A SWARA-COPRAS APPROACH TO THE ALLOCATION OF RISK IN WATER AND SEWERAGE PUBLIC–PRIVATE PARTNERSHIP PROJECTS IN MALAYSIA

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Abstract. In a situation of growing water demand, inadequate public funding, poor asset condition and lack of maintenance in developing countries, public-private partnerships (PPPs) play an important role in the development of infrastructure, such as water supply and sewerage services. The purpose of this study is to develop a quantitative approach to appropriate risk allocation, with attention directed to the impact of positive and negative factors in water and sewerage projects. The paper presents a hybrid SWARA-COPRAS approach to examine risk allocation, particularly for PPP water supply and sewerage projects in the context of Malaysia. In addition to PPP infrastructure projects, the approach has the potential to be adapted to other applications. The proposed method enables decision makers to utilise qualitative linguistic terms in the allocation of risk between the public and private sector, and to select the best strategy for risk allocation in a contract. Finally, 24 significant risks were identified: six risks would preferably be allocated to the public sector, while seven risks would be assigned to the private sector, and eleven risks would preferably be shared by both parties. The finding from this study can help the government of Malaysia to determine an attractive political strategy for private investors to support a PPP water and sewerage infrastructure project.

Keywords: water and sewerage projects, PPP, risk allocation, SWARA, COPRAS method.

Introduction

The provision of quality and efficient water and sewerage services is essential in ensuring rapid urbanisation and economic development. During the Tenth Malaysia Plan, 2011–2015, efforts were undertaken to improve water supply and sewerage services to ensure their sustainability (Economic Planning Unit, Prime Minister's Department, 2010). Water and sewerage infrastructure projects in Malaysia have become larger and thereby more complex and more innovative (FAO/ESCAP, 2001; Tan, 2012). This causes, among other things, a need for combined expertise and collaboration between public and private parties. This causes, among other things, a need for combined expertise and collaboration between public and private parties. Public-private partnerships allow for this collaboration to a large extent, mitigate the risk of local debt and increase

financing capacity (Yang, Long, Cui, Zhu, & Chen, 2017). Therefore, to boost economic growth through participation of the private sector, 16 water and sewerage PPP projects were initiated worth US$10.144 million. According to the World Bank (2016), eight unsuccessful or failed water and sewerage PPP projects in Malaysia, such as the National Sewerage Project, the Kelantan Water Supply Project, the Indah Wastewater Urban Sewerage Rehabilitation and Sarawak Water Supply Project, were initiated at a cost of US$6.218 million. Hence, a public-private partnership offers both advantages and disadvantages. For instance, PPPs provide essential public benefits in the form of assets or services. Conversely, the procurement process for PPP projects is longer and more expensive than traditional procurement processes. A public-private partnership therefore involves risks for the private sector

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organisation, which expects compensation for accepting those risks, which can increase government costs.

Due to their complexity and unique characteristics, water supply and sewerage projects carry inherent risks. Following Ameyaw and Chan (2016), the PPP model proposes to find ways to resolve these risks and allocate them between the public and private sector. Therefore, risk management is essential for PPP water supply and sewerage projects. Appropriate risk allocation and shared targets are essential to the success of PPP projects (Osei-Kyei & Chan, 2015; Grasso & Soldo, 2017). Hence, a focus on collaboration is required for appropriate risk allocation, rather than merely allocating all risks to one party without an assessment of a party's ability to bear and control the risk.

In general, the goal of the private sector is to profit from its capacity and experience in managing businesses, while the primary objective of the public sector is to meet public needs effectively and efficiently. These different interests lead to disagreements over risk allocation preferences between public and private sector parties. The allocation of risk should be carried out optimally; otherwise, the actual value of the money target will probably be threatened. Imperfect risk allocation comprises one of the main causes of the failure of private sector participation (Marques & Berg, 2011). Improper risk allocation has negative impacts on the success of a PPP project in terms of time, cost and quality (Ke, Wang, & Chan, 2013; Jae-Seung & Yea-Sang, 2017). Equitable risk allocation depends on many criteria and barriers, such as the ability to manage risk and the attitude of stakeholders towards shared responsibility (Iqbal, Choudhry, Holschemacher, Ali, & Tamošaitienė, 2015; Zhang, Ding, Wu, & Skibniewski, 2017). There are several barriers associated with risk allocation in the PPP projects, such as cooperation, negotiation, teamwork, collaboration, trust and communication. Therefore, it is necessary to broadly consider the criteria and barriers of risk allocation to achieve appropriate risk allocation (Valipour, Mohammadi, Yahaya, Sarvari, & Noor, 2014; Grasso & Soldo, 2017). It is also essential for public and private sector parties to apply efficient risk allocation approaches in PPP projects to experience a more effective process of agreement arbitration and to reduce the occurrence of disputes during the concession period (Alireza, Mohammadreza, Zin, Yahaya, & Noor, 2013).

Earlier research studies on public-private partnerships indicate that equitable risk allocation among different parties is crucial to the successful implementation of PPP projects. However, current studies in this research area related to water supply and sewerage PPP projects in Malaysia are limited. The lack of research within a Malaysian context reinforces the significance of this study. This research is thus essential and timely to further enrich the knowledge base on water supply and sewerage PPP projects in Malaysia. Little is known about how to determine the party responsible for ensuring optimal risk management considering the criteria and the barriers of risk allocation. It is vital for the private and public sector to understand the various risks related to water supply and sewerage PPPs through the entire life cycle of infrastructure projects, the significance of risks, and the best way to allocate risks to ensure the long-term success of such partnerships. The identification, classification, evaluation and investigation of problems with this particular current practice of the allocation of risk and the evaluation of positive and negative factors to optimal risk allocation in the water supply and sewerage PPP project can represent an authentic contribution to the body of knowledge and to PPP projects. The aim of this study is to represent and propagate a decision model based on efficiency and capability in handling uncertainty.

To realise this goal, the hybrid SWARA-COPRAS approach is used to provide an accurate range of the uncertainty, simulating the ambiguity of expert judgment and the simultaneous consideration of the impact of positive and negative factors in fair risk allocation. An in-depth understanding of risk allocation is essential to the PPP agreement. The model developed in this study represents a significant contribution to the original body of information on water and sewerage PPP projects, as well as construction projects. The proposed model can be used as a reliable and practical risk management model for fair risk allocation in PPP projects. The findings from the research may also help the public and private sector in the development of a framework that can be used for bidding to predict and respond to risks in water and sewerage projects in Malaysia. Even though a rather large body of literature has been published on PPPs, there is a lack of both experience and published studies related to risk allocation in water and sewerage PPP projects in Malaysia. The results of this study provide insights into the development and performance improvement of water supply and sewerage PPP projects, especially in Malaysia.

1. Literature review

Many researchers have studied risks in PPP water supply and sewerage projects from various perspectives. Chan, Lam, Wen, Ameyaw, Wang, and Ke (2015) identified and evaluated typical risks associated with PPP projects in the Chinese water supply sector. Sixteen critical risk factors (CRFs) were identified through a comprehensive literature review, a Delphi survey and face-to-face interviews. The findings revealed that completion risk, inflation and price change risk have a higher impact on Chinese water PPP projects; whereas government corruption, an imperfect legal and supervisory system, and changes in market demand have a lower impact on the water supply sector. Xu, Chan, and Yeung (2010) developed a risk allocation model for PPP projects in China. Twenty-three risk factors were identified through a comprehensive literature review. The most critical nine risk allocation criteria were identified, validated and compiled based on expert knowledge via face-to-face interviews. Tan (2012) argued that problems were related to political rent seeking and weak (and highly politicised) regulation and identified overstated investments by the

private sector as the most important risks in Malaysia's PPP water and sewerage projects. Yang et al. (2017) analysed types of risk and problems that affect the implementation of the PPP model in urban sewage treatment projects in China. Wibowo and Mohamed (2010) analysed risk criticality and allocation in the context of PPP water supply development projects in Indonesia. They reported that variables such as the non-availability of raw water, the entry of new competitors, construction cost escalation, tariff-setting uncertainty and breach of contract by the government are the most critical risks among 39 risk factors identified. Ameyaw and Chan (2015) provided a list of 22 critical risk factors that have a strong impact on PPP water projects in Ghana. The top-ranked risks include the foreign exchange rate, corruption, water theft, non-payment of bills and political interference. Choi, Chung, and Lee (2010) found that the revocation of a fixed return policy, the current low level of water prices and the difficulty of adjustment are the most significant risks that cause foreign companies to retreat from China's water PPP market. According to Zeng, Wan, Tam, and Liu (2007), top-ranked risks in China's build-operate-transfer (BOT) water projects include tax policy change, interest rate fluctuation, raw water price instability, foreign exchange rates and competitors. Thus, it is important to determine the most significant risks for PPP projects. However, there is no universal set of risk factors applicable to all PPP projects and agreed upon as the most prevalent. Such risks differ across different projects, sectors and countries.

Risk allocation in PPP projects is not a new issue. Previous studies in this area can be divided into three types of research approaches. The quantitative methods were first developed for risk allocation. Chang (2014) investigated the optimal risk-sharing ratio between owners and contractors. An integrated fuzzy system dynamics approach was provided for risk allocation. Ameyaw and Chan (2016) proposed a quantitative fuzzy approach for risk allocation in water-infrastructure projects in Ghana. Alireza et al. (2013) used a hybrid AHP and genetic algorithm for allocation of risk in Malaysian PPP projects. G. Khazaeni, M. Khanzadi, and Afshar (2012a) proposed a fuzzy AHP approach to provide a method of balancing risk allocation in construction projects. Jin and Zhang (2011) applied artificial neural network (ANN) models to model the risk allocation decision-making process in PPP projects, primarily drawing upon transaction cost economics. In summary, a variety of methods has been employed for risk allocation. The second set of approaches focuses on the principles of risk allocation. Several studies (Lam, Wang, Lee, & Tsang, 2007; Jin & Doloi 2008; Xu et al., 2010; Khazaeni et al., 2012a, 2012b; Ameyaw & Chan, 2016) have suggested criteria and principles for equitable risk allocation. All of these risk allocation principles commonly use natural language and the qualitative judgment of experts. The qualitative methods represent the third approach to risk allocation based on the questionnaire survey. El-Sayegh (2008) identified significant risks in the United Arab Emirates (UAE) construction industry and addressed their proper allocation to the appropriate contracting party. A questionnaire was used to obtain the perceptions of construction experts. Loosemore and McCarthy (2008) studied risk allocation in construction and supply chains using a questionnaire survey. The survey indicated that the key to better managing perceptions of risk is fundamentally one of communication, consultation and involvement in contractual decision-making. Jin and Doloi (2008) proposed a theoretical framework for risk allocation in PPP projects. This framework was tested using an industry-wide survey. Carbonara, Costantino, Gunnigan, and Pellegrino (2015) defined the most significant risks in PPP motorway projects and identified both effective allocation and suitable mitigation strategies. Hwang, Zhao, and Yu (2016) identified the critical risks faced by parties that perform underground rail construction projects as part of international construction joint ventures. Although the survey respondents recognised that the allocation of risk between major parties is crucial, obstacles to risk allocation still exist. From the perspective of foreign contractors, differences in culture and working styles had the most negative influence on appropriate risk allocation, while local firms regarded the unclear division of responsibilities and risks as the major obstacle. Bing, Akintoye, Edwards, and Hardcastle (2005) explored risk allocation in PPP construction projects in the UK. The research findings showed that the public sector partner should retain site availability and political risks. Both parties should share relationship risks, force majeure risks and the risks of legislative changes. However, the majority of the remaining project risks, especially those at the meso risk level, should be allocated to the private sector partner. Hwang, Zhao, and Gay (2013) studied perceptions of risk allocation in PPP projects in Singapore and identified 11 risks that public and private sector partners preferred to share.

A review of previous studies revealed that researchers strove to find appropriate risk allocation patterns for construction projects, but very few publications were written specifically to address risk allocation in PPP projects in the water and sewerage sector – especially in Malaysia. One of the weak aspects of common models for risk allocation in PPP infrastructure projects is a lack of attention to the impact of criteria (positive factors) and barriers (negative factors). The influence from criteria and barriers can lead to a significant variation in decision outcomes regarding risk allocation based on attitude, acceptability and manageability of the risk between public and private sectors. This paper strives to fill these gaps by developing a hybrid SWARA-COPRAS approach. The main objective of the study to deploy the best risk allocation experience and practice of the PPP water supply and sewerage projects in Malaysia, and to provide the industry with the approach that can be used for the proper allocation of risks to the party best able to manage them.

2. Research framework

The primary stages of the research framework are illustrated in Figure 1. Each stage is described in greater depth in the following sections.

Stage 1: to identify significant risks in PPP water supply and sewerage projects in Malaysia. This stage includes a comprehensive literature review and interviews with experts to identify all types of risk in these projects. A risk matrix is used to identify significant risks.

Stage 2: to identify and determine the importance of risk allocation criteria and barriers. This stage includes a comprehensive literature review and interviews with experts to identify all types of criteria and barriers. The weights of the criteria and barriers are determined using the SWARA method.

Stage 3: to develop a hybrid SWARA-COPRAS evaluation model to determine equitable risk allocation between the public and private sector considering the criteria and barriers. This section includes the survey design and analysis of the results using the COPRAS method.

To enhance the representativeness of the sample, participants associated with the public and private sector in water and sewerage PPP projects were surveyed. The participants for the survey were drawn from the Construction Industry Development Board (CIDB), the Real Estate and Housing Developers' Association Malaysia (REHDA), the Public Private Partnership Unit (known as UKAS), and an international company working on water supply and sewerage PPP projects in Malaysia. The expert panel included a project manager/estimator, the primary contractor, a quantity surveying manager, a sub-contractor, and the technical director of the Malaysian PPP project. Finally, 110 respondents were identified who could answer the questionnaires for this research project. The types of respondents' roles for this study were categorised into two

groups: public and private roles. There were 62 respondents working in private sector roles and 48 respondents working in public sector roles. Overall, the results demonstrate that the majority of the respondents were working in private roles. All respondents had experience in water and sewerage PPP projects. Sixty-five respondents had experience in risk management of PPP projects.

2.1. Questionnaire

The questionnaire survey was conducted as a secondary resource to collect data for this research. Three types of questionnaires were used in this research. Questionnaire type A was designed to obtain the rank of each risk based on impact and frequency. The first section provided general information regarding the respondents, such as years of experience in PPP projects, especially water supply and sewerage projects, type of project involved, type of role in the project and background information about the individual completing the questionnaire. These questions were designed to identify the background of the respondents and to certify their responses. The second part included the primary questions about the weight of each risk assessment. The risk factors were rated on a 5-point Likert scale according to frequency (1 = Very low frequency, 2 = Low frequency, 3 = Moderate frequency, 4 = High frequency, 5 = Very high frequency) and impact (1 = Insignificant, 2 = Minor, 3 = Moderate, 4 = Major, 5 = Severe).

The type B questionnaire included two sections. The first section asked for the same general information from respondents as the same section in questionnaire type A. The second part included the primary questions regarding the evaluation of each risk allocation's criteria and barriers. To measure the importance of each risk allocation's criteria and barriers, respondents were required to separately indicate the level of each risk allocation's criteria and barriers. The 5 – point Likert scale (1 = Equal importance, 2 = Moderate importance, 3 = Strong importance, 4 = Very strong importance, 5 = Extreme importance) was used for this section. The weight of each risk allocation's criteria and barriers were obtained by SWARA method.

The type C questionnaire was designed for the SWARA-COPRAS method. This type of questionnaire focused on respondents' perceptions regarding the allocation of PPP risks. In other words, respondents were asked to allocate the risk based on criteria and barriers, whether under public, private or shared obligations. The researchers asked respondents to determine the optimal risk allocation between partners or as a shared risk in a PPP project in a simple questionnaire. The 5 – point Likert scale was used for this part same, as was the case for type B.

2.2. Risk analysis matrix

To identify the significant risks in Malaysian water and sewerage PPP projects, the respondents were required to reveal the level of frequency of the risk event and the
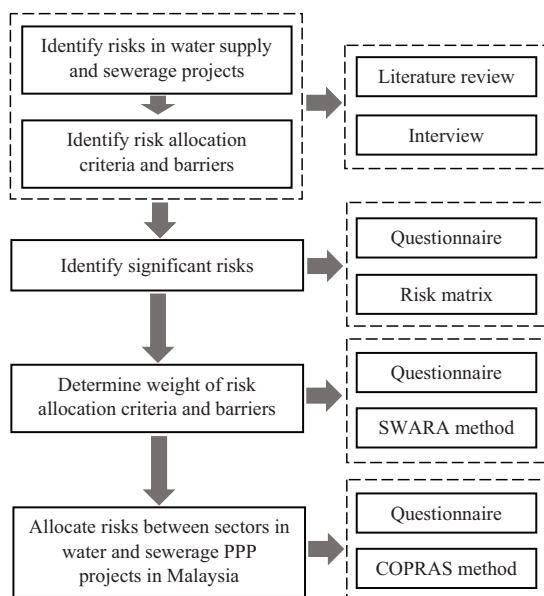

Figure 1. Research method schematic

amount of risk impact. The risk scores are determined by multiplying the mean of frequency and the mean of the impact of risk as follows (Alireza et al., 2013).

$$Risk\ score = F_r \times I_r, \tag{1}$$

where: F_r is the mean of frequency of risk occurrence and I_r is the mean of the impact of risk. Table 1 shows the rating of the risk analysis matrix. Consequently, a list of the major risks in Malaysian PPPs is the core objective of this step.

The risk priority is based on the following ranges (DOSH, 2008):

- Score 15–25: A HIGH risk requires immediate action to control the hazard, as detailed in the hierarchy of control. Actions taken must be documented on the risk assessment form, including date of completion.
- Score 5–14: A MEDIUM risk requires a planned approach to control the hazard and apply temporary measures if required. Actions taken must be documented on the risk assessment form, including date of completion.
- Score 1–4: A risk identified as LOW may be considered acceptable, and further reductions may not be necessary. However, if the risk can be resolved quickly and efficiently, control measures should be implemented and recorded.

2.3. Step-wise weight assessment ratio analysis (SWARA) method

In this paper, the step-wise weight assessment ratio analysis (SWARA) method was used to obtain the weight of risk allocation criteria and barriers. Using SWARA, the criteria are ranked by experts in terms of their importance, i.e., the most significant criterion is given rank 1, and the least significant criterion is given the last rank. The overall ranks for the group of experts are determined according to the median value of the ranks. The SWARA method for the criteria weights determination can be described as follows:

1. Sorting the evaluation criteria in descending order based on their expected importance;
2. Evaluation of the degree to which the C_j criterion is more important than the C_{j+1} criterion (s_j);
3. Determination of coefficient k_j;
4. Determination of recalculated weight w_j;
5. Determination of weight q_j.

The procedure for the criteria weight determination is presented in Figure 2.

For a comprehensive overview of the SWARA methodology, the reader is referred to Keršuliene, Zavadskas, and Turskis (2010) and Karabašević, Stanujkić, Urošević, and Maksimović (2016). Several researchers (Aghdaie, Zolfani, & Zavadskas, 2013; Zolfani & Saparauskas 2013; Zolfani & Bahrami 2014) have attempted to use the SWARA method to solve different problems. However, the SWARA method has not been applied to determine the most significant criteria for risk allocation in PPP projects.

2.4. COPRAS method

The COmplex PRoportional ASsessment (COPRAS) method was first introduced by Zavadskas and Kaklauskas (1996). This method can be used in situations where decision makers have to choose between alternatives with respect to a particular set of inconsistent criteria. COPRAS has the ability to account for both positive (maximising) and negative (minimising) evaluation criteria.

The COPRAS method determines a solution with the ratio to the best solution. This method assumes direct and proportional dependence of significance and priority of investigated alternatives for a set of evaluation criteria, criteria weights and values. Since COPRAS has been widely discussed in the literature, we prefer to discuss only the results here. For a comprehensive overview of the COPRAS method, the reader is referred to Kaklauskas, Zavadskas, Raslanas, Ginevicius, Komka, and Malinauskas (2006) and Zavadskas, Kaklauskas, Turskis, and Tamošaitiene (2008).

Several researchers (Zavadskas, Kaklauskas, Peldschus, & Turskis, 2007; Zavadskas, Turskis, & Tamosaitiene 2010; Kundakcı & Işık, 2016; Mulliner, Malys, & Maliene, 2016; Organ & Yalçın, 2016) have attempted to use the COPRAS method for different decision making situations.

3. Data analysis and discussion

3.1. Reliability analysis for study

A pilot questionnaire was conducted prior to the distribution of questionnaires to test the feasibility of intended questionnaires to be undertaken and to perfect the

Table 1. Risk matrix (Department of Occupational Safety and Health [DOSH], 2008)

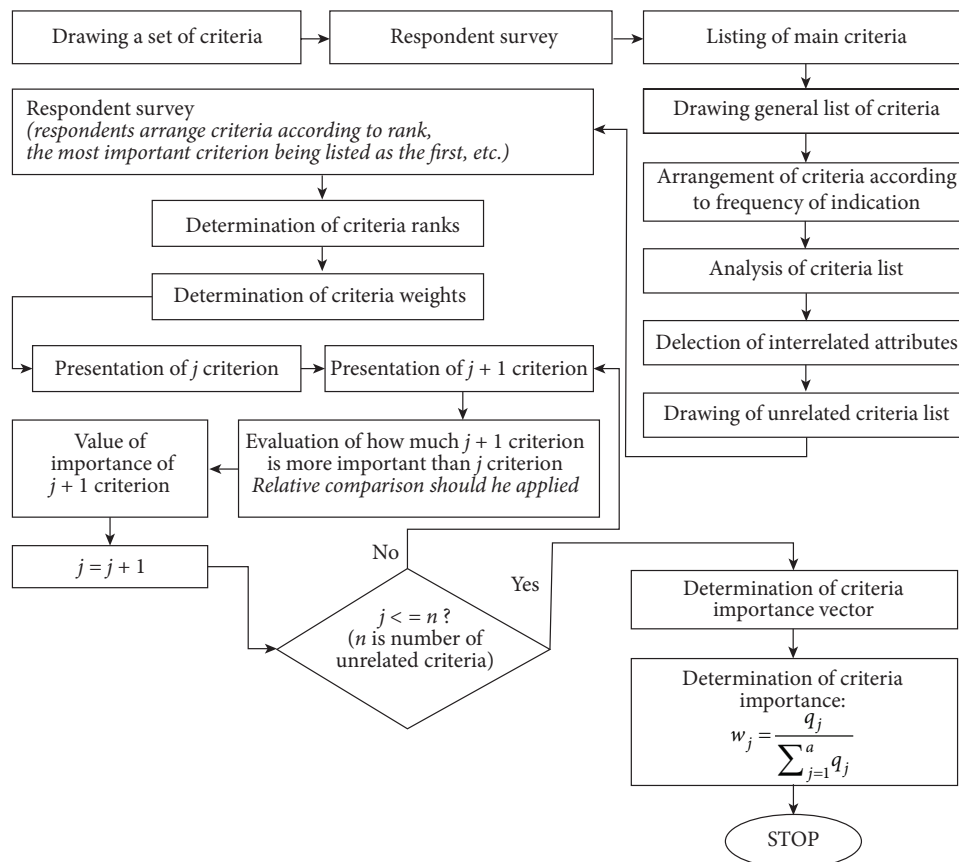| Frequency		Risk impact				
		Insignificant	Minor	Moderate	Major	Severe
		1	2	3	4	5
Very high	5	5	10	15	20	25
High	4	4	8	12	16	20
Moderate	3	3	6	9	12	15
Low	2	2	4	6	8	10
Very low	1	1	2	3	4	5

Figure 2. Determining of the criteria weights based on SWARA

questionnaire concepts and wording. Participants in the pilot study involved 20 experts who have experience with PPP projects within Malaysia.

In this study, the reliability test was performed for each type of questionnaire. Cronbach's alpha was used as the measure of internal consistency. In all three questionnaires, the reliability appears to be excellent ($\alpha > 0.9$) (Bhatnagar, Kim, & Many 2014), with Cronbach's alpha above 0.7 (see Table 2).

Table 2. Cronbach's alpha value for questionnaire

Type of questionnaire	Cronbach's alpha value
Type A	0.946
Type B	0.924
Type C	0.936

3.2. Questionnaire return rate

A total of 110 questionnaires were distributed, with 45 sets distributed by e-mail and 65 questionnaires handed directly to the participants. In total, 105 questionnaires were returned (see Table 3), representing a response rate of 95.45%. Of the 105 returned questionnaires, only 93 (84.54%) were deemed adequate for the research purposes.

Table 3. Sample characteristics

	Quantity	Percentage, %
Questionnaire distributed	110	100
Questionnaire returned and valid	93	84.55
Questionnaire returned but invalid	12	10.9
Missing	5	4.55

Table 4 shows the background information of the respondents: 82.8% came from the construction industry, and 17.2% came from the academic sector. Furthermore, nearly 60.2% of the respondents had more than 10 years of experience.

3.3. Significant risks in Malaysian PPP sewerage and water supply projects

Preliminary data was collected through a literature review of papers related to risk identification, risk assessment and risk allocation in water and sewerage PPP projects. The risk factors were generated based on an extensive literature review, with an emphasis on the works of Zeng et al. (2007), Choi et al. (2010), Wibowo and Mohamed (2010), Tan (2012), Ameyaw and Chan (2013), Ameyaw and Chan (2015), Valipour et al. (2015) and Ameyaw and

Table 4. Background characteristics of the respondents

Role		
Sector	Construction/industrial	Academic
Number	77	16
Percentage, %	82.8	17.2

Position						
Category	Project manager	Quality manager	Investor	Sub-contractor	Deputy director	Technical director	Academic
Number	15	12	16	14	12	8	16
Percentage, %	16.1	12.9	17.2	15.1	12.9	8.6	17.2

Industrial experience		
Years	5–10	11–15	≥16
Number	37	47	9
Percentage, %	39.8	50.5	9.7

Table 5. Significant risks in water and sewerage PPP projects in Malaysia

Risks group	Risk factor	Frequency F_r	Impact I_r	Risk score $F_r \times I_r$	Rank of each risk
R_1: Operational risks	R_{11}: High operational cost	3.7	3.9	14.43	19
	R_{12}: Equipment defect and lack of maintenance	4.1	3.9	15.99	9
	R_{13}: Poor performance	4.4	3.6	15.84	11
	R_{14}: Water theft	4.4	4.1	17.22	3
R_2: Political and regulatory risks	R_{21}: Political interference	4.4	4.2	18.48	1
	R_{22}: Termination of contract by government	4	4.1	16.4	7
	R_{23}: Government's commitment risk	3.8	4	15.52	15
	R_{24}: Political corruption	4.3	4.2	18.06	2
	R_{25}: Weak regulatory and monitoring regime	3.7	3.8	14.06	23
R_3: Financial risks	R_{31}: Financial availability	4.1	3.5	14.35	21
	R_{32}: Unfavourable global private investment climate	4	3.3	13.2	24
	R_{33}: Foreign exchange rate	4	4.3	17.2	4
R_4: Market/revenue risks	R_{41}: Delayed and non-payment of bills	4	4.2	16.8	5
	R_{42}: Uncertain tariff reviews	3.1	4.1	12.71	21
R_5: Relationship risks	R_{51}: Strained relationships	3.7	4	14.76	18
	R_{52}: Poor commitment from private party	3.84	4.1	15.74	12
	R_{53}: No risk allocation mechanism	4.2	3.7	15.54	14
	R_{54}: Weak capacity of public and private partners	3.7	4.1	15.17	16
	R_{55}: Inexperience in PPPs	4.7	3.5	16.45	6
R_6: Social risks	R_{61}: Public opposition	3.8	4.1	15.58	13
	R_{62}: Delayed process	4.3	3.7	15.91	10
	R_{63}: No-pro-poor measures	4	3.6	14.41	20
R_7: Force majeure	R_{71}: Severe weather	3.7	4	14.8	17
	R_{72}: natural disasters	3.9	4.2	16.38	8

Chan (2016). Interviews with experts were conducted as secondary resources to achieve the results of this section. Experts were asked to identify significant risks for water and sewerage PPP projects in Malaysia based on risks identified from the literature review. As a result, 43 risk factors in water and sewerage PPP projects were successfully identified. In order to achieve the first objective of the paper, the experts were required to indicate the level of frequency of risk occurrence and the level of impact of risk. Mean analysis was used to find the mean of frequency and the impact of risk. As shown in Table 1, the risk score can be calculated by multiplying the mean of frequency and the mean of the impact of risk. As a result, 24 significant risk factors (i.e., a risk score above 14) in six group (see Table 5) were successfully identified in Malaysian water supply and sewerage PPP projects.

Referring to Table 6, political interference risk (R_{21}) was the most critical risk factor, which ranked first with a score of 18.44. Political interference risk affects PPPs in all aspects, but water is unique given its public health, social, political and environmental repercussions (Ameyaw & Chan, 2015). Political interference has been identified

Table 6. The weight of risk allocation criteria

Criteria (+)	Comparative importance of average value s_j	Coefficient $k_j = s_j + 1$	Recalculated weight $w_j = \dfrac{w_{j-1}}{k_j}$	Weight $q_j = \dfrac{w_j}{\sum_{j=1}^{n} w_j}$
C_1: Bear the risk at the lowest price	–	1	1	0.1671
C_2: Foreseeing risk	0.21	1.21	0.8264	0.1381
C_3: Control the chance of risk	0.160	1.16	0.7124	0.1191
C_4: Risk attitude	0.136	1.136	0.6271	0.1048
C_5: Resources of risk control	0.108	1.108	0.5660	0.0946
C_6: Capability of control risk	0.09	1.09	0.5192	0.0868
C_7: Direct assumption of risk	0.082	1.082	0.4799	0.0802
C_8: Obtain intangible asset	0.079	1.079	0.4447	0.0743
C_9: Minimize loss if risk occurs	0.072	1.072	0.4149	0.0693
C_{10}: Sustain the consequence	0.063	1.063	0.3903	0.0652
			$\sum_{j=1}^{n} w_j = 5.9809$	

S_j is calculated based on the average of the expert's judgement. The information was gained individually from each expert. The importance of each criterion is calculated based on the relative importance of higher criterion. For example, 0.21 shows the relative difference of C_2 and C_1. For other criteria, the processes are the same.

as a major failure factor in water and sewerage PPP projects and adversely affects the efficiency of water provision (Kauffmann & Pérard, 2007). It is apparent and important in tariff setting and the adjustment of top management (including the managing director). Economic tariffs are prerequisites to the sustainment of water supply systems. Tariff setting and approval have historically been the domain of the sector ministers prior to the creation of an "independent" economic regulator, which has not significantly addressed the problem.

Political corruption risk (R_{24}) was the second-most significant water PPP project risk, with a score of 18.06. Water and sewerage projects are very prone to corruption risk, including bid shopping, payment games, falsified claims, overbilling and unbalanced bids (Hall & Lobina, 2007). Corruption has the consequence of eroding anticipated gains from PPPs while transferring costs to consumers in the form of increased tariffs and low-quality service. The long-term nature of water contracts serves to increase the incentive for corruption (Hall & Lobina, 2007). Corruption risk in public procurement is attributable to a lack of commitment of political leadership to combat corrupt practices (Abdulai, 2009).

Water theft (R_{14}) was the risk ranked third, with score of 17.22. In the urban water sector, water theft is prevalent. This risk can affect the commercial operations of a service provider. Private operators in Malaysia will continue to battle water theft without yielding desired results.

Foreign exchange risk (R_{33}) was ranked fourth, with a score of 17.2. The local currency of Malaysia (RM) has experienced substantial depreciation against the major trading currencies (US dollar, Euro) since 2010. Foreign exchange rate exposure has a negative impact on financial and budgetary implementation of PPP projects in Malaysia. Foreign exchange rates can also impact the private sector investment of water and sewerage projects because of lengthy payback periods, financing needs, and pricing and tariff adjustment difficulties. Non-payment of bills (R_{41}) was the fifth-most significant risk in the Malaysian water PPP project, with a score of 16.8.

3.4. Evaluation of risk allocation barriers and criteria

Identification and evaluation of risk allocation criteria and barriers is needed to achieve optimal risk allocation for PPP projects (Valipour et al., 2014). Criteria and barriers to optimal risk allocation have to be determined before the risk is allocated, and all parties involved must anticipate the risk in order to be more organized and prepared. Criteria and barriers to optimal risk allocation must be determined before the risk is allocated, and all parties involved must anticipate the risk in order to be more organised and prepared. Preliminary data was collected through a literature review of papers related to risk allocation and management in PPP projects and construction projects (Jin & Doloi, 2008; Xu et al., 2010; Khazaeni et al., 2012a, 2012b; Ameyaw & Chan, 2016). The interviews were conducted as secondary resources to determine the risk allocation criteria and barriers associated with Malaysian PPP water and sewerage projects.

In the next step, SWARA was applied to obtain the weight of each barrier and each criterion. Therefore, the questionnaire design was based on the SWARA method and was distributed by email to experts in identified PPP

Table 7. The weight of risk allocation barriers

Barriers (–)	Comparative importance of average value s_j	Coefficient $k_j = s_j + 1$	Recalculated weight $w_j = \dfrac{w_{j-1}}{k_j}$	Weight $q_j = \dfrac{w_j}{\sum_{j=1}^{n} w_j}$
B_1: Aversion to risk by project participants	–	1	1	0.2067
B_2: Lack of efficient risk allocation mechanisms	0.26	1.26	0.7936	0.1640
B_3: Lack of understanding of the benefits of optimal allocation	0.180	1.180	0.6725	0.1390
B_4: Competitive attitude	0.161	1.161	0.5793	0.1197
B_5: Contract complexity	0.138	1.138	0.5090	0.1052
B_6: Poor risk management communication	0.104	1.104	0.4611	0.0953
B_7: Imbalance and abuse of power	0.086	1.086	0.4245	0.0877
B_8: Lack of trust among project participants	0.071	1.071	0.3964	0.0819
			$\sum_{j=1}^{n} w_j = 4.8364$	

water supply projects in order to ask each expert, based on their own experiences and implicit knowledge, to rank the importance of each criteria and barrier. As a result, the 10 criteria (C_1–C_{10}, see Table 6) and 8 barriers (B_1–B_{10}, see Table 7) to optimal risk allocation of PPP water and sewerage projects were identified. These criteria and barriers are divided into two parts, with attention accorded to the impact of risk allocation. Criteria were beneficial factors (+), and barriers were non-beneficial factors (–); beneficial criteria are maximised, whereas non-beneficial criteria are minimised. The outcome of this step is used in the COPRAS method for the assessment of risks.

3.5. Allocation of risk between parties using the SWARA-COPRAS method

The primary objective of this study is to allocate types of risk in Malaysian water and sewerage PPP projects. The analysis of this section covered the perceptions of the public and private sector regarding allocation of PPP project risks. Risks are allocated by respondents to the party who can best handle them. This means respondents have selected the party actually taking the risk from one of the following three choices: public, private and shared by both the public and private sector.

Following the identification and evaluation of important risks, and after obtaining the weight of each risk allocation criteria and barrier, a COPRAS structure and questionnaire was designed and constructed by 10 experts to create mutual influence between each risk factor, criteria, barrier and alternative based on risk allocation. The 1–9 scale was used for this portion of the research.

Data were processed using Microsoft Excel to determine the initial decision-making matrix for risk allocation. Table 8 provides an example of the initial decision-making matrix and the weighted normalised decision-making matrix of risk allocation for uncertain tariff reviews (R_{42}) describing the compared risk allocation criteria and barriers.

The sums of the weighted normalised values for the beneficial criteria (P_i) and the non-beneficial criteria (or barriers, R_i), the priority value (Q_i), and the quantitative utility (N_i) for uncertain tariff reviews (R_{42}) are shown in Table 9. According to Table 9, uncertain tariff reviews risk (R_{42}) must be allocated to the public sector.

The results of risk allocation for water and sewerage PPP projects in Malaysia are shown in Table 10. Referring to Table 10, the seven risks must be allocated to the private sector, namely 'R_{11}: High operational cost', 'R_{12}: Equipment defect and lack of maintenance', 'R_{13}: Poor performance', 'R_{31}: Financial availability', 'R_{32}: Unfavourable global private investment climate', 'R_{52}: Poor commitment from private party' and 'R_{62}: Delayed process'. This means the private sector has the ability to bear the least cost, control, foresee and assess, sustain, and assume and manage the occurrence and consequence (or loss) of these risks.

The output from the model reveals the six risks that must be allocated to the public sector, which included 'R_{21}: Political interference', 'R_{22}: Termination of contract by government', 'R_{23}: Government's commitment risk', 'R_{42}: Uncertain tariff reviews' and 'R_{61}: Public opposition'. This means the public sector has the ability to control and manage these risks. For example, uncertain tariff and political interference are directly under the public's control, which therefore has a high capability to assume these risks in proportions of 0.922 and 0.954, with the private sector having a low capability to control these risks. The government, through tariff resets and tariff indexation formulas, must extend a political commitment and charge economic tariffs. Therefore, it is the government's responsibility to prepare a well-functioning framework to encourage increases in water tariffs to help the private sector improve operations and services.

Table 10 shows that the 10 risk factors should be allocated between the public and private sector. These risks include 'R_{14}: Water theft', 'R_{24}: Political corruption (government and

Table 8. Sample of initial and weighted normalised decision-making matrix

	Weight	Initial matrix			Weighted normalized matrix		
		Public	Shared	Private	Public	Shared	Private
C_1	0.1671	8	1	3	0.1114	0.0139	0.0418
C_2	0.1381	9	2	2	0.0956	0.0212	0.0213
C_3	0.1191	8	3	3	0.0681	0.0266	0.0255
C_4	0.1048	7	2	2	0.0667	0.0191	0.0191
C_5	0.0946	9	2	3	0.0608	0.0135	0.0203
C_6	0.0868	8	1	2	0.0631	0.0079	0.0158
C_7	0.0802	6	2	3	0.0438	0.0146	0.0219
C_8	0.0743	7	2	3	0.0433	0.0124	0.0186
C_9	0.0693	8	2	4	0.0396	0.0099	0.0198
C_{10}	0.0652	8	2	4	0.0373	0.0093	0.0187
B_1	0.2067	7	6	5	0.0804	0.0689	0.0574
B_2	0.164	9	8	6	0.0642	0.0570	0.0428
B_3	0.139	8	7	8	0.0485	0.0423	0.0484
B_4	0.1197	8	6	7	0.0456	0.0342	0.0399
B_5	0.1052	9	8	7	0.0395	0.0351	0.0307
B_6	0.0953	8	7	6	0.0363	0.0318	0.0272
B_7	0.0877	8	6	8	0.0319	0.0239	0.0319
B_8	0.0819	7	5	7	0.0302	0.0216	0.0302

Table 9. Risk allocation for uncertain tariff reviews risk

	P_i	R_i	$Q_i = P_i + \dfrac{\sum_{i=1}^{n} R_i}{R_i \sum_{i=1}^{n} \dfrac{1}{R_i}}$	$N_i = \dfrac{Q_i}{Q_{max}} \cdot 100\%$
Public	0.6296	0.3763	0.9225	100
Shared	0.1473	0.3148	0.4972	53.9
Private	0.2225	0.3084	0.5799	62.84

Table 10. Result of risk allocation in PPP water and sewerage projects in Malaysia

Risk	Q_i			N_i (%)			Allocated
	Public	Shared	Private	Public	Shared	Private	
R_{11}	0.535	0.564	0.942	46.1	59.8	100	Private
R_{12}	0.521	0.443	0.896	58.1	49.4	100	Private
R_{13}	0.465	0.384	0.912	50.9	42.1	100	Private
R_{14}	0.345	0.943	0.446	36.5	100	57.9	Shared
R_{21}	0.954	0.234	0.324	100	24.5	33.9	Public
R_{22}	0.879	0.123	0.236	100	13.99	26.8	Public
R_{23}	0.768	0.321	0.223	100	41.8	55.07	Public
R_{24}	0.435	0.675	0.365	64.5	100	54.07	Shared
R_{25}	0.763	0.324	0.365	100	42.4	59.5	Public
R_{31}	0.521	0.453	0.897	58.08	50.5	100	Private
R_{32}	0.342	0.546	0.786	43.5	69.4	100	Private
R_{33}	0.546	0.923	0.432	59.15	100	61.5	Shared
R_{41}	0.432	0.896	0.426	48.21	100	58.7	Shared
R_{42}	0.923	0.497	0.580	100	53.9	62.83	Public
R_{51}	0.342	0.845	0.453	40.4	100	53.6	Shared
R_{52}	0.543	0.321	0.863	16.57	37.19	100	Private
R_{53}	0.326	0.876	0.231	37.21	100	26.36	Shared
R_{54}	0.442	0.768	0.274	44.5	100	35.6	Shared
R_{55}	0.331	0.896	0.432	25.7	100	48.2	Shared
R_{61}	0.764	0.342	0.274	100	44.7	35.8	Public
R_{62}	0.265	0.543	0.861	30.7	63.06	100	Private
R_{63}	0.342	0.845	0.362	40.47	100	51.1	Shared
R_{71}	0.425	0.768	0.312	55.5	100	40.69	Shared
R_{72}	0.243	0.812	0.368	29.92	100	57.63	Shared

private sector)', 'R$_{33}$: Foreign exchange rate', 'R$_{41}$: Delayed and non-payment of bills', 'R$_{51}$: Strained relationships', 'R$_{53}$: No risk allocation mechanism', 'R$_{54}$: Weak capacity of public and private partners', 'R$_{55}$: Inexperience in PPPs', 'R$_{63}$: No-pro-poor measures', 'R$_{71}$: Severe weather' and 'R$_{72}$: Natural disasters'. This allocation for foreign exchange rates shows that this risk is not directly under the control of the public sector (government) or the private sector (investor), and no partner has a high capability to manage it. According to corruption risk, the private sector is more likely to unduly influence the procurement process through bribe offerings. The contracting authority, or the public sector, has a responsibility to ensure open, fair, transparent and competitive tendering without receiving bribes from the private sector or competing firms. The private sector should observe the rules of the game and gain the confidence of the market-place, without making an offer. Water theft risk is allocated between the public and the private sector. This means the private sector should take steps to detect theft, discipline staff who facilitate theft and disconnect illegal connections. On the other hand, it is the public sector's responsibility to uphold the law and arrest and punish thieves, and the private sector or operator can claim compensation for losses. Non-payment of bills risk should be allocated between both sectors. The public sector should be committed to effecting strict collection policies and legal actions against defaulting customers, especially public institutions. The private sector also has the responsibility of identifying and disconnecting delinquent customers.

4. Validation of model

The model validation, through face-to-face interviews, was carried out in December 2015. Ten experts with direct hands-on experience in water and sewerage PPP projects in Malaysia were invited to evaluate: (1) the degree of comprehensiveness of risks included in the model; (2) the degree of objectivity of the model; (3) the degree of clarity of the model; (4) the overall reliability of the model; and (5) the degree of practicality of the model. The results of the validation experts are tabulated in Table 11. The average scores of all five criteria are well above 3.50 (Yeung, A. P. C. Chan, D. W. M. Chan, & Li, 2007). Therefore, the result confirmed that the SWARA-COPRAS model is considered comprehensive, clear, objective, practical and reliable by the experts in the validation exercise.

4.1. Balance allocation index

Balance regarding allocation of risk is a crucial project success factor. The balance allocation index (BAI) was employed to verify the balanced risk allocation results between the proposed model and the previous study. It offers a realistic scale for assessing how any risk allocation model is actually balanced by reconciling the conflicting interests of contracting sectors (Khazaeni et al., 2012a). The BAI ratio can be measured by the contractor's share of risk allocation (private sector) against the employer's share of risk allocation (public sector).

$$BAI = \left(\frac{private's\ share}{public's\ share} \right) \ if$$

$$\left\{ \begin{array}{ll} BAI > 1 & private's\ share\ more\ than\ public \\ BAI = 1 & balanced\ risk\ allocation\ between\ sectors \\ BAI < 1 & public's\ share\ more\ than\ private \end{array} \right\} . \quad (2)$$

The BAI ratio was measured from the findings of this study related to the risk allocation of PPP projects and is presented in Table 12 to confirm whether the balanced concept is well utilised inside the risk allocation models. In this study, private and public sector shares have a ratio of 12.359 and 12.451, respectively. From Table 12, it can be concluded that the allocation model presented by this study is more balanced and may provide a more stable model for the public and private sector, with a BAI ratio of 0.992.

Table 12. BAI measurement in risk allocation frameworks

Share	Ratio
Private's share	12.359
Public's share	12.451
	BAI = 0.992

4.2. Sensitivity analysis

A sensitivity analysis is conducted to determine changes in the particular ranking of alternatives, as well as changes in particular weights from the main factors proposed by the respondents employed in this study. To test the stability of our decision, this study performed a sensitivity analysis to test the robustness of the decision with respect to changes in the weighting of the criteria and barriers. To determine sensitivity ranges and to change

Table 11. Results of validation exercise for SWARA-COPRAS risk allocation model

Validation criteria	Scores rated by experts										Average scores
1. Degree of comprehensiveness of risks included in the model	4	5	3	4	5	4	5	4	5	4	4.3
2. Degree of objectivity of the model	5	4	5	4	3	4	5	5	4	4	4.3
3. Degree of clarity of the model	4	4	5	3	4	4	5	3	3	5	4
4. Overall reliability of the model	4	5	3	4	4	4	4	5	5	5	4.7
5. Degree of practicality of the model	3	3	4	5	5	4	4	4	4	4	4

Table 13. Values to sensitivity analysis for uncertain tariff reviews risk based on criteria

Input value	Priority of criteria	Weight of each part		
		Private	Public	Shared
–	0.01	0.25	0.18	0.57
0.05	0.06	0.25	0.18	0.57
0.11	0.11	0.25	0.18	0.58
0.16	0.17	0.24	0.18	0.58
0.21	0.22	0.24	0.18	0.58
0.26	0.27	0.24	0.18	0.59
0.32	0.32	0.24	0.17	0.59
0.37	0.37	0.23	0.17	0.59
0.42	0.43	0.23	0.17	0.60
0.47	0.48	0.23	0.17	0.60
0.50	0.53	0.22	0.17	0.60
0.58	0.58	0.22	0.17	0.61
0.63	0.64	0.22	0.17	0.61
0.68	0.69	0.21	0.17	0.62
0.74	0.74	0.21	0.17	0.62
0.79	0.79	0.21	0.17	0.62
0.84	0.84	0.20	0.17	0.63
0.89	0.90	0.20	0.17	0.63
0.95	0.95	0.20	0.17	0.63
1	1	0.19	0.17	0.64

Figure 3. Sensitivity analysis for uncertain tariff reviews risk based on barriers

the weights of main factors, we adopted two processes. First, the major impacting factors and subfactors were determined. The weights of major impacting factors and subfactors vary from (0.05 to 1). Various values were investigated to examine the impact of barrier factors and criteria on the final weights; this section discusses the three alternatives; similar outcomes were found for related sub-elements. A sample sensitivity analysis of the final decision of 'uncertain tariff reviews' risk is shown in Table 13. The alternative rating does not change if the relative significance is increased from 0.5 and decreased from 0.5. This reveals that ranking of alternatives does not change if managerial preferences and expert judgments increase or decrease. Therefore, at this particular level, the solution is extremely robust, with little change in ultimate selection. Stakeholders in PPP projects can be confident that sharing between partners for each risk is a better choice. The sample of the sensitivity analysis of the final decision of 'uncertain tariff reviews' risk is shown in Figure 3. Therefore, the proposed model can help stakeholders in sewerage and water supply PPP projects to determine the best strategy for sharing risk.

Conclusions

Appropriate risk allocation between the public and private sector is a vital factor in achieving success in the implementation of public-private partnership (PPP) projects.
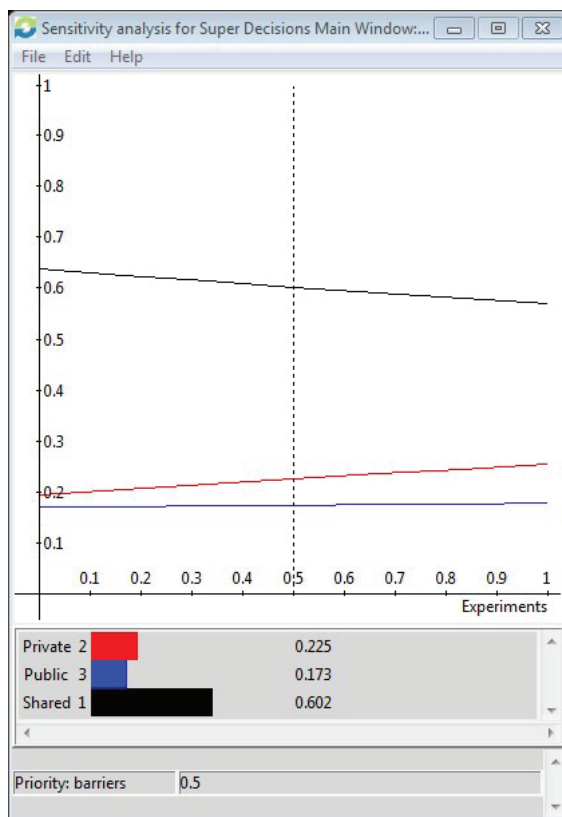
Risk allocation may fail to be achieved due to the lack of a joint risk management mechanism. In addition, inappropriate risk allocation can negatively affect the project management triangle of time, cost, and quality, in realising the success of PPP projects. Remarkably, the process of risk allocation should be recognised based on the abilities of both parties in PPP projects. In fact, both responsibility and accountability play significant roles in PPP projects. The proper allocation of risk in PPP projects is a flexible and complex procedure, which often causes conflict between the partners. Equitable risk allocation depends on many factors, such as the ability to manage risk and the attitude of stakeholders towards risk. This paper has explained risk allocation in PPP water and sewerage projects in Malaysia based on the SWARA-COPRAS method, which can be modelled to reflect risk allocation criteria and barriers. In this research, the criteria were considered positive factors and the barriers were considered negative factors based on the COPRAS method. The COPRAS technique is adopted for analysis and decision-making because it deals well with the ambiguity in the barriers and criteria for risk allocation and accurately accounts for the expert knowledge that characterises risk-allocation decision-making. In this study, the risk matrix was used to identify significant risks. Based on the questionnaire survey and the risk assessment matrix, the 24 important risks inherent in Malaysian water and sewerage PPP projects were identified, in addition to five significant risk

factors in PPP water and sewerage in Malaysia, including 'Political interference (R_{21})', 'Political corruption risk (R_{24})', 'Water theft (R_{14})', 'Foreign exchange' and 'Non-payment bills (R_{41})'. The 10 criteria and eight barriers to risk allocation were identified through a literature review, and the weight of each criterion and barrier was obtained by analysis using the SWARA method. Finally, the results obtained from the COPRAS method included a total of 24 significant risks, with six risks allocated to the public sector, seven risks allocated to the private sector, and 11 risks shared between the public and private sector.

It is vital for the private and public sector to understand the various risks related to water supply and sewerage PPPs through the entire life cycle of infrastructure projects, as well as the significance of risks and the best way to allocate them to ensure long-term achievement of partnerships. The identification, classification, evaluation and investigation of problems of this particular current practice of allocation of risk, and the evaluation of positive and negative factors to optimal risk allocation in water supply and sewerage PPP projects, represent an authentic contribution to the body of knowledge and to the PPP projects. The findings from this research may help the public and private sector to develop a framework that can be used for bidding to predict and respond to risks in water and sewerage projects, therefore saving time in arbitration and contract transactions. This study should help project stakeholders in terms of better risk management, time savings, reduced overall cost, and the enhancement of the general quality of PPP water and sewerage projects. The model provides an innovative and helpful instrument to PPP industry experts and providers through the introduction of a realistic mechanism regarding the development of a better decision support model for optimal risk allocation. Furthermore, the results would certainly help to impact public policy improvement towards PPP and the way in which various sectors can carry out PPP contracts with due respect for their risk perceptions.

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