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EVALUATING THE SUCCESS FACTORS OF POLYURETHANE COATINGS SUSTAINABLE CONSTRUCTION MANAGEMENT: IMPLICATIONS FOR GOVERNMENT POLICY

Mishal H. Aljarbou[1]

[1]Department of Civil and Environmental Engineering, College of Engineering, Majmaah University, Al-Majmaah , 11952, Saudi Arabia,

m.aljarbou@mu.edu.sa[1]

Abstract

The increasing focus on sustainability in the construction industry has emphasized the need for innovative materials such as Polyurethane Coatings (PUCs) to enhance the durability and performance of construction projects. Despite their potential benefits, including fire resistance, water resistance, and flexibility, PUCs are primarily utilized in large-scale projects, leaving a significant gap in their adoption in small to medium-sized construction initiatives. This study aims to evaluate the key success factors for the effective implementation of PUCs in construction projects and their impact on performance, sustainability, functionality, and aesthetics. A mixed-methods approach was adopted, beginning with a pilot survey to identify success factors from existing global literature. Exploratory Factor Analysis (EFA) was conducted on the pilot data, resulting in the identification of four critical constructs. A quantitative survey followed, targeting construction project personnel, with data analyzed using Structural Equation Modeling (SEM) to develop a structural model. The results demonstrate a significant relationship between sustainability and the successful implementation of PUCs, supported by robust model reliability and validity. This research addresses the theoretical gap in understanding the broader application of PUCs and provides actionable insights for stakeholders aiming to integrate these coatings into sustainable construction practices. The findings offer a framework for future research and practical recommendations for expanding the adoption of PUCs, particularly in small to medium-sized projects, to drive sustainability and innovation in the construction sector.

Keywords: Polyurethane Coatings, Sustainability, Construction Projects, Success Factors, Structural Equation Modeling.

1 Introduction

In the last decade, the construction industry has been gradually shifting its focus towards sustainability considering environmental concerns and energy efficiency imperatives. The use of Polyurethane Coatings has been one of the modern ways through which sustainability can be increasingly realized in construction [1]. PUC has various advantages, including durability, fire resistance, flexibility, and water resistance, thereby making it a very good choice for enhancing durability and performance in constructing materials [2]. Given the growing concerns related to environmental impact and the need for efficiency in construction practices, PUCs actually offer opportunities to increase overall performance in building projects while reducing waste, resource use, and maintenance [3].

Even then, PUCs find their applications in large-scale construction projects. Most small and medium-scale construction projects have not fully enchased the benefits accruable from PUC, which is a limitation to wider diffusion in the industry [4]. This, therefore, creates the potential to improve sustainability and performance of construction material; a detailed analysis of the drivers of successful application of PUC on a construction project is highly essential.

Although Polyurethane Coating has a lot of benefits, it is still not widely used in the construction industry, especially in the smaller and medium category of projects. While big projects were quickly able to employ PUC in their building materials, smaller construction efforts were slower. According to the main reasons mentioned in the study, this disparity is due to lack of understanding of the performance benefits, application costs, and environmental advantages of PUCs. Moreover, existing studies have focused primarily on the material's performance in controlled environments; thus, there is a lack of input on practical application and success factors in real construction projects.

While the advantages of Polyurethane Coatings, especially resistance to fire and efficiency in the consumption of energy, particularly in mega projects, have been reviewed in the current literature, there still exists a wide gap in addressing those factors affecting the successful application of PUCs among different kinds and scales of construction projects, especially among the small and medium scale sectors. Besides, very few studies focus on the sustainability issues of PUCs with respect to their long-term environmental impact and economic viability. Understanding these success factors can bridge the knowledge gap and enable the wider adoption of PUC in a broader range of construction projects.

The primary objective of this research is to identify the success factors and evaluate the positive impact of Polyurethane Coatings (PUC) in construction projects. Specifically, the study aims to:

Identify the key factors that contribute to the successful implementation of PUC in construction projects.

Evaluate the positive impact of PUC on enhancing the performance, sustainability, and aesthetic value of construction projects.

This will be an important study in that it provides a comprehensive perspective on the factors of successful adoption in construction projects, especially small-scale ones of Polyurethane Coatings. Using identifications and analyses, the study should henceforth be able to make recommendations for stakeholders in the construction industry through which they can make informed decisions in using PUC on sustainable building practices. This is novel research, as opposed to the existing controlled and laboratory-based studies of PUC in real construction project settings. The study also bridges the gap that has hitherto existed between the technical performance of PUC and implementation for sustainability enhancement by giving a comprehensive framework for future application.

2 Related Work

According to studies, PUCs offer better fire protection compared to standard coatings, hence safer for building projects. According to Maj et al. (2018) and Szafran & Matusiak (2020), PUCs had limited fire spread and low smoke generation, hence suitable for application on sites that raise fire safety concerns [5], [6]. The research studied the effect of PUCs on the energy efficiency of building projects. The research highlighted identifying how PUCs could reduce energy use by improving the thermal performance of building elements, increasing the energy efficiency of housing units, and reducing heating and cooling costs. Here, the researchers investigated the effect of PUCs on the mechanical properties of the construction materials [7]. These findings proved that PUCs can enhance strength, rigidity, and tensile strength of building components; hence, making them resistant to damage and deterioration. Other literature analyzes the effects of PUC with respect to the thermal performance of the building components within. Królikowska & Augustyński 2016 and Mohotti et al. 2021 note that the use of PUCs may result in a gain concerning the main benefits-therein of reducing heat transfer and penetration between building components, improving the dwellings' thermal performance, and energy consumption reduction [8], [9]. It also discusses the impact of the PUCs on the resistance of environmental stresses such as water, moisture, and UV radiation. From the study done by J. Liu et al. in 2022, it was evident that PUC can protect building components against ecological exposure and hence are durable and dependable for building projects [10]. Study of indoor air quality during building projects considering the impacts of PUCs is discussed. PUCs have the ability to reduce VOCs indoors, thus enhancing indoor air quality and generally making homes a safer and healthier place.

The impact of PUC in extending the service life of the building components is discussed. Kalamees, Põldaru, et al. (2020), and Yang et al. (2020) determined that the PUCs may extend the lifetime of the building elements through protection against environmental stresses and physical deterioration [11], [12]. It examines the impact that PUCs will have on the sustainability of the building projects. Daee & El Naggar 2016, and Y. Zhang et al. 2019 established that PUCs can reduce the footprint of dwellings through energy efficiency gains, reduction in waste, and conservation of resources [13], [14]. This research studied the effect of using PUCs in building projects concerning efficiency and speed. Some evidence proved that PUCs could be used to speed up the process of building by reducing time and effort on surface finishing and sealing. One of the studies investigated how the use of PUCs affected the aesthetic appeal of building projects. J. Li et al. (2020) and Jianhua Xu et al. (2018) indicated that PUCs can offer some enhanced aesthetic appeal to structures due to their smooth, shiny, and durable surface finish [15], [16]. The paper explores the impact of PUC on fire resistance in building projects. According to B, the researchers indicated that PUC can impart strength to fire resistance through the delay of the dissemination rate of the fights and minimizing smoke and dangerous chemical fumes during fire outbreaks. Reference Li et al., 2019 Jun Hyeok Song & Eun, 2021 The Paper reviews the impact of PUC on the sound proofing of building Projects [17], [18]. The research discovered that PUCs might increase good insulation by lowering noise transmission across rooms and among the interior and exterior of dwellings.

In this research, PUCs on water resistance are studied for a building project. X. Chen et al. found that the use of PUC could prevent moisture from seeping into the building component to cause damage [19]. PUC's influence on the thermal insulation material in building projects was investigated by the author. Che et al. (2019) illustrated that PUCs have the potential to increase thermal insulation through reduced heat transfer hence leveraging energy efficiency in structures [20]. It looked into how PUC might impact the maintenance demands over the life of the building projects. Indeed, Arzhakov et al. (2021), and Attard & Soltanid, 2020) determined that the PUCs can save time and resources on maintenance and upkeep by offering a resilient and durable surface finish [21], [22]. This study investigates the impacts of PUCs mainly on the durability aspects of building projects. The study has identified that PUCs can increase the durability of housing by offering a weathering-resistant surface or wear and tear. Sun et al. (2021) and Parniani & Toutanji (2015) researched the effects of using the PUC as it relates to sustainability in building projects [23], [24]. The study revealed that PUCs improve house sustainability by reducing energy demand for heating and cooling, besides embodied carbon integrated into building and maintenance.

These C.-C. Chen & Linzell (2014) and Jang et al. (2022) show the various advantages and benefits that PUCs can offer in building projects and point out that this area shall be further studied for complete understanding of the possible offering of this new type of material [25], [26]. Gao et al. (2019) indicate that using PUCs in building projects may provide a variety of advantages, such as excellent durability, sustainability, environmental friendliness, cost-effectiveness, and aesthetic appeal [27]. Various potential benefits in building projects of PUCs are outstanding durability, sustainability, eco-friendliness, cost-effectiveness, and aesthetic appeal according to Gao et al.

(2019) [42]. Though there is still a lot to learn about this revolutionary material, this current research points to a promising outlook for the usage of PUCs in the building sector. Initial findings clearly suggest that PUCs hold huge possibilities for transforming home building and maintenance[27].

Table 1 Identified success factors.

Code	Description	References
R1	PUCs are resistant to fire and may aid in protecting homes from fire damage.	[28], [29]
R2	PUCs may enhance the acoustics of homes by minimizing noise transmission between rooms and between the building's interior and outside.	[30], [31]
R3	The rapid curing of PUCs expedites the completion of building projects and minimizes downtime.	[7], [32]
R4	PUCs may be applied to several surfaces, including concrete, wood, and metal, making them appropriate for various building projects.	[5], [9]
R5	PUCs offer outstanding water resistance, making them appropriate for usage humid and wet environments.	[36], [41]
R6	PUCs offer a high level of resistance to chemicals and substances such as oil, gas, and other pollutants, which is crucial in building projects where exposure to these compounds is a worry.	[33], [34]
R7	PUCs may aid in boosting the energy efficiency of buildings by decreasing air penetration and increasing insulation.	[6], [7]
R8	PUCs are often more sustainable than conventional coatings because they have a longer lifetime, decreasing the need for frequent replacement.	[17], [20]
R9	PUCs are resistant to mold development, which may improve indoor air quality and minimize the risk of health issues in structures.	[21], [22]
R10	Applying PUCs may improve the aesthetics of homes and raise their value.	[35], [36]
R11	PUCs may be applied fast, shortening the home-building project duration.	[37], [38]
R12	PUCs are very flexible and can accept movement, making them excellent for projects where surfaces may expand and contract due to temperature fluctuations.	[35], [39]
R13	PUCs are renowned for their exceptional resistance to wear and tear and long-lasting performance.	[28], [30]
R14	PUCs are low-emitting and do not contain dangerous VOCs, helping enhance the air quality within dwellings.	[29]
R15	PUCs are often more ecologically friendly than conventional coatings since they release fewer VOCs (volatile organic compounds) and have a more negligible environmental effect.	[40]
R16	PUCs are available in many colors and textures, allowing for customization and some design possibilities in building projects.	[36], [41]
R17	PUCs are non-toxic, non-combustible, and acceptable for building projects. This may offer homeowners peace of mind and additional safety.	[42], [43]
R18	PUCs need less periodic washing to maintain their brand-new appearance.	[44], [45]

3 Methodology

In this study, statically techniques have been adopted to identify the success factors for adopting PUC. The methodology is shown in Figure 1. The quantitative analysis is taken out among the experts. Once the analysis has been done, and the model has been developed, a validation survey is carried out in which 20 experts have been contacted and questioned about the validation and agreement of the model.

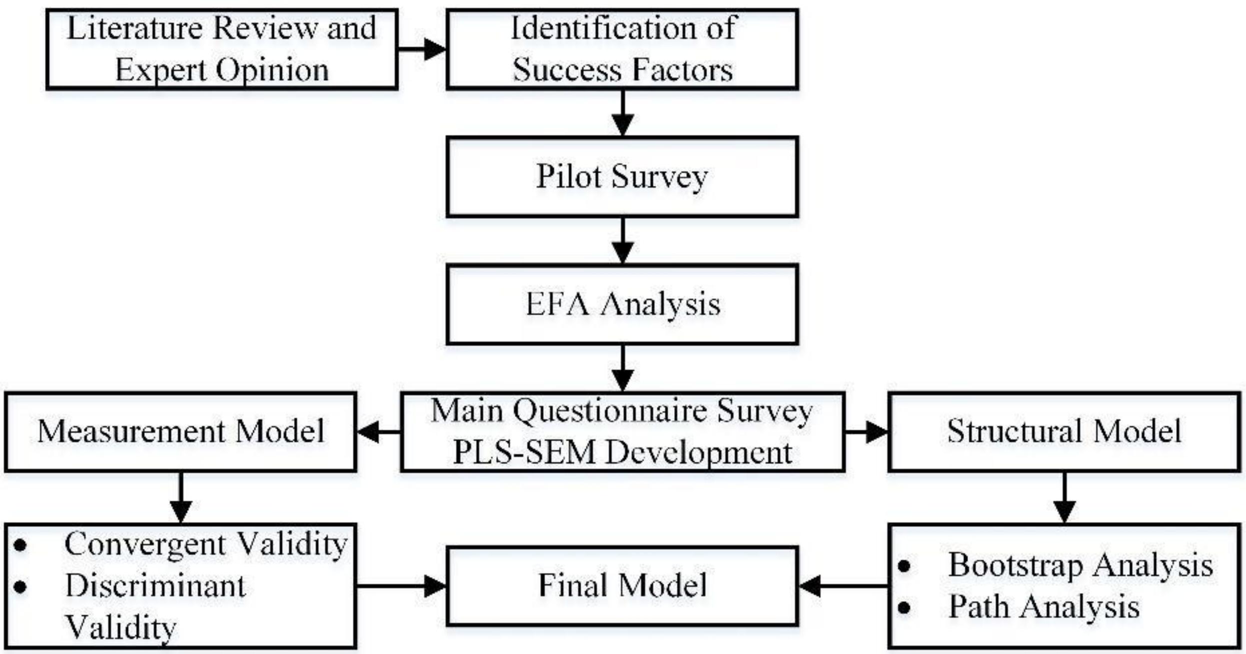

Figure 1 Flow chart of study

3.1 Questionnaire Survey

3.1.1 Exploratory Factor Analysis

In this research, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were used to analyze the success of employing PUC paint in building projects. The EFA was used to explore the connections between distinct components and reduce the variables into interpretable forms. EFA also used principal component analysis (PCA) to produce early findings. The Varimax rotation method is used to guide the Oblimin or Promax rotation to facilitate a reduction in the dispersion of loads between the parameters. This method is appropriate for PCA because it provides the ability to generate an archetypical sample within the limits of requirement. Based on 23 metrics and questionnaires, this study samples data from 207 individuals of medium to small sized Saudi Arabian companies with an age limit of between 18 and 65 years. [36], [42]. Data obtained were sufficient for PCA and gave a very good overview of the effectiveness of adopting PUCs in building projects. In this work, the respondents were asked to give on a Likert-scale material the effectiveness of adopting PUC in building projects. The questionnaires were targeted at eliciting materials involving several aspects of PUC adoption, namely, durability, wear and tear resistance, ease of application, and cost-effectiveness. This information was then analyzed using both EFA and CFA to determine the most important factors contributing to the success of PUC adoption in this business [28], [30]. From these EFA and CFA results, one could develop a complete model that shows the major elements contributing to success when using PUC in building projects. This model can be used to help construction experts, contractors, and legislators assess the possible benefits and disadvantages of adopting PUC in this industry. PCA has been really important in this research since it allowed reducing so big a number of variables to just some interpretable components. It would be easy to see links between various features and understand what was lying underneath the structure of the data.

In conclusion, the findings of this research are likely to give valuable insights into the success of employing PUC in building projects [35], [39]. The results of this research will be helpful for the building industry and other nations experiencing similar issues in the construction sector. This study is a step towards a more sustainable future in construction. It emphasizes the potential of PUC to enhance the durability and lifetime of building projects.

3.2 Development of PLS-SEM Model

The Structural Equation Modeling (SEM) approach is a rigorous analytical tool that has garnered widespread acceptance across various disciplines, notably in the business and social sciences. This method uses mathematical models to analyze and comprehend the connections between various factors and the structure that these variables form. Numerous studies have used SEM to study a wide range of research issues, and the results of these investigations have been published in respectable academic journals [36], [41], [43].

In the current study, cutting-edge smart PLS 4 software was used for data analysis and modeling of the significance of PUC construction projects. The decision of SEM was predicated on the fact that it can give a comprehensive examination of the efficiency of using this coating technique in the corporate environment [35], [43]. The statistical analysis included measurement methods and structural assessment, allowing for a comprehensive examination of the findings. The results of this study are expected to provide substantial insights into the benefits and drawbacks of employing PUC in construction projects.

3.3 Common Method Bias

Common method bias is the systematic mistake that arises in measuring a variable when a single common technique is used to gather data from all participants. Harman Single Factor Analysis is a widely used technique for detecting typical method bias in scientific investigations and examining the structure of the correlation matrix to evaluate whether a single component accounts for a substantial percentage of the data's variability [29]. If a single element accounts for a significant variance of less than 50 percent, it shows that a common approach may impact the findings and that more research is required to address this bias. The Harman Single Factor Analysis offers researchers vital information to consider when interpreting their study's results and making required modifications to reduce the influence of typical technique bias on their findings.

3.4 Measurement Model

The measurement model is an essential component of structural equation modeling and is used to assess the validity and reliability of the gathered data. This research examined two features of the measurement model: convergent validity as well as discriminant validity. Three tests were used to examine convergent validity: Cronbach Alpha, Average Variance Extracted (AVE), and composite reliability. These test results were used to estimate the minimum valid range for convergent validity [33], [46]. The Cronbach Alpha test determines the internal consistency of the data, with a minimum acceptable range of 0.7. AVE evaluates the number of data variables the constructs can explain; a range of at least 0.5 is considered good. Composite reliability quantifies the total dependability of the data, with a minimum acceptable range of 0.70.

Three tests were used to assess discriminant validity: cross-loading, the Heterotrait-Monotrait Ratio of Correlations (HTMT), and the Fornell-Larcker criteria. The cross-loading test assesses the correlation between latent variables and indicators with a minimum acceptable range of 0.30. Cross-loading is an additional way to evaluate discriminant validity. In this strategy, a particular object must have a more significant loading on its parent construct than other constructions in the research [7], [8]. If an item loads more strongly onto a different construct than its parent construct, it suggests a discriminant validity problem. An HTMT score near 1 implies a lack of discriminant validity since it shows that the two components are too closely connected. It is compared to a predetermined threshold to assess if the HTMT has discriminant validity. Some sources recommend a point of 0.85 [9], [33]. If the value of the HTMT exceeds this level, it might be stated that discriminant validity is lacking. In Structural Equation Modeling, the Fornell-Larker criterion is another way to evaluate discriminant validity (SEM). The requirements consist of two components: (1) the square root of each construct's Average Variance Extracted (AVE) is more significant than its correlation with another construct, and (2) each item loads most heavily on its corresponding construct. The first component of the criterion guarantees that the variance recorded by each construct is distinct [13], [14].

In contrast, the second component ensures that each item predominantly measures the construct it is supposed to measure. To satisfy the Fornell-Larker criterion, the findings of the SEM analysis must indicate that the square root of the AVE for each construct is more prominent than its correlation with other constructs and that each item loads most heavily on the related construct. This criterion contributes to the validity and dependability of SEM findings [7], [46]. The measurement model was assessed using the SMART-PLS program, which proved to be an efficient instrument for determining the data's reliability and validity [47], [48]. The analytical findings determined each test's minimum and maximum value ranges.

4 Results

4.1 Exploratory Factor Analysis

The following Table 2 presents the rotating component matrix of exploratory factor analysis. A total of 4 components are found to be significant concerning the evaluation of all the factors. R8 is excluded from the results because it has shown less than 0.5-factor loading, the minimum acceptable limit for this test. The reliability status for each of the constructs is presented in the last column of the table, which is also significant as all the values of the reliability constant is greater than 0.7 [49], [50]. This effectively confirms the availability of results, while the net variance explained by the overall four components is greater than 50%, which is the minimum limit for this test, and is, therefore, ultimately enough to establish future positive outcomes. Table 3 presents the variables following each component, renamed according to the nature of the factors involved in the construct [51], [52]. These are the final factors evident from the pilot survey. Further, they present the most appropriate success outcomes of utilizing the coatings in construction projects, and therefore they are fully strengthening how the data can be used in further analysis.

Table 2 EFA Results

Variables	**1**	**2**	**3**	**4**	**Cronbach Alpha**
R13	.769				0.759
R11	.693				
R7	.679				

R4	.666				
R2	.640				
R12		.871			0.827
R5		.864			
R3		.748			
R15			.679		0.724
R6			.616		
R1			.616		
R17			.563		
R14			.555		
R9			.510		
R8					
R16				.734	0.755
R10				.639	
R18				.574	
Eigenvalue	2.954	2.671	2.573	2.086	
Variance	16.409	14.839	14.297	11.592	

Table 3 shows the categorization of the variables on the basis of EFA analysis conducted above. The EFA divided variables into four groups so next stage was to give name to these groups. So names of groups or constructs are shown below.

Table 3 Grouped success factors based on EFA findings.

Constructs	Assigned Code	Variables
Performance	R13	PUCs are renowned for their exceptional resistance to wear and tear and long-lasting performance.
	R11	PUCs may be applied fast, shortening the home-building project duration.
	R7	PUCs may aid in boosting the energy efficiency of buildings by decreasing air penetration and increasing insulation.
	R4	PUCs may be applied to several surfaces, including concrete, wood, and metal, making them appropriate for various building projects.
	R2	PUCs may enhance the acoustics of homes by minimizing noise transmission between rooms and between the buildings's interior and outside.
Functional	R12	PUCs are very flexible and can accept movement, making them excellent for projects where surfaces may expand and contract due to temperature fluctuations.
	R5	PUCs offer outstanding water resistance, making them appropriate for usage humid and wet environments.
	R3	The rapid curing of PUCs expedites the completion of building projects and minimizes downtime.

Sustainability	R15	PUCs are often more ecologically friendly than conventional coatings since they release fewer VOCs (volatile organic compounds) and have a more negligible environmental effect.
	R6	PUCs offer a high level of resistance to chemicals and substances such as oil, gas, and other pollutants, which is crucial in building projects where exposure to these compounds is a worry.
	R1	PUCs are resistant to fire and may aid in protecting homes from fire damage.
	R17	PUCs are non-toxic, non-combustible, and acceptable for building projects. This may offer homeowners peace of mind and additional safety.
	R14	PUCs are low-emitting and do not contain dangerous VOCs, helping enhance the air quality within dwellings.
	R9	PUCs are resistant to mold development, which may improve indoor air quality and minimize the risk of health issues in structures.
Aesthetics	R16	PUCs are available in many colors and textures, allowing for customization and some design possibilities in building projects.
	R10	Applying PUCs may improve the aesthetics of homes and raise their value.
	R18	PUCs need less periodic washing to maintain their brand-new appearance.

Figure 2 shows the hypothesis of the study developed after EFA analysis. The total four hypothesis has been developed at this stage on the basis of categorization of data.

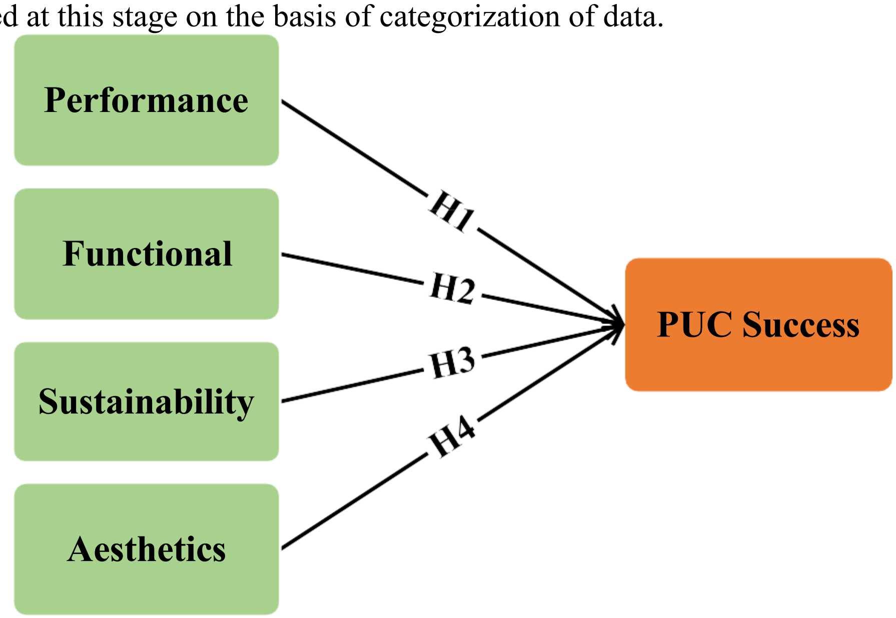

Figure 2 Study Hypothesis

H1: A significant relationship exists between performance success construct and PUC.
H2: A significant relationship exists between functional success construct and PUC.
H3: A significant relationship exists between sustainability success construct and PUC.
H4: A significant relationship exists between aesthetic success construct and PUC.

4.2 Demographic Profile

Table 4 presents the demographic profile in which the most critical categories of demographics were investigated. From an age standpoint, 31% of participants are between the ages of 26 and 30, and 35% are between the ages of 31 and 35. The overall demographics of the construction industry equates to 66% of the participants from the appropriate age group responding. Furthermore, 41% of participants have experience ranging from 11 to 15 years, while 22% have experience ranging from 16 to 20 years. This number is significant as 63% of the participants belong to the experience group, which is critical to providing a valid response in terms of understanding the nature of the questions asked and minimizing the biased approach.

Table 4 Demographics

Category	**Parameter**	**Percentage (%)**
Age	21 to 25 years	19
	26 to 30 years	31
	31 to 35 years	35
	36 to 40 years	5
	Above 40 years	10
Experience	0-5 Years	5
	11 to 15 Years	41
	16-20 Years	22
	5-10 Years	15
	Above 20 Years	17

4.3 Analytical Model

The data was analyzed after it was obtained from the main questionnaire survey. Analytical modeling aims to effectively determine the relationship between all the success factors identified from exploratory factor analysis to provide successful outcomes for construction projects. Structural equation modeling is performed along with other secondary tests to determine the significance of the final model.

4.3.1 Convergent Validity

The model reliability is evaluated in convergent validity testing, while the most important parameters are item loading, Cronbach's alpha, composite reliability, and AVE. According to item loading, R11, R15, R16, and R18 showed less than 0.6 loadings, indicating that these factors were removed from the final set of factors important for developing a structural model. Further, the reliability quotient has indicated acceptable results because all the values are greater than 0.7 and, therefore, acceptable concerning the fact that every construct has contributed well to creating an impact on the latent variable as shown in Table 5. The composer reliability is also significant, as all values are greater than 0.8, implying that the model relationships are significant. AVE has indicated acceptable statistics as all the values are greater than 0.5, which indicates an effective explanation of various variables by every construct involved in the model [53]. This also indicates acceptable statistics regarding the great reliability of the structural model.

Table 5 Model reliability statistics

Constructs	Assigned Code	Loadings	Cronbach Alpha	Composite Reliability	AVE
Performance	R13	0.782	0.73	0.831	0.553
	R11	Removed			
	R7	0.733			
	R4	0.782			
	R2	0.672			
Functional	R12	0.908	0.828	0.897	0.745
	R5	0.897			
	R3	0.779			
Sustainability	R15	Removed	0.814	0.879	0.649
	R6	Removed			
	R1	0.873			
	R17	0.605			
	R14	0.875			
	R9	0.839			
Aesthetics	R16	0.920	0.756	0.89	0.802
	R10	0.871			
	R18	Removed			

The Table 6 indicates a correlation matrix consisting of 17 variables, denoted as R1 through R17, and their respective pairwise correlations. The matrix comprises cells that denote the correlation between two variables. Notably, the diagonal cells, such as R1-R1, R2-R2, and so on, indicate the correlation between a variable and itself, which is invariably equal to 1. The numerical values present in the cells of the range span from negative one to positive one. A value of one signifies a flawless positive correlation, where an increase in one variable is accompanied by a proportionate increase in the other variable. A value of zero indicates the absence of any correlation, while a value of negative one indicates a perfect negative correlation, where an increase in one variable is accompanied by a proportionate decrease in the other variable. Upon examining the initial row of the matrix, it is evident that R1 exhibits a flawless positive correlation with itself (1), a robust positive correlation with R13 (0.398), and a moderate positive correlation with R5 (0.321), R14 (0.708), R10 (0.187), R2 (0.276), R12 (0.354), R9 (0.357), R16 (0.249), and R15 (0.245), among other variables.

Table 6 Empirical correlation matrix

Variable	R1	R10	R11	R12	R13	R14	R15	R16	R17	R2	R3	R4	R5	R6	R7	R8	R9

R3	R2	R17	R16	R15	R14	R13	R12	R11	R10	R1
0.175	0.276	0.357	0.249	0.245	0.708	0.398	0.354	0.185	0.187	1
0.12	0.126	0.173	0.607	0.018	0.247	0.006	0.088	0.155	1	0.187
0.162	0.344	0.152	0.064	-0.135	0.185	0.364	-0.103	1	0.155	0.185
0.561	0.106	0.134	0.185	-0.117	0.285	0.141	1	-0.103	0.088	0.354
0.132	0.444	0.109	0.15	-0.186	0.389	1	0.141	0.364	0.006	0.398
0.074	0.275	0.397	0.24	0.093	1	0.389	0.285	0.185	0.247	0.708
-0.104	-0.013	0.13	0.069	1	0.093	-0.186	-0.117	-0.135	0.018	0.245
0.158	0.203	0.168	1	0.069	0.24	0.15	0.185	0.064	0.607	0.249
0.126	0.112	1	0.168	0.13	0.397	0.109	0.134	0.152	0.173	0.357
-0.092	1	0.112	0.203	-0.013	0.275	0.444	0.106	0.344	0.126	0.276
1	-0.092	0.126	0.158	-0.104	0.074	0.132	0.561	0.162	0.12	0.175
0.157	0.351	0.305	0.191	-0.032	0.267	0.411	0.238	0.377	0.08	0.342
0.55	0.071	0.16	0.128	-0.045	0.27	0.103	0.739	0.028	0.028	0.321
-0.08	-0.005	0.183	-0.011	0.502	0.091	0.026	-0.144	0.119	0.299	0.098
0.242	0.268	0.103	0.01	-0.061	0.204	0.445	0.208	0.361	-0.04	0.236
0.05	0.236	0.271	0.208	0.084	0.639	0.354	0.257	0.108	0.249	0.669
0.048	0.28	0.39	0.175	0.049	0.635	0.351	0.239	0.173	0.191	0.643

	R4	R5	R6	R7	R8	R9
	0.342	0.321	0.098	0.236	0.669	0.643
	0.08	0.028	0.299	-0.04	0.249	0.191
	0.377	0.028	0.119	0.361	0.108	0.173
	0.238	0.739	-0.144	0.208	0.257	0.239
	0.411	0.103	0.026	0.445	0.354	0.351
	0.267	0.27	0.091	0.204	0.639	0.635
	-0.032	-0.045	0.502	-0.061	0.084	0.049
	0.191	0.128	-0.011	0.01	0.208	0.175
	0.305	0.16	0.183	0.103	0.271	0.39
	0.351	0.071	-0.005	0.268	0.236	0.28
	0.157	0.55	-0.08	0.242	0.05	0.048
	1	0.214	0.145	0.498	0.186	0.253
	0.214	1	-0.128	0.261	0.24	0.216
	0.145	-0.128	1	0.04	-0.002	0.056
	0.498	0.261	0.04	1	0.161	0.188
	0.186	0.24	-0.002	0.161	1	0.575
	0.253	0.216	0.056	0.188	0.575	1

4.3.2 Discriminant Validity

Fornell and Larcker's statistics, presented in Table 7, have indicated acceptable results because all the values were greater than zero and also have shown acceptable results in providing significant correlations between the constructs. It also helped exclude normal behavior from analysis and further make it relative to the variation explained by all the constructs in the latent variable. HTMT statistics in Table 8, have also indicated acceptable results because all the relative values are greater than 0.5, while the significant results are produced by other factors constituting correlations between the constructs [18], [22]. Under the requirements of subtraction modeling, the findings are appropriate, and further, they confirm that the model is valid with effective path significance.

Table 7 Fornell Larker statistics

Constructs	**Aesthetics**	**Functional**	**Performance**	**Sustainability**
Aesthetics				
Functional	0.193			
Performance	0.203	0.329		
Sustainability	0.362	0.353	0.557	

Table 8 HTMT statistics

Constructs	Aesthetics	Functional	Performance	Sustainability
Aesthetics	0.895			
Functional	0.155	0.863		
Performance	0.146	0.238	0.744	
Sustainability	0.284	0.307	0.442	0.806

Table 9 presents the cross-loading model analysis, and these are all the factors that constitute each of the items relative to the constructs in the model. The most important part is obtaining cross-loadings of factors greater than 0.5 for all items. This effectively confirms the model's validity and provides great reliability statistics in justifying the impact of each of the constructs on the success of using PUC in construction projects.

Table 9 Cross loadings observed from structural model analysis

	Aesthetics	Functional	Performance	Sustainability
R16	**0.92**	0.182	0.189	0.261
R10	**0.871**	0.087	0.057	0.247
R12	0.158	**0.908**	0.236	0.326
R3	0.157	**0.779**	0.153	0.13
R5	0.093	**0.897**	0.219	0.308
R13	0.096	0.144	**0.782**	0.406
R7	-0.014	0.272	**0.733**	0.234
R4	0.158	0.239	**0.782**	0.358
R2	0.188	0.046	**0.672**	0.303
R1	0.246	0.338	0.426	**0.873**
R14	0.271	0.256	0.385	**0.875**
R17	0.19	0.162	0.219	**0.605**
R9	0.203	0.206	0.362	**0.839**

4.3.3 Bootstrapping Structural Path Analysis

Table 10 presents the path analysis of the second-order model involving the bootstrapping analysis. The most critical contract observed from the analysis is sustainability because it can be associated with adopting coatings in construction projects. The next important factor is performance, with a path coefficient of 0.394, which is significant enough to have a marginal impact on the success of coatings in construction projects. For all of the constructs, the observed significance values are less than 0.05, which means that these constructs are valid and further sustainable in providing great reliability to the model. VIF values are less than 3.5 for all the constructs and greater than 1, which confirms that the constructs are contributing well to explaining the variation in latent variables, such as the success of using coating in construction projects in [28]. Figure 4 presents the model with path significance indications, Figure 5 indicates the t-stats of model, while Figure 6 indicates the frequency variation of all of the constructs involved in the model following their path significance.

Table 10 Utilizing Bootstrap for Testing Second-Order Models in the Constructive Phase

Path	**β**	**SE**	**t-values**	**p-values**	**VIF**
Aesthetics -> PU Coat	0.291	0.016	15.775	<0.001	1.194
Functional -> PU Coat	0.339	0.017	15.084	<0.001	1.164
Performance -> PU Coat	0.394	0.022	17.96	<0.001	1.262
Sustainability -> PU Coat	0.444	0.023	22.435	<0.001	1.437

4.3.4 Predictive Relevance

The model's predictive power in Table 11, is significant enough to impact future research positively, and the latent variable can provide useful outcomes. In this study, the acceptable value for the q square was 0.2, producing significant results in justifying the predictive relevance of the model.

Table 11 Predictive Relevance Results

Latent Variable	**SS0**	**SSE**	**Predict-Q^2**
The success of using PUC	4811.000	3545.371	0.263

4.4 Success Model Validation

The results of an expert validation of a statistical model created to evaluate the success factors of PUC in building projects are shown in Table 12. The comments from the 20 respondents support the model's concept, purpose, and conclusions, and the average answers to the validation questions demonstrate that the recommended essential criteria may be employed. The resultant structural models are conventional and all-encompassing, and this research contains a respectable amount of truth. The model is crucial to the construction industry because, when followed, it enables clients and contractors to complete projects to a defined standard while safeguarding their advantages. The model's data may be useful for engineers, project managers, quantity surveyors, and enterprises. Moreover, this tactic guarantees that contractors work hard to maintain their competitive advantage. The respondents mostly supported the survey's encouraging results.

Table 12 Validation results.

Respondent	Q1	Q2	Q3	Q4	Q5
1	5	4	4	4	4
2	2	5	4	5	2
3	3	4	5	4	3
4	3	4	5	5	4
5	4	4	4	4	5
6	4	4	4	4	4
7	4	5	4	4	4
8	4	4	5	4	4
9	4	4	4	4	5
10	5	4	5	4	4
11	4	4	5	5	2
12	4	3	4	5	5
13	3	4	4	3	3
14	5	5	4	5	5

15	5	3	5	4	5
16	4	4	4	5	5
17	4	5	5	4	5
18	4	4	4	5	5
19	5	4	4	5	5
20	5	5	4	5	5
	4.05	4.15	4.35	4.40	4.20

5 Discussion

The performance formative construct (β=0.349) includes R13 "PUCs are renowned for their exceptional resistance to wear and tear and long-lasting performance," R7 "PUCs may aid in boosting the energy efficiency of buildings by decreasing air penetration and increasing insulation, " R4 "PUCs may be applied to several surfaces, including concrete, wood, and metal, making them appropriate for various building projects " and R2 " PUCs may enhance the acoustics of homes by minimizing noise transmission between rooms and between the building's interior and outside." The greater the emphasis placed on the success of implementing PUC to improve wear resistance and its ability to be applied to any construction material, a unique behavior is observed in this contract, as it has provided an exceptional understanding of how PUC can improve the performance of construction materials in the construction sector. Based on the results of the structural model and Feng et al. (2013) and Juan Xu et al. (2017), it is clear that a PUC can significantly improve performance [35], [39]. By the existing studies, it is important to consider the efficient performance-based applications of coatings in construction. As a result, one-of-a-kind results are produced that critically justify the exceptional relationship coefficient of performance and success of using PUC in construction projects.

The functional formative construct (β=0.339) includes R12 "PUCs are very flexible and can accept movement, making them excellent for use in building projects where surfaces may expand and contract due to temperature fluctuations," R5 "PUCs offer outstanding water resistance, making them appropriate for usage humid and wet environments," R3 "The rapid curing of PUCs expedites the completion of building projects and minimizes downtime." More emphasis is placed on the fact that PUCs provide flexibility to the material, which ultimately improves the material's ability to be successfully used in construction projects. According to Huang et al. (2020) and Yu et al. (2020), it is truly evident that the unique quality of coating can ultimately improve flexibility in the construction material and also bring more functional reliability, which is evident from the relationship identified in the structural model [30], [38]. It can be effectively justified that functional improvements can be important to successfully implementing coating in construction projects. For this reason, the unique aspect is observed, where significant attention is given to the most critical flexibility property of a coating. At the same time, other factors related to water resistance and rapid curing are also justified in accordance with existing research.

The formative sustainability construct (β=0.444) includes R1, "PUCs are resistant to fire and may aid in protecting homes from fire damage," R17 "PUCs are non-toxic, non-combustible, and acceptable for building projects. This may offer homeowners peace of mind and additional safety", R14 "PUCs are low-emitting and do not contain dangerous VOCs, so helping to enhance the air quality within dwellings," and R9 "PUCs are resistant to mold development, which may improve indoor air quality and minimize the risk of health issues in structures." The most critical factor observed is how the coatings do not negatively impact the environment from the perspective of producing carbon emissions. For this reason, these coatings can ultimately be used to improve the quality of construction in structures while also taking into account the factor of sustainability, which is highly valued modern construction industry [54]. Following Fang et al. (2019) and Jun Hyeok Song et al. (2020), it is for this reason that it all adds up to maximizing how the success of using PUC in construction projects can be justified [37], [41]. Further, the other factors related to sustainability, such as the improvement of indoor air quality and increased fire resistance, can ultimately maximize the success of implementing the coating in construction projects.

The aesthetics formative construct (β=0.291) include R16, "PUCs are available in many colors and textures, allowing for customization and some design possibilities in building projects," and R10, "Applying PUCs may improve the aesthetics of homes and raise their value." More emphasis is placed on the fact that these coatings will eventually be available in various colors and textures, which are critical for maximizing aesthetics in construction sector [29], [40]. This can ultimately maximize the success of coating in presentation projects and maximize the effective coating implementation. It is, therefore, effectively justified by the findings that the coatings will produce an aesthetic impact on the construction sector and ultimately will maximize the sustainability of buildings.

6 Conclusion

All the hypothesis has been achieved and proved that PUCs are important for construction projects. Most of the characteristic properties of PUC are linked with increasing the chances of success and therefore confirming the acceptability of the structural model. EFA analysis helped exclude the insignificant factors and provide the most critical variables for further evaluation in the context of implementation success. The research employed improving the implementation of Structural Equation Modeling to determine that the four essential constructs of sustainability, performance, function, and aesthetics are connected to the successful aspects of PUC implementation. The demographic profile was also found to be significant and unbiased. The pilot and main surveys contributed significantly to creating the structural model underlying the study's findings.

Consequently, running a pilot survey in addition to the main questionnaire is crucial, which will help verify the findings and guarantee the structural model's reliability. The reason for achieving significant relevance of sustainability construct with the successful implementation of PUC is because the innovative PUC produced with low carbon emissions and helps the construction projects exhibit high sustainability. Compared to existing limited research on adopting PUCs in construction projects, the results are unique. While successfully fulfilling the research gap, the results indicated the final structural model with significant path coefficients that can be effectively used for better achievement of implementation success in the construction sector. Overall, the research sheds light on what makes using PUC in building projects effective. Decision-makers, contractors, and other stakeholders in building industry may utilize this study's findings to assess the efficacy of PUC and make educated judgments regarding its use.

7 Managerial and empirical implications

Consequently, PUC is increasingly used in construction projects for its capacity to withstand the elements and defend against water and chemical damage. Since PUCs last longer than conventional and need less upkeep, they might be economical. The visual quality of building projects might be enhanced using PUCs, which come in various colors and finishes. Since PUCs harden quickly, they may be applied in shorter amounts of time, minimizing disruptions and maximizing productivity on building sites. Research into PUCs reveals information on material science and the way substances interact with surfaces. Building science is crucial to guaranteeing buildings' long-term durability and sustainability, as shown by using PUCs in construction projects. Research into the use of PUCs in building projects advances surface engineering by giving useful applications and insights into the behavior of materials when applied to various surfaces. This study's outcomes will benefit overall construction sector and help it adopt more efficient PUCs. It is expected that construction industry will normalize the use of PUCs as a big step towards sustainability, and this study provides ground knowledge to achieve success.

8 Limitations

Inconsistent findings and faulty product comparisons may come from the absence of defined testing procedures and criteria for assessing the performance of PUCs in building projects. However, further research is required to properly understand PUCs' effects on the environment in the long run, especially in the context of building projects. Requiring advanced technical competence and skilled staff in this area may hamper the broad use of PUCs for building projects. Standardized testing techniques and criteria for assessing the performance of PUCs in building projects are needed to increase the reliability and accuracy of the assessment. It is important to conduct more studies to evaluate the long-term environmental impact of PUCs used in building projects and to identify the most effective ways to lessen that impact. The need for more technical skills in applying PUCs in building projects may be mitigated by investing in training and education programs.

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9 Appendix

Questionnaire

Code	Description	Likert Scale (1-5)
R1	PUCs are resistant to fire and may aid in protecting homes from fire damage.	Strongly Disagree- Strongly Agree
R2	PUCs may enhance the acoustics of homes by minimizing noise transmission between rooms and between the building's interior and outside.	Strongly Disagree- Strongly Agree
R3	The rapid curing of PUCs expedites the completion of building projects and minimizes downtime.	Strongly Disagree- Strongly Agree
R4	PUCs may be applied to several surfaces, including concrete, wood, and metal, making them appropriate for various building projects.	Strongly Disagree- Strongly Agree
R5	PUCs offer outstanding water resistance, making them appropriate for usage humid and wet environments.	Strongly Disagree- Strongly Agree
R6	PUCs offer a high level of resistance to chemicals and substances such as oil, gas, and other pollutants, which is crucial in building projects where exposure to these compounds is a worry.	Strongly Disagree- Strongly Agree
R7	PUCs may aid in boosting the energy efficiency of buildings by decreasing air penetration and increasing insulation.	Strongly Disagree- Strongly Agree
R8	PUCs are often more sustainable than conventional coatings because they have a longer lifetime, decreasing the need for frequent replacement.	Strongly Disagree- Strongly Agree
R9	PUCs are resistant to mold development, which may improve indoor air quality and minimize the risk of health issues in structures.	Strongly Disagree- Strongly Agree
R10	Applying PUCs may improve the aesthetics of homes and raise their value.	Strongly Disagree-

		Strongly Agree
R11	PUCs may be applied fast, shortening the home-building project duration.	Strongly Disagree-Strongly Agree
R12	PUCs are very flexible and can accept movement, making them excellent for projects where surfaces may expand and contract due to temperature fluctuations.	Strongly Disagree-Strongly Agree
R13	PUCs are renowned for their exceptional resistance to wear and tear and long-lasting performance.	Strongly Disagree-Strongly Agree
R14	PUCs are low-emitting and do not contain dangerous VOCs, helping enhance the air quality within dwellings.	Strongly Disagree-Strongly Agree
R15	PUCs are often more ecologically friendly than conventional coatings since they release fewer VOCs (volatile organic compounds) and have a more negligible environmental effect.	Strongly Disagree-Strongly Agree
R16	PUCs are available in many colors and textures, allowing for customization and some design possibilities in building projects.	Strongly Disagree-Strongly Agree
R17	PUCs are non-toxic, non-combustible, and acceptable for building projects. This may offer homeowners peace of mind and additional safety.	Strongly Disagree-Strongly Agree
R18	PUCs need less periodic washing to maintain their brand-new appearance.	Strongly Disagree-Strongly Agree