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Research Article

Risk Factors for Time and Cost Overruns of Pipeline Projects in Saudi Arabia

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Evaluating risks is crucial for the smooth execution of pipeline projects. In Saudi Arabia, pipeline building projects frequently experience delays and cost overruns. This study tries to identify these risk factors. Thus, risk factors were collected from the literature and presented to four experts to identify the 26 most common factors for pipeline construction in Saudi Arabia. The risk factors were then assessed using a questionnaire to measure the degree of impact of the 26 factors by 135 participants. Partial least square structure equation model (PLS-SEM) and relative importance index (RII) methods were utilized to rank the significant factors after performing the reliability and discriminant validity of the questionnaire data. The findings show that the top five factors based on PLS-SEM were discrepancy between implementation requirements and specifications, financial failure/bankruptcy, poor pipeline material quality, supplying invalid materials, and weak ability to identify and monitor the threats. The ranking of the factors using PLS-SEM is different in the RII method. This difference is due to applying the Cronbach's α formula in the two methods. The PLS-SEM computes the coefficients of the groups, while the RII computes the coefficients for all factors. The study results can assist pipeline project managers in identifying and ranking risk variables to efficiently utilize the limited financial and human resources available for the risk management.

1. Introduction

Building infrastructure is a process that involves several different disciplines working together, including designing buildings, budgetary and administrative supervisors, technological expertise, transportation and supply chains, sustainability, managing risks, and project management. Construction projects may be roughly categorized into residential, building, and industry-specific projects. Construction is one of the most permanent and ongoing industries, with consistent development in the recent decades. The 2030 vision of Saudi Arabia has expanded construction activity. Nevertheless, Saudi Arabia's construction sector has had considerable cost and schedule overruns. All parties engaged in the building process are impacted by these cost overruns.

Infrastructure projects vary from country to country because of the cultural differences, governance systems, geographic location (climate, terrain, and natural resources), economic development, public demand, and environmental concerns. In addition, the factors in their ranking differ from one infrastructure project to another depending on type and size [1]. Water supply systems are expensive to develop and maintain. They also require careful consideration of financial, environmental, and institutional factors. Studying pipeline projects in Saudi Arabia is significant due to water scarcity challenges, growing population, food security, economic development, environmental impact, climate resilience, government policies, and its potential contributions to global discussions on water resource management. As significant projects involve many stakeholders, drinking water supply projects are vulnerable to factors [2]. Pipeline systems are essential for the developing countries' economic growth and welfare [3]. They provide a reliable way to transport water, sewage, and other essential services. The benefits of pipeline projects can lead to improved health outcomes, economic development, and environmental sustainability. For example, pipes can transport oil and gas, essential commodities for many industries [4]. Pipelines can also be used to transport agricultural products, which can help to improve food security. In addition, pipelines reduce the environmental impact of development [5]. For instance, pipelines can collect and transport rainwater, which can help in reducing the need for groundwater extraction. Pipes can also be utilized to transport wastewater for treatment, which can assist in reducing pollution.

Investigating water pipeline projects are essential due to critical factors like corrosion control (addressing rust concerns) and water leakage prevention (conserving resources and ensuring a reliable supply). These factors collectively emphasize the need for a comprehensive evaluation of such projects. Pipeline construction projects are exposed to an uncertain environment due to factors such as the complexity of planning and design, various interest groups, limited resources, and economic inflation [6]. A variety of factors and uncertainties often cause delays and cost overruns. Numerous studies were conducted to recognize risk factors in the global construction industry [7–11]. Concentrating on identifying the factors unique to pipeline projects in Saudi Arabia is crucial. The partial least square structure equation model (PLS-SEM) possesses several criteria in the risk assessment. The PLS-SEM was utilized to recognize and rank the pipeline construction factors. Pipeline projects share specific characteristics and challenges, making them more susceptible to certain factors.

This study aims to identify and rank the essential factors of pipe construction that lead to cost overrun and time delays by conducting a questionnaire survey and using PLS-SEM due to having several assessments for the questionnaire data, such as construct and reliability validity and discriminant validity.

2. Literature Review

2.1. Risk Factors Leading to Cost and Time Overruns. According to Dey [12], risk analysis and management is a vital project management practice to ensure minimal surprises occur while the project is ongoing. He stated that organizations may lessen the possibility of project failure by recognizing, evaluating, and adopting solutions to manage possible factors. According to Issa et al. [13], organizations should use a suitable method of project factor management to reduce the adverse effects of factors and enhance the advantages of opportunities. They state that this is essential to ensure the success of any project.

Over 70% of public building projects in Saudi Arabia suffered from delays, according to research by Alzara et al. [14]. The study recognized several factors that cause these delays, including inadequate collaboration between project participants, low productivity of employees, insufficient planning and scheduling, payment difficulties, rising material costs, poor site management, unattainable contract duration times, change orders, inadequate work quality, and workers ineffectiveness. Ineffective management frequently contributes to the construction delays. They may be viewed as a risk for infrastructure projects that might be controlled and reduced if correctly detected, examined, and managed throughout the project life cycle [15].

The top five causes for delays were the consultant's frequent design revisions, the consultant's faults in design discovered after construction, and the consultant's underestimation of project length throughout the planning phase [16]. Similarly, the research determined 27 extremely serious factors that led to cost overruns in OWWCE (Oromia Water Works Construction Enterprise) projects, with the underestimation of the project's duration, payment delays, a lack of coordination and coordination during the planning phase, and changes in the cost of raw materials ranking as the top five factors. The primary repercussions of the concerns were the incapacity to provide sufficient value for funds and failure to acquire project financing or the difficulty to acquire it at higher prices owing to the other reasons emerging from a negative reputation [17]. Average cost overrun rates for pipeline supplies, workers, ROW (right of way), and overall spending are 4.9%, 22.4%, −0.9%, 9.1%, and 6.5% [18].

Defective design risk is ranked first among the eight major risk factors, affecting about 50% of wastewater projects. The study divided factors in the wastewater projects into two main groups: technical factors, such as defective design, and managerial factors, such as permits and information unavailability. Finally, in wastewater projects, the study concluded that technical factors are more frequent than the managerial risks [19]. "Government intervention" and "Public credit" were rated as severe for all three categories of projects. According to the data, the most severe issues are government-related [20]. The most critical causes of cost overrun were payment delays by the client, delays in decision-making by the government, inadequate cost estimates by the consultant, and the client's insufficient experience in the contract management [21].

About 70% of the cost of a pipeline project is made up of pipe and labor expenses [22]. The top five factors were the state of the economy, design changes, the custom of selecting the contractor who offers the lowest price, delays, and design flaws. It is crucial to note that, per the studied data, awarding a contract to the lowest bid is not among the top five causes of delay in other nations. Incompatible methods of management, inadequate client-staff communication, a lack of contractor and consultant planning before the project, inadequate collaboration with the government agencies, and a lack of stakeholder participation during the conceptual phase are additional factors that contribute to the cost overruns of Saudi infrastructure projects. The time needed to provide labor visas to foreign employees is a Saudi Arabia-specific factor [23]. Table 1 provides an overview of the risk variables that cause schedule and expense overruns and their causes from earlier studies.

2.2. PLS-SEM Methods. PLS-SEM is usually utilized to test the interrelationships among groups after checking the validity between groups on their construct and discriminant validity factors. Hence, PLS-SEM can detect insignificant factors for each group by performing several statistical operations. Several studies used PLS-SEM for ranking factors in the different applications, as shown in Table 2.

2.3. Gap Knowledge. Most studies dealt with the general detection of essential risk factors in the construction projects.

Table 1: Causes of risk factors leading to time and cost overrun.

Group	Risk factor	References
Design risk	Defective design	[24]
	Design change due to change orders	[21]
	Delay in drawing approval	[25]
Health, safety and environment	Force majeure (earthquake, pandemics, etc.)	[19]
	Night work (poor visibility, slip, and trip)	[26]
	Exposed existing pipelines during construction	
	Inadequate site safety procedures	
	Government permit approval delay	[22, 27]
	Accidents (human, vehicle, etc.)	
	Geological factors like soil movement and landslides	
Security & Social	Terrorism and sabotage	[22, 27]
	Reduction in the productive capacity of labor and machinery	[19]
	Labor strike	[17]
Supply risk	Supplying invalid materials	[19]
	Materials monopoly by suppliers	[19]
	Delays in materials and equipment supply	[21]
Financial risk	Financial failure/bankruptcy	[19]
	Inflation and interest rate increase	[25]
	Increase in tax regulation	[25]
	Increase of contractor project cost (Cost overruns)	[25]
Construction risk	The discrepancy between implementation requirements and specifications	[19]
	Variation orders	[17]
	Poor pipeline material quality	[18, 28]
	Corrosion of pipeline during its life cycle time	
	Weakness in identifying and monitoring dangers.	[22, 27]
	Operational errors (human error and equipment failure)	
	Unforeseen site circumstances (differing site conditions)	[24, 25]

Table 2: Studies used PLS-SEM to rank their applications.

References	Purpose	Field
[7]	Ranking causes of cost deviation	Construction
[29]	Factors influencing the cost-effectiveness of large-scale road development.	Construction
[30]	Ranking of factors of the University competitiveness	Education
[31]	Study factors of the understanding cryptocurrency adoption	Financial

However, the factors differ from one project to another depending on the type and size. Moreover, these factors may differ from one country to another country. Some studies have addressed the critical factors for tube construction based on the relative importance index (RII) method. However, RII values of factors sometimes suffer from convergence and coincidence of their values, which leads to difficulty in classifying those factors. In addition, the only validity performed with the RII method was Cronbach's α validity. PLS-SEM was used in this research to overcome the convergence values, and several evaluations were utilized before the classification process, such as composite reliability, extracted mean-variance, Fronell–Larcker, and cross-loading.

3. Methodology

The methodology is divided into five stages, which are explained in detail below:

Data collection: this stage involves collecting data on the common factors associated with pipeline construction projects. The data were collected from various sources, such as reviews of published papers, historical data, and public data. The completion of this step results in a preliminary list of risk factors. The preliminary list is then validated by subject matter experts (SMEs) via open-ended interviews. Based on their agreement, a revised list of risk factors is created. Questionnaire design and distribution: once SMEs have created the revised factors, a questionnaire was designed (close-

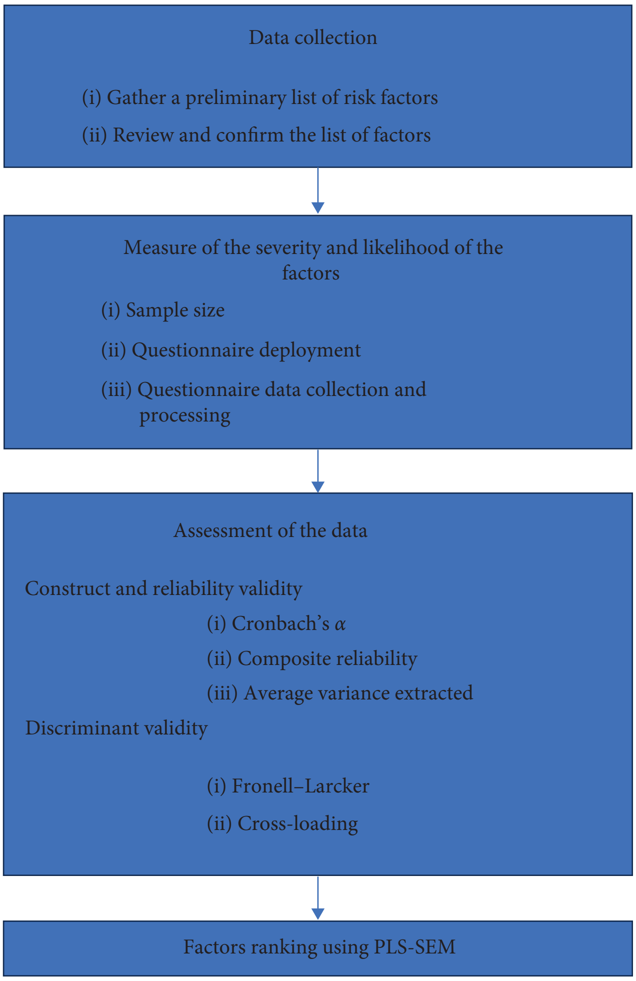

Figure 1: Methodology flowchart.

ended) to assess the severity of each risk. The questionnaire was conducted in the Kingdom of Saudi Arabia in 2023, where it was distributed among engineers and water project managers employed by the construction and consulting firms. The questionnaire was then sent to a representative sample of industry professionals to get their input on these factors. Questionnaire data assessment: the questionnaire data were assessed to ensure validity and reliability. This assessment is done by checking for the outliers and consistency of responses. The data were also analyzed to identify any patterns or trends. Risk ranking: the factors were then ranked using statistical analysis involving statistical techniques, relative impotence index, and PLS-SEM to analyze the questionnaire data and identify the factors with the highest impact. Comparison of results: the risk ranking results using PLS-SEM were compared with those using RII methods, and discuss the differences between the two methods. Figure 1 shows the steps involved in each stage. The boxes in the flowchart represent the tasks that need to be completed, and the arrows represent the order in which the tasks need to be completed. The methodology is designed to be comprehensive and objective in identifying the most significant factors associated with the pipeline construction projects.

3.1. Data Collection. The phase of data gathering can be separated into two parts: risk identification and risk evaluation. The project team recognized all potential hazards to the project throughout the risk identification process. This identification was done by interviewing industry experts, reviewing historical data, and publishing papers. During the risk assessment subphase, the likelihood of each risk was assessed.

3.1.1. Gather a Preliminary List of Risk Factors. The preliminary list of risk factors was identified by conducting a thorough literature review examining various sources, including academic articles and research papers. The preliminary list consists of 50 risk factors.

3.1.2. Review and Confirm the List of Factors. The preliminary list was presented to six SMEs from clients, consultants, and contractors to evaluate each risk factor's relevance and probability of occurrence. The selected SMEs have experience in mega pipeline projects in Saudi Arabia. These projects are significant to the economy, with values ranging between SAR 800 and1,000 million. All SMEs were fully involved in these projects throughout their lifecycles, from initiation to completion. The experts identified factors, including six engineers with experience between 10 and 30 years of working on a variety of infrastructure construction projects, including pipeline projects. The expert's qualifications include one Ph.D., three Masters, and two B.Sc. in civil, mechanical, and chemical engineering, in addition to engineering management and law. The goal was to determine the most common factors in the pipeline construction projects in Saudi Arabia. The results of the SME interview concluded 26 factors. SME structure interviews then revised these factors. They confirmed and agreed that 26 factors were common in Saudi pipe construction. The 26 factors have been divided into six groups (design, HSE, security and social, supply, financial, and construction), as shown in Table 3.

3.2. Measure of the Severity and Likelihood of the Factors. After determining the 26 common pipeline construction factors, an electronic questionnaire was designed to assess the severity and likelihood of the identified factors of each risk using a 5-point Likert scale ranging from 1 (very low) to 5 (very high). The questionnaire should be easy to understand, complete, and tailored to the specific project. The questionnaire implementation phase involves distributing the questionnaire to a representative sample of industry professionals and collecting the responses. Before distributing the electronic questionnaire to participants, the applicability of the questionnaire should be assessed by presenting it to the limited participants.

3.2.1. Sample Size. The sample size of a study is the number of individuals or units selected to participate in the study. The sample size should be large enough to represent the studied population but not so large that collecting data from all individuals or units is impractical or expensive. A sample size of 135 is considered sufficient for this paper, and all selected individuals to participate in the questionnaire are

Table 3: Questionnaire results.

Risk group	Risk code	Risk factor	Mode	Standard deviation
Design	D1	Defective design	Moderate	0.71
	D2	Design change due to change orders	High	0.70
	D3	Delay in drawing approval	High	0.83
Health, safety and environment	HSE1	Force majeure (earthquake, pandemics, etc.)	Low	1.05
	HSE2	Night Work (poor visibility, slip, and trip)	Moderate	0.75
	HSE3	Exposed existing pipelines during construction	Moderate	0.83
	HSE4	Inadequate site safety procedures	Moderate	0.81
	HSE5	Government permit approval delay	High	0.77
	HSE6	Geological factors like soil movement and landslides	Moderate	0.76
	HSE7	Accidents (human, vehicle, etc.)	Moderate	0.91
Security and social	SS1	Terrorism and sabotage	Moderate	1.00
	SS2	Reduction in the productive capacity of labor and machinery	Moderate	0.77
Supply	S1	Supplying invalid materials	Moderate	0.72
	S2	Materials monopoly by suppliers	High	0.70
	S3	Delays in materials and equipment supply	High	0.73
Financial	F1	Financial failure/bankruptcy	High	0.83
	F2	Inflation and Interest rate increase	High	0.78
	F3	Increase in tax regulation	High	0.76
	F4	Increase of contractor's project cost (cost overruns)	Moderate	0.71
Construction	C1	The discrepancy between implementation requirements and specifications	Moderate	0.76
	C2	Variation orders	High	0.74
	C3	Poor pipeline material quality	High	0.83
	C4	Corrosion of pipeline during its life cycle time	High	0.81
	C5	Weakness in identifying and monitoring dangers.	Moderate	0.68
	C6	Operational errors (human error and equipment failure)	High	0.75
	C7	Unforeseen site circumstances (differing site conditions)	Moderate	0.64

from pipeline construction backgrounds that worked in Saudi Arabia for at least 10 years.

The selection of the 135 participants for this study was carried out with specific criteria in mind to ensure a representative and diverse sample that reflected various organizations and a range of expertise in pipeline projects. The criteria for participant selection included:

Organizational diversity: the participants were intentionally drawn from a wide spectrum of organizations involved in the pipeline projects. This diversity encompassed governments, owners, designers, consultants, contractors, and subcontractors to provide a holistic view of pipeline projects.

Geographical diversity: to ensure a broad perspective, participants were selected from different geographical regions within KSA. This geographical diversity aimed to capture regional variations in pipeline project management, regulations, and challenges.

Project experience: participants were chosen to represent a range of expertise levels in the pipeline projects. This included individuals with extensive experience in managing and executing pipeline projects as well as those with more intermediate exposure. The intent was to gather insights from both seasoned professionals and individuals relatively new to the field.

Roles and responsibilities: the selection process considered the roles and responsibilities of the participants within their respective organizations. This ensured that a cross-section of perspectives was included, encompassing project managers, engineers, regulatory experts, specialists, and other relevant roles involved in the pipeline projects.

Size of organizations: to capture variations in project management practices, participants were selected from organizations of the different sizes, ranging from small, local firms to large multinational corporations. This accounted for the impact of organizational scale on pipeline project execution.

By adhering to these criteria, the study aimed to create a well-rounded and diverse participant pool, thereby providing a comprehensive and nuanced understanding of pipeline projects, the challenges they entail, and the various strategies employed across different organizations and expertise levels. This approach ensured that the findings and insights derived from the study were representative of the broader pipeline project landscape.

3.2.2. Questionnaire Deployment. The process of sending a close-ended questionnaire can be divided into the following steps:

(1) Pilot tests questionnaire: this involves giving the questionnaire to a small group to test for clarity, comprehension, and length. Any necessary changes should be made before the questionnaire is sent to the broader population.
(2) Choose a delivery method: the questionnaire will be delivered online. The method of delivery, which is online, is determined by the target audience and the questionnaire purpose.

3.2.3. Questionnaire Data Collection and Processing. The process of collecting questionnaire data can be divided into the following steps:

(1) Follow-up with norespondents: follow-up with people who have yet to respond to the questionnaire. This step is done by sending reminder emails.
(2) Clean data: this involves checking the data for errors and inconsistencies. Any errors should be corrected before the data are analyzed.

The questionnaire used to assess the 26 revised risk factors was close-ended. The respondents were asked to choose from a set of predetermined answers, a 5-point Likert scale to measure the impact degree of each risk factor on pipeline installation time and cost. Table 3 also presents the results of a questionnaire administered to a sample of 135 SMEs and shows each risk factor's mode and standard deviation. The questionnaire participants were a diverse group of SMEs to ensure that the results represented the general population, 25% clients, 25% consultants, and 50% contractors with a wide range of ages and occupations. The most common occupations among the participants were civil and mechanical contracting/engineering. The questionnaire participants are of different nationalities working in the pipeline projects within Saudi Arabia.

3.3. Assessment of the Data. The questionnaire data were assessed for construct reliability and discriminant validity. The construct and reliability validity aim to identify the necessary indicators and remove the insignificant ones, while the discriminant validity aims to examine if a group is unique. There are three coefficients to measure the construct validity of the six-factor groups: Cronbach's alpha (α), composite reliability (CR), and average variance extracted (AVE). The α, CR, and AVE formulas can be computed using Equations (1)–(3) [32].

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K} s_i^2}{s_t^2}\right), \quad (1)$$

$$\mathrm{CR} = \frac{\left(\sum_{i=1}^{K} \lambda_i\right)^2}{\left(\sum_{i=1}^{K} \lambda_i\right)^2 + \mathrm{Var}(\varepsilon_i)}, \quad (2)$$

$$\mathrm{AVE} = \frac{\sum_{i=1}^{K} \lambda_i^2}{\sum_{i=1}^{K} \lambda_i^2 + \mathrm{Var}(\varepsilon_i)}, \quad (3)$$

where K is the number of the factors, s_i^2 is the variance of *the* ith factor, s_t^2 is the total variance, λ_i is the standardized loading value of the ith factor, and $\mathrm{Var}(\varepsilon_i)$ is the error variance of the ith factor. The threshold value of α and CR is 0.7, and for AVE, it is 0.5 [32]. To ensure these factors represent the related groups. When one of the three construct coefficients (α, CR, and AVE) values do not satisfy the threshold value, the impact of the elimination of each factor on the value of the unsatisfied coefficient was studied. For example, if the elimination of the ith factor leads to an increase in the value of the unsatisfied factor, this factor should be deleted unless the factor should remain. It is attributed that the remaining factor has no detrimental impact on the three construct coefficients. Two criteria satisfied the discriminant: Fronell–Larcker among the groups and cross-loading for the factors and groups. Due to the simplified usage, the SmartPLS program was utilized in this paper to carry out the contract and discriminant validity. The outer (relationship of groups with their factors) and inner model (relationships among groups) are shown in Figure 2.

3.4. Factor Ranking Using PLS-SEM and RII Methods. After assessing the data, the remainder of the factors were ranked based on the two methods. The first method is the RII. The second method is based on the relative weight computed using PLS-SEM.

The RII of each remainder formula can be computed based on the frequency response Likert scale (n_1, n_2, n_3, n_4, and n_5) and total response (N), as shown in Equation (4)

$$\mathrm{RII} = \frac{f_1 \times n_1 + f_2 \times n_2 + f_3 \times n_3 + f_4 \times n_4 + f_5 \times n_5}{f_5 N}, \quad (4)$$

where f_1–f_5 represents the 5-point Likert scales as Equations (1)–(5). The frequency responses of f_1, f_2, f_3, f_4, and f_5 are n_1, n_2, n_3, n_4, and n_5, respectively. The RII method is performed after assessing construct validity regarding Cronbach's α.

The Smart PLS program was utilized in the paper for the PLS-SEM method due to its simplicity. The outer weight is the relative importance of an indicator in the measurement model of the outer weight of the factors being ranked after implementing the construct and discriminant validity.

4. Results and Discussion

Figure 3 shows the factors (yellow box) that satisfied the discriminant validity and construct validity for CR and AVE, at least except security social, in which α and CR were less than 0.7 and did not satisfy the reliability validity with values of 0.198 and 0.678, respectively, as shown in Table 4. Hence, its factors are insignificant and were

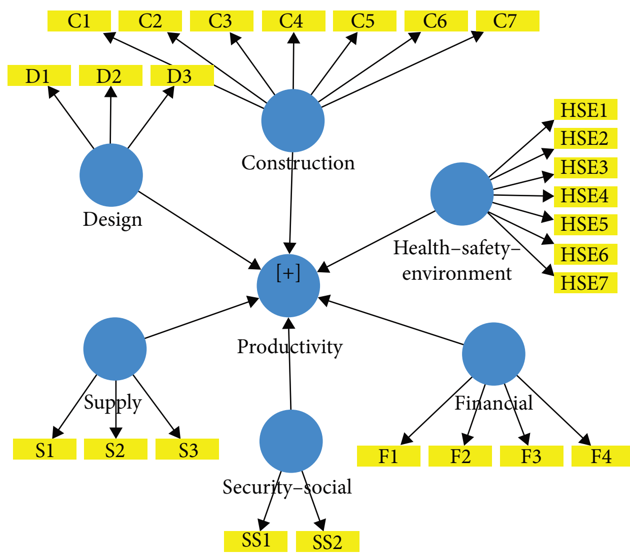

Figure 2: The PLS-SEM model.

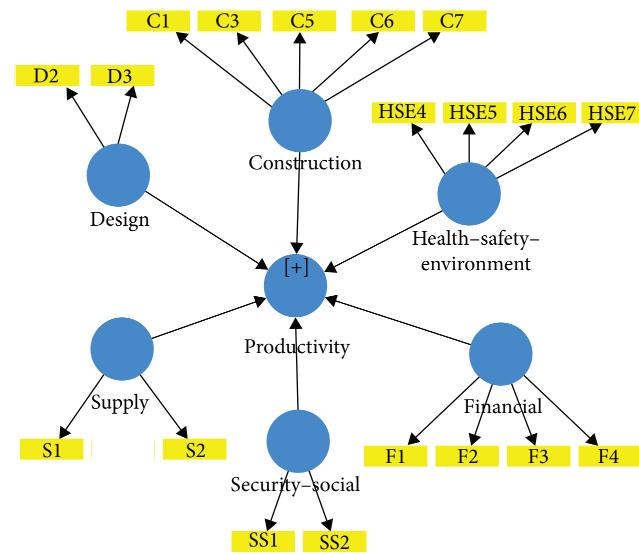

Figure 3: The significant factors that satisfied the construct and discriminant validity.

Table 4: Construct validity of the six groups.

	Cronbach's α	Composite reliability	Average variance extracted (AVE)
Construction	0.786	0.855	0.542
Design	0.626	0.843	0.728
Financial	0.765	0.851	0.588
Health–safety–environment	0.674	0.802	0.504
Security–social	0.198	0.678	0.541
Supply	0.632	0.845	0.731

Table 5: Fornell and Larcker for the discriminant validity of the six groups.

	Construction	Design	Financial	Health–safety–environment	Security–social	Supply
Construction	0.736					
Design	0.372	0.853				
Financial	0.710	0.276	0.767			
Health–safety–environment	0.517	0.295	0.387	0.710		
Security–social	0.519	0.366	0.486	0.580	0.735	
Supply	0.550	0.392	0.593	0.428	0.545	0.855

excluded from the ranking process. The α of the supply and design group was 0.632 and 0.626, respectively. These values fall below the minimum allowed level (0.7); this low value can be explained by the latent variable's small number of variables (it consists of just two factors). Composite reliability is indicated to evaluate the consistency reliability of groups since Cronbach's α is susceptible to several variables and understates internal consistency reliability [33]. The AVE of the six groups was accepted with a value of more than 0.5, as shown in Table 4. In terms of the discriminant validity among the six groups, Table 5 shows the Fronell–Larcker criterion analysis, the square root of the AVE value, which shows in the diagonal element are higher than the covariances among the groups, which is shown in nondiagonal elements as shown in Table 5.

Regarding the cross-loadings, an indicator's loading with the related latent group should be more significant than its loadings with all the other latent groups [33]. Table 6 shows the cross-loading of the significant factors with the six groups; the outer loading of the factors with their latent groups was higher than the outer loading of these factors with another latent group. Hence, the variance of the latent group depends on its factors more than the factors of the other latent group.

The SmatPLS provides the outer weight of the factors. These procedures allow calculating the factor's outer weights: the inner weights, the regression coefficients linking the factors to the group, are estimated first. The group scores are then estimated using the inner weights. The outer weights are

Table 6: Cross-loading.

	Construction	Design	Financial	Health–safety–environment	Security–social	Supply
C1	0.791	0.212	0.510	0.380	0.413	0.506
C3	0.777	0.182	0.531	0.363	0.373	0.421
C5	0.774	0.224	0.602	0.323	0.268	0.327
C6	0.635	0.412	0.483	0.392	0.477	0.406
C7	0.692	0.347	0.483	0.444	0.377	0.357
D2	0.283	0.856	0.256	0.229	0.371	0.377
D3	0.352	0.851	0.214	0.274	0.252	0.292
F1	0.525	0.206	0.738	0.396	0.389	0.555
F2	0.523	0.192	0.817	0.289	0.384	0.379
F3	0.600	0.221	0.798	0.200	0.367	0.368
F4	0.528	0.226	0.711	0.297	0.348	0.509
HSE4	0.319	0.321	0.221	0.676	0.267	0.229
HSE5	0.392	0.218	0.279	0.705	0.518	0.414
HSE6	0.442	0.161	0.429	0.786	0.425	0.310
HSE7	0.288	0.152	0.109	0.666	0.424	0.237
S1	0.486	0.302	0.574	0.333	0.448	0.862
S3	0.455	0.370	0.436	0.400	0.485	0.848
SS1	0.187	0.175	0.193	0.208	0.457	0.181
SS2	0.505	0.339	0.466	0.565	0.934	0.537

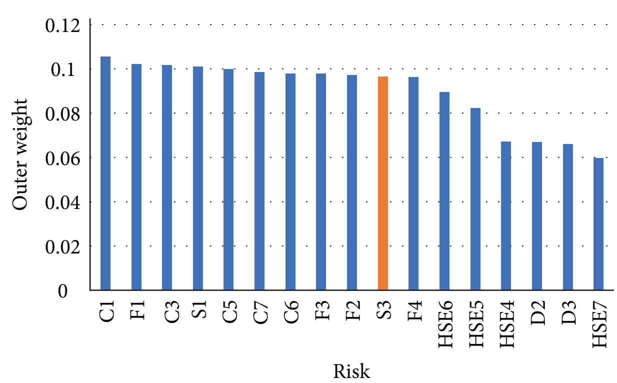

Figure 4: Ranking of the 17 factors based on the outer weight in PLS-SEM.

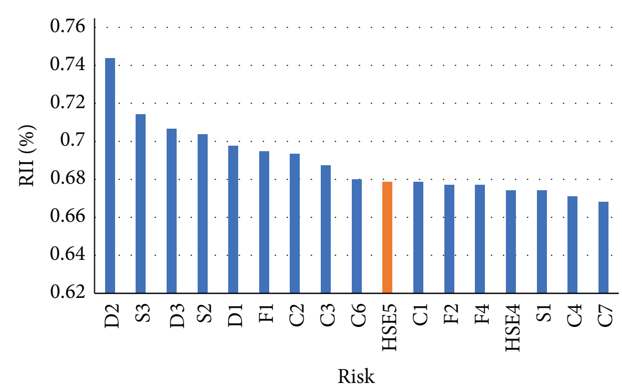

Figure 5: Ranking of the 17 factors using the RII method.

then estimated by regressing each indicator on the group's scores. Figure 4 shows the order of factors from the most significant outer weight value to the smallest. The five top five factors based on PLS-SEM were C1, F1, C3, S1, and C5. The construction factors take 60% of the top five factors. At the same time, the financial (F1) and supply (S1) groups participate in 20% of the top five factors, respectively. The most significant financial and supply factors were (F1) and (S1), respectively.

Figure 5 shows the first 17 factors rankings based on the RII method. The top five factors were D2, S3, D3, S2, and D1. Unlike the PLS-SEM ranking, the RII method provides that 60% of the top five factors are from the design group (D1–D3), and 40% are from the supply group factors (S2 and S3). The difference between the two methods is attributed to the application α formula for the two methods, where the reliability validity was examined for each group using the PLS-SEM method. The α value for the 26 factors (all factors) was 0.890, considering a perfect level of reliability. This result means the questionnaire items consistently measure the same construct and are highly correlated.

On the other hand, the reliability validity was examined for all factors (26 factors) disregarding their groups. Therefore, the α in the second method (RII) provides an overestimated value due to the factor's number [33]. Therefore, the PLS-SEM provides a more stable coefficient than the RII.

Asghari [21] confirmed the critical role of (financial failure/bankruptcy, F1) in pipeline construction performance. The order of risk F1 was second and sixth for PLS-SEM and RII methods, respectively. In addition, Metz et al. [16] and Kraidi et al. [22] stated that the design change is, in many cases, due to the change order (D2) and its influence on the construction performance.

PLS-SEM and RII rankings are two different research approaches with distinct characteristics and outcomes.

PLS-SEM is a robust statistical method for modeling complex relationships among variables and is well-suited for exploring unknown or less-established theories. However, it requires a larger sample size and provides detailed insights into relationships. On the other hand, RII rankings offer a simpler way to identify important variables based on criteria like correlation or contribution, without modeling the relationships. RII is suitable for smaller datasets but lacks the depth of understanding. Several reliability indices used in PLE-SEM, such as, Cronbach' α, composite reliability, and average variance extracted. However, the Cronbach' α is only used to examine the reliability in RII method. The discriminant validity representing Fronell–Larcker, and cross-loading value is utilized in PLS-SEM method, while this validity is not used in RII method. The choice between PLS-SEM and RII depends on research goals, with PLS-SEM being ideal for in-depth exploration and validation of the complex relationships but it can be complex with small samples. RII is quicker but may oversimplify the intricate relationships.

PLS-SEM and RII agree that delays in materials and equipment supply (S3), financial failure or bankruptcy (F1), poor pipeline material quality (C3), and operational errors (C6) are the most important factors among the top 10 factors for each pipe construction method. The RII method classified factors of design change due to change orders (D2), delay in drawing approval (D3), and government permit approval delay (HSE5) as more important factors, unlike the PLS-SEM method, where the ranking of these factors was from the 11th to the 17th rank. This difference is due to the difference in computational techniques in the two methods, as the RII relies on direct measurements of the influence degree of the factors. In contrast, the PLS-SEM method considers the relationships between the latent groups. On the other hand, the PLS-SEM method considered the factors of materials monopoly by suppliers (S2), defective design (D1), and variation orders (C2) to be insignificant factors because these factors did not satisfy reliability and discriminant validity with their latent groups.

5. Conclusion

The paper dealt with identifying the most common risk factors encountered in the pipeline projects in KSA using quantitative analysis. The analysis consists of five main sequence stages. The first stage collected the most pipeline project factors in the literature and confirmed them using open-ended interviews with six SMEs in KSA's pipeline projects. The second stage was to design and implement a questionnaire for 135 participants to measure the degree of impact of the 26 common factors. The third stage was to check the reliability and discriminant validity of the data. The fourth stage represents the ranking process by PLS-SEM and RII methods. The fifth stage was to compare the results of the two methods with the literature. The results revealed that the five top five factors based on PLS-SEM were C1 (discrepancy between implementation requirements and specifications), F1 (financial failure/bankruptcy), C3 (poor pipeline material quality), S1 (supplying invalid materials), and C5 (weak ability to identify and monitor the threats).

On the other hand, the most significant risk based on the RII method was D2 (design change due to change orders), S3 (delays in materials and equipment supply), D3 (delay in drawing approval), S2 (materials monopoly by suppliers), and D1 (defective design). Finally, it is noticeable that each risk's RII value is relatively near each other. Thus, the partial least squares path modeling shall be used to obtain a clear distinction among the risk factors and conduct an internal comparison of each vital risk factor. This study aids decision-makers in developing a more profound knowledge of the influencing risk factors, enabling them to plan pipeline projects more effectively and exercise greater control over them. The study helps project managers identify and prioritize risk factors to plan and manage steps for mitigating the factors and improving the chances of project success.

5.1. Limitations and Future Research Directions. This research has been conducted comprehensively, but still, some limitations need to be assessed in the future work. This study was undertaken in Saudi Arabia; therefore, it is vital to research other countries. In the study, only four experts were consulted to provide their feedback; thus, more inclusions of experts would provide significant results. This study has used the PLS-SEM methodology for assessing the risk factors. In future research studies, selection of criteria. Each criterion has a different relative importance. So, it is vital to assign a weight to each criterion to quantify its degree of importance. Thus, the (AHP) adopts each criterion's weight based on the feedback from the experts [34]. It is very difficult for the decision-makers to decide on any multifaceted decision problem because of the numerous uncertainties that arise while analyzing the problem [35]. Future research could use other decision-making methods such as ANP, TOPSIS, DEMATEL, and VIKOR methods to obtain the more robust results [36]. The Delphi approach is used to obtain the most critical factors and subfactors. The main purpose of this technique is to refine the crucial factors for further investigation [37]. However, further research can shed much lighter on this topic.

Data Availability

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

Disclosure

The submitting author is responsible for the co-author's interests.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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