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Significant Factors Affecting the Quality of Housing Infrastructure Project Construction in Saudi Arabia Using PLS-SEM

Nasser Aljarallah, Abdullah M. Alsugair, Abdulmohsen S. Almohsen and Khalid S. Al-Gahtani *

Department of Civil Engineering, King Saud University, P.O. Box 2454, Riyadh 11421, Saudi Arabia; 438106307@student.ksu.edu.sa (N.A.); amsugair@ksu.edu.sa (A.M.A.); asmohsen@ksu.edu.sa (A.S.A.)
* Correspondence: kgahtani@ksu.edu.sa

Abstract: Quality construction contributes to the overall sustainability of the built environment, especially for infrastructure projects. High-quality housing infrastructure projects benefit individuals, communities, and the economy. Most studies are concerned with identifying the reasons for the quality of a construction project. However, only a few of them have been concerned with housing infrastructure. In addition, no studies have considered the interdependencies among the factors affecting the quality of housing infrastructure projects, leading to these causes not being evaluated effectively. This paper aims to specify and organize the significant factors affecting the quality of housing infrastructure projects. These projects suffer from the availability of all infrastructure services simultaneously before their execution. A comprehensive literature review was implemented to collect all the factors affecting their quality. Construction sector experts designed and filled out a questionnaire based on the collected data. The survey data were then statistically analyzed using a partial least squares structural equation model (PLS-SEM) to organize the causes and examine the interdependencies among the quality of each cause. Our main finding revealed that based on the PLS-SEM, the top three factors affecting the construction quality were the skill and experience of supervisory staff, errors and omissions in design documents, and the lack of communication between supervisors and laborers. Based on the PLS-SEM ranking, labor, equipment, and site staff were responsible for more than half of the top 10 causes. The PLS-SEM results showed that the contractor material (CM) and project design (PD) percentages were 20% and 30%.. In addition, there is an interaction influence between the labor/equipment/site staff (LES) causes and PD causes. This study assists stakeholders in understanding how to use Six Sigma construction concepts to enhance performance in the nation's construction industry, which helps contractors make improvements in variability reduction and save costs in construction projects.

Keywords: quality; PLS-SEM; causes; weight; construction; design; material; labor

Citation: Aljarallah, N.; Alsugair, A.M.; Almohsen, A.S.; Al-Gahtani, K.S. Significant Factors Affecting the Quality of Housing Infrastructure Project Construction in Saudi Arabia Using PLS-SEM. *Sustainability* **2023**, *15*, 14998. https://doi.org/10.3390/su152014998

Academic Editors: Qin Su and Chenglong Li

Received: 11 September 2023
Revised: 11 October 2023
Accepted: 16 October 2023
Published: 18 October 2023

1. Introduction

Quality construction, particularly for infrastructure projects, contributes to the overall sustainability of the built environment. The construction sector is one of the most significant global economic sectors [1]. Most governments' construction spending ranges from 9% to 15% of their gross domestic product (GDP), and up to 50% of a country's investment goes to the built environment [2]. There are currently more than 600,000 residential units planned, with the Saudi capital, Riyadh, accounting for 18% of the USD 229 billion in active real estate and development projects. This development includes plans to build more than 241,000 dwellings by 2030 [3]. In addition, the Kingdom's 2030 vision includes several projects, one of which is the USD 20 billion Diriyah Gate. When Diriyah, a city-sized historic neighborhood, is finished in 2027, 20,000 more residences will have been added to Riyadh's residential stock. USD 5 billion have already been spent on construction, and it is estimated to be 46% complete [4]. Despite its enormous economic significance, the construction industry is beset with inefficiencies. Moreover, productivity in the construction sector has scarcely improved. It may even have dropped over the past five decades, in contrast to many other industries in which it has been continuously rising [2]. The level of success of construction projects depends dramatically on the quality of performance. For building projects, clients, contractors, and consultants aim to deliver projects based on acceptable and agreed standards [5]. The quality of projects is one of the conventional and international measurements of project performance.

Quality management (QM) plays a role one way or another in boosting emerging economies [6]. QM originated in Japan in the late 1940s; the emphasis was on improving quality and using quality control tools in the manufacturing sector. Then, this concept was applied in different industrial sectors in the USA, UK, and other countries [7]. QM is a management approach for producing better goods and services and a mechanism that aims to enhance efficiency and put companies in a more desirable competitive position. The authors of [8] highlighted the significant association between quality and productivity, which reduces wastage or reworks, consequently improving quality and enhancing customer loyalty. Although QM is most commonly used in the manufacturing and service sectors, it has also been used in the construction industry, in which clients demand the high-quality delivery of large and complex buildings (building quality management). Although delays and defects might or might not be able to be avoided in construction, though much more so than in a more controlled manufacturing environment, the implementors of QM are constantly looking for opportunities to improve existing problems rather than monitoring works and spotting errors. Therefore, applying QM will raise the quality of buildings and infrastructure, contributing to consumers' and visitors' quality of life and improving their satisfaction level. Accordingly, it will raise the national income and the income of companies, as shown in Figure 1. This study aims to raise consumers' and visitors' quality of life in Saudi cities, which can be applied to cities in other countries.

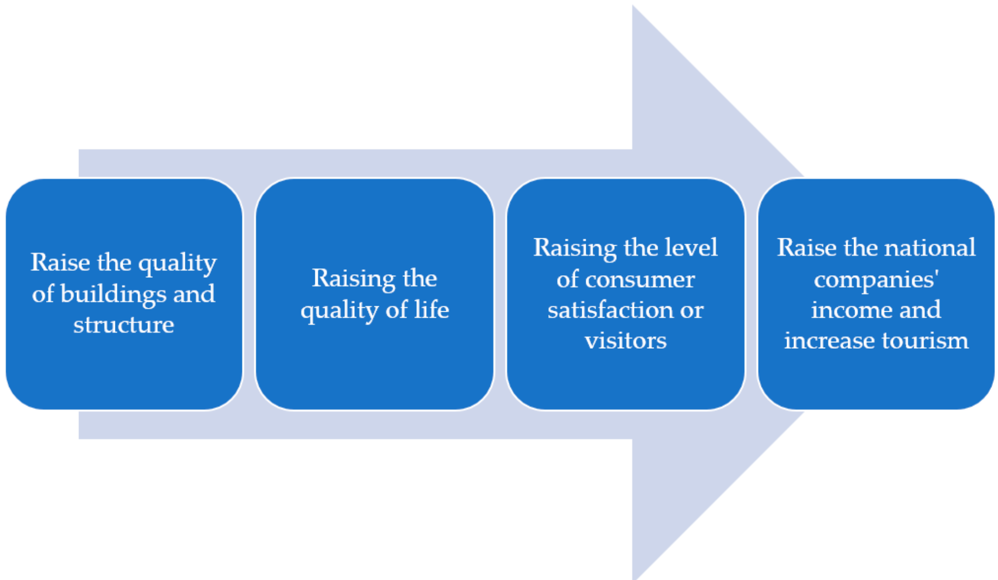

Figure 1. The benefits of QM.

Building QM is reflected in a building's quality of life, which may be represented by its safety, durability, functionality, aesthetics, and resale value. For instance, poorly constructed buildings may be uncomfortable, inconvenient, or unusable. Moreover, quality construction is vital in safety, aesthetics, and release value issues. Concerning safety in construction, poorly constructed buildings can be dangerous, leading to accidents, injuries, and even death. Poorly constructed buildings may need to be repaired or replaced more often, which can be costly and inconvenient [9,10]. For aesthetics, a quality construction project is attractive to the community. Poorly constructed buildings may be unpleasant or unattractive [11,12].

Regarding resale value, a quality construction project will retain its value better than a poorly constructed building [13]. This factor is essential for both homeowners and businesses. In addition to this reason, quality construction projects can also help to improve the local economy. They create jobs, stimulate spending, and generate tax revenue. Investing in quality construction can create a safer, more durable, and more beautiful world.

Different studies have increased the quality of projects by identifying the causes of poor construction performance and establishing solutions to mitigate these causes. These causes can be classified into construction organization [14], the quality of teams [15], QM [16,17], monitoring and inspection [5], material and labor issues [18,19], and the influence of the Industrial Revolution [19,20].

The interdependencies among construction quality elements were not considered in earlier studies. A thorough analysis was conducted to fill this gap and to gather the variables that had the most significant impact on the caliber of construction projects. A questionnaire was created and given to experts in the construction sector. The survey results were then statistically examined using the PLS-SEM method to pinpoint the essential variables that directly impact the quality and how those variables interact with one another.

Considering the interdependencies among the factors affecting the quality has several benefits. For example, an analysis of these interdependencies enables a more comprehensive understanding of the quality elements of housing infrastructure projects. It makes it easier for academics and industry professionals to understand how various aspects of project quality interact with and impact one another. Additionally, taking into account the interdependencies among quality indicators facilitates improves decision making. It assists in locating crucial relationships and dependencies that might affect a project's overall quality. Based on a thorough understanding of the potential effects of changes in one quality component on others, decision makers can prioritize resources and initiatives.

2. Literature Review

Various factors, including project requirements, significantly influence the quality of construction projects. The accuracy and completeness of these requirements directly relate to the quality of the outcome. Achieving a high-quality result becomes challenging if the requirements are poorly defined [21]. However, several studies have focused on identifying factors contributing to subpar construction performance and developing mitigation strategies to improve project quality. These factors include construction management, monitoring and inspection, quality material, equipment, labor performance, and the impact of the Industrial Revolution.

Within construction management, the construction management team plays a crucial role in determining project quality. A well-organized team with clear communication channels is more likely to deliver a high-quality product [14]. Implementing quality teams can also significantly enhance the quality of construction projects. These teams consist of representatives of various project aspects, including owners, contractors, and designers. Regular meetings are held to discuss progress and identify potential quality issues. Abas et al. [15] emphasized the importance of factors such as steady advancements, joint work, communication, the availability of technical personnel, ISO certification, and the contractor's procurement unit. In addition, the study Amoah [22] carried out for a housing project in South Africa revealed that the significant factors of poor-quality housing construction are related to project management. Quality management factors, including having a customer focus, making continuous improvements, applying strategic-based approaches, and utilizing total employee involvement, have been found to positively and significantly impact the performance of medium-sized construction projects [16]. Fang et al. [23] stated the importance of management in construction. They determined the precise empirical relations among the functional conduct of management, the safety of groups in an environment, and employee safety in construction settings.

Monitoring and inspection are crucial for ensuring the quality of a construction project. Regular inspections help identify potential quality issues, allowing for immediate corrective action. Oke et al. [5] highlighted the significance of proper site management and supervision to ensure adherence to drawings and specifications. Allocating an adequate amount of time for a project in contract documents is also important for achieving a high level of quality.

The quality of materials and equipment significantly affects a construction project's overall quality. Using high-quality materials and well-maintained equipment is essential. Oke et al. [5] recommended adopting proper and modern construction equipment, techniques, and methods to minimize the impact of material and equipment factors and enhance construction project performance. In addition, Sawan et al. [24] developed a model for the procurement of construction materials, emphasizing the importance of tailoring appraisal expenditure to each purchase order to maximize benefits. Additionally, the maintenance of construction equipment is important to a project's quality, the safety of a construction site, and a project's budget. For instance, improper equipment maintenance is one of the most frequent causes of occupational accidents and damage, according to Karuppiah et al. [25]. Moreover, Deshmukh and Menkudle [26] evaluated the consequences of time and cost overruns on construction projects in India. They concluded that inadequate maintenance equipment represents one of the five most common causes of project delays.

Companies with a high level of labor performance can achieve high-quality outcomes, improve productivity, enhance safety, and minimize delays. For example, Alaghbari et al. [27] studied factors affecting construction labor productivity in Yemen. They identified the availability of materials on-site, leadership and efficiency in site management, leadership of the labor force, market availability of materials, and political and security conditions as the top five factors impacting labor productivity. Al-Saffar and Obeidat [28] stated the effect of experienced workers on the total quality of projects in Qatar ministries. Their results contribute to developing and implementing various strategic directions that improve workers' performance by adopting total quality management and disseminating a culture of knowledge sharing.

Handling design errors in housing projects can improve their total quality, guarantee compliance with regulations, enhance user satisfaction, minimize rework and cost overruns, and improve the long-term durability and value of housing units. For instance, Islam et al. [29] investigated the influence of design error on project performance regarding cost overruns by systematically reviewing previous studies. They revealed that design flaws might result in cost overruns of between 5 and 40% of the project cost. In addition, other factors affecting design modifications that result in cost overruns from the viewpoints of owners, consultants, and contractors were investigated. Owner-induced design flaws led to the closure of several projects. However, the quantity of these adjustments may not be substantial. The effects of design mistakes caused by consultants and contractors might vary and are common.

Industrial Revolution techniques play a vital role in the construction industry. Perera et al. [19] explored the application of blockchain principles in construction and found that blockchain has significant potential due to its various uses, investments, and contributions to Industry 4.0. Furthermore, Alaloul et al. [20] identified social and technical factors as critical issues delaying the implementation of the Fourth Industrial Revolution in the construction industry. They concluded that all contributing factors significantly influence its successful implementation despite the importance of the identified critical factors.

2.1. Partial Least Square Structural Equation Modeling

PLS-SEM is a statistical approach for investigating complex relationships between variables. The method is flexible and can be implemented to test many research hypotheses, including those containing causal relationships [30]. PLS-SEM has been applied in different scientific applications with several purposes, as shown in Table 1.

Table 1. Application of PLS-SEM in different fields.

Reference	Application	Purpose
[31]	Architectural engineering	Learning teaching course
[32]	Construction engineering	Identifying the failure factors of Yemen's construction industry
[33]	Business	Planning business promotion strategies
[34]	Business	Enhancing the usage of PLS-SEM for commercial marketing research
[35]	Education	Studying the impact of massive open online courses
[36]	Electric	Analysis of factors influencing the quality of electric power
[37]	Construction engineering	Studying the direct and indirect relationships among a group's factors affecting.

2.2. The Gap in Previous Studies

Previous studies did not consider the interdependencies among the quality factors of housing infrastructure projects. This gap is due to the complexity of issues or the objectives of the previous studies. For instance, housing infrastructure projects take a variety of quality factors into account. It can be complex and confusing to analyze how these elements interact. Additionally, prior research has concentrated on comprehending and resolving specific quality problems within housing infrastructure projects. Researchers have given more weight to studying individual quality criteria than to examining how these aspects interact in situations. This issue can lead to unsuitable risk examinations and decreased effectiveness in risk treatments. Therefore, this study aimed to specify and examine the interrelationships among the factors affecting the quality of housing infrastructure projects in Saudi Arabia using PLS-SEM.

3. Methodology

Our methodology mainly consisted of three stages: pre-analysis, analysis, and post-analysis, as shown in Figure 2. The pre-analysis stage includes gathering data (to study and collect all factors affecting quality in the literature), establishing and carrying out a questionnaire (to evaluate the factors' influence on the Saudi construction sector), and obtaining information (to prepare survey responses and import into the SmartPLS program). The analysis stage aims to apply the PLS-SEM approach. The post-analysis stage aims to rank the critical factors affecting quality, examine how these factors interact, and compare our findings to those of earlier research.

3.1. Pre-Processing

This section aims to obtain data on the importance and degree of factors affecting the quality of the housing infrastructure project and use them to develop PLS-SEM (in processing). This purpose can be achieved by following three steps. First, gather data; second, establish and carry out a questionnaire; and third, prepare data.

3.1.1. Gathering Data

A preliminary list of frequently reported factors affecting quality has been gathered for the Kingdom of Saudi Arabia (KSA) and many other nations through an extensive search of the literature [38–40]. Three semi-structured interviews were selected to simplify giving and receiving data and allow for conversational and two-way communication at this stage [41]. The main objectives of these interviews were to identify and filter the preliminary list of the factors affecting quality by adding, merging, or writing them off to describe the current situation in the KSA construction industry. As a result, nine experts were assigned to these factors for three lengthy dissections. The experts were four consultant office project directors of mega projects in the Kingdom and five contractor project managers. The nine experts have more than 25 years of experience.

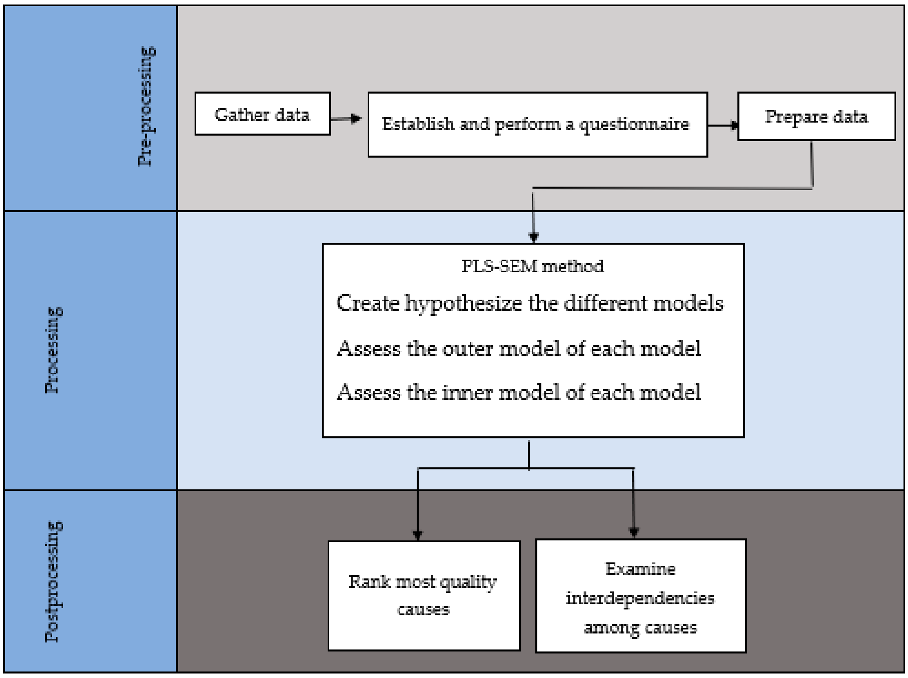

Figure 2. Methodology flow chart.

We determined and classified the factors based on who manages and controls them. According to their level of responsibility, a final list of quality-affecting factors was assigned and categorized. Table 2 summarizes the 35 quality-affecting factors, which are classified into four groups: project design (PD), contractor material (CM), labor/equipment/site staff (LES), and other (OTHER). Project design is responsible for only seven quality-affecting factors. At the same time, contractor material is responsible for seven factors, and labor, equipment, site, and staff are responsible for seven factors.

3.1.2. Establishing and Performing a Survey

A questionnaire was developed based on primary and secondary data gathered through extensive literature reviews and semi-structured interviews with industry professionals in construction infrastructure for housing projects in the KSA. After that, a pilot survey was conducted to evaluate the sufficiency and validity of the questions. The survey included two parts. The first part represented demographic data about the experts. The second part represented and listed different factors that affect construction quality. It categorizes these factors into groups based on the responsibilities of the groups in generating these factors.. The experts were asked to respond regarding the importance level of each factor according to their experiences. They were given closed-ended questions and options on a five-point Likert scale.

The survey was conducted with a sample size of 300 Saudi construction industry experts who had adequate experience in the supervision and execution of construction projects. Through email, personal interviews, and direct observation, 47 respondents responded to each questionnaire that was distributed.

The qualifications of the respondents, in addition to their actual experiences working on construction projects as well as their high-level credentials such as M.Sc. and Ph.D. degrees or consulting and PMP certificates, show the degree of reliability of the data they provided, and their opinions are believed to reflect the situation as it exists in this industry.

Table 2. Identified factors that affect the quality of housing infrastructure construction projects.

No.	Symbol	Description	Group
1	PD1	Scope of the project (type and nature)	Project design
2	PD2	Impact of poor assessment of the project site	
3	PD3	Complex execution of the project	
4	PD4	Project duration	
5	PD5	Incompleteness and inconsistency of design documents	
6	PD6	Drawings not prepared in full detail	
7	PD7	Variability to codes & specifications	
8	CM1	The delay caused by the contractor	Contractor material
9	CM2	Lack of planning and management by the contractor	
10	CM3	Unsatisfactory quality of contractor's work	
11	CM4	Implementation errors by contractor	
12	CM5	Misunderstanding/non-cooperation between contractor and supplier	
13	CM6	The climate affects the quality of construction	
14	CM7	Improper storage and handling system	
15	LES1	Overtime affects the quality of the project	Labor/equipment/site staff
16	LES2	Lack of communication between supervisors and laborers affects construction quality	
17	LES3	Excessive confidence and differing perspectives influence the quality of the project	
18	LES4	Negligence of equipment maintenance	
19	LES5	Skill and experience of supervisory staff	
20	LES6	Skill and experience of contractors	
21	LES7	Lack of communication between supervision and contractors	
22	OTH1	Lack of consultation with the client by the contractor team	Other
23	OTH2	Lack of timely judgments and corrective activities by the contractor crew	
24	OTH3	Errors and omissions in design documents	
25	OTH4	Lack of communication and coordination within the contractor site team	
26	OTH5	Hazardous training at the site (shortage of safety requirements on site)	
27	OTH6	Change in schedule	
28	OTH7	Late material delivery & poor inventory	
29	OTH8	Lack of supervision	
30	OTH9	Lack of financing	
31	OTH10	Frequent changes in design	
32	OTH11	Faulty pre-project survey	
33	OTH12	Delay in getting clearance from regularity authorities	
34	OTH13	Delays due to walkouts	
35	OTH14	Weather situations	

3.1.3. Preparing Data (Questionnaire Responses)

The second section of the questionnaire's responses was recorded using one to five scale in MS Excel, where one indicated "very low" and five "very high". When a responder chooses two options for a particular question, their response is regarded as missing data and must be handled by the SPSS program. Based on the participants' responses, there were two types of anomalous data: one in which the participant selected multiple points on the Likert scale and the other in which the question was not answered (missing data). The first type was considered in this paper as missing data. In SPSS, missing data concerns can be resolved in one of five ways: series mean, mean of nearby point, median of nearby point, linear interpolation, or linear trend at the point. The method considered in the paper was the mean nearby point method. To handle the missing data, data were exported to an MS Excel file for further processing after being treated in the SPSS application. In this study, more than 57% of the professionals who took the survey had more than 15 years of experience managing or carrying out building projects. A total of 48.4% of those surveyed believed they scored highly. The factors affecting quality were classified into four groups: project design (PD), contractor material (CM), labor/equipment/site staff, and other (LES).

3.2. Processing

This section displays the principles and laws utilized in the PLS-SEM method.

3.2.1. Partial Least Square Structural Model Method

PLS-SEM can handle complex models with multiple latent variables and observed indicators. It allows for estimating a measurement model (relationships between the groups and their indicators) and a structural model (relationships between the groups). This flexibility is valuable when examining complex causal relationships among constructs [42]. In addition, PLS-SEM enables researchers to examine interrelationships and trends in data, identify crucial factors, and produce new hypotheses for further investigation. It is suitable for exploratory research because of its adaptability and capacity for handling tiny sample numbers [43]. This section aims to identify the significant factors affecting quality and investigate their interrelationships by developing different PLS-SEM models. The general procedure for developing the PLS-SEM model is shown in Figure 3.

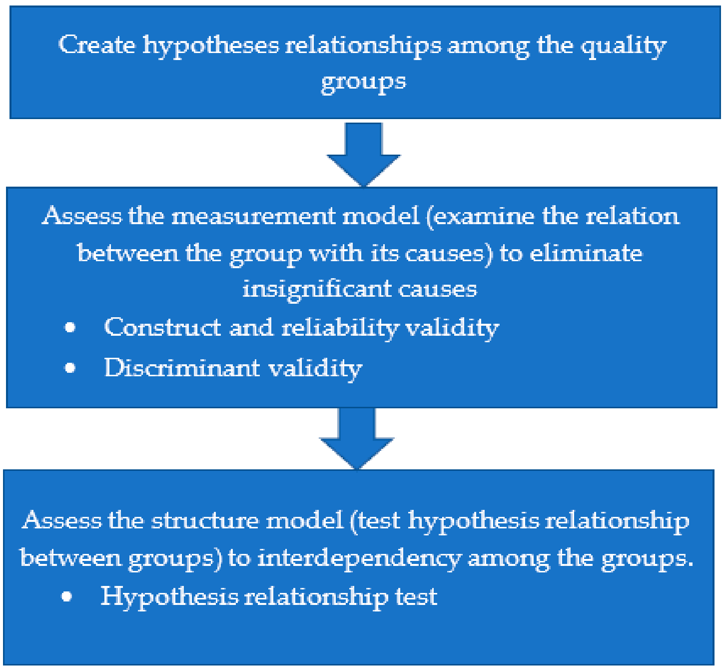

Figure 3. General procedure of PLS-SEM.

Figure 4 presents the flowchart of the PLS-SEM algorithm, which consists of a sequence of five steps: initialization, inner approximation, outer approximation, calculation of factor score, and convergence.

3.2.2. Creating Hypotheses of Relationships among the Quality Groups

The number of models utilized to study the interrelationships among groups depends on the number of groups (four groups of factors affecting the quality). Ignoring the "OTHER" group, the number of models can be computed as n! [$n! = n \times (n-1) \times (n-2) \ldots \times 1$], where n is the number of groups, which was three (PD, CM, and LES). The OTHER group is ignored because its causes cannot be classified into distinct groups. Therefore, the number of models was six, and one model was used to identify the significant factors affecting quality. Hence, the total number of models was seven. Each model was constructed using four hypotheses among the quality groups (H1–H4). The number of the hypothesis is attributed to the number of the quality groups, which equals four. This creation of hypotheses results in two sub-models being formed: the measurement model and structure model. The measurement model is the associations between groups (constructs) with their factors that affect quality (indicators).

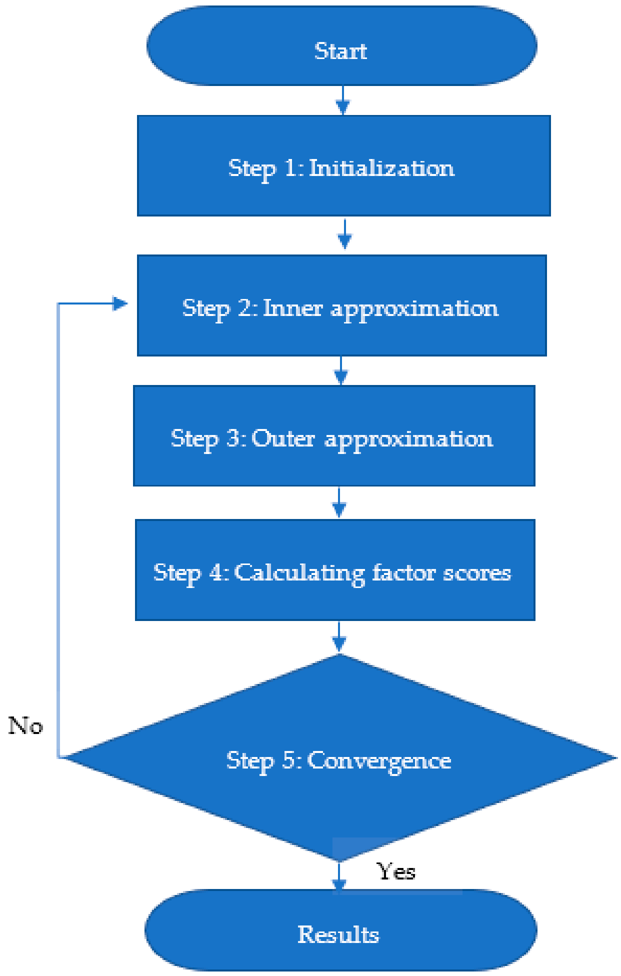

Figure 4. Flowchart algorithms of PLS-SEM.

On the other hand, the structural model describes the paths among the groups. The groups with their factors that affect quality are illustrated in Table 2. The purpose of the models (Model 1–Model 7) is illustrated in the following section.

The purpose of Model 1 was to examine the direct impact of PD, CM, LES, and others on the quality (Q) and identify the significant factors that affect quality, as shown in Figure 5a. Furthermore, Model 2–Model 7 tested the interdependencies' influence among the three groups (PD, CH, and LES). The seven models were constructed as shown in Figure 5. The four groups of Model 1 are exogenous latent (group), while the Q (quality group) is indigenous latent. Model 2 (Figure 5b) was created to examine the influence of the project and design (PD) on factors affecting contractor material quality (CM). Therefore, the PD, LES, and OTHER are exogenous, and the CM and Q are indigenous.

Furthermore, Model 3 was used to investigate the impact of the factor of project design on the factors of labor/equipment/site staff, as shown in Figure 3c. Hence, the LES and Q are only indigenous, while the others are exogenous. Model 4 (Figure 5d) and Model 5 (Figure 4e) aim to examine the contractor material's effects on the project design and labor/equipment/site staff, respectively. Hence, the PD and Q are indigenous for Model 4, while the LES and Q are indigenous for Model 5. The aims of Model 6 and Model 7 are to explore the influence of labor/equipment/site staff on the factors of the project design and contractor material, respectively. The seven models with their hypotheses (a relationship is represented by arrows) are shown in Figure 5. These seven models were developed using the SmpartPLS program to capture the interrelationships among the four groups (P.D., CM, LES, and OTH). The hypotheses associated with each model are shown in Table 3.

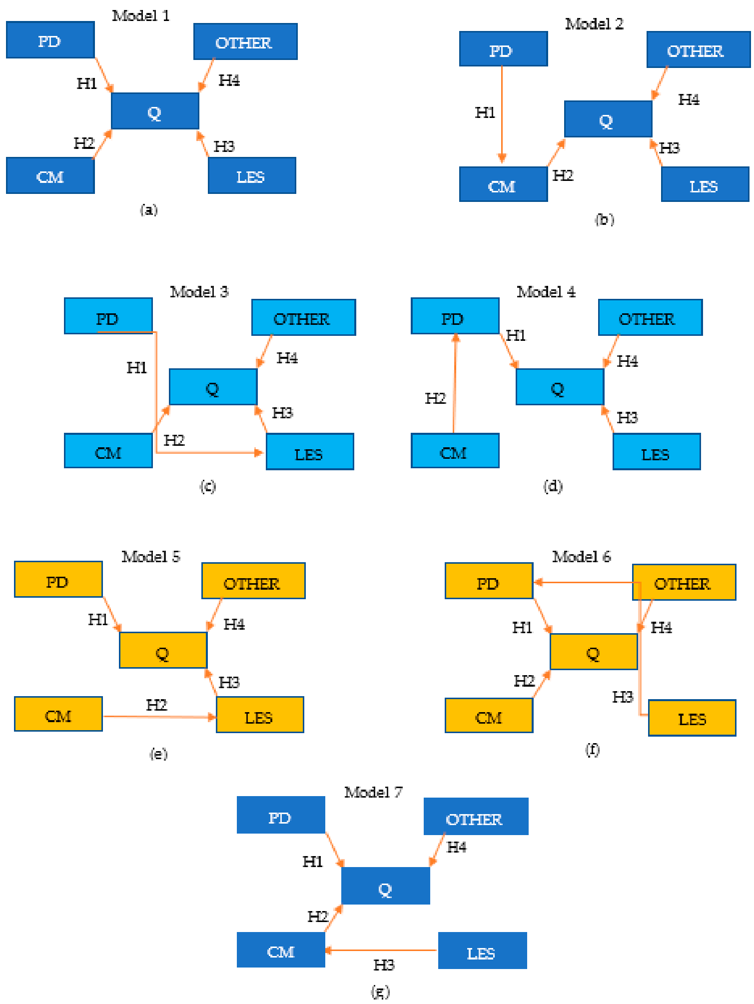

Figure 5. The structure of the seven models (**a**) Model 1, (**b**) Model 2, (**c**) Model 3, (**d**) Model 4, (**e**) Model 5, (**f**) Model 6, (**g**) Model 7.

Table 3. Hypotheses of the seven models.

No	Model	H1	H2	H3	H4
1	Model 1	PD→Q	CM→Q	LES→Q	OTHER→Q
2	Model 2	PD→CM	CM→Q	LES→Q	OTHER→Q
3	Model 3	PD→LES	CM→OC	LES→Q	OTHER→Q
4	Model 4	PD→Q	CM→PD	LES→Q	OTHER→Q
5	Model 5	PD→Q	CM→LES	LES→W	OTHER→Q
6	Model 6	PD→Q	CM→Q	LES→PD	OTHER→Q
7	Model 7	PD→Q	CM→Q	LES→CM	OTHER→Q

3.2.3. Assessing the Measurement Model

The measurement model assessment aims to eliminate insignificant factors that affect quality. The measurement model evaluation was achieved by assessing the construct and reliability validity and discriminant validity. Investigating the causes (indicators) that positively affect a group is the aim of construct validity test. Cronbach's alpha (α), composite reliability (CR), and average variance retrieved (AVE) for the four groups with their factors that affect quality were utilized to construct reliability validity test. The outer loading of the influencing causes (indicators) affects the construct reliability coefficients. The α, CR, and AVE are related to the outer loading of indicators' value (factors affecting quality). Equations (1) and (2) can be utilized to calculate α and CR, respectively.

$$\alpha = \left(\frac{M}{M-1}\right)\left(1 - \frac{\sum_{i=1}^{M} {s_i}^2}{s_t^2}\right) \tag{1}$$

$$CR = \frac{\left(\sum_{i=1}^{M} l_i\right)^2}{\left(\sum_{i=1}^{M} l_i\right)^2 + \sum_{i=1}^{M} var(e_i)} \tag{2}$$

The symbol of s_i^2 is the variance of cause I, and s_t^2 indicates the variance related to the observed total factors of a given group. l_i is the standardized outer loading of a given group's ith cause (indicator), M is natural cause in a given group, and $var(e_i)$ is a variance of measurement errors.

Additionally, the average variance extended (AVE), computed using Equation (3), was assessed to determine the reliability of any group in the model. It must be larger than the threshold value (>0.5) by leaving out the factor with the lowest outer loading (l) [44].

$$AVE = \frac{\sum_{i=1}^{M} l^2}{M} \tag{3}$$

The following steps were performed to satisfy each group's construct and reliability validity for all models, as summarized in Figure 6.

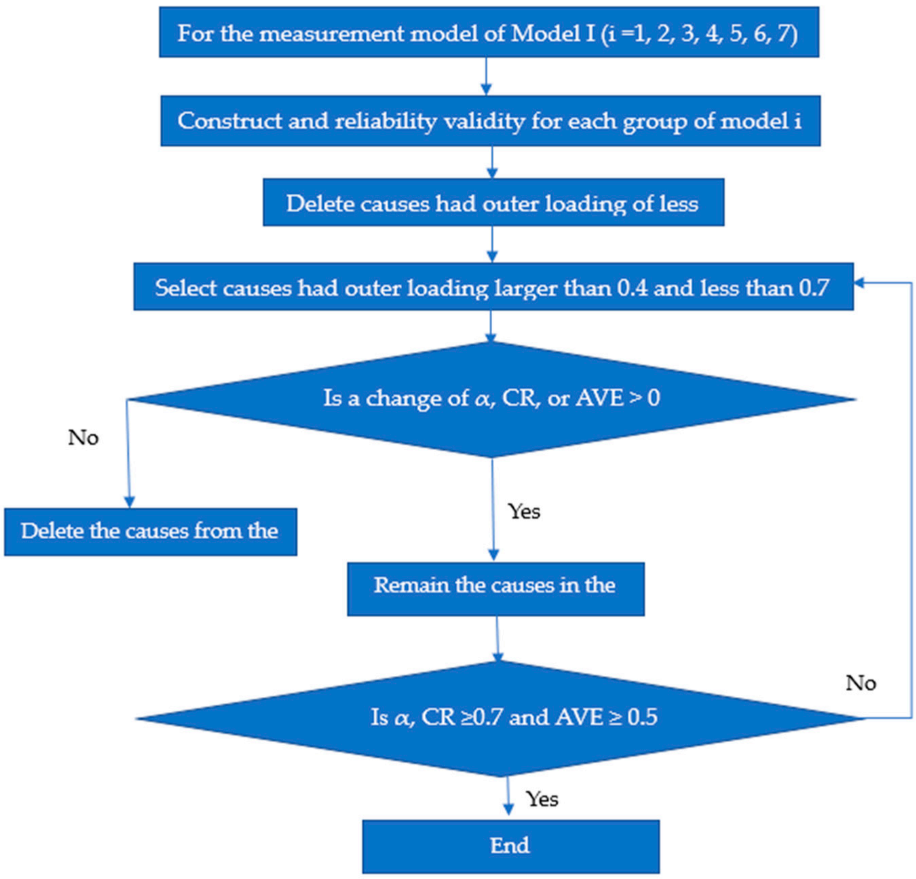

Figure 6. Flowchart of construct and reliability validity steps.

- Select one group (PD, CM, LES, or OTHER);
- Show the outer loading values of the causes of that group;
- Delete any causes that had an outer loading value less than 0.4.;
- Study the deletion of causes with outer loading ranging from 0.4 to 0.7;
- If this deletion leads to an increase in α, CR, and *AVE* of the group, the cause is deleted. Otherwise, the cause remains in the group;
- Repeat the above steps for the remainder of the causes until Cronbac h′s α and CR are at higher acceptable levels (0.7) and the *AVE* is higher than 0.5.

Cross-loadings and the Fornell–Larcker criterion have been set forth as crucial discriminant validity measures. We determined whether a latent group shares more variance than another latent group variable using the Fornell–Larcker criterion. Each latent group's square root of its *AVE* should be greater than the covariance between the group and other groups to fulfill the requirement mentioned above [45]. According to cross-loadings, an indicator should have a higher loading with the relevant latent group than all the other latent groups [45]. The discriminant validity steps are summarized in Figure 7.

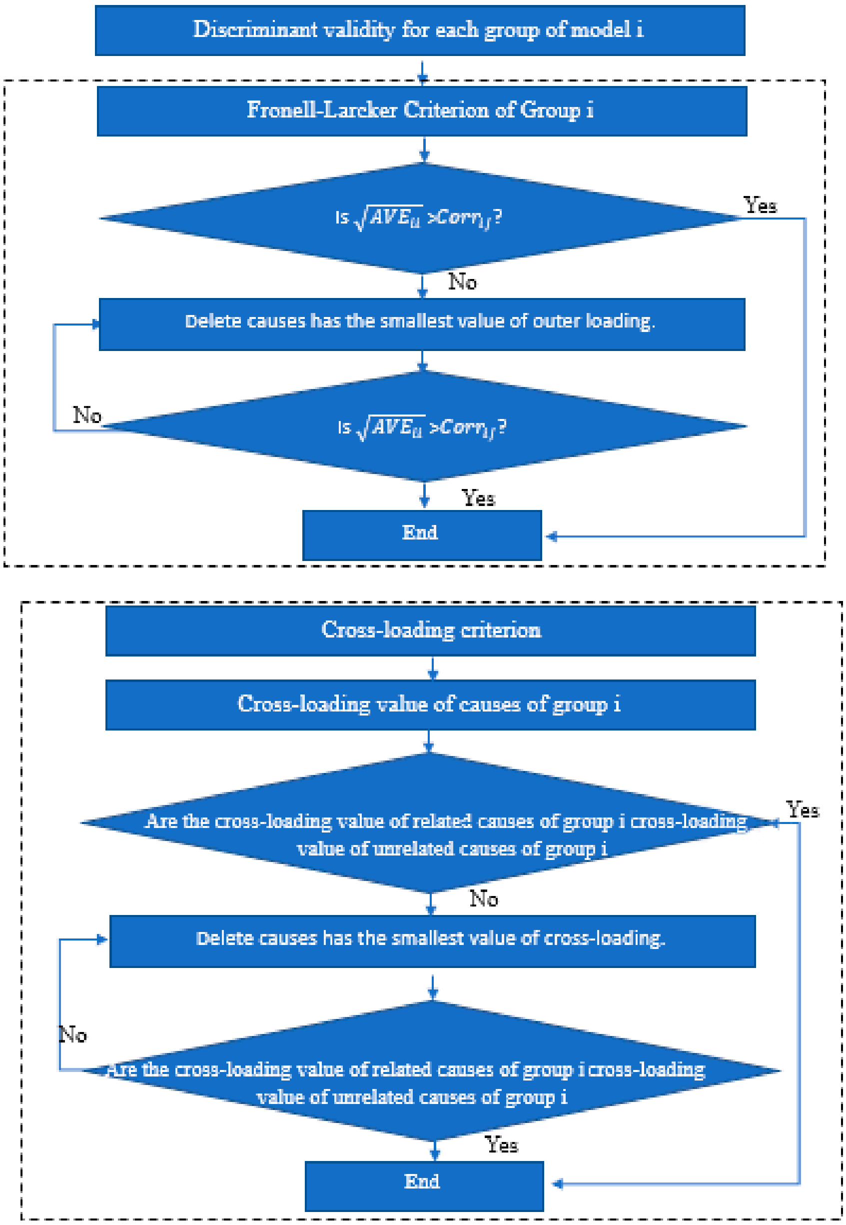

Figure 7. Flowchart of discriminant validity steps.

3.2.4. Assessing the Structure Model

The purpose of evaluating the structural model is to test hypotheses' relationships among the quality groups to detect the influence of the groups on each other. After carrying out the measurement model evaluation for the models, the structural models' prediction of the path coefficients is dependent on ordinary least square (OLS) regressions of each variable (factor) on its corresponding group. The path coefficients may be deviated, similar to regular multiple regression, if the estimation includes significant construct-level collinearity [44].

The hypotheses' relationship was examined by computing one of the two coefficients (t-value or *p*-value) based on the standard error obtained via bootstrapping generated in the SmartPLS program. The findings of the test hypotheses rely on either the t-value or *p*-value. Regarding the t-value, the coefficient is considered statistically significant when the t-value exceeds the critical value (i.e., significance level). Researchers typically utilize a confidence level of 5% when examining a hypothesis. Therefore, the level considered in this paper is 5%, with critical t and *p* values of 1.96 and 0.05, respectively. In other works, when the t-value is greater than or equal to 1.96, the null hypothesis that represents no relation between the two groups (b = 0) is rejected, and the alternative hypothesis, which confirms a relationship between the two groups ($b \neq 0$), is accepted.

4. Results and Discussion

Figure 8 presents the factors affecting the quality (indicators) that satisfied the outer model evaluation regarding the construct and discriminant validity. The significant causes of PD and CM are (PD2, PD5, PD6, and PD7) and (CM2, CM3, CM4, and CM5), respectively. Moreover, the critical causes of the LES and OTH are (LES2, LES3, LES4, LES5, LES6, and LES7) and (OTH1, OTH2, OTH3, OTH4, and OTH8), respectively.

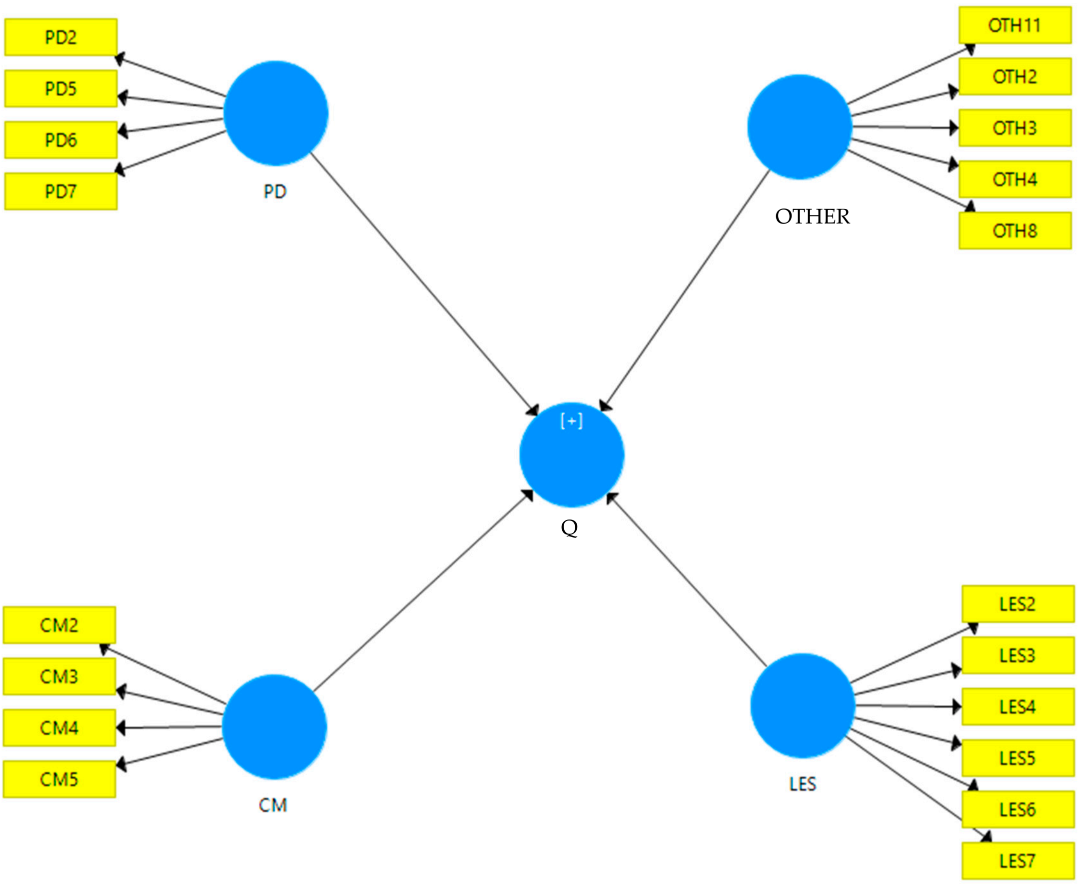

Figure 8. The remainder of the causes that satisfied the reliability and discriminant validity requirements.

For the satisfaction of the construct validity, the outer model provides an α value with a range from 0.813 to 0.859 for the four model groups, which were above the threshold value (0.7). The *CR* changed from 0.870 to 0.905, respectively, with more than 0.7, as shown in Table 4. The CM has a maximum *α* and *CR* value. However, those indices are the minimum for the OTH, as shown in Table 4. Regarding the *AVE*, the minimum value was for the OTH (0.574), while the maximum was for the CM (0.706). These values are higher than the threshold value (0.5).

Table 4. Construct and reliability validity.

	α	*CR*	*AVE*
CM	0.859	0.905	0.706
LES	0.856	0.895	0.588
OTH	0.813	0.870	0.574
PD	0.856	0.904	0.703

The discriminant validity for the groups, checked using the Fornell–Larcker criteria and the examination of the factors affecting the quality by cross-loading, is shown in Tables 5 and 6, respectively. The *AVE* of the groups, shown in the diagonal cell of Table 5, is higher than the covariance between the groups (the other cells of Table 5). It means that the variance of the group depended on itself more than the change from the other groups. The influence of the causes within its group should be more significant than that of the other causes. This was examined by determining each group's cross-loading of the 19 causes (indicators). As shown in Table 6, the cross-loading value of the related causes in the group was higher than those of unrelated causes in the same group. For example, the cross-loading of CM2, CM3, CM4, and CM5 to the group of CM was 0.749,0.901, 0.834, and 0.870, respectively. These values are higher than the cross-loading values of OTH1, OTH2, OTH3, OTH4, OTH8, LES2, LES3, LES4, LES5, LES6, PD2, PD5, PD6, and PD7 in the CM group, as shown in Table 6. Hence, the causes that are out of the group are no more influential than the causes within the group.

Table 5. Fornell–Larcker criterion of the four models' groups.

	CM	LE	OTHER	PD
CM	0.840			
LE	0.482	0.767		
OTH	0.655	0.737	0.757	
PD	0.193	0.631	0.432	0.838

Table 6. Cross-loading value of the causes of the groups.

	CM	LES	OTHER	PD
CM2	0.749	0.369	0.564	0.217
CM3	0.901	0.396	0.581	0.160
CM4	0.834	0.464	0.578	0.127
CM5	0.870	0.387	0.470	0.147
OTH11	0.475	0.372	0.683	0.193
OTH2	0.417	0.599	0.748	0.338
OTH3	0.444	0.677	0.736	0.502
OTH4	0.627	0.571	0.782	0.205
OTH8	0.521	0.528	0.831	0.356
LES2	0.447	0.814	0.516	0.452
LES3	0.280	0.798	0.522	0.540
LES4	0.542	0.699	0.631	0.398
LES5	0.284	0.855	0.576	0.601
LES6	0.221	0.790	0.465	0.622
LES7	0.439	0.622	0.678	0.269
PD2	0.189	0.560	0.361	0.703
PD5	0.143	0.635	0.483	0.896
PD6	0.166	0.362	0.215	0.848
PD7	0.152	0.507	0.338	0.892

The inner model of the PLS-SEM represents the relationships among the model's groups in the hypotheses. Table 7 shows the *p*-value and weight of the relationships (paths) in the seven models. Model 1 indicates that the null hypothesis (H1, H2, H3, and H4) was rejected, and there was a direct influence on the quality (Q). By examining the relationships' weight values, the LES comprises a significant part of the factors affecting the quality, followed by the OTH and CM. However, the PD has the smallest value for the weight of the relationship to the quality.

Table 7. The *p*-value and weights of the different paths of the seven models.

Model		H1	H2	H3	H4
Model 1	*p*-value	<0.001	<0.001	<0.001	<0.001
	Status	Accepted	Accepted	Accepted	Accepted
	weight	0.239	0.251	0.408	0.321
Model 2	*p*-value	**0.279**	0.001	<0.001	<0.001
	Status	**Rejected**	Accepted	Accepted	Accepted
	weight	**0.2**	0.236	0.548	0.342
Model 3	*p*-value	<0.001	0.002	<0.001	<0.001
	Status	Accepted	Accepted	Accepted	Accepted
	weight	0.649	0.24	0.542	0.35
Model 4	*p*-value	0.007	**0.285**	<0.001	<0.001
	Status	Accepted	**Rejected**	Accepted	Accepted
	weight	0.223	**0.204**	0.445	0.461
Model 5	*p*-value	0.005	<0.001	<0.001	<0.001
	Status	Accepted	Accepted	Accepted	Accepted
	weight	0.226	0.495	0.451	0.452
Model 6	*p*-value	<0.001	0.005	<0.001	<0.001
	Status	Accepted	Accepted	Accepted	Accepted
	weight	0.393	0.295	0.657	0.532
Model 7	*p*-value	<0.001	0.005	<0.001	<0.001
	Status	Accepted	Accepted	Accepted	Accepted
	weight	0.391	0.294	0.535	0.536

Model 2 examines the effect of project design on the contractor material by studying their relationship (H1). The *p*-value was 0.279, more than 0.05; hence, the PD has no impact on the CM, as shown in Table 7. Moreover, the influence of the project design on labor/equipment/site staff was examined in Model 3 by investigating (H1). The *p*-value of H1 was less than 0.001. Therefore, the alternative hypothesis was accepted, and there was an influence of the PD on the LES. Model 4 and Model 5 were tested to determine the influence of the factors affecting the quality of the contractor material on the project design and labor/equipment/site staff by examining H2 for the two models, respectively. The results shown in Table 7 revealed that the *p*-value of H2 for model 4 was 0.285, which is more than 0.05; thus, the null hypothesis is accepted, and the contractor material has no impact on the project design.

On the other hand, the *p*-value of H2 for model 5 is less than 0.001. Hence, the alternative hypothesis is accepted, and the contractor material influences the labor/equipment/site staff with a weight relationship of 0.495, as shown in Table 7. Based on the *p*-values of H3 for model 6 and model 7, which were less than 0.05, the factors affecting the quality of labor/equipment/site staff influence the factors affecting the quality of the project design and contractor material with relationship coefficients of 0.657 and 0.535, respectively, as shown in Table 7. Based on the above information, the authors concluded that labor/equipment/site staff factors doubly influence the project design and contractor material factors. A few studies have focused on the interaction influence among the factors that affect the quality. The authors of [18] pointed out that the construction material influences the labor performance in the construction industry. This finding agrees with the results of this paper, shown in the significant *p*-value of H2 in model 5.

For determining the most essential causes and ranking the nineteen factors affecting the quality (the causes that satisfied the outer model assessment), Model 1 was considered. The outer weight on the Q can be found by multiplying the outer weight on its group with the weight coefficient of the path that represents the relation from the group to the W group. For example, the outer weight of the LES1 on the group of the LES was 0.225, the weight coefficient of the path (LES→Q: H3 in Model 1) was 0.408 (as shown in Table 7), and the outer weight on the Q (quality group) was. Table 8 shows the outer weight of the causes. The causes were ranked by their outer weight and are shown in Figure 9.

Table 8. Outer weight of the factors on their group.

Quality Affected Causes	Outer Weight
LES5	0.095
OTH3	0.094
LES2	0.091
LES4	0.091
OTH8	0.089
OTH4	0.088
LES3	0.088
LES6	0.086
OTH2	0.085
PD5	0.084
LES7	0.082
CM3	0.078
CM4	0.078
CM2	0.072
PD7	0.072
CM5	0.071
PD2	0.071
OTH11	0.068
PD6	0.058

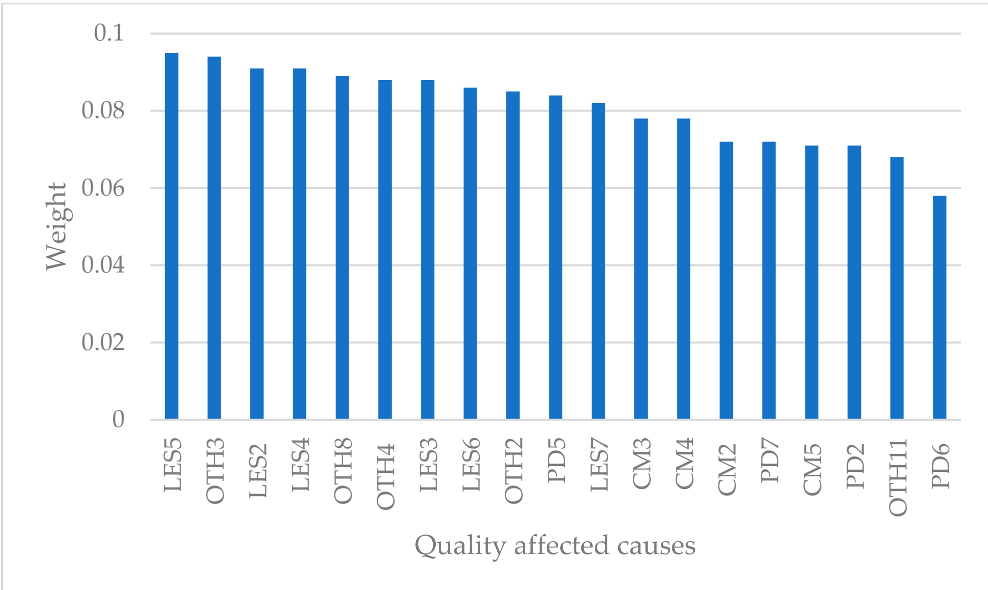

Figure 9. Ranking of the factors that affect quality using PLS-SEM.

The causes were ranked based on their outer-loading values, as shown in Table 8. Figure 9 displays the ranking of the 19 factors. The top ten causes of waste were the skill and experience of supervisory staff (LES5), errors and omissions in design documents (OTH3), negligence of equipment maintenance (LES4), lack of communication between supervisors and laborers (LES2), lack of supervision (OTH8), excessive confidence and differing perspectives influence the quality of the project (LES3), lack of communication and coordination within the contractor site team (OTH4), skill and experience of the contractors (LES6), and incompleteness and inconsistency of design documents (PD5). Labor/equipment/site staff represent 60% of the top ten factors affecting the quality. In addition, the OTH and PD percentages obtained by the PLS-SEM were 40% and 10%, respectively. The PLS-SEM method deviated toward the factors of labor/equipment/site staff. This deviation is attributed to the interdependencies among the factors affecting the quality, in which the LES influenced the CM, and the PD influenced the factors. The importance of the LES groups displayed in Figure 9 is confirmed in Table 7, which shows that the LES factors influenced both the factors of CM and PD.

For presenting the impact of the top three factors affecting the quality shown in Figure 9 on the project performance, regarding LES5, management staff with adequate skills and experience can effectively monitor and manage the quality of work during projects. They possess the knowledge and expertise to recognize potential issues, ensure compliance with standards and specifications, and execute quality control standards. Their ability to detect and promptly address quality issues can significantly enhance a project's overall performance. In addition, a professional supervision team better understands project risks and can proactively identify and mitigate potential risks. They can expect challenges, develop contingency plans, and implement risk management strategies. Their ability to assess risks accurately and take appropriate actions helps minimize disruptions, delays, and cost overruns, enhancing project performance. This role of the causes in the succession project was confirmed in [28,46].

Regarding errors and omissions in design documents (OTH3), design documents serve as the blueprint for a project, outlining the specifications, requirements, and expectations. Errors and omissions in these documents can lead to discrepancies, inconsistencies, and gaps in the design. This issue can compromise the quality of the project and hinder effective quality control efforts. In addition, OTH3 often results in rework and revisions during the construction phase. This issue leads to delays in project timelines and increases project costs. The need for rework can disrupt the smooth flow of activities, impacting the overall project schedule and performance. The impact of OTH3 on project cost was confirmed by Islam et al. [29]'s study, which indicated that design errors lead to a cost overrun of 40%.

Lack of maintenance increases the risk of unanticipated equipment failures during construction project processes. Equipment breakdowns can disrupt project activities, lead to unexpected downtime, and require costly repairs or replacements. These disturbances can negatively impact project programs, budgets, and overall performance [47]. In addition, LES4 can create safety hazards for project personnel. Malfunctioning or inadequately maintained tools may pose hazards in terms of accidents, damages, or even fatalities. Ensuring regular maintenance, inspections, and repairs is critical to maintaining a safe working environment and protecting the well-being of project group members. Karuppiah et al. [25] revealed that impaired equipment maintenance is one of the most common factors that initiates occupational accidents and damages. In terms of the impact of LES4 on the cost overrun of projects, neglected equipment maintenance often leads to higher operational costs and unexpected expenses [26]. Equipment defeats may demand emergency repairs, replacement parts, or even the hire of alternative equipment, which can significantly raise project expenses. These cost overruns can strain project allocations and impact their financial performance.

On the other hand, LES4 significantly influences the total quality of management. Equipment malfunctions resulting from insufficient maintenance can lead to quality problems in project deliverables. Faulty equipment may produce subpar outputs or lead to errors and flaws in the work. This problem can negatively affect the overall quality of the project, client satisfaction, and the reputation of the project team. The study of [48] stated that it is essential for the site management team to provide sufficient safety equipment. In addition, the site management group in this study noted that appointing a separate safety leader is important. Moreover, the study's authors recommended supplying more safety training [48].

Oke et al. [5] stated that significant factors affecting the performance quality of construction projects are related to the use of unskilled and incompetent trade contractors. They also illustrated the impact of site supervision, inadequate on-site supervision, and a lack of dedication on the part of the personnel in charge of monitoring compliance with established standards. These findings agreed with the study results represented by LES2 and LES5, ranked in the top ten causes by both PLS-SEMs. In addition, the role of LES2 and LES5 was also confirmed by [49]. The role of the lack of CM2 (planning and management of contractors) in quality construction was confirmed by Oke et al [5].

Moreover, the results in terms of CM2 (incompleteness and inconsistency of design documents) and PD5 (incompleteness and inconsistency of design documents) were agreed upon by [49]. They stated that LES2, LES5, CM2, and PD5 are essential critical factors in rework issues, which are reflected in the quality of construction. They also showed the roles of OTH10 (frequent change in design) and PD1 (project scope management) in the reworking and quality of construction projects. However, PD1 and OTH10 did not rank within the top ten when using the PLS-SEM method. The importance of PD6 (drawings not prepared in full detail), ranked as the sixth and fourth cause based on the PLS-SEMs, was illustrated by [50]. They stated that the lack of complete, accurate, and transparent data undermines the construction procedure and may lead to stakeholder conflicts.

5. The Study's Limitations

This study focuses on one type of project construction, housing infrastructure structures, due to the high frequency of this type of project in the KSA. Therefore, the domain of the study was the KSA. The construction representatives included site engineers, general managers, surveyors, consultant engineers, and contractors. This study's results can be generalized to other projects in different countries.

6. Conclusions

The overall sustainability of the constructed environment is enhanced through high-quality construction, particularly for infrastructure projects. The construction industry has experienced considerable growth, leading to global construction quality difficulties. A project's performance over its life cycle is influenced by the quality of its construction. This paper aims to identify and rank the significant factors affecting the quality of housing infrastructure projects. Our methodology included a pre-analysis, analysis, and post-analysis. The pre-analysis entailed obtaining information (to prepare the survey responses and import them into the SmartPLS program), gathering data (to study and collect all factors affecting quality in the literature), and conducting a questionnaire to assess the impact of the factors gathered on the Saudi construction sector. Applying PLS-SEM strategies was the goal of the analysis step. The post-analysis aimed to identify the most essential quality factors, establish the interactions between them, and contrast the results with those of prior studies. According to the PLS-SEM ranking, the results indicated that labor/equipment/site staff were responsible for more than half of the top 10 causes. The OTH, CM, and PD percentages were 20%, 30%, and 10%, respectively.

Regarding the interdependencies among the groups, the factors affecting the quality of labor/equipment/site staff influence the factors affecting the quality of the project design and contractor material with relationship coefficients of 0.657 and 0.535, respectively. In addition, the top five most important factors affecting the quality of labor/equipment/site staff are the skill and experience of supervisory staff (LES5), lack of communication between supervisors and laborers (LES2), negligence of equipment maintenance (LES4), excessive confidence and differing perspectives influence the quality of the project (LES3), and skill and experience of contractors (LES 6). This study is the first of its kind in the KSA and might help stakeholders better understand how to improve performance in the country's construction sector using Six Sigma construction principles.

Author Contributions: Conceptualization, N.A., A.M.A. and A.S.A.; Data curation, N.A.; Formal analysis, N.A.; Funding acquisition, N.A.; Investigation, N.A. and A.M.A.; Methodology, N.A., A.M.A., A.S.A. and K.S.A.-G.; Project administration, A.M.A., A.S.A. and K.S.A.-G.; Resources, N.A.; Software, N.A.; Supervision, A.M.A., A.S.A. and K.S.A.-G.; Validation, N.A., A.M.A. and K.S.A.-G.; Visualization, N.A., A.M.A. and A.S.A.; Writing—original draft, N.A.; Writing—review and editing, N.A., A.M.A. and K.S.A.-G. All authors have read and agreed to the published version of the manuscript.

Funding: The authors extend their appreciation to the Deputyship for Research and Innovation, Ministry of Education in Saudi Arabia, for funding this research work through project no. (IFKSUOR3-380-4).

Data Availability Statement: The raw data supporting the findings of this paper are available on request from the corresponding author.

Conflicts of Interest: No conflict of interest exist. The submitting author is responsible for the co-author's interest.

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