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Perceived Risk Assessment Criteria for Public–Private Partnership Projects in the Water and Sewage Sector: Comparison of Perspectives from Iranian Public and Private Sectors

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Abstract: This research used the SWARA approach to analyze risk assessment criteria for public–private partnership (PPP) projects in Iran's water and sewage sectors to identify and prioritize the most significant elements influencing project success from public and private viewpoints. Key results show that the public sector considers "risk probability" to be the most important aspect, highlighting the requirement for stability and predictability in project outcomes. In contrast, the private sector prioritizes the "ability to predict and discover risk", emphasizing efficiently anticipating and managing uncertainty. Furthermore, this study revealed five common major risk characteristics, including "risk manageability" and "uncertainty of risk"; however, their rankings differ per industry, demonstrating various risk prioritizing methodologies. This study is unique in that it focuses only on Iran's water and sewage infrastructure, an area historically neglected in PPP research, providing a rare investigation of sector-specific hazards as well as the interaction between public and private interests in a developing country environment. The paper makes specific suggestions, calling for more openness, improved communication, and the use of sophisticated risk management techniques to bridge the gap across sectors. These findings not only add to the scholarly knowledge of PPP dynamics in emerging countries but also provide practical recommendations for governments and private investors navigating Iran's infrastructure issues.

Keywords: risk assessment criteria; PPP; water and sewage industry; SWARA method

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1. Introduction

Governments have investigated many public–private partnership (PPP) schemes in recent decades. Increased attention has been paid to PPP projects as a result of the rise in demand and the public sector's financial (budgetary) shortfalls (as well as the requirement for greater infrastructure project efficiency). PPP projects are contracts between the public and private sectors in which the private sector plays a larger role than in conventional design, construction, and supply contracts [1]. The public sector plays a vital role in the PPP contract [2]. Particularly in the case of large projects, diverse stakeholders and their expectations generate a variety of ambiguities and complexity.

This study now stresses the rising importance of public–private partnership (PPP) projects in the water and sewage sectors, particularly as a technique for addressing the budgetary restrictions and efficiency requirements of infrastructure development [3]. However, to improve the study's clarity and relevance, the research gap it attempts to solve must be properly highlighted. While PPPs have been extensively examined in global settings, there is a significant void in the literature that focuses on the unique difficulties and dynamics

of Iran's water and sewage sector. Many previous studies have focused on industrialized nations or areas with mature PPP frameworks, leaving the unique traits and challenges of emerging countries such as Iran unexplored. Iran's economic, political, and environmental backdrop provides unique risks and possibilities for PPP implementation, which vary greatly from those in more stable contexts, highlighting the need for specialized research on PPP risk assessment criteria adapted to this context. This study intends to close that gap by identifying the most important risk variables from both public and private viewpoints, thus contributing to a more comprehensive understanding of PPP success determinants in developing countries.

The growing significance of sustainable water management in Iran, a nation grappling with severe water shortages and resource management difficulties, adds to this study's relevance. As the Iranian government continues to use PPPs to reduce financial burdens and improve infrastructure development, it is critical to understand the particular risk factors that affect PPP projects in the water and sewage sectors. This research not only tries to analyze and rate the risks associated with PPP projects but also adds to the current literature by providing insights that are particularly relevant to Iran's socioeconomic and environmental situations. By concentrating on Iran's specific challenges—such as limited financial resources, political risks, and stakeholder complexity—this study contributes to a better understanding of how PPPs may be modified and maximized in circumstances in which typical infrastructure development models are inadequate. Thus, it makes an important contribution to both the theoretical and practical elements of PPP implementation in developing countries, providing a framework to help politicians, investors, and developers to make educated choices [4].

Project size and dependency are elements that influence project complexity [5]. Complexity diminishes the likelihood of preserving the overall behavior and manageability of a large project [6]. Complexity can contribute to project failure in companies [7]. Considering that as projects become larger and more intricate, the risk of network interaction and the complexity of the risk path rise, a high level of risk should be seen as a significant impediment to the project's success in project management [8].

Studies have demonstrated that as the size and scope of a project increase, so do the related risks. Cost, time, and quality are three significant aspects that influence the risks involved with PPP initiatives. Construction completion risks, operational risks, demand risks, law change risks, political and regulatory risks, expropriation and nationalization risks, environmental risks, social risks, capital renewal and financial repayment risks, currency risks, and interest rate risks are examples of PPP project risks [9].

The facts of the country's most recent budget bill indicate that PPP construction projects in Iran are economically and financially justifiable for both the public and private sectors. Among the projects targeted by PPP (Budget Law of 2016, 2018), 302 projects out of 6049 national construction projects (representing 5%) and 52,889 provincial projects (representing 3%) are under consideration for PPPs (budget law of the year, construction sector 2017, 2019). Therefore, government, semi-government, and private contracts regarding the country's water and sewage projects should be thoroughly examined and investigated.

The provision of financial resources and technical skills and the development of infrastructure project productivity are among the benefits of the PPP technique. However, because of the existence of varied stakeholders with diverse expectations and organizational habits, PPP projects are fraught with several hazards and perils (according to the type of project). Consequently, there will be several project types and risk levels [10,11].

Water and sewage projects are being considered in Iran due to the dearth of water resources. The extension of these projects and hazards, such as the absence of appropriate financial resources for PPPs, is a positive strategy for addressing the issue of insufficient public funding for these projects. Investors are still wary of this strategy, even though PPP water and sewage projects have the potential to reduce the amount of debt held by the government [1].

According to our prior discussion, risk identification and assessment are significant factors in attaining the success of PPP projects. Meanwhile, selecting evaluation criteria can be crucial in assessing the risks as correctly as possible. Therefore, the purpose of the current study is to address the lack of research in this area by determining and analyzing the significant factors that should be considered for risk assessment in PPP water and sewage projects.

The aim of this study is to evaluate and rank the risk assessment criteria for public–private partnership projects in Iran's water and sewage sector, employing the SWARA method to determine the key factors from the perspectives of both the public and private sectors. This research distinguishes itself by focusing specifically on Iran's water and sewage infrastructure, a sector with unique economic and environmental challenges, thereby filling a gap in the existing literature on PPP risk assessment in developing countries.

2. Literature Review

A risk assessment model for public–private partnership (PPP) projects in China was created by [12]. Considering that the overall risk of PPP highway projects has been assessed to fall somewhere between "moderate risk" and "high risk", investing in PPP highway projects in China may be fraught with peril. The participants in the Delphi survey ranked "government intervention" as the most prevalent critical risk group. This was followed, in order, by "risk of economic stability", "risk to market environment", "risk of building and operation", and "macroeconomic risk". According to the findings, inadequate laws and regulatory structures, as well as weak public decision-making procedures, maybe the most significant factors preventing the success of PPP highway projects in China [13]. These factors may also contribute to government meddling and corruption.

Carbonara et al. [14] investigated risk management in public–private partnership (PPP) highway construction projects. An examination of previous research concluded that a context-sensitive approach should be utilized while carrying out risk assessment and management. Using the Delphi technique, they presented public and private partners with advice for major risks in PPP highway projects. These guidelines facilitate the identification of effective allocation and mitigation methods.

Using network analysis, Daraji Jahormi et al. [15] found and prioritized new risk assessment criteria for building projects. Due to the problem's complexity and inherent unpredictability, the network analysis framework (ANP) was utilized to rank the risk assessment criteria. Interviews, a literature review, and questionnaires distributed to house-building specialists were used to collect data. The results of the ranking of the criteria for risk assessment in mass construction projects indicated that treatability, consequence, risk manageability, and the probability of risk occurrence were the most relevant factors. Those participating in housing massification projects might use the results to better control risk.

A risk evaluation of China's public–private partnership initiatives was carried out by Li et al. [16] According to the results of their research, China's political and economic policies, as well as the connections between various stakeholder groups, are intricately interwoven with ten major risks. For public–private partnership (PPP) endeavors to be successful, the authorities within the government must first create an atmosphere that is hospitable from a political, social, and economic standpoint, as well as an effective institutional structure.

Furthermore, S. K. Herath and L. M. Herath [17] examined the role of public–private partnerships (PPPs) in fostering sustainable infrastructure, focusing on key success factors, and benefits, and providing recommendations for effective collaboration between government and private sectors. Study [13] assessed the implementation of enabling strategies for affordable housing in Saudi Arabia, identifying key challenges like high costs, traditional land tenure, and limited financing, while highlighting the government's shift from direct provision to enabling roles through programs and local manufacturing initiatives to improve access. Badi and M. Alhosani [18] assessed the implementation of enabling strategies for affordable housing in Saudi Arabia, identifying key challenges like high costs, tradi-

tional land tenure, and limited financing, while highlighting the government's shift from direct provision to enabling roles through programs and local manufacturing initiatives to improve access. In another work [3], the Indian diaspora used their experiences in developed countries to contribute to sustainable development in India through public–private partnerships, remittances, and social entrepreneurship, helping local communities solve problems, create jobs, develop skills, and promote environmental education.

The objective of the study by Rassouli et al. [19] was to identify, analyze, and assign the essential risks of water and wastewater sector projects in Iran's Gilan province at various phases and within each stage. In their study, executive agents with direct accountability were employed in the build–operate–transfer (BOT) approach of public–private partnerships to extract critical risks. In the water and wastewater business of Gilan province, the results revealed a substantial correlation between risks with a significance level of more than three at different stages of PPP. Additionally, this association was substantial for each risk at each stage, except in one case.

Moreover, Fazli et al. [20] discovered and evaluated the risks posed by environmentally friendly building projects in Amol, Iran by utilizing a technique that incorporated SWARA and COPRAS. Their research showed that there is a considerable threat posed by low-quality materials and equipment, resistance from stakeholders in accepting environmentally friendly approaches, and a lack of goals that are feasible. The approach that has been developed has the potential to assist the beneficiaries of green construction efforts in developing nations in more effectively controlling the risks associated with the project.

Hussain Khahro et al. [21] found that inflation, income risk from the final consumer, foreign currency volatility, political environment, law and order, and corruption are the greatest threats to the effective management of PPP projects in developing nations. Sayadi et al. [22] evaluated and prioritized risk in southwest Iran tunneling projects using the linear allocation approach. Economic considerations and legal conditions had the greatest and lowest risk ratings, respectively, according to the data. Amiri et al. [23] conducted their research to identify and evaluate the risks that are posed by all parties that are involved in PPP water and sewage projects from the point of view of an investor. Table 1 outlines, according to our study of the literature, the risks that are connected to public–private partnership projects.

Table 1. The criteria for risk assessment in public–private partnership projects.

Code	Criteria for Risk Assessment	Criteria Description	Criterion Effect	Sources
C_1	Vulnerability	Vulnerability and frailty are assets that can lead to an occurrence	cost (−)	[2,10,20,22,24]
C_2	Threat	A threat is an incident with the potential to negatively affect project objectives (time, cost, and quality)	cost (−)	[2,12,20,24]
C_3	The consequence/consequences of risk occurrence	A result or achievement is expressed as an event or incident	cost (−)	[19,25]
C_4	Uniqueness of risk	A risk may attract special attention when dealing with a particular issue	cost (−)	[2,20,24]
C_5	Uncertainty and vagueness of risk	Insufficient knowledge of the nature of the probability distribution function of risk measures	cost (−)	[20–22]
C_6	Proximity to the risk occurrence time	Risk proximity is the distance over which the occurrence of a risk is anticipated	cost (−)	[2,20]

Table 1. *Cont.*

Code	Criteria for Risk Assessment	Criteria Description	Criterion Effect	Sources
C_7	The mutual effect of each risk	The impact that one risk has on other risks	cost (−)	[20,26]
C_8	Reaction to the occurrence of risk	The appropriate response to reduce the impact of the incident	profit (+)	[20,24,26]
C_9	Allocability of risk	This criterion determines to what extent the departments involved in the project are willing to accept a certain risk	profit (+)	[27,28]
C_{10}	Risk manageability	The degree of controllability of a given risk	profit (+)	[10,16,20,22,27]
C_{11}	The ability to predict and discover risk	Ability to detect and identify risk and when and where risk may occur in the project	profit (+)	[20,24,29]
C_{12}	Risk probability	The probability that each risk will occur	profit (+)	[2,10,16,20,21]
C_{13}	The amount of exposure to risk	The amount of exposure to each risk that may occur	profit (+)	[22]
		Zegordi et al. [30]		

3. Research Methodology

This study develops an issue determination algorithm based on the discovery and ranking of risk assessment criteria for PPP projects. The phases of the inquiry are shown in Figure 1. In the first section, the risks of public and private partnership projects in Iran's water and sewage industry are identified through a review of pertinent literature, including scientific articles, internet resources, and documents available from construction companies, followed by the creation of an expert questionnaire. It is suggested that they assess the original questionnaire so that it can be approved after including their feedback and a second review. The validity and dependability of the items are next evaluated. After confirming the questionnaire's validity and reliability, the specialists working on Iran's water and sewage projects will be given the final questionnaire to evaluate the weight of each criterion using the SWARA method.

It is noteworthy that the SWARA technique was selected for this research over other multi-criteria decision-making (MCDM) methods because of its particular strengths in dealing with complicated decision-making situations, including subjective expert assessments. Unlike approaches like the AHP (Analytic Hierarchy Process) or TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), SWARA provides a more organized but flexible approach to prioritizing criteria based on expert feedback. The approach's main benefit is its ability to include the relative relevance of each criterion in a stepwise fashion, resulting in a more intuitive and clear method of ranking items based on their significance. This is especially beneficial in settings like PPP projects in Iran's water and sewage sectors, where expert risk assessments are fundamentally qualitative and need an adaptive framework that can handle changing project complexity. Furthermore, SWARA reduces the possibility of biases that may occur in standard MCDM approaches by allowing experts to revise their assessments repeatedly, ensuring that the final weightings appropriately represent the collective expert view. This recurrent refining is crucial in sectors with high uncertainty, such as PPP projects, where the magnitude of risks might change depending on political, environmental, and economic factors. Furthermore, SWARA's ability to handle smaller expert groups without losing reliability is consistent with the constraints of this study, making it an appropriate and effective choice for evaluating risk assessment criteria in Iran's specific context, where access to a large pool of experts is limited. As a result, the choice to adopt SWARA improves the study's capacity to give a nuanced, expert-driven knowledge of PPP risks, making it a useful and dependable tool for decision makers in the field.

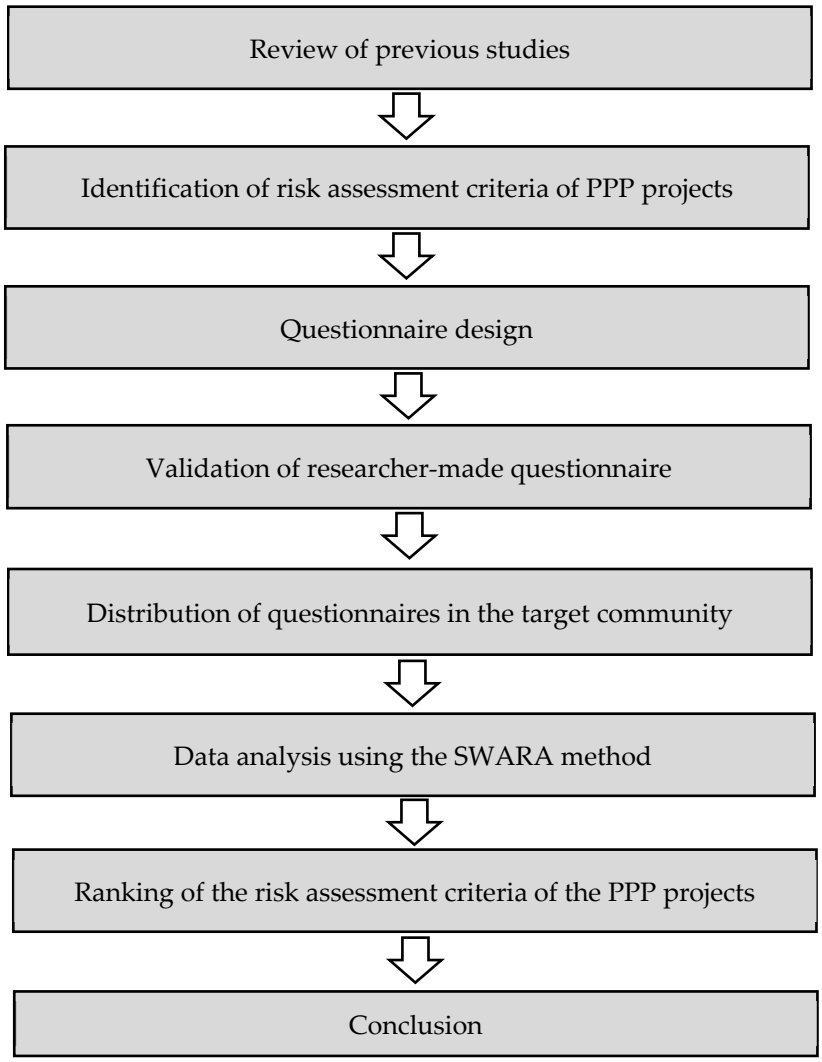

Figure 1. Flow diagram of the research implementation procedure.

3.1. Questionnaire Design

Based on the principles of testing that are given in Table 1, a questionnaire was prepared that details the risks that are connected with public–private partnership projects in the water and sewerage sector. With 13 items, the initial questionnaire was created using the Delphi approach. The initial questionnaire was then distributed to ten specialists [1,31]. They signed off on the questionnaire. The characteristics of participants has been presented in Table 2. The validity of the questions was then examined. For an accepted validity analysis, Chadwick et al. [32] specified a validity coefficient of 0.6 or above as a minimum. The number of eight individuals satisfies this level. Ten persons participated in the validation of the questionnaire in this study. Possessing at least one hour of free time to complete the questionnaire was another entry requirement for the study [33]. Lawshe created the indicator of content validity ratio (CVR) in 1957. The CVR is calculated as follows, using Equation (1):

$$CVR = \frac{\left[n - \frac{N}{2}\right]}{\frac{N}{2}} \quad (1)$$

where N represents the total number of experts, and n represents the number of experts who have selected the required option. The lowest admissible value for the CVR index with 10 experts is 0.62 based on the number of experts who examined the questions [34,35]. Questions whose computed CVR index value is less than the appropriate value based on

the number of experts analyzing the questions should be removed from the examination because they lack sufficient content validity according to the *CVR* index.

Table 2. Characteristics of participants in validity process.

		Delphi Experts	Content Validity
		No. (%)	**No. (%)**
Age	Male	10 (100%)	6 (60%)
	Female	0	4 (40%)
Education	Bachelor's degree	1 (10%)	3 (30%)
	Master's degree	7 (70%)	7 (70%)
	PhD	2 (20%)	0
Engaged in PPP projects	Below 5 projects	0	5 (50%)
	6 and 10 projects	2 (20%)	1 (10%)
	11 and 15 projects	4 (40%)	0
	Above 16 Projects	4 (40%)	4 (40%)
Work experience in PPP	Below 10 years	0	6 (60%)
	11 and 20 years	7 (70%)	4 (20%)
	Above 21 years	3 (30%)	0
Work experience in water and sewage	Below 10 years	2 (20%)	10 (100%)
	11 and 20 years	8 (80%)	9 (90%)
	Above 21 years	0	0
Work experience in construction	Below 10 years	0	0
	11 and 20 years	6 (60%)	8 (80%)
	Above 21 years	4 (40%)	2 (20%)

The content validity index was examined using the Waltz and Bausell [36] technique (*CVI*). Using a 4-point Likert scale, professionals defined the "relevance", "clarity", and "simplicity" of each criterion. Experts judged the relevancy of each topic on a scale ranging from 1 ("not relevant") to 4 ("totally relevant"). The item's simplicity varied from 1 ("not simple") to 2 ("very simple") to 3 ("simple") to 4 ("quite simple"), and its clarity ran from 1 ("not clear") to 2 ("pretty clear") to 3 ("clear") to 4 ("it is clear"). The ratio of content validity is computed using Equation (2):

$$Content\ Validity\ Index\ (CVI) = \frac{Number\ of\ raters\ giving\ of\ 3\ and\ 4}{Total\ number\ of\ raters} \quad (2)$$

The minimum allowable *CVI* value is 0.79; if an item's *CVI* is less than 0.79, it must be deleted [35]. Ten specialists filled out the content validity questionnaire. Table 1 displays the characteristics of participants in the identification and validity tests (2). The content validity results indicated that all thirteen items exhibit content validity.

At this level, the questions' dependability was evaluated. By reviewing the reliability of the questions at this stage, any questions that lacked appropriate reliability or whose removal would raise the test's reliability could be eliminated. There are several approaches for determining dependability. SPSS software v.23 was used to examine the test's reliability using Cronbach's alpha. The minimum necessary Cronbach's alpha value is 0.70 [37–40]. In this study, Cronbach's alpha was determined to be 0.908, showing that all scales contained the necessary internal consistency.

This study involved only 10 experts due to the specialized nature of public–private partnership projects in Iran's water and sewage sector. These experts were selected for their extensive experience and deep knowledge in this specific field, ensuring that their input

would be both highly relevant and reliable. Additionally, the targeted nature of the study necessitated experts who could provide informed perspectives on complex risk assessment criteria, which justified the smaller, focused sample size.

Finally, the risk assessment criteria of PPP projects, which are listed in Table 1, were given in the form of a questionnaire to 20 professionals who are working on a water and sewage project. The purpose of this was to identify the criteria, evaluate the weights, and determine the final ranking using the SWARA method. The characteristics of the experts who participated in the study are detailed in Table 3.

Table 3. Characteristics of participants in the study.

		Private Sector	Public Section
		No. (%)	**No. (%)**
Age	under 30 years	2 (20%)	1 (10%)
	30 and 40 years	5 (50%)	3 (30%)
	40 and 50 years	2 (20%)	5 (50%)
	50 years or more	1 (10%)	1 (10%)
Education	Bachelor's degree	2 (20%)	6 (60%)
	Master's degree	6 (60%)	4 (40%)
	PhD.	2 (20%)	0
Gender	Male	8 (80%)	10 (100%)
	Female	2 (20%)	0
Work experience	Less than 10 years	0	0
	10–15 years	4 (40%)	3 (30%)
	15–20 years	6 (60%)	5 (50%)
	More than 20 years	0	2 (20%)
Work category	Employer/employer's representative	0	2 (20%)
	Contractors	6 (60%)	6 (60%)
	Consultant	2 (20%)	2 (20%)
	Faculty member	2 (20%)	0

As shown in Table 3, fifty percent of the commercial sector and public sector participants in this study were between the ages of thirty and forty and between the ages of forty and fifty. These age ranges were chosen at random. A master's degree was held by sixty percent of those who took part in the study from the commercial sector, and sixty percent of those who participated from the public sector had a bachelor's degree. The fact that men make up 80 percent of the participants from the private sector indicates that there are more men than women involved in this research. Everyone who took part in the government sector was male, and that accounts for one hundred percent of the total. Sixty percent of the persons who took part in the survey were employed in the private sector. Their average length of employment ranged from 15 to 20 years. People with between 15 and 20 years of experience in the work force made up fifty percent of those who took part in the study from the public sector. In terms of work classification, contractors made up sixty percent of the persons that took part in the event from both the public and private sectors.

3.2. Ranking Criteria Using the SWARA Method

SWARA is one of the multi-criteria decision-making (MCDM) approaches presented by Keršuliene et al. [41,42]. The method that has been proposed makes it possible to evaluate the differences in the relevance of the characteristics that define the possibilities for decision making. The ability of the SWARA method to incorporate the input of competent individuals into the process of determining the relative weight of numerous criteria is the defining quality of the method [41].

Step 1: Criteria should be ranked according to their importance. At this stage, experts evaluate the significance of the given criteria. For instance, the most significant value is ranked first, the least significant value is ranked last, and other values are placed between the two extremes based on their significance.

Step 2: The relative importance of each criterion should be determined (*Sj*). In this stage, the relative value of each criterion is established in comparison to the preceding criteria. This value is expressed in the SWARA method process by *Sj*.

Step 3: The coefficient *Kj* should be calculated. Using Equation (3), the coefficient Kj, which is a function of the relative importance of each criterion, is calculated:

$$K_j = S_j + 1 \tag{3}$$

Step 4: The initial weight of each criterion is calculated. The starting weight of the criteria is determined using an Equation (4). In this regard, it is crucial to emphasize that the weight of the first, most important criterion, is deemed to be 1.

$$W_j = \left(x_j - 1\right) \tag{4}$$

Step 5: The final normal weight is calculated. In the final step of the SWARA approach, the final weight of the indicators, also known as the normalized weight, is computed using the following Equation (5). Normalization is performed using a straightforward linear technique. Table 4 displays the final normal weight of each criterion.

$$q_j = \frac{w_j}{\sum_{j=1}^{n} w_j} \tag{5}$$

Table 4. The final weight of each criterion.

Risk Assessment Criteria for PPP Projects	Rank (Average Opinion of Experts)	S_j	K_j	W_j	q_j
C_1	8	0.650	0.012	0.027	1.650
C_2	6	0.620	0.031	0.072	1.620
C_3	5	0.625	0.050	0.116	1.625
C_4	10	0.550	0.004	0.010	1.550
C_5	3	0.690	0.134	0.311	1.690
C_6	12	0.540	0.002	0.004	1.540
C_7	13	0.630	0.001	0.003	1.630
C_8	9	0.700	0.007	0.016	1.700
C_9	11	0.585	0.003	0.007	1.585
C_{10}	4	0.645	0.081	0.189	1.645
C_{11}	2	0.905	0.226	0.525	1.905
C_{12}	1	0.000	0.430	1.000	1.000
C_{13}	7	0.595	0.019	0.045	1.595

4. Results and Discussion

In order to gain a greater understanding of one another, the public and private sectors each offered their views on the risks associated with public–private partnership initiatives, ranked them, and then compared them. The ultimate weight that should be attributed to each criterion is illustrated in Table 5 from the perspectives of both public and private sector specialists. The overall rating risk assessment criteria for PPP projects, from both the public sector and private sector specialists' perspectives, are shown in Table 6.

Table 5. The final weight of each criterion is from the perspective of the public sector and private sector experts.

Risk Assessment Criteria for PPP Projects	Public Sector				Private Sector			
	q_j	W_j	K_j	S_j	q_j	W_j	K_j	S_j
C_1	0.650	1.650	0.029	0.012	0.650	1.650	0.026	0.012
C_2	0.620	1.620	0.048	0.020	0.640	1.640	0.067	0.030
C_3	0.680	1.680	0.201	0.083	0.630	1.630	0.109	0.049
C_4	0.770	1.770	0.016	0.007	0.510	1.510	0.010	0.005
C_5	0.680	1.680	0.338	0.139	0.610	1.610	0.178	0.080
C_6	0610	1.610	0.003	0.001	0.580	1.580	0.004	0.002
C_7	0.500	1.500	0.004	0.002	0.650	1.650	0.003	0.001
C_8	0.590	1.590	0.010	0.004	0.630	1.630	0.016	0.007
C_9	0.630	1.630	0.006	0.003	0.540	1.540	0.007	0.003
C_{10}	0.620	1.620	0.124	0.051	0.700	1.700	0.287	0.128
C_{11}	0.760	1.760	0.568	0.234	0.000	1.000	1.000	0.447
C_{12}	0.000	1.000	1.000	0.412	1.050	2.050	0.488	0.218
C_{13}	0.600	1.600	0.078	0.032	0.570	1.570	0.042	0.019

Table 6. Rating of criteria by private and public sectors.

Risk Assessment Criteria for PPP Projects	Overall Rating for All Experts	Rating from the View of the Private Sector	Rating from the View of the Public Sector
Vulnerability	8	8	8
Threat	6	6	7
The consequence/consequences of risk occurrence	5	5	4
Uniqueness of risk	10	10	9
Uncertainty and vagueness of risk	3	4	3
Proximity to the risk occurrence time	12	12	13
The mutual effect of each risk	13	13	12
Reaction to the occurrence of risk	9	9	10
Allocability of risk	11	11	11
Risk manageability	4	3	5
The ability to predict and discover risk	2	1	2
Risk probability	1	2	1
The amount of exposure to risk	7	7	6

According to the research carried out by Daraji Jahormi et al. [43], the criterion "risk manageability" was placed in third place, and the criterion of "risk occurrence likelihood" was placed in fourth place. The criteria "risk likelihood" and "risk manageability" were ranked first and fourth, respectively, in the present investigation's rankings of the criteria for risk. The similar findings of the two studies indicate that the criteria of "risk likelihood" and "risk manageability" are essential when it comes to evaluating the risks associated with PPP projects in Iran.

In the research conducted by Jokar et al. [11], the "recognizability" criterion was placed in second place following an analysis using the SWARA approach. According to the findings of this study, the criterion "ability to forecast and discover risk" was also ranked second. This indicates that the "ability to predict and discover risk" is an essential factor to consider when evaluating the risks associated with PPP projects in Iran.

The criteria "response to risk" and the criterion of "uniqueness of risk" were ranked first and third, respectively, in the research that was conducted by Jokar et al. [11]. The criteria known as "reaction to the occurrence of risk" and "uniqueness of risk" were placed ninth and tenth, respectively, in the order of importance in the current research. This disparity in findings can be attributed to the fact that the two articles in question used very different case studies to reach their conclusions. The North Freeway project was the

subject of the case study in which Jokar et al. [11] examined the criteria for risk assessment of public–private partnership projects in Iran's water and sewage industry, which were also investigated in this study.

The credibility of research conducted with a small sample of 10 experts, while limited in statistical robustness, can still be considered valuable when the participants are highly specialized and have significant experience in the specific field of study, in this case, public–private partnership projects in Iran's water and sewage sector. In specialty sectors with a limited pool of competent experts, attaining a bigger sample size may not be possible without sacrificing input quality. Nonetheless, a significantly bigger sample size may improve the results' reliability and generalizability, offering a more comprehensive view of risk assessment criteria. The small sample size in this research may have an impact on the outcomes by introducing bias or restricting the variety of opinions, which is why the selection criteria were designed to ensure that the participants were prominent experts with significant direct experience. Expanding the expert group might help to address these restrictions; however, engaging additional experts in such a specialized topic proved difficult given the limits of accessibility, availability, and skill needed. This issue, although recognized, does not invalidate the results since the Delphi approach and other validation procedures were used to reduce possible biases. Future research might benefit from more diversified expert involvement to strengthen the findings and allow for statistical confirmation of the risk assessment criteria.

The criteria of "risk manageability" and the "chance of risk occurrence" were ranked third and fourth, respectively, in the research carried out by Valipour et al. [27]. In the current investigation, the criterion "risk probability" was placed first, while the criterion "risk manageability" was ranked fourth. The results indicate that the criteria "risk likelihood" and "risk manageability" are used to evaluate the risks associated with the partnership project. The results of both types of research are very similar and highlight the importance of the public–private partnership (PPP) concept in Iran [44,45].

In the research carried out by Fazli et al. [20], the "recognizability" criterion was placed in the first place. According to this particular research, the criterion "ability to forecast and uncover risk" comes in second place. The same findings of the two studies indicate that it is essential to include "the ability to forecast and uncover risk" while evaluating the risks posed by public–private partnership (PPP) initiatives in Iran.

To give the public and private sectors a deeper understanding of one another, the risks associated with PPP projects were reviewed and studied in a different but parallel process by experts from both the public and private sectors. "Risk likelihood" is the most significant criterion for the public sector, but "the ability to anticipate and recognize risk" is the most critical condition for the private sector. It is important to note that while the public and private sectors share five key traits, their respective agendas are distinct.

In addition, Figure 2 gives a visual comparison between the public and private sector perspectives on risk assessment criteria for PPP projects. The chart illustrates the differences in how each sector ranks the significance of various risks, with lower numbers indicating higher importance. This visual aid highlights that while both sectors agree on some critical risks, like "Ability to Predict and Discover Risk" and "Risk Probability", they differ on others, such as "Risk Manageability" and "Consequence of Risk Occurrence". This comparison provides a clearer understanding of the distinct priorities and concerns between the public and private sectors regarding PPP risks.

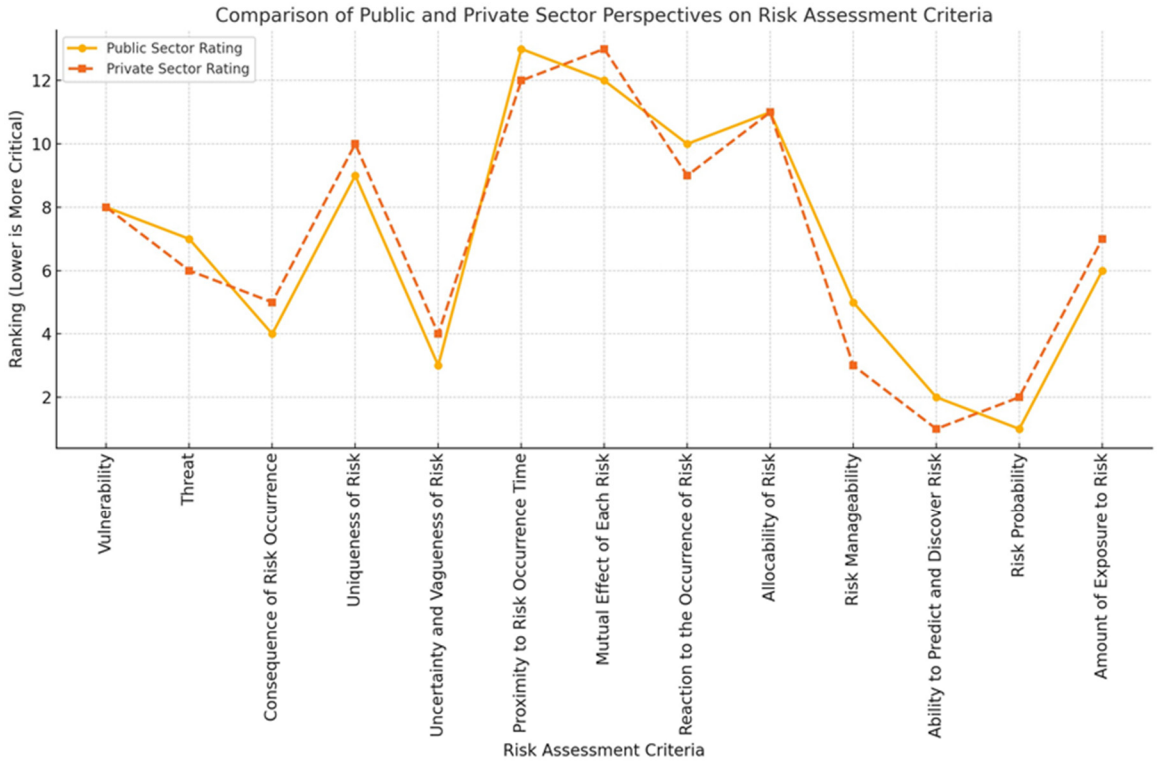

Figure 2. Comparison of public and private sector perspectives on risk assessment criteria for PPP Projects: The chart highlights differences in risk prioritization, with lower rankings indicating higher importance, thus revealing distinct concerns between the sectors regarding project risks.

5. Conclusions

In this article, the risk assessment criteria for PPP projects in Iran's water and sewage industry were analyzed and then graded in order of severity. According to the findings, the factors that are given the highest priority are "risk likelihood", "the ability to forecast and detect risk", "uncertainty and vagueness of risk", "risk manageability", and "the consequence/consequences of risk occurrence", in that order. Also, for the public and private sectors to have a better understanding of one another, the risks associated with PPP projects were assessed and compared in a manner that was distinct from one another by experts from both the public and private sectors. "Risk likelihood" is the most essential criterion from the point of view of the public sector, but "the ability to foresee and identify risk" is the most important criterion from the point of view of the private sector. It is interesting to observe that five essential characteristics are the same between the public and private sectors, but the priorities of each sector are different. The results of this study will provide substantial backing for the participation of investors and contractors in the water and sewage industry initiatives being undertaken in Iran. In addition to this, it lays the groundwork for risk management in PPP projects and assists construction businesses in Iran and other developing nations in more readily monitoring and identifying hazards in PPP projects. Considering the findings of this study, it has been suggested that different MCDM methods be utilized to evaluate and investigate the control measures used for identified risks. This will allow for a comparison of the sensitivity of the various methods.

To increase the study's practical applicability, numerous focused suggestions might be given to parties participating in PPP initiatives in Iran's water and sewage sectors. To address the significant priority given to "Risk Probability" by the public sector, government officials must work on improving openness and predictability in regulatory environments. This might include clearer rules for project schedules, costs, and policy stability. Private sector stakeholders who emphasize the "ability to predict and discover risk" can invest in sophisticated risk management technologies and data analytics to increase risk-forecasting

skills, perhaps leading to more accurate evaluations of project feasibility. Furthermore, collaborative training sessions for public and private sector leaders might help to close the risk knowledge gap, resulting in improved communication and cooperation. Introducing prototype projects with mixed financing from both sectors might serve as a testing ground for novel risk-sharing methods, enabling both parties to alter their risk reduction techniques in real time. These approaches would not only increase the overall success rate of PPP projects but would also help to construct a more robust and sustainable water and sewage infrastructure in Iran.

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References

1. Sarvari, H.; Cristofaro, M.; Chan, D.W.; Noor, N.M.; Amini, M. Completing abandoned public facility projects by the private sector: Results of a Delphi survey in the Iranian Water and Wastewater Company. *J. Facil. Manag.* **2020**, *18*, 547–566. [CrossRef]
2. Wang, Y.; Wang, Y.; Wu, X.; Li, J. Exploring the risk factors of infrastructure PPP projects for sustainable delivery: A social network perspective. *Sustainability* **2020**, *12*, 4152. [CrossRef]
3. Sadri, M.; Aristidou, A.; Ravasi, D. Cross-Sector Partnership Research at Theoretical Interstices: Integrating and Advancing Theory across Phases. *J. Manag. Stud.* **2024**. [CrossRef]
4. Kjaerulf, F.; Andersen, S.V.; Ronsbo, H. *Leadership Development as Catalyst in Partnership Projects*; Researchgate: Berlin, Germany, 2024.
5. Biygautane, M.; Neesham, C.; Al-Yahya, K.O. Institutional entrepreneurship and infrastructure public-private partnership (PPP): Unpacking the role of social actors in implementing PPP projects. *Int. J. Proj. Manag.* **2019**, *37*, 192–219. [CrossRef]
6. Babatunde, S.O.; Perera, S. Analysis of financial close delay in PPP infrastructure projects in developing countries. *Benchmarking Int. J.* **2017**, *24*, 1690–1708. [CrossRef]
7. Liu, T.; Wang, Y.; Wilkinson, S. Identifying critical factors affecting the effectiveness and efficiency of tendering processes in Public–Private Partnerships (PPPs): A comparative analysis of Australia and China. *Int. J. Proj. Manag.* **2016**, *34*, 701–716. [CrossRef]
8. Shrestha, N. Factor analysis as a tool for survey analysis. *Am. J. Appl. Math. Stat.* **2021**, *9*, 4–11. [CrossRef]
9. Pezeshki, M.Z.; Shadman, A.; Alizadeh, M.; Hakimi, S.; Heidari, F. Validity and reliability of the questionnaire for assessing women's reproductive history in Azar cohort study. *J. Caring Sci.* **2017**, *6*, 183. [CrossRef]
10. Jokar, E.; Aminnejad, B.; Lorak, A. Risk prioritization and selection of contractor participating in public-private partnership (PPP) infrastructure project using hybrid fuzzy AHP and fuzzy TOPSIS (case study: Saveh-Salafchegan freeway project). *J. Constr. Eng. Manag. Innov.* **2020**, *3*, 1–16. [CrossRef]
11. Jokar, E.; Aminnejad, B.; Lork, A. Assessing and prioritizing risks in public-private partnership (PPP) projects using the integration of fuzzy multi-criteria decision-making methods. *Oper. Res. Perspect.* **2021**, *8*, 100190. [CrossRef]
12. Xu, Y.; Yeung, J.F.; Chan, A.P.; Chan, D.W.; Wang, S.Q.; Ke, Y. Developing a risk assessment model for PPP projects in China—A fuzzy synthetic evaluation approach. *Autom. Constr.* **2010**, *19*, 929–943. [CrossRef]
13. Alhajri, M.F. Transformation of the Saudi Housing Sector through an Enabling Approach to Affordable Housing. *Land* **2024**, *13*, 718. [CrossRef]
14. Carbonara, N.; Costantino, N.; Gunnigan, L.; Pellegrino, R. Risk management in motorway PPP projects: Empirical-based guidelines. *Transp. Rev.* **2015**, *35*, 162–182. [CrossRef]
15. Shakeri, E.; Dadpour, M.; Jahromi, H.A. The combination of fuzzy electre and swot to select private sectors in partnership projects Case study of water treatment project in Iran. *Int. J. Civ. Eng.* **2015**, *13*, 55–67.
16. Li, Y.; Wang, X. Risk assessment for public–private partnership projects: Using a fuzzy analytic hierarchical process method and expert opinion in China. *J. Risk Res.* **2018**, *21*, 952–973. [CrossRef]
17. Herath, S.K.; Herath, L.M. Key Success Factors for Implementing Public-Private Partnership Infrastructure Projects. In *Achieving the Sustainable Development Goals through Infrastructure Development*; IGI Global: Hershey, PA, USA, 2023; pp. 1–38.

18. Badi, S.; Alhosani, M. Public-private partnerships (PPPs) for the realisation of the sustainable development agenda in the built environment. In *The Elgar Companion to the Built Environment and the Sustainable Development Goals*; Edward Elgar Publishing: Cheltenham, UK, 2024; pp. 457–480.
19. Rassouli, B.; Kheradyar, S.; Banimahd, B. Identify, rank and allocate critical risk the stages of public–Private partnership by Delphi technique in the context of resistance economy (case study: Water and sewage industry Guilan Province). *J. Invest. Knowl.* **2018**, *7*, 125–140.
20. Fazli, M.; GafarZadeh Afshari, A.; Hajiaghaei-Keshteli, M. Identification and ranking the risks of green building projects using the hybrid SWARA-COPRAS approach:(the case: Amol county). *Ind. Manag. Stud.* **2020**, *18*, 139–192.
21. Khahro, S.H.; Ali, T.H.; Hassan, S.; Zainun, N.Y.; Javed, Y.; Memon, S.A. Risk severity matrix for sustainable public-private partnership projects in developing countries. *Sustainability* **2021**, *13*, 3292. [CrossRef]
22. Sayadi, A.; Hayati, M.; Azar, A. Assessment and Ranking of Risks in Tunneling Projects Using Linear Assignment Technique. *Int. J. Ind. Eng. Prod. Res.* **2011**, *22*, 27–38.
23. Amiri, O.; Ayazi, A.; Rahimi, M.; Khazaeni, G. Risks of water and wastewater PPP projects: An investors' perspective. *Constr. Innov.* **2022**, *22*, 1104–1121. [CrossRef]
24. Jokar, E.; Aminnejad, B.; Lork, A. Risk Assessment and Prioritization in Projects with Private Public Participation Method Based on Combination of Fuzzy Multi-criteria Decision-Making Techniques (Case Study: North Freeway). *Amirkabir J. Civ. Eng.* **2021**, *53*, 847–862.
25. Shen, L.Y.; Wu, G.W.; Ng, C.S. Risk assessment for construction joint ventures in China. *J. Constr. Eng. Manag.* **2001**, *127*, 76–81. [CrossRef]
26. Taylan, O.; Bafail, A.O.; Abdulaal, R.M.; Kabli, M.R. Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies. *Appl. Soft Comput.* **2014**, *17*, 105–116. [CrossRef]
27. Valipour, A.; Moharnrnadi, F.; Yahaya, N.; Sarvari, H.; Noor, N.M. Malaysian public private partnership project case study. *J. Appl. Sci.* **2014**, *14*, 2023–2031. [CrossRef]
28. Alijani, M.; Joneydi, L. Risk Allocation in Contracts of Public Private Partnership. *J. Res. Dev. Comp. Law* **2020**, *3*, 93–118.
29. Zarbakhshnia, N.; Soleimani, H.; Ghaderi, H. Sustainable third-party reverse logistics provider evaluation and selection using fuzzy SWARA and developed fuzzy COPRAS in the presence of risk criteria. *Appl. Soft Comput.* **2018**, *65*, 307–319. [CrossRef]
30. Zegordi, S.H.; Davarzani, H. Developing a supply chain disruption analysis model: Application of colored Petri-nets. *Expert Syst. Appl.* **2012**, *39*, 2102–2111. [CrossRef]
31. Brady, S.R. Utilizing and adapting the Delphi method for use in qualitative research. *Int. J. Qual. Methods* **2015**, *14*, 1609406915621381. [CrossRef]
32. Chadwick, P.; Creasy, C. Modified entropic elasticity of rubberlike materials. *J. Mech. Phys. Solids* **1984**, *32*, 337–357. [CrossRef]
33. Hassanzadeh Rangi, N.; Allahyari, T.; Khosravi, Y.; Zaeri, F.; Saremi, M. Development of an Occupational Cognitive Failure Questionnaire (OCFQ): Evaluation validity and reliability. *Iran Occup. Health* **2012**, *9*, 29–40.
34. Valizadeh Zare, N.; Mohammadi, E.; Zare, K.; Ehahi, N. Design and psychometric evaluation of coping scale in recipients of kidney transplant. *Evid. Based Care* **2017**, *7*, 45–53.
35. Arghami, S.; Sadeghi, G.; Abbasi Chenari, M.; Kamali, K. Psychometric properties re-evaluation of the Persian version of Manchester driving behavior questionnaire. *Iran Occup. Health* **2020**, *17*, 1–19.
36. Waltz, C.F.; Bausell, B.R. *Nursing Research: Design Statistics and Computer Analysis*; Davis Fa: Philadelphia, PE, USA, 1981.
37. Tamošaitienė, J.; Sarvari, H.; Chan, D.W.M.; Cristofaro, M. Assessing the Barriers and Risks to Private Sector Participation in Infrastructure Construction Projects in Developing Countries of Middle East. *Sustainability* **2021**, *13*, 153. [CrossRef]
38. Sarvari, H.; Valipour, A.; Yahya, N.; Noor, N.M.; Beer, M.; Banaitiene, N. Approaches to Risk Identification in Public–Private Partnership Projects: Malaysian Private Partners' Overview. *Adm. Sci.* **2019**, *9*, 17. [CrossRef]
39. Chan, D.W.M.; Sarvari, H.; Husein, A.A.J.A.; Awadh, K.M.; Golestanizadeh, M.; Cristofaro, M. Barriers to Attracting Private Sector Investment in Public Road Infrastructure Projects in the Developing Country of Iran. *Sustainability* **2023**, *15*, 1452. [CrossRef]
40. Moradi Shahdadi, L.; Aminnejad, B.; Sarvari, H.; Chan, D.W.M. Determining the Critical Risk Factors of Implementing Public–Private Partnership in Water and Wastewater Infrastructure Facilities: Perspectives of Private and Public Partners in Iran. *Buildings* **2023**, *13*, 2735. [CrossRef]
41. Keršuliene, V.; Zavadskas, E.K.; Turskis, Z. Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA). *J. Bus. Econ. Manag.* **2010**, *11*, 243–258. [CrossRef]
42. Nejatyan, E.; Sarvari, H.; Hosseini, S.A.; Javanshir, H. Deploying Value Engineering Strategies for Ameliorating Construction Project Management Performance: A Delphi-SWARA Study Approach. *Buildings* **2024**, *14*, 2291. [CrossRef]
43. Ali, J.D.; Alireza, W.; Ali, P. Ranking of risk assessment criteria in construction projects using network analysis. In Proceedings of the 4th International Congress on Civil Engineering, Architecture and Urban Development, Tehran, Iran, 7–9 December 2015. (In Persian).

44. Chan, D.W.M.; Abdul Hadi Sadeq, D.; Mohammed Fadhil, A.; Cristofaro, M.; Sarvari, H. Barriers and solutions in adopting public–private partnerships in road transportation infrastructure projects for developing countries: Results of a Delphi survey in Iran. *J. Facil. Manag.* **2024**, *22*, 683–708. [CrossRef]
45. Jafari Ramiani, A.; Sarvari, H.; Chan, D.W.; Nassereddine, H.; Lotfata, A. Critical success factors for private sector participation in accomplishing abandoned public sports facilities projects in Iran. *Int. J. Constr. Manag.* **2024**, *24*, 586–600. [CrossRef]