessment of convergent validity, discriminant validity, and internal reliability. Once the reliability and validity of the measurement model were established, the structural model was evaluated (Hair et al., 2010). As shown in Table 5, all constructs in the model meet the specified thresholds (with values >0.70), which denotes their acceptability (Hair et al., 2016).

Table 5 presents evidence that the constructs exhibit satisfactory levels of internal consistency, as their AVE values are greater than 0.5 (Fornell and Larcker, 1981). This suggests that the measurement model has a strong internal consistency and convergence. Moreover, these results imply that the indicators used to measure each construct are precise and distinct from one another. The high outer loadings observed for the items associated with each construct indicate a strong association between them. According to the recommended threshold, items with outer loadings below 0.4 should be excluded (Hair et al., 2011). As illustrated in Figure 3, all items in the measurement models met the acceptable criteria for outer loading.

4.3.2 Discriminant validity

Table 6 indicates that the square roots of the AVE values have stronger correlations within their respective constructs than with any other construct. This finding suggests that there were no prior links between the constructs. Furthermore, the data show that every predictor achieved its highest loading on the intended construct, emphasizing the adequacy of the constructs. This indicates that a significant degree of one-dimensionality can be achieved for each construct.

4.3.3 Path model validation

The variance inflation factor (VIF) was assessed to evaluate the extent of collinearity among the formative indicators of the constructs. In this study, the VIF values for all indicators were below

TABLE 4 Dynamic project optimization.

Factor component	Code	CSFs	Loading
Agile project foundation	CSF1	Adaptability to changing requirements	0.79
	CSF2	Improved collaboration among project teams	0.664
	CSF3	Risk management and mitigation and adaptation to uncertainties	0.674
	CSF4	Enhanced stakeholder engagement	0.65
	CSF5	Managing complex projects	0.86
	CSF6	Efficient resource utilization	0.67
Dynamic project optimization	CSF13	Transparency	0.889
	CSF14	Empowered and engaged teams	0.788
	CSF7	Faster delivery of projects	0.745
	CSF8	Employee empowerment and engaged teams	0.641
	CSF9	Reduced waste and rework	0.71
	CSF10	Rapid changes and innovation	0.82
	CSF11	Enhanced project quality and efficiency	0.740
	CSF12	Sustainability and green building	0.90

TABLE 5 The result of convergent validity.

Constructs	Cronbach's alpha	Composite reliability	Average variance extracted
Agile project foundations	0.924	0.941	0.726
Dynamic project optimization	0.948	0.956	0.706

3.5, suggesting that the subdomains made a substantial contribution to higher-level constructs. Additionally, bootstrapping was applied to determine the statistical significance of the path coefficients, which showed that all paths were statistically significant, as shown in Figure 4 and detailed in Table 7 (Hulland, 1999).

5 Discussion

The results of the SEM analysis show that the implementation of APM for sustainable residential building projects is closely aligned with the findings of Macheridis (2009b) and Salameh (2014). These scholars emphasized the intricate nature of the construction industry and its business processes. Projects involve various stakeholders such as strategic suppliers, outsourced vendors, diverse customers, partnerships, and competitors, which require a flexible and adaptable project management approach to meet the varying demands and ensure timely delivery of services and products to achieve project completion and customer satisfaction.

The findings of the SEM highlight the significance of adaptability to evolving requirements, heightened collaboration among project teams, intensified stakeholder engagement, and optimum resource utilization as essential success factors in the agile project framework. These elements are crucial for managing intricacies and nurturing a cooperative atmosphere with all parties involved, including suppliers, vendors, and customers. Agile methodologies, with their focus on flexibility, relentless improvement, and stakeholder involvement, equip project managers with the requisite means to tackle these challenges efficiently.

The dynamic project optimization framework is designed to handle complex construction projects, incorporating rapid changes and innovation while emphasizing sustainability and green building practices. This framework recognizes the importance of adapting to the complex and dynamic environments of today's construction projects. By prioritizing efficient and sustainable project completion, this framework caters to the need for quick service delivery and high levels of customer satisfaction.

Therefore, the results of the SEM analysis not only confirm the CSFs recognized for the effective implementation of APM in the construction sector but also corroborate the claims made by Salameh (2014) and Macheridis (2009b). This underscores the importance of adopting a flexible and adaptive project management approach to navigate the intricate nature of contemporary construction projects and to achieve timely, efficient, and satisfactory results for all stakeholders involved. The alignment between the outcomes

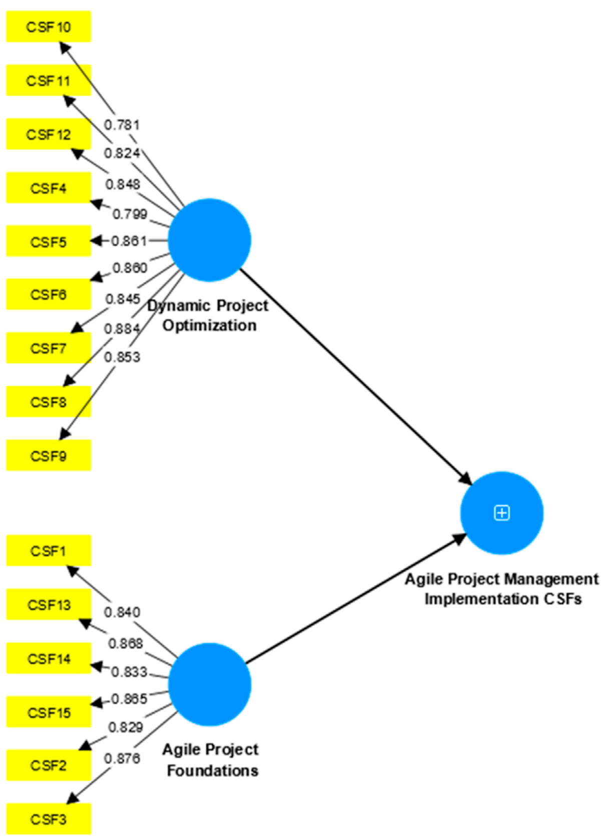

FIGURE 3
The PLS-SEM model.

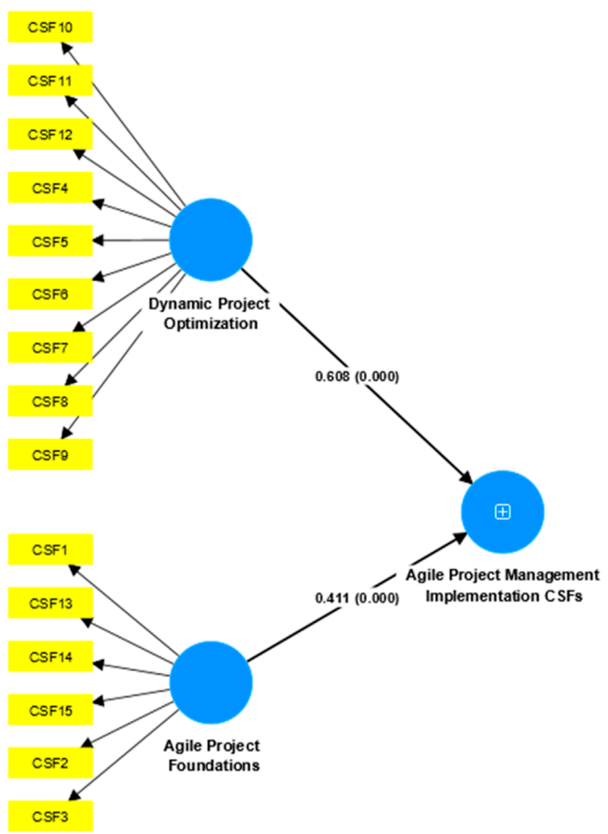

FIGURE 4
The PLS-SEM structural model.

TABLE 6 Discriminant validity.

	Agile project foundation	Dynamic project optimization
Agile project foundation	0.852	
Dynamic project optimization	0.924	0.840

TABLE 7 Results of structural model analysis.

Path	Standardized coefficient (β)	*p*-value	Decision
Dynamic project optimization → Agile project management implementation CSFs	0.693	<0.001	Supported
Agile project foundations → Agile project management implementation CSFs	0.411	<0.001	Supported

of the SEM analysis and observations made by Salameh and Mecheridis highlights the relevance and applicability of APM methodologies in addressing the present challenges confronting the construction industry.

5.1 Managerial implications

- The development of the final model, based on CSFs, provides an exemplary blueprint for residential building professionals (such as contractors, project owners, and stakeholders) to implement APM more effectively in their projects. It acts as a benchmarking tool or framework to enable successful transformation within the processes and operations of the construction industry through APM. This transformation is crucial for developing countries such as Nigeria, aiming for a competitive, stable, and sustainable economic landscape. The model and roadmap developed in this study highlight the urgency of emerging economies to foster the adoption of APM methodologies (Oke and Aghimien, 2018). This push is vital because these countries often face hurdles in embracing new technologies, including cost constraints, technological expertise, and a widespread lack of awareness of APM methodologies. As illustrated in this study, APM methodologies offer a pathway for embedding sustainability and other key innovations into the design phases of construction projects (Kineber et al., 2023; Oke et al., 2023). Consequently, this study enriches the literature by detailing various ways in which APM can advance the construction industry.

- First, this research creates a foundation for understanding the standards of the APM methodology and the factors that affect them, aiming to evaluate their potential for success and growth in the global market through the integration of the APM methodology.
- Second, it advocates for professionals in the residential building sector (including contractors, project owners, and stakeholders) to initiate the adoption of APM methodology in their projects, enhancing the effectiveness, planning, constructability, and uniformity of their construction.
- Third, it offers concrete evidence to developing countries such as Nigeria that the advantages of embracing APM far surpass its limitations.
- Fourth, developed countries have led the application and research of the APM methodology. Countries such as Australia, China, Hong Kong, Saudi Arabia, the United Kingdom, and the United States have been researching the impact of APM methodology on their construction industries. With limited research in the context of developing countries, including Nigeria, this study promotes a shift from traditional construction practices to a more digitalized method. This study bridges a significant gap by introducing APM to the Nigerian construction industry. This serves as a reference for future research on integrating the APM methodology into Nigeria's construction industry processes and activities.
- This study also stands out for its methodological contribution. Previous research on APM in the construction industry has often relied on a range of statistical techniques such as analysis of variance, content analysis, multiple analysis of variance, and regression modeling. By adopting PLS-SEM, this study overcame the limitations associated with traditional first-generation analysis methods.
- This study additionally provides a thorough insight into the myriad motivations behind adopting and deploying the APM methodology in the construction industry's procedures and actions. Beyond fostering sustainability in projects, the APM methodology can contribute to the timely completion of projects, enhance information flow throughout the organization, increase efficiency in operations, improve communication processes, encourage innovation, heighten the international competitiveness of construction project delivery, and enhance return on investment, among others.
- This research additionally offers residential building professionals (such as contractors, project owners, and stakeholders) insights into how to embed APM methodology within the construction industry, thereby boosting project performance.
- Moreover, this study provides substantial benefits to regulatory bodies within the construction sector, particularly in policy formulation aimed at integrating this technology into the updated regulatory framework of the construction industry (Kineber et al., 2023; Oke et al., 2023). By analyzing the CSFs and integration factors, the APM methodology can be smoothly and incrementally introduced into Nigerian construction processes.

5.2 Theoretical implications

Although the concept of sustainable development is not new, it plays a crucial role in shaping perceptions of the construction industry's operations and activities (Broccardo and Zicari, 2020; Baldassare et al., 2020). This study highlights the significance of integrating the APM methodology in constructing sustainable residential projects. It aims to identify and assess the CSFs necessary for implementing the APM methodology in developing countries, with Nigeria serving as a focal point. The evaluation of these CSFs was essential in navigating the challenges of APM's successful deployment in Nigeria's construction sector. This study presents a unique aim as APM CSFs have not been examined previously in the Nigerian context. Thus, this study established a benchmark for future research on the integration of APM into the practices and processes of Nigeria's construction industry. The two constructs of the APM CSFs were rigorously tested using PLS-SEM, with insights derived from both the analysis and bootstrapping methods (Hair et al., 2010).

6 Conclusion

APM methodology is regarded as an essential tool for enhancing value and promoting project goals and sustainability worldwide. However, its adoption in developing countries has progressed slowly and significant strides are still required. In places such as Nigeria, the integration of the APM methodology faces numerous obstacles, which have led to uneven progress in infrastructure development. Implementing the APM methodology in Nigeria's construction sector is a key strategy to address these issues.

This study leveraged PLS-SEM to investigate the CSFs for applying the APM methodology in Nigeria's construction industry. The CSFs identified in the literature underwent EFA before further investigation using PLS-SEM. This study's reliance on a purely quantitative analysis to assess CSFs is a limitation. Future research could enhance the robustness by incorporating qualitative or mixed-method approaches to address the drawbacks of a single-method approach. The use of purposive and snowball sampling methods in this study also restricts the generalizability of the findings to a broader population.

While this study provides valuable insights into the CSFs for APM implementation in Nigeria's construction industry, several limitations should be acknowledged. The reliance on a purely quantitative analysis limits the depth of understanding that could be gained from qualitative insights. Future research should consider employing qualitative or mixed-method approaches to provide a more comprehensive analysis of the CSFs. Furthermore, the sampling methods used, purposive and snowball sampling, may introduce biases and limit the generalizability of the findings. Future studies should explore alternative sampling strategies to minimize these biases and enhance the representativeness of the results.

In conclusion, while this study sheds light on the critical factors for APM adoption in the Nigerian construction sector, ongoing research is needed to refine these findings and support the broader application of APM principles in diverse construction environments. Future research should also investigate the long-term impacts of APM implementation on project outcomes and sustainability in developing countries.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AK: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing–original draft, Writing–review and editing. AO: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing–original draft, Writing–review and editing. NE: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing–original draft, Writing–review and editing. ZA: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing–original draft, Writing–review and editing. ME: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing–original draft, Writing–review and editing. AZ: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing–original draft, Writing–review and editing. MA: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing–original draft, Writing–review and editing. SI: Project administration, Resources, Software, Supervision, Validation, Visualization, Writing–original draft, Writing–review and editing, Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This study is supported via funding from Prince Sattam bin Abdulaziz University project number (PSAU/2024/R/1445). Furthermore, the authors express their gratitude to the Middle East University in Amman, Jordan for providing financial support to cover the publication fees associated with this research article.

Acknowledgments

The authors express their gratitude to the Middle East University in Jordan for providing financial support to cover the publication fees associated with this research article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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