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RESEARCH ARTICLE

Ranking Risks of BOT Toll Road Investment Projects in Indonesia Using Fuzzy Interpretive Structural Modelling

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Abstract

The Government of Indonesia implemented the Build, Operate, and Transfer (BOT) model, relying on private investment to bridge the financing gap in developing public infrastructure facilities, including toll roads. Toll road investments, like other greenfield infrastructure projects, are typically characterized by high project risk, which discourages private sector investment. Many previous studies have investigated the various risk events in toll road investment projects, but only a few have assessed the interrelationships of risk events in the Indonesian context. This study fills this knowledge gap by determining which risk event influences other events most. Fuzzy interpretive structural modelling combined with the matrix impact of cross-references multiplication applied to a classification method was used to determine the hierarchy of risk events and analyze their influences on other risk events. A total of fourteen risk events were identified and analyzed. An unclear output specification was found to be the most significant risk event, with the biggest driving power affecting other risks. The findings and limitations of this study point the way forward for future research.

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Keywords

Risk Ranking; Toll Roads; Build-Operate-Transfer; Fuzzy Interpretive Structural Modelling; Indonesia

Introduction

Indonesia's toll road industry began in 1978 with the construction of the Jakarta–Bogor–Ciawi (Jagorawi) toll road, the first country's toll road. Based on Government Regulation No. 4 of 1978, the Government of Indonesia (GoI) established PT Jasa Marga (PTJM) as a state-owned enterprise with a mandate to build and operate toll roads. The PTJM was Indonesia's sole toll road operator until the late 1980s. In 1990, the GoI issued Law No. 8 concerning Toll Roads, ushering in the era of private toll roads under Public-Private Partnership (PPP) with the Build, Operate, and Transfer (BOT) model under the condition that the private sector must partner with PTJM when investing in toll roads. Under the BOT model, the private sector is required to build and operate the toll road commercially for a set period, known as the concession period, and then transfer all the assets back to the contracting agency after the end of the concession period.

In 2004, the GoI initiated massive policy reforms, including amending old regulations that had hampered private investment in infrastructure. For instance, the GoI lifted the PTJM's monopoly power and allowed the private sector to compete with it for BOT contracts. The GoI is clearly paying close attention to the development of toll road infrastructure as part of the national strategic plan to help overcome the country's connectivity issues and promote national economic growth. In the 2019–2024 mid-term development plan, the GoI set a new goal of developing approximately 2,000 kilometres of new toll roads, exceeding the previous target. From 1978 to 2021, for instance, the total length of built toll roads was only 2,391 km (or about 56 kilometres per year)—a slow rate of toll road development compared to other countries such as China and India. This goal necessitates massive capital funding, which the GoI cannot provide on its own. As a result, the GoI strongly encourages the private sector to participate in toll road development under the BOT contract.

Attracting private investment in public infrastructure is not as trivial as it appears. Most developing and developed countries have historically failed to attract private investment (Osei-Kyei and Chan, 2017). This failure can be attributed to the nature of toll road investment, which frequently involves a multitude of project risks; this is especially prevalent in BOT projects due to the long-term nature of the agreement, as risks can occur at any stage and jeopardize the project's sustainability. Some studies have reported that one of the most common reasons for the failure of PPP projects is improper risk identification, assessment, and mitigation (Zou, Wang, and Fang, 2008). Proper risk management is thus crucial for successfully implementing PPP projects (Bypaneni and Tran, 2018; Karaca and Nunez, 2019; Rzempała, Borkowski, and Rzempała, 2022). Risks must first be identified and categorized to be well managed (Le et al., 2019).

Earlier studies have explored the risks of toll road projects (Chi, Bunker, and Teo, 2017; Nguyen, Mollik, and Chih, 2018; Patel, Haupt, and Bhatt, 2020). By nature, many project risks are interrelated in their occurrences and impacts. Failing to take this into account can result in inaccurate risk assessments and impede project implementation (Wang et al., 2020). Given that, some studies have focused on investigating interrelationships among risks in construction and infrastructure projects (Boateng, Chen, and Ogunlana, 2015; Han et al., 2019; Li and Wang, 2019; Shoar et al., 2021; Erol et al., 2022). Nevertheless, studies on risk interrelationships in BOT toll road projects are scarce.

This study makes contributions in two areas. First, it identifies and ranks risk factors in Indonesia's BOT toll road projects, with interrelationships among them considered. Every major capital investment project entails a plethora of project risks. While some risks are shared by many projects, others are unique to a specific project-and-country context. Even though Indonesia is among the most active PPP markets in the Asian region, it has received little attention in global PPP research. This study's findings are compared and contrasted with similar studies in different country settings, thereby contributing to the existing literature on BOT risk management. This study adopted the fuzzy interpretive structural modelling (FISM) to determine the factor interrelationships and the impact matrix cross-reference multiplication applied to a classification (MICMAC) technique to classify the factors based on the driving and dependence powers. This study's methodology can also be extrapolated to other countries facing similar challenges. Second, from a practical standpoint, this study provides a list of influential risk factors that merit special consideration. Key stakeholders who have control over the risks can prepare necessary measures to mitigate them early in the project lifecycle. A timely risk response strategy would help make toll road projects more attractive for private financing.

Literature review

Risks exist in every project and can lead to considerable delays or cost overruns. Project risks can be classified into risk groups, categories, and events. Risk groups are further divided into internal and external risks. The former is related to and occurs under the management team's control, while the latter is beyond the control of management (El-Sayegh, 2008). Classifications of categories and events can take on a variety of forms. Some studies have divided risk categories into risk events based on project phases or activities (Doloi, 2012; Effah Ameyaw and Chan, 2013; The World Bank, 2017; PT. Penjaminan Infrastruktur Indonesia, 2020).

Risk events in infrastructure projects can vary greatly depending on the sector and the country's circumstances (e.g., law enforcement and macroeconomic environment). Likewise, risk allocation can differ depending on the delivery system (Bypaneni and Tran, 2018). Under a BOT agreement, risks over a 30–40year contract period are allocated between the public and private contracting parties under the efficient risk-sharing principle: risk should be borne by the party best able to deal with it.

Risk management is an essential aspect of project management that contributes to the success of PPP projects (Wang and Chou, 2003; Le et al., 2019). Numerous studies have demonstrated the significance of risk management in BOT projects, with some concentrating on risk identification and assessment (Wibowo and Mohamed, 2010; Ke et al., 2011; Trangkanont and Charoenngam, 2014; Patel, Haupt, and Bhatt, 2020); risk allocation between the public and private sectors (Jin, 2010; Ameyaw and Chan, 2016; El-Kholy and Akal, 2021); and specific project risks (Yuan et al., 2009; Carpintero, Vassallo, and Soliño, 2015; Roumboutsos and Pantelias, 2015; Shao, Yuan, and Li, 2017).

Risks can occur in all phases of toll road projects, from pre-construction to operation, and can be categorized differently. During the land acquisition phase, the projects are vulnerable to cost and time overruns due to lengthy and protracted land acquisition processes, particularly when the land acquisitions are carried out simultaneously with construction activities (Bagui and Ghosh, 2013; Babatunde, Adeniyi, and Awodele, 2017; Le et al., 2019). During the design and construction phases, there are many construction-related risk events, including unclear output specifications (Akintoye and Beck, 2009; Javed and Lam, 2013; Javed, Lam, and Chan, 2014); increase in construction costs (Flyvbjerg, Bruzelius, and Rothengatter, 2003; Bain, 2007); and changes in the scope of work after the contract is signed (Tan, 2009; Walker and Jacobsson, 2014; Permatasari, Hardjosoekarto, and Salomo, 2020).

During the operational phase, projects are exposed to operational and maintenance (O&M) risks, which can affect the cash flow and increase costs due to various factors. The increase in O&M costs is one of the major concerns for both the public and private sectors (Sharma, Bindal, and Cantt, 2014; Karaca and Nunez, 2019). Regular maintenance and reliable operator are required to control the O&M risk. Also, revenue-related risks emerge among the most significant and highly unpredictable risks in toll road investments. Risk events include low traffic in the early years of operation, often referred to as the ramp-up period (Flyvbjerg et al., 2009); estimation error, and change in volume projection or optimism bias (Carbonara et al., 2014; Alasad and Motawa, 2016; Phong, Likhitruangsilp, and Onishi, 2017); uncertain tariff adjustments or tariff adjustments that do not match expectations (Kerf et al., 1998; Ke et al., 2010); and initial tariff miscalculation (Malini, 1999; Ng, Xie, and Kumaraswamy, 2010).

Financial-related risks may emerge over the course of the contract. These can include a failure to achieve financial close (Iyer and Sagheer, 2010; Kurniawan, Mudjanarko, and Ogunlana, 2015; Asian Development Bank, 2020; Endo, Gianoli, and Edelenbos, 2021); land bailout refunds (Guild, 2019; Sungkono and Kurniawan, 2019; Endo, Gianoli, and Edelenbos, 2021); the currency exchange rate (Oladokun and Dada, 2008; Ameyaw and Chan, 2015; Osei-Kyei and Chan, 2017; Nour and Hao, 2019); increasing interest rates (Zhang, 2005; Xu et al., 2014; Pellegrino et al., 2019); and insurance risk (Demirag et al., 2012; Moody's Investors Service, 2016).

According to the literature mentioned above, numerous publications have focused on project risks in toll road projects, but most studies did not adequately consider the interrelationships between project risk events. Only a handful of studies have examined this issue, including Iyer and Sagheer (2010) and Bhatt and Sarkar (2020) on toll roads, Han et al. (2019) on brownfield remediation projects, and Jiang et al. (2019) and Li and Wang (2019) on general risk assessment. In addition, previous studies mainly indicate that land unavailability (Nguyen, Mollik and Chih, 2018) and legal aspects pose the greatest threat in China, India, the UK, and Vietnam (Boateng, Chen and Ogunlana, 2015; Han et al., 2019; Li and Wang, 2019).

Research methodology

RISK IDENTIFICATION

This study adopted the identification and categorization of risk events on BOT toll road projects from the Risk Allocation Guideline published by PT. Penjaminan Infrastruktur Indonesia (2020). Aside from avoiding unnecessary repetition, there are two additional reasons for this adoption. First, the identified risks were defined within the Indonesian context; second, the Guideline is reviewed annually by selected stakeholders as mandated by the Ministry of Finance Regulation 260/2010, ensuring the risk identification's validity and relevance.

The list included fourteen risk events and clustered into the following groups: (i) location risk; (ii) construction and test operation design risks; (iii) financial risk; (iv) operating risks; and (v) revenue risks. This list has also been supported and confirmed by the relevant literature. Table 1 shows the relevant risk events and categories.

Table 1. Risk categories and events in toll roads

Risk Category	Risk Event	Code	Description	Project Stage	Supporting Literature
Location Risk	Delays and increases in land acquisition costs	A 1	Delays and increased costs due to prolonged land acquisition processes	Pre-Construction and Construction	(Bagui and Ghosh, 2013; Babatunde, Adeniyi, and Awodele, 2017)
Design and Construction Risk	Unclear output specifications	A 2	Delays and cost increases due to unclear output specifications	Pre-Construction	(Akintoye and Beck, 2009; Javed and Lam, 2013; Javed, Lam, and Chan, 2014)

Table 1. continued

Risk Category	Risk Event	Code	Description	Project Stage	Supporting Literature
	Increases in construction costs	A 3	Construction cost increases due to changes in work volume or material prices	Construction	(Flyvbjerg, Bruzelius, and Rothengatter, 2003; Bain, 2007)
	Changes in the scope of work after signing the contract	A 4	Changes in capital expenditure and operational expenditure due to changes in the scope of work at the request of the contracting agency and private sector proposals	All Stages	(Tan, 2009; Walker and Jacobsson, 2014; Permatasari, Hardjosoekarto, and Salomo, 2020)
Financial Risk	Failure to achieve financial close	A 5	Failure to achieve a financial close due to uncertainty in market conditions or non-optimal project capital structure	Pre-Construction	(Iyer and Sagheer, 2010; Kurniawan, Mudjanarko, and Ogunlana, 2015; Asian Development Bank, 2020; Endo, Gianoli and Edelenbos, 2020)
	Land bailout refund	A 6	The delayed reimbursement of land costs by the Government (Lembaga Manajemen Aset Negara; LMAN) to the private sector	Construction	(Guild, 2019; Sungkono and Kurniawan, 2019; Endo, Gianoli, and Edelenbos, 2021)
	Currency exchange rate	A 7	Fluctuations (non-extreme) in exchange rates	All Stages	(Oladokun and Dada, 2008; Ameyaw and Chan, 2015; Osei-Kyei and Chan, 2017; Nour and Hao, 2019)

Table 1. continued

Risk Category	Risk Event	Code	Description	Project Stage	Supporting Literature
	Increase interest rates	A 8	Increases (non-extreme) in interest rates	All Stages	(Zhang, 2005; Xu et al., 2014; Pellegrino et al., 2019)
	Insurance risk	A 9	Insurance coverage for certain risks no longer available on the market, with a substantial increase in premium rates against initial estimates	All Stages	(Demirag et al., 2012; Moody's Investors Service, 2016)
Operational Risk	Increase in O&M costs	A 10	Risk arising from incorrect estimates of O&M costs or unexpected increases	Operation	(Sharma et al., 2014; Malek and Gad, 2017; Karaca and Nunez, 2019)
Revenue Risk	Risk of low traffic in the early year operation (ramp-up period)	A 11	Errors in input parameters and model design cause estimation results to deviate, resulting in decreased revenues and deficits at the start of the operating period	Operation	(Flyvbjerg et al., 2009)
	Estimation error and change in volume projection	A 12	Errors in input parameters and model design cause the estimation results to deviate, resulting in a decrease in revenues and financial losses for the private sector	Operation	(Carbonara et al., 2014; Alasad and Motawa, 2016; Phong, Likhitruangsilp, and Onishi, 2017)

Table 1. continued

Risk Category	Risk Event	Code	Description	Project Stage	Supporting Literature
	Tariff adjustments do not match expectations	A 13	Risk caused by the private sector's inability to meet the minimum standards or achieve the agreed-upon indexation and rebasing rates	Operation	(Kerf et al., 1998; Ke et al., 2010)
	Errors in calculating the initial rate estimate	A 14	Tariff settings too optimistic or above the users' willingness to pay	Operation	(Malini, 1999; Wibowo, 2006; Ng et al., 2010)

FUZZY INTERPRETIVE STRUCTURE MODELLING

As previously mentioned, this study used FISM. This method was introduced by Saxena et al. (1992) to clarify the interaction relationship among BOT risk events and establish a risk hierarchy. It integrates the fuzzy set theory (FST) and interpretive structural modeling (ISM).

The ISM, which was developed by (Warfield, 1973, 1974), is a technique to simplify complex problems into simple ones via tiered structure modeling. It can provide decision-makers with a clear picture by identifying current conditions and allowing them to make the best decisions with limited resources (Wang et al., 2018). It is particularly suitable for presenting a complicated system in a simplified way, providing an interpretation of the fixed object, facilitating the identification of the structure within a system, and analyzing one factor's influence on other factors (Gardas, Raut and Narkhede, 2017; Qureshi et al., 2007). While ISM variables are considered to be interrelated, the FISM can demonstrate the strength of these relationships. The FISM takes into account variations in the relationship between variables and specific aspects of elements that cannot be given crisp and precise values (Jiang et al., 2019; Ajmera and Jain, 2020).

On another front, the FST addresses imprecision, ambiguity, and uncertainty in decision-making. In this study, the FST was used to convert the assessments expressed in linguistic terms into fuzzy numbers, which took the form of triangular fuzzy numbers (TFNs; see Figure 1). The TFNs provide a three-point estimate—that is, a minimum value (l), most likely (m), and maximum values (r)—instead of a crisp value as in the ISM, to represent the influence level of the relationship between factors. The TFN was selected as it is easy to use and appropriate for promoting representation and information processing in a fuzzy environment (Zhao, Hwang, and Low, 2013).

Linguistic Variables	Code	Triangular Fuzzy Number (d_{ij})
Very Low	VL	(0.00; 0.10; 0.30)
Low	L	(0.10; 0.30; 0.50)
Medium	M	(0.30 ; 0,50; 0.70)
High	H	(0.50; 0.70; 0,90)
Very High	VH	(0.70; 0.90; 1.00)

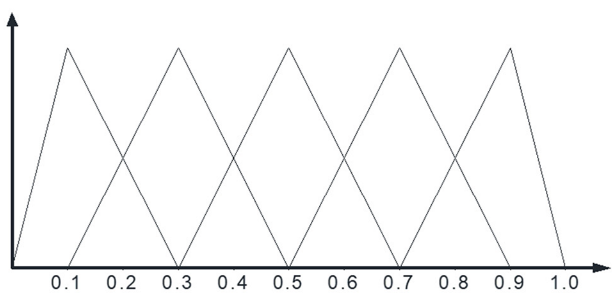

Figure 1. Linguistic variables on triangular fuzzy numbers

DATA COLLECTION

The data were collected through a questionnaire distributed to the chosen respondents. For research using respondents from expert groups, including the FISM method, the ideal number of experts is between three and seven people (Hora, 2004). Some FISM-based studies used less than ten respondents, such as Lee, Kang and Chang (2011); Kumar, Luthra and Haleem (2013); Balaji et al. (2016); Das, Azmi and James (2020); Bakhtari et al. (2021). Given that the results depend upon the judgments of the experts who make decisions, the respondents must possess sufficient knowledge of the study context, as indicated by the length of their hands-on experience, which should not be less than ten years in more than two BOT projects. The questionnaire was administered with Google Forms. The questionnaires were distributed to ten experts, but only six completed and returned valid responses. Despite the small number of respondents, it is still within the acceptable range. Table 2 shows the demographic profiles of respondents willing to participate in the survey.

Table 2. Demographic profiles of respondents

Code	Educational background	Working experience	Length of years of working experience (years)	Position in affiliation	Organization type of affiliation	Number of BOT projects involved	Infrastrucutre sector
R1	Master	Practitioner	10-15	First Line Management	Public sector	> 5 projects	Multisector
R2	Bachelor	Practitioner	> 20	Senior Engineer	Public sector	> 5 projects	Multisector
R3	Bachelor	Practitioner	> 20	Middle Management	Private sector (guarantee agency)	> 5 projects	Multisector
R4	Master	Practitioner	> 20	Top Management	Public sector	> 5 projects	Road
R5	Master	Practitioner	> 20	Top Management	Public sector (contracting agency)	3 – 4 projects	Road
R6	Master	Practitioner and Academician	15 – 20	Special advisor	Public sector (contracting agency)	> 5 projects	Multisector

In the survey, each respondent was asked to rate the effect of one risk event on other events using the following linguistic terms: “very high” (VH), “high” (H), “medium” (M), “low” (L), and “very low” (VL). Examples of the survey questions include “how much influence does the increase in construction costs have on an increase in interest rates”? and “how much influence does the increase in interest rates have on the increase in construction costs”?

DATA ANALYSIS

Based on the questionnaire results, a triangular fuzzy relations (TFR) matrix was employed to assess the strength of the relationship between risk events. In the TFR matrix, $\tilde{D}^k$ is expressed in terms of

$\tilde{d}_{ij}^k = \left(l_{ij}^k, m_{ij}^k, r_{ij}^k\right)$, which represents the results of the assessment from expert k, on the degree of influence of risk events i on j, as follows:

$$\tilde{\boldsymbol{D}}^k = \begin{bmatrix} 0 & \tilde{\boldsymbol{d}}_{12}^k & \cdots & \tilde{\boldsymbol{d}}_{1n}^k \\ \tilde{\boldsymbol{d}}_{21}^k & 0 & \cdots & \tilde{\boldsymbol{d}}_{1n}^k \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{\boldsymbol{d}}_{n2}^k & \tilde{\boldsymbol{d}}_{n2}^k & \cdots & 0 \end{bmatrix} \tag{1}$$

The notation (~) is placed above a symbol (D), indicating a fuzzy *set*. The value $\tilde{d}_{ij}^k = \left(\tilde{l}_{ij}^k, \tilde{m}_{ij}^k, \tilde{r}_{ij}^k\right)$ is a fuzzy evaluation of experts-k (k =1,2,3,…, p) of the extent to which risk event i affects j, where p is the number of experts.

Defuzzification method

There are various methods to perform defuzzification. The most common method is the centroid method, but this cannot distinguish between two fuzzy numbers with the same crisp value but different shapes. Therefore, this study converted fuzzy data into crisp scores to solve this problem (Opricovic and Tzeng, 2003); this process determines the left and right values based on the smallest and largest fuzzy values. The procedure to generate ISM and MICMAC diagrams is as follows:

i. Normalizing TFNs:

$$a_{ij}^k = \frac{\left(l_{ij}^k - \min l_{ij}^k\right)}{\Delta_{min}^{max}},\ b_{ij}^k = \frac{\left(m_{ij}^k - \min l_{ij}^k\right)}{\Delta_{min}^{max}},\ c_{ij}^k = \frac{\left(r_{ij}^k - \min l_{ij}^k\right)}{\Delta_{min}^{max}} \tag{2}$$

$$\Delta_{min}^{max} = \max_{k\in\{1,\ 2,\ \ldots,p\}} r_{ij}^k - \min_{k\in\{1,\ 2,\ \ldots,p\}} l_{ij}^k \tag{3}$$

ii. Calculating the left and right limits of the normalized value:

$$u_{ij}^k = \frac{b_{ij}^k}{\left(1 + b_{ij}^k - a_{ij}^k\right)} \tag{4}$$

$$v_{ij}^k = \frac{c_{ij}^k}{\left(1 + c_{ij}^k - b_{ij}^k\right)} \tag{5}$$

iii. Calculating the normalized total crisp value:

$$w_{ij}^k = \frac{u_{ij}^k\left(1 - u_{ij}^k\right) + \left(v_{ij}^k\right)^2}{\left(1 + b_{ij}^k - a_{ij}^k\right)} \tag{6}$$

iv. Calculating the crisp value:

$$d_{ij}^k = \min l_{ij}^k + w_{ij}^k \cdot \Delta_{min}^{max} \tag{7}$$

v. Integrating the crisp values:

$$d_{ij} = \frac{1}{p} \cdot \sum_{k=1}^{p} d_{ij}^k \tag{8}$$

vi. Determining the fuzzy direct relation matrix, D:

$$D = \begin{bmatrix} 0 & d_{12} & \cdots & d_{1n} \\ d_{21} & 0 & \cdots & d_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1} & d_{n2} & \cdots & 0 \end{bmatrix} \tag{9}$$

vii. Setting the intercept coefficient (α)
The fuzzy direct relation matrix can be converted into the initial reachability matrix **[T]** using an intercept coefficient (α). An element equal to or greater than α will be replaced with a value of 1; otherwise, they are set to 0.

$$t_{ij} = \begin{cases} 1, \textit{ if } (d_{ij} \geq \alpha) \\ 0, \textit{ if } (d_{ij} < \alpha) \end{cases} \quad (10)$$

The threshold value (α) was set at 0.5, following Jiang et al. (2019).

viii. Drawing ISM diagrams
After the initial reachability matrix is constructed, the transitivity of each element must be examined (i.e., if variable A has an effect on B, and B has an impact on C, then A must affect C). The transitivity check refers to the Floyd Warshall algorithm, which finds the shortest path between all pairs of elements in a graph to obtain the final reachability matrix (Floyd, 1962; Warshall, 1962). A partitioning matrix was performed based on the final reachability matrix, and finally, the ISM diagram was produced to describe the relationship between factors (Anand and Bansal, 2017).

ix. Developing the MICMAC diagram
The MICMAC diagram was used to determine the driving and dependence powers of risk events and to classify risk events. Driving and dependence powers are associated with the number of risks that can be affected and those affecting that event (Bhosale and Kant, 2016). This method can maintain a higher level of consistency and reduce the uncertainty inherent in expert responses (Wang et al., 2017).
The MICMAC diagram is partitioned into four quadrants: "autonomous," "dependent," "linkage," and "independent." Risk events with low driving and dependence power are located in Quadrant I (autonomous), and those with high dependence and driving power are located in Quadrant III (linkage). Risk events with high driving power but low dependence power are located in Quadrant II (independent), and those with high dependence but low driving power are in Quadrant IV (dependent) (Chakraborty et al., 2019). Figure 2 shows this study's methodological framework.

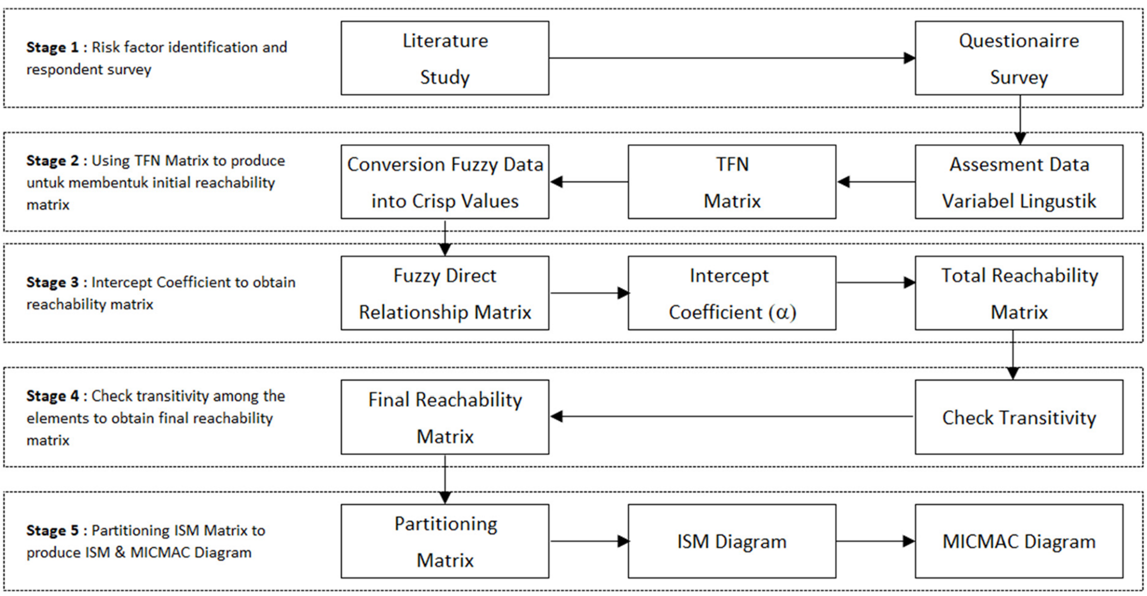

Figure 2. Research methodological framework

Results and discussion

The assessment from each expert was converted into a matrix of linguistic variables. Equations (2) and (7) were applied to generate the total normalized crisp values. The average result of the six experts was calculated using Equation (8) to obtain a fuzzy direct relation matrix. The final reachability matrix was obtained by applying the α value. Figure 3 depicts the partitioning matrix used to generate the risk event hierarchy.

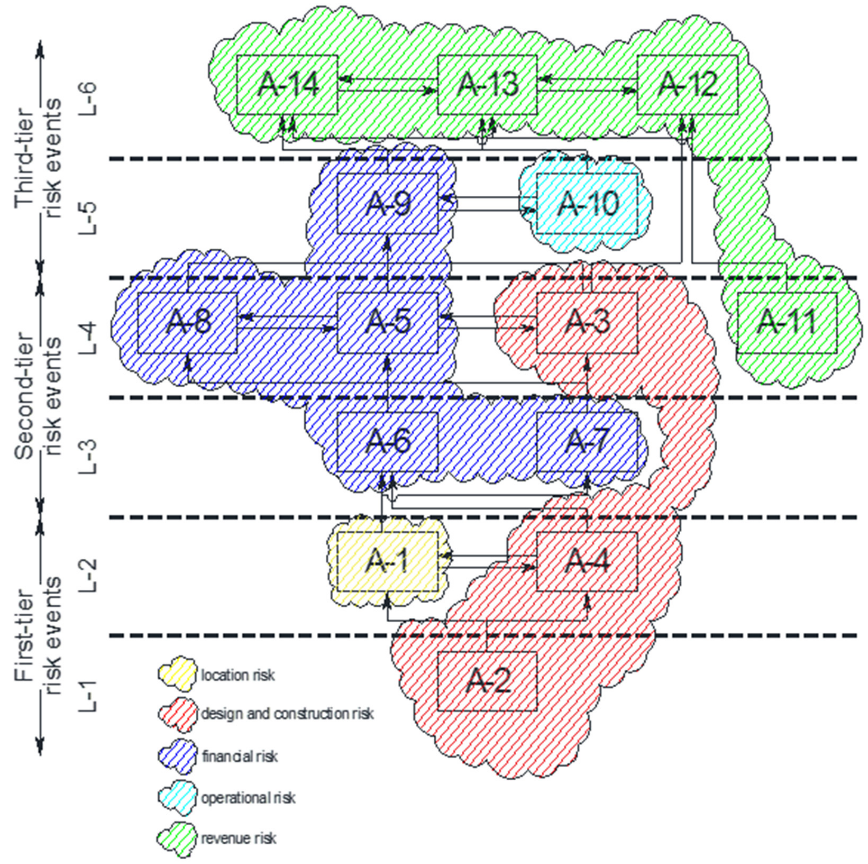

Figure 3. ISM diagram on BOT risk events

The MICMAC method was developed by plotting each risk event on the Cartesian system using the value of each risk's driving and dependence power in the final reachability matrix. The fourteen risks were plotted into their respective quadrants, as shown in Figure 4.

Based on their positions in the ISM diagram, risk events were partitioned into first-tier risk events (levels 1 and 2), second-tier events (levels 3 and 4), and third-tier risk events (levels 5 and 6).

FIRST-TIER RISKS EVENTS

First-tier risk events include "delays and increases in land acquisition costs" (A1), "unclear output specifications" (A2), and "changes in the scope of work after signing the contract" (A4). The A1 and A2 risk events are located in Quadrant II, with high driving and low dependence power. The A4 risk event has high driving power and moderate dependence power. It is directly affected by land acquisition costs, unclear output specifications, and other risk events such as construction cost and time (Tan, 2009; Walker and Jacobsson, 2014; Permatasari et al., 2020).

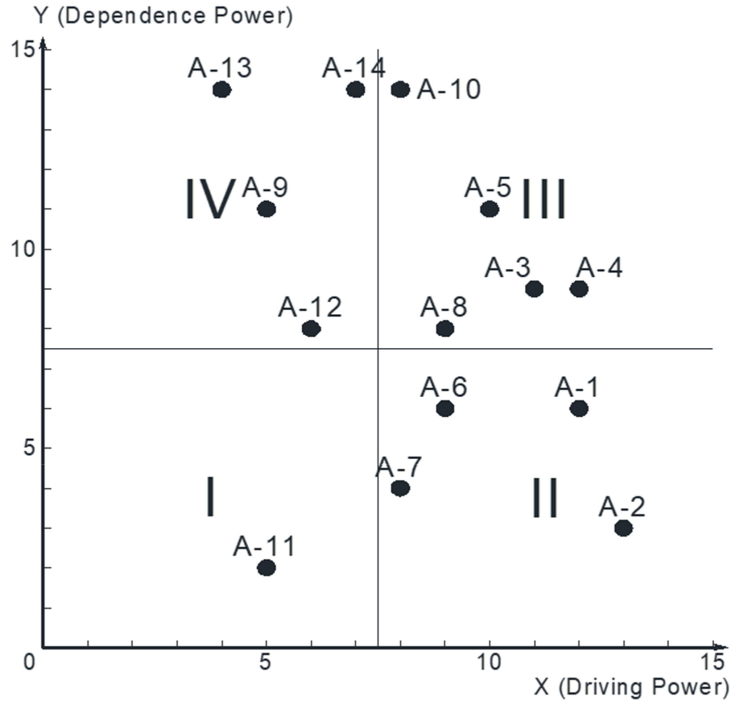

Figure 4. Diagram of driving and dependence powers

Several studies have confirmed the significance of risks associated with land acquisition (Bagui and Ghosh, 2013; Babatunde, Adeniyi, and Awodele, 2017; Le et al., 2019). The Asian Development Bank (2015) stated that land acquisition and licensing are the primary issues in BOT toll road projects that can cause delays and recommended that at least 80% of the required land be acquired before bidding. Bhatt and Sarkar (2020) show that the land acquisition risk is also critical in India. Indonesia is in a similar situation. Some strategic toll road projects, such as the 2800-km Trans Sumatera Project and the 62-km Cileunyi–Sumedang–Dawuan Project, were delayed due to prolonged land acquisition processes (Parama and Gorbiano, 2020).

This study corroborates the findings of Akintoye and Beck (2009) and Javed and Lam (2013), highlighting the importance of establishing robust output specifications. A failure to define the expected output specifications will affect subsequent phases (PPP Book, 2020). A robust output specification should clearly outline the public sector's needs (Akintoye and Beck, 2009). Output specifications serve as a guideline for implementing BOTs as they specify the minimum requirements established during the project's planning phase. Output specifications must be well defined early in project development (Javed, Lam, and Chan, 2013). They are an integral part of project documentation for procurement and performance monitoring of PPPs throughout the project life cycle (Lam and Javed, 2015). Unclear output specifications can impede the entire process, including the land acquisition process and the scope of work, which are the initial part of development implementation. However, developing sound output specifications requires a great deal of time and effort from each party involved in monitoring until the concession period has been completed (Javed and Lam, 2013).

In the case of Indonesia's BOT toll road projects, the GoI has provided the general specifications and minimum service level requirements for toll roads to be included in the BOT contracts. The tariffs can only increase if the requirements have been satisfactorily met. To this extent, the risk associated with unclear output specifications appears well managed. However, empirical evidence also reveals that actual construction costs for some toll road projects can considerably deviate from the initial estimates due to the changes in their scope of work.

A rough estimate indicates that the risk of changes in the scope of works eventuated in one of every two projects, resulting in an average cost increase of about 60% and 70%. Although these statistics must be treated with extreme caution due to the small sample size (76 toll roads), they can at least shed light on the significance of the risk of the scope of work changes. Suppose the contracting agency causes the changes. In that case, the private operator must be compensated with a concession period extension or tariff adjustments at toll road users' expenses to maintain the expected projects' rates of return at an acceptable level. From the public viewpoint, the value for money of these projects can thus be questionable. As this study may suggest, the changes can be associated with output specifications (see Figure 3).

SECOND-TIER RISK EVENTS

Second-tier risk events are "increase in construction costs" (A3), "failure to achieve financial closure" (A5), "land bailout refund risk" (A6), "currency exchange rates" (A7), "increase in interest rates" (A8), and "ramp-up period" (A11). A6 and A7 are risk events with high driving and low dependence power in Quadrant II, and only first-tier risk events can influence them.

In Indonesia, Presidential Regulation No. 102/2016 is the basis for the Lembaga Manajemen Aset Negara (LMAN, State Asset Management Agency) to bear the cost of land acquisition directly or indirectly as a result of land bailout refund risks. The risk associated with land acquisition rests with the GoI for public infrastructure development by regulation. Given the public budget constraints, the private sector is, in some instances, permitted to cover the land cost in advance to speed up land acquisition and will be reimbursed. However, delays in land cost reimbursement by the LMAN can be challenging for the private sector in managing its cash flows.

Currency exchange rates in developed countries are relatively stable, but this is not the case in developing countries (Osei-Kyei and A. P. C. Chan, 2017; Nour and Hao, 2019). The high importance of this risk has also been affirmed by Ameyaw and Chan (2015). Toll road investments are often characterized by a significant asset-liability mismatch where revenues are denominated in local currency, but debt is in foreign currencies. Therefore, exchange rate volatility can be detrimental to the project's financial sustainability. The 1999 Asian crisis, which hit Indonesia the worst, provides a compelling example of how private investors in toll roads should manage risk appropriately, as the Indonesian Rupiah plunged to 15,000 from 2,400 to the US dollar, making the US dollar-denominated debt value escalate six times higher in terms of local currency (see details in Wibowo, 2005).

Risk events A6 and A7 have no direct relation but equally affect the other three second-tier risk events: "increase in construction costs" (A3), "failure to achieve financial closure" (A5), and "increased interest rates" (A8). These three events have high driving and dependence power and are located in Quadrant III. As shown, risk events in Quadrant III can affect other tiered risk events but are also influenced by lower-risk events.

Under this group level, special attention is given to traffic risk during the ramp-up period. Interestingly, this risk event is the only one in Quadrant I, denoting that it has low driving and dependence power. It has no relationship with the other risk events in the central part of the project, but it directly influences the event risk of changes in volume projections, the estimated error rate adjustment, and the initial rate.

The ramp-up period is one of the characteristics of toll road investment, where traffic volume requires time for the public to become aware of and use the newly opened toll road facilities (Asian Development Bank, 2020). Based on four interurban toll roads in Java and Bali, Meviany, Joewono and Wibowo (2019) estimate that the ramp-up period can range from nine months (the Jakarta Outer Ring Road) to four years (Bali Mandara). However, it is believed that the ramp-up can span much longer in cases of intraurban toll roads, particularly in regions other than Java. As Bain (2009) noted, the severity and magnitude of the ramp-up are often underestimated, leading to traffic forecasting errors.

THIRD-TIER RISKS EVENTS

The third-tier risk events consist of "insurance risk" (A9), "increase in O&M costs" (A10), "estimation error and changes in volume projection" (A12), "tariff adjustments that do not match expectations" (A13), and "error in calculating the initial rate estimate" (A14). These risk events are located in Quadrant IV, indicating high dependence power but low driving power, except for A10, in Quadrant III. There is a solid relationship between risk events A12, A13, and A14. Likewise, there is a close relationship between A9 and A10 as the direct cause of A12, A13, and A14.

Some risk events specific to toll road investment projects deserve a more profound discussion at this level: traffic forecasting errors and uncertainty in initial and future tariff settings. Empirical findings suggest that significant errors and considerable optimism bias often characterize toll road forecasts (Bain, 2009). Highly inaccurate traffic forecasts can pose substantial financial and economic risks (Flyvbjerg, Holm, and Buhl, 2006), and demand forecasting errors are found in many BOT toll-road projects (Alasad and Motawa, 2016; Phong et al., 2017).

Traffic risk is also prevalent on Indonesia's toll roads. The private sector asserted that traffic forecasts developed in the government-prepared feasibility studies often differ from the actual traffic, resulting in losses to the private sector. Although the GoI has made a counterclaim, arguing that forecast errors were not always present, it has conceded that there was no standardized forecasting methodology and that consulting firms did not possess the same levels of expertise.

The initial tariff is the toll rate for the first year of operation. It is determined by a survey of the willingness to pay and micro-economic forecasts (Malini, 1999). The tariff level is typically set as the bid parameter for Indonesia's toll roads: the private bidder that offers the lowest tariff wins the contract. By law, the tariff is adjusted every two years following inflation. Under this price-cap system, the private sector bears the demand risk. During the 1990s, the private sector faced significant tariff risk, as tariffs could not be adjusted according to the BOT contract. However, since 2004, especially after the passage of Government Law 38/2004, the private sector has been relatively protected from the risk, as the GoI will compensate the private sector for financial losses incurred due to tariffs falling below the agreed-upon level. The private sector may also demand a government guarantee protecting it against any breach of contract by the GoI, such as the failure to approve tariff adjustments promptly.

Conclusions

This study ranks risk events that affect BOT toll road projects within Indonesia. Fourteen risk events were identified and grouped into different risk categories. The FISM method was used to determine the hierarchy of each risk event, and MICMAC was used to determine driving and dependence powers. This study resulted in six levels of risk events, classified into three tiers. The first-tier events included unclear output specifications, problems with land acquisition, and changes in the scope of work, which are worth particular notice, although other risk events should not be neglected.

Developing a clear output specification is crucial to successfully implementing BOT projects. It must reflect what the public sector requires from the projects and incentivize the private sector to leverage its financial, technical, and management resources to reduce lifecycle costs and improve the quality of service, thereby maximizing the public's value for money. Output specifications should not be prescriptive so as not to discourage innovation and risk-taking from the private sector.

Land acquisition remains one of the most significant obstacles to the development of toll roads in Indonesia, despite the government's repeated issuance and revision of land-acquisition regulations for public infrastructure. The GoI must find a way to resolve land-related issues before the start of construction activities although it is not easy, as the issues are often politically and socially sensitive.

Changes in the scope of work might be inevitable given the long-term nature of BOT projects. The changes can be attributed to the contracting agency, the private partner, or external events, but regardless of the source, there must be a formal process for scoping and reaching an agreement on such changes. The GoI needs to ascertain that existing BOT contracts contain scope management provisions to reduce opportunistic behaviors and disputes between the contracting parties. A clear output specification can help manage changes, if foreseeable, in the contract duration (Lam and Javed, 2015). This is because scope changes most likely occur during construction to meet the actual conditions to achieve output specifications (APMG International, 2016).

This study has two limitations. First, it was based on a limited number of respondents participating in the survey, although the number can still be considered acceptable in terms of the minimum requirements. In order to obtain a clearer picture of significant risk events, it is recommended that future studies include a greater number of participants. Second, the study context is limited to Indonesia, making the findings not readily extendable to other contexts. However, as mentioned previously, it can contribute to remedying the dearth of studies on risk ranking for Indonesia's BOT toll roads.

The findings and limitations of this study can provide directions for future research. First, future research could investigate the robustness of output specifications and the quality of Indonesia's BOT contract documents. Second, it could focus on finding innovative solutions to the land acquisition problem, a long-standing issue that has not been resolved. Thirdly, it should include a larger number of respondents to enhance the finding generalization. It would also be worthwhile to investigate the empirical comparison of risk events between Indonesia's BOT toll road projects and those of countries with comparable characteristics.

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