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A NOVEL ROUGH FUZZY BASED DELPHI METHOD FOR HIGHWAY PROJECTS RISK ANALYSIS: THE SOE ASSIGNMENT SCHEME CASE STUDY

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ABSTRACT: In accelerating the development of the area in Sumatra, the Indonesia Government assigned to PT. X to manage toll-road concessions on 24 Sumatra toll roads. PT X is an enterprise with full ownership by the government. Sumatra toll-road development is economically but not financially viable; therefore, this scheme was implemented to avoid abuse of authority and legal uncertainty issues from government administrators. The Indonesian government named it the "State-Owned Enterprise (SOE) Assignment Scheme," but this project has several technical and non-technical problems. The technical problems are material, geotechnical Condition, equipment, and others. The non-technical problems are policy, financial, and others. These problems may impact the time and cost of the Sumatran toll-road development. This study aims to list the risks and evaluate each factor corresponding to the Sumatran toll-road development based on the Rough Fuzzy Based Delphi Method. Questionnaires have been collected from seven experts. There are 12 critical risk factors in this study that will impact the project. The proposed method can reduce the level of uncertainty and subjectivity that exists in the process of risk identification and analysis. The results of this study will increase our understanding of the impact of each criterion, which can be valuable for future studies on toll-road projects with the SOE assignment scheme.

Keywords: Rough Numbers, Fuzzy, Risk, Delphi, State-Owned Enterprise

1. INTRODUCTION

One of the reasons for soaring logistics cost in Indonesia is the poor quality of the road which causes extended average travel time compared to other countries with 2.7 hours/100 km [1]. One solution for this issue is the construction of highway infrastructure, commonly known as “toll roads.” When a country's economy relies heavily on land transportation, the means of transportation in the form of roads especially toll roads will certainly drive economic efficiency.

If a country's economy relies on land transportation, then of course, transportation facilities in the form of roads, especially toll roads, will encourage the creation of economic efficiency in it [1].

Indonesia's government has encountered several obstacles in developing toll-road networks, one of which is a high discrepancy between the number of roads built, and the number of roads still needed (backlog) [2]. Consequently, the road length per 1,000 population (expressway density) is low at around 0.05 km/1,000 population.

Based on Presidential Regulation No. 117 of 2015 and Amendments to Presidential Regulation No. 100 of 2014 on the Acceleration of Toll-Road Development in Sumatra, TSTR (Trans-Sumatra Toll Road) is one of the National Strategic Projects (NSP). TSTR will connect Lampung Province to Aceh Province via 24 toll roads totaling 2,988 km, consisting of main corridors (backbone) of 2,069 km in length, and support corridors of 919 km in length [3].

The construction of the trans-Sumatra toll road will be carried out with a SOE assignment scheme because it is economically but not financially feasible. Upon the implementation of the assignment-scheme project, many problems that caused delays and wasted costs were found. Therefore, it is necessary to conduct a risk analysis on this assignment-scheme project.

This paper aims to identify important risks with a Rough Fuzzy Based Delphi Method analysis. It is based on the analysis of experts who directly underwent the assignment-scheme project because the experience gap is important to make the right risk decision during project-risk assessment [4].

2. RESEARCH SIGNIFICANCE

In the implementation of this assignment, many problems affected the cost overrun and delay. Therefore, this paper aimed to identify, evaluate, and rank the critical factors that affected the Sumatera toll-road construction with this assignment scheme using the Rough Fuzzy Delphi Method.

This method is a combination of rough and fuzzy set numbers of the Delphi Method application that is used to decrease the ambiguity and subjectivity levels calculated by the experts who participated in the completion of this study.

3. MATERIAL AND METHODS

3.1 BackGround of Case Study

The construction of the TSTR was estimated to cost up to US $33.2 billion (equivalent to Rp 476 trillion), thereby making it the most expensive mega-project ever undertaken by an SOE to date (bumn.info, 2020). This toll road is expected to give rise to new economic centers that can be formed from industrial areas and serve as the main access road connecting various provinces on the island of Sumatra (Kemenkeu, 2021). Until February 2021, 653 km (9 toll section) of the TSTR were officially operational, consisting of the Bakauheni-Terbanggi Besar section (140 km), the Terbanggi Besar-Kayu Agung section (189 km), the Kayu Agung-Palembang-Betung section (38 km), the Belawan-Medan-Tanjung Morawa section (43 km), the Medan-Binjai section (13 km), the Medan-Kualanamu-Tebing Tinggi section (62 km), the Palembang-Indralaya section (22 km), the Sigli-Banda Aceh section 4 (14 km), and the Pekanbaru-Dumai section (132 km) [3].

To accelerate regional development in Sumatra, Presidential Regulation No. 100 of 2014 has been amended by Presidential Regulation No. 117 of 2015, which concern Amendments to Presidential Regulation No. 100 of 2015, which further concerns the Acceleration of Toll-Road Development in Sumatra. The government assigned PT. X to carry out toll-road concessions on 24 toll-road sections in Sumatra that are economically but overall not financially viable.

3.2 Highway Project Risk Indicator

Several studies have investigated issues related to the implementation of toll-road construction projects and their performance. The initial step in risk management is to identify and categorize the risks.

According to Toan and Ozawa [5] risks in development projects are divided into two broad lines: (1) general risks (e.g., policy, financial, environmental, and stakeholder risks), and (2) project-specific risks (e.g., pre-construction and operational risks).

3.2.1 Policy Factor

Policy Risk includes termination of concessions, tax increases, tariffs not in accordance with implementation, inappropriate rate increases, enforcement of new government policies, and contracts that affect financial performance and project timetables [6-9].

3.2.2 Financing Factor

Financial Risk is defined as a real or potential threat due to inflation, interest-rate fluctuations, and other factors that affect project cost performance [9-11].

3.2.3 Environmental Factor

Environmental Risk is the real or potential threat of adverse effects on living organisms and the environment by effluents, emissions, waste, resource depletion, etc. These arise from project activities and can cause damage to part of the project; therefore, additional costs are needed to repair them [9, 12, 13].

3.2.4 Stakeholder Factor

Institutions can be affected by decisions, treatments, strategies, and/or processes. Stakeholders can be individuals, agencies, and/or groups within an organization (e.g., management), which may change at any time during the process, thereby affecting the cost and timetable of the toll-road construction project [9, 14, 15].

3.2.5 Pre-Construction Factor

Pre-Construction Risk is contributed to an increase in time and costs during the pre-construction stage (e.g., design, land acquisition, and other matters that occur prior to the start of construction) [12, 16].

3.2.6 Construction Factor

Construction Risk contributes to an increase in time and costs during the construction stage that deviates from what was agreed upon at the time of planning, thereby causing the delay of operational services by the project owner to the customer beyond the specified time [7, 16].

3.2.7 Operation Factor

Risk caused by ineffective and/or inefficient operational and maintenance systems result in high overhead costs that may affect income during the concession period [7, 13, 16].

3.3 Rough Set

In the rough-number theory, an assumption or response that cannot be explained with certainty is described as the "upper and lower limits" of the response [17].

$$\overline{\mathbf{APR}}(\mathbf{r}_{\mathbf{ij}}^{\mathbf{k}}) = \mathbf{U}(\mathbf{X}\epsilon\mathbf{U}/\mathbf{R}(\mathbf{Y}) \geq \mathbf{r}_{\mathbf{ij}}^{\mathbf{k}}) \quad (1)$$

$$\underline{\mathbf{APR}}(\mathbf{r}_{\mathbf{ij}}^{\mathbf{k}}) = \mathbf{U}(\mathbf{X}\epsilon\mathbf{U}/\mathbf{R}(\mathbf{Y}) \leq \mathbf{r}_{\mathbf{ij}}^{\mathbf{k}}) \quad (2)$$

The assumption from the response giver, r_{ij}^{k} can be expressed as lower limit $\underline{Limit}\left(r_{ij}^{l}\right)$ and upper limit $\overline{Limit}\left(r_{ij}^{U}\right)$ with the following formulation [18].

$$\underline{Limit}\left(r_{ij}^{l}\right) = \left(\prod_{K=1}^{n_{ijL}} x_{ij}\right)^{\frac{1}{N_{ijl}}} \quad (3)$$

$$\overline{Limit}\left(r_{ij}^{U}\right) = \left(\prod_{K=1}^{n_{ijU}} x_{ij}\right)^{\frac{1}{N_{ijl}}} \quad (4)$$

Thus, it can be expressed by the equation below

$$RN\left(r_{ij}^{k}\right) = \left[\overline{Limit}\left(r_{ij}^{k}\right), \underline{Limit}\left(r_{ij}^{k}\right)\right] \quad (5)$$

Therefore:

$$RN(r_{ij}) = \left(\left[r_{ij}^{1L}, r_{ij}^{1U}\right], \left[r_{ij}^{2L}, r_{ij}^{2U}\right], , \left[r_{ij}^{ML}, r_{ij}^{MU}\right]\right) \quad (6)$$

3.4 Fuzzy Set Theory

Fuzzy Set theory is a mathematical theory designed to model the ambiguity or imprecision of human error [19, 20], Fuzzy Set theory assumes that the elements have some degree of membership to the fuzzy set. A triangular fuzzy number is denoted as (l,m,u), whose membership function is $F_{\tilde{a}}(X)$ as follows:

$$F_{\tilde{a}}(X) \begin{cases} 0, x < l \; or \; x > u \\ \dfrac{x-l}{m-l}, l \le x \le m \\ \dfrac{u-x}{u-m}, m \le x \le u \end{cases} \quad (7)$$

A basic triangular fuzzy number equation can be done in the following way [21]:

$$\tilde{a}_1 + \tilde{a}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (8)$$

$$\tilde{a}_1 - \tilde{a}_2 = (l_1 - l_2, m_1 - m_2, u_1 - u_2) \quad (9)$$

$$\tilde{a}_1 x \tilde{a}_2 = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2) \quad (10)$$

$$\tilde{a}_1 : \tilde{a}_2 = (l_1 : l_2, m_1 : m_2, u_1 : u_2) \quad (11)$$

3.5 Rough Fuzzy Based Delphi Method

In this section a Rough Fuzzy Delphy method is proposed to obtain the objective of this study. Here are the steps:

Step 1. Form a group of n experts to evaluate risk factors. Based on Habibi [22], At least 5 experts for evaluation of the recommended criteria, and we set the minimum of expert's qualification are bachelor degree with 10 years of experience.

Step 2. In this step, the n expert team evaluates the criteria by means of the triangular fuzzy number values specified in the table below.

Table 1 Fuzzy Scales Number

Numb.	Linguistic Term	Fuzzy Scales
1	Strongly Disagree	0,0,0.25
2	Disagree	0,0.25,0.5
3	Neutral	0.25,0.5,0.75
4	Agree	0.5,0.75,1
5	Strongly Agree	0.75,1,1

Step 3. The rough number formulation of $RN\left(l_{ij}^{k}\right), RN\left(u_{ij}^{k}\right)$ and $RN\left(u_{ij}^{k}\right)$ can be expressed with the following equation [18]:

$$RN\left(l_{ij}^{k}\right) = \left[\underline{Limit}\left(l_{ij}^{k}\right), \overline{Limit}\left(l_{ij}^{k}\right)\right] \quad (12)$$

$$RN\left(m_{ij}^{k}\right) = \left[\underline{Limit}\left(m_{ij}^{k}\right), \overline{Limit}\left(m_{ij}^{k}\right)\right] \quad (13)$$

$$RN\left(u_{ij}^{k}\right) = \left[\underline{Limit}\left(u_{ij}^{k}\right), \overline{Limit}\left(u_{ij}^{k}\right)\right] \quad (14)$$

Therefore, the average rough number of $RN\left(l_{ij}^{k}\right), RN\left(u_{ij}^{k}\right)$ and $RN\left(u_{ij}^{k}\right)$ can be written as follows [18]:

$$RN\left(\hat{l}_{ij}\right) = \left[\left(\prod_{S=1}^{R} l_{ij}^{sl}\right)^{\frac{1}{R}}, \left(\prod_{S=1}^{R} l_{ij}^{su}\right)^{\frac{1}{R}}\right] \quad (15)$$

$$RN\left(\widehat{m}_{ij}\right) = \left[\left(\prod_{S=1}^{R} m_{ij}^{sl}\right)^{\frac{1}{R}}, \left(\prod_{S=1}^{R} m_{ij}^{su}\right)^{\frac{1}{R}}\right] \quad (16)$$

$$RN\left(\hat{u}_{ij}\right) = \left[\left(\prod_{S=1}^{R} u_{ij}^{sl}\right)^{\frac{1}{R}}, \left(\prod_{S=1}^{R} u_{ij}^{su}\right)^{\frac{1}{R}}\right] \quad (17)$$

Thus, the rough triangular fuzzy number can be expressed with the following equation:

$$RN\left(\hat{z}_{ij}\right) = \left[\hat{Z}_{ij}^{l}, \hat{Z}_{ij}^{u}\right] \quad (18)$$

$$\hat{Z}_{ij}^{l} = \left[l_{ij}^{l}, m_{ij}^{l}, u_{ij}^{l}\right] \quad (19)$$

$$\hat{Z}_{ij}^{u} = \left[l_{ij}^{u}, m_{ij}^{u}, u_{ij}^{u}\right] \quad (20)$$

Step 4. Defuzzification of fuzzy numbers using the Best Non Fuzzy Performance (BNP) method, when $\hat{Z}_{ij}^{l}$ and $\hat{Z}_{ij}^{u}$ then defuzcation can be performed with:

$$\text{BNP}\left(\hat{Z}_{ij}^{l}\right) = \frac{\left(U_{ij}^{l} - l_{ij}^{l}\right) - \left(m_{ij}^{l} - l_{ij}^{l}\right)}{3} + l_{ij}^{l} \quad (21)$$

$$\text{BNP}\left(\hat{Z}_{ij}^{u}\right) = \frac{\left(U_{ij}^{u} - l_{ij}^{u}\right) - \left(m_{ij}^{u} - l_{ij}^{u}\right)}{3} + l_{ij}^{u} \quad (22)$$

Step 5. Determining the crisp value of the rough number is done in a way according to normalization [23]:

$$\tilde{Z}_{i}^{l} = \left(\tilde{Z}_{i}^{l} - min_i z_i^{L} / \Delta_{Min}^{Max}\right) \quad (23)$$

$$\tilde{Z}_{i}^{u} = \left(\tilde{Z}_{i}^{u} - min_i z_i^{L} / \Delta_{Min}^{Max}\right) \quad (24)$$

$$\Delta_{Min}^{Max} = Max_i \, z_i^{u} \text{-} Min_i z_i^{l} \quad (25)$$

The determination of the total of crisp value with equation:

$$\beta_i = \frac{\tilde{Z}_i^l \times (1 - \tilde{Z}_i^l) + \tilde{Z}_i^u \times \tilde{Z}_i^u}{1 - \tilde{Z}_i^l + \tilde{Z}_i^u} \quad (26)$$

Then calculate with the crisp value for the last value.

$$\tilde{Z}_i^{der} = min_i z_i^L + \beta_i \Delta_{Min}^{Max} \quad (27)$$

Step 6. Determine whether the risk is important in the construction of the trans-Sumatra toll road with reference to the table below.

Table 2 Risk Category

No	Reference	Criteria
1	0≤CV<0.6	Low
2	0.6 ≤CV<0.8	Mild
3	0.8 ≤CV<1	Critical

Step 7. Rank each risk for each indicator of the risk, in order to determine the priority risk of each indicator according to expert opinion

4. RESULT AND DISCUSSION

Risk management can help project stakeholders identify project risks and manage them effectively [24]. This study did not only aim to generate the list of risks in the construction project but also to determine the factors of critical risks that could affect the implementation of the Sumatera toll-road construction project using the task scheme.

By reviewing the previous case studies on toll roads, as well as an in-depth interview with five experienced professionals, 104 risks were collected.

The common risks were divided into Policy, Financial, Environmental, and Stakeholders. The specific risks of the project were further divided into the following categories: Design & Procurement, Construction, and Operation.

Seven experts who filled out the questionnaire had the following criteria.

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Table 3. Expert Criteria

No	Degree	Experience (Year)	Institution
1	Master's Degree	17	Public
2	Master's Degree	20	Public
3	Master's Degree	37	SOE
4	Bachelor's Degree	15	SOE
5	Bachelor's Degree	11	SOE
6	Master's Degree	40	Consultant
7	Doctoral Degree	30	Academic

The result of the Rough Fuzzy Delphi for Risk analysis can be seen in the table below:

Table 4. Data Processing Results

No	Indicator[reference]	$\tilde{Z}_i^l$	$\tilde{Z}_i^u$	Crisp Value	Criteria	Rank
X.1	POLICY FACTOR					
1.1	Contract Terminated By Government [8]	0.54	0.74	0.59	Low	14
1.2	Change In Regulation [7, 8, 16]	0.71	0.79	0.75	Mild	3
1.3	Late on Project Permit And Approval [25, 26]	0.62	0.80	0.69	Mild	8
1.4	Asset Ownership [8, 25]	0.53	0.69	0.61	Mild	12
1.5	Lack Of Standard Contract Agreement [7]	0.58	0.74	0.68	Mild	9
1.6	Government Intervention [13]	0.68	0.74	0.70	Mild	5
1.7	Corruption [12, 26]	0.67	0.81	0.73	Mild	4
1.8	Lack Of Regulatory And Supervisory System [12, 26]	0.58	0.74	0.64	Mild	11
1.9	Domestic Political Situation [16, 25]	0.75	0.75	0.75	Mild	2
1.10	Bureaucratic of Tender System [25, 26]	0.45	0.69	0.54	Low	16
1.11	Concession Period [7, 27]	0.52	0.74	0.65	Mild	10
1.12	Lack Of Policy Support For Investors[7]	0.69	0.84	0.76	Mild	1
1.13	Nationalization Of Projects/Assets[7, 16]	0.49	0.69	0.53	Low	17
1.14	Strict Import-Export Permits[28]	0.37	0.63	0.45	Low	18
1.15	Wrong Decision By The Government[12]	0.49	0.67	0.54	Low	15
1.16	SPV Violate Policies[28]	0.68	0.74	0.70	Mild	5
1.17	Conflict On Contract[8, 26]	0.68	0.74	0.70	Mild	5
1.18	Difference Between Specification And Code[16]	0.48	0.72	0.61	Mild	13
X.2	FINANCING FACTOR					
2.1	Land Cost Increase [8, 16]	0.72	0.82	0.77	Mild	9
2.2	Inflation [16, 25, 26]	0.77	0.81	0.78	Mild	5

No	Indicator[reference]	$\widetilde{Z}_i^l$	$\widetilde{Z}_i^u$	Crisp Value	Criteria	Rank
2.3	Financial Difficulties [8, 25, 27]	0.78	0.84	0.80	Critical	4
2.4	Interest Rate Fluctuation [7, 26]	0.66	0.77	0.71	Mild	12
2.5	Foreign Currency Fluctuation [25, 26]	0.64	0.75	0.68	Mild	14
2.6	Lack Of Investor Interest In Project Finance [29]	0.76	0.78	0.76	Mild	10
2.7	High Cost Of Funding [28]	0.64	0.75	0.68	Mild	14
2.8	Additional Tax Fee[25]	0.56	0.67	0.59	Low	19
2.9	Late Payments On Completed Work [6, 7]	0.84	0.89	0.85	Critical	2
2.10	Construction Cost Estimation Error [6]	0.87	0.90	0.92	Critical	1
2.11	Delay Financial Closure [25]	0.77	0.81	0.78	Mild	5
2.12	Difficulty Getting A Bank Loan [7]	0.77	0.81	0.78	Mild	5
2.13	Rising Material Costs [7]	0.66	0.77	0.71	Mild	12
2.14	Financing Delays From The Government [16]	0.80	0.87	0.83	Critical	3
2.15	Government Credit Risk [12]	0.60	0.73	0.64	Mild	17
2.16	Spv Change [12]	0.47	0.66	0.49	Low	22
2.17	Profits That Are Not As Expected [7]	0.77	0.81	0.78	Mild	5
2.18	Devaluation [30]	0.64	0.75	0.68	Mild	16
2.19	Liquidity [30]	0.60	0.69	0.63	Mild	18
2.20	Changes In Discriminatory Tax On Projects [30]	0.55	0.68	0.58	Low	20
2.21	Financial Unclosed [in-depth interview]	0.70	0.76	0.73	Mild	11
2.22	World Economic Crisis [in-depth interview]	0.43	0.71	0.54	Low	21
X.3	**ENVIRONMENTAL FACTOR**					
3.1	Bad Weather[6]	0.47	0.69	0.58	Low	5
3.2	Natural Disasters[16]	0.68	0.74	0.70	Mild	3
3.3	There Are Important Things[29]	0.66	0.79	0.74	Mild	2
3.4	Unexpected Field Conditions[7]	0.71	0.79	0.75	Mild	1
3.5	Environmental Protection [27]	0.54	0.72	0.64	Mild	4
X.4	**STAKEHOLDER FACTOR**					
4.1	Political Agenda Related To Project Decision[31]	0.54	0.69	0.58	Low	6
4.2	Lack Of Information Dissemination [31]	0.60	0.69	0.63	Mild	4
4.3	Lack Of Attention From The Government [31]	0.53	0.72	0.56	Low	7
4.4	Lack Of Staff Capacity In Project Implementation [32]	0.71	0.79	0.74	Mild	3
4.5	Lack Of Efficient Conflict Management[31]	0.80	0.87	0.83	Critical	1
4.6	Difficulty In Assessing The Expectations Of Each Stakeholder [32]	0.58	0.70	0.62	Mild	5
4.7	Lack Of Coordination Between The Stakeholders Involved [32]	0.71	0.79	0.75	Mild	2
X.5	**PRE-CONSTRUCTRION FACTOR**					
5.1	Tender System Risk [25]	0.41	0.66	0.46	Low	16
5.2	Poor Feasibility Study [25, 26]	0.67	0.80	0.73	Mild	6
5.3	Not Good Risk Allocation [7, 26]	0.55	0.75	0.59	Low	14
5.4	Lack Of SPV Ability [26]	0.78	0.84	0.80	Critical	1
5.5	Late Land Acquisition [6, 25, 26]	0.78	0.84	0.80	Critical	1
5.6	Late Compensation Affected By The Project [26, 29]	0.77	0.81	0.78	Mild	4
5.7	Late Clearing And Rehabilitating Workplace [29]	0.44	0.66	0.55	Low	15
5.8	Government Breach Of Contract [26]	0.61	0.79	0.65	Mild	11
5.9	Many Of Land Brokers [16]	0.78	0.84	0.80	Critical	1
5.10	Conflicts On Design And Specifications [25]	0.66	0.79	0.67	Mild	9
5.11	Long Planning Time[6, 28]	0.63	0.76	0.67	Mild	10
5.12	Less Detailed Design [27]	0.55	0.75	0.63	Mild	13
5.13	Lack Of Consulting Experience [27]	0.71	0.79	0.75	Mild	5
5.14	Land Status [16]	0.66	0.77	0.71	Mild	7
5.15	Rejection By Project-Affected Communities [16]	0.54	0.77	0.63	Mild	12
5.16	Delay In Selecting Contractors During Tender Period[28]	0.64	0.75	0.68	Mild	8

No	Indicator[reference]	$\tilde{Z}_i^l$	$\tilde{Z}_i^u$	Crisp Value	Criteria	Rank
X.6	**CONSTRUCTION FACTOR**					
6.1	Lack Of Contractor's Technical Ability[25, 26]	0.84	0.89	0.85	Critical	1
6.2	Lack Of Supporting Infrastructure[28]	0.76	0.78	0.76	Mild	5
6.3	Limited Amount Of Material [25, 26]	0.70	0.76	0.73	Mild	9
6.4	Limited Number Of Workers [25, 28]	0.70	0.76	0.73	Mild	9
6.5	Many Changes In The Scope Of Work[8, 29]	0.71	0.79	0.75	Mild	7
6.6	Problems Due To Differences Of Opinion In Practice[26]	0.54	0.72	0.64	Mild	15
6.7	Construction Price Escalation [7]	0.77	0.81	0.78	Mild	3
6.8	Material Procurement Delay [16]	0.79	0.84	0.81	Critical	2
6.9	Mismanagement By The Contractor [25]	0.76	0.78	0.76	Mild	5
6.10	Design Error [25]	0.64	0.76	0.68	Mild	13
6.11	Geotechnical Condition [27]	0.72	0.81	0.73	Mild	8
6.12	Theft [7]	0.51	0.66	0.55	Low	21
6.13	Subcon Ability[7]	0.72	0.78	0.72	Mild	11
6.14	Construction Delay Risk [7, 27]	0.75	0.86	0.77	Mild	4
6.15	Lack Of equipment Capability [27]	0.57	0.74	0.63	Mild	16
6.16	Lack Of Construction Quality [28]	0.72	0.78	0.72	Mild	11
6.17	Lack Of Procurement Of Tools [16, 27]	0.57	0.74	0.63	Mild	16
6.18	Specification Change [12]	0.55	0.78	0.64	Mild	14
6.19	Lack Of Labor Productivity [7, 27]	0.57	0.74	0.63	Mild	16
6.20	Re-Work [27]	0.57	0.72	0.61	Mild	20
6.21	Contractor Change [in-depth interview]	0.57	0.74	0.63	Mild	16
X.7	**OPERATION FACTOR**					
7.1	Default Operators [8, 26]	0.57	0.74	0.63	Mild	16
7.2	Excess Operating Costs [8, 16, 29]	0.72	0.81	0.73	Mild	4
7.3	High Maintenance Cost [8]	0.73	0.84	0.75	Mild	3
7.4	Tariff Adjustment [8]	0.59	0.80	0.68	Mild	7
7.5	There Are Infrastructure Defects [12, 26]	0.72	0.81	0.73	Mild	4
7.6	Income Risk [12, 26]	0.76	0.89	0.80	Critical	1
7.7	Demand Risk [25, 26]	0.60	0.72	0.63	Mild	9
7.8	Lack Of Operator Ability[29]	0.48	0.69	0.55	Low	13
7.9	Lack Of Service Quality[12, 29]	0.57	0.72	0.61	Mild	10
7.10	Not Effective And Efficient During Operation And Maintenance[7, 28]	0.57	0.72	0.61	Mild	10
7.11	Many Traffic Accidents [7, 16]	0.52	0.69	0.57	Low	12
7.12	Toll Road Disruption Due To Demonstrations [7, 16]	0.49	0.67	0.54	Low	15
7.13	Overload Risk[7, 16]	0.62	0.76	0.70	Mild	6
7.14	Low Traffic Volume[7, 16]	0.71	0.87	0.80	Critical	2
7.15	Competitive Route [7, 16]	0.54	0.79	0.65	Mild	8
7.16	Vandalism [7, 16]	0.49	0.64	0.55	Low	14

From the Rough Fuzzy Based Delphi Method analysis, the results obtained from the questionnaire survey are the risk level presented in the structure, as illustrated in the table above.

The critical risk is in the following indicators: Financial, Stakeholders, Pre-Construction, and Operational. The assignment scheme indicates the available critical risks in the Sumatera toll-road construction.

The critical risks in the Financial indicator are Error in Construction Estimation, Late Payments on Completed Work, and Financing Delays from the Government. The State-Owned Corporation carried out the construction estimation while preparing construction by coordinating with the governmental party [33], The late payments and financial delays happened because the assignment-scheme financing of the equity part mostly relied on the State Equity Participation scheme; according to Fakhrin [33] it is important to find another financing scheme to prevent the financing delays.

Additionally, there is a critical risk known as "Lack of Efficient Conflict Management" in the Stakeholders indicator. This is because many stakeholders were identified in the execution of the Sumatera toll-road construction project, so it was difficult to manage conflict, as the stakeholder involvement was quite high [33].

In the Pre-Construction factor, the critical risk is the Lack of SPV Ability. The SPV recruitment in the State-Owned Corporation is extremely limited in this assignment scheme; therefore, few other alternatives involve the private sector. In addition, it is the first toll-road construction project with the assignment scheme, so adaptation is needed. Moreover, Late Land Acquisition and Many Land Brokers also became the critical factors in the land-clearing process that minimized project performance, thereby inhibiting the Sumatera toll-road construction. This is because the land clearing for toll areas is vastly different from other projects; in the toll-road project, the area that needed to be cleared was quite large, and either not all areas from the affected owners could be used, or they could only be used partially [26].

The critical risks that hindered the TranSumatera toll-road construction with the assignment scheme were the Lack of Contractor's Technical Ability and Material Procurement Delay. These were similar to the TransJawa toll-road construction—specifically in Semarang-Solo—with the PPP scheme based on the owner's perception [6].

In the Operational and Risk Factor Maintenance Period, the risk factors with critical value were Income Risk and Low Traffic Volume. These are interrelated, as the low traffic volume that crosses the Sumatra toll road will result in its low income.

Out of 104 total risks identified from both the literature and in-depth interviews, the Sumatera Toll-Road Construction with the assignment scheme had 12 risks with critical value, 72 risks with mild value, and 20 risks with low value.

The risk factors included in this group were crucial in the toll-road construction project with the assignment scheme, and they must receive special attention.

Failure to deal with these risks will be the main cause of significant added costs, as well as decreased targeted performance of the toll-road construction with this State-Owned Corporate assignment scheme.

5. CONCLUSIONS

The purpose of this paper was to identify the risk factors responsible for the excessive time and cost on the assignment scheme-based toll road project and identify which of the factors above has a significant impact on excessive time and cost on the assignment scheme-based toll road project.

The 107 risk factors causing the waste of time and money were identified by a literature review and survey that were conducted to identify the most impactful risk factor among the 107 main risk factors that caused the time and cost overrun,

The analysis of the survey result and the processing using the Rough Fuzzy Delphi reveals that 12 major risk factors significantly impact the assignment scheme-based highway projects in terms of excessive time and cost.

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7. REFERENCES

[1] Suprayitno, B., Privatisasi Jalan Tol Sebagai Solusi Dalam Mempercepat Terwujudnya Infrastruktur Jalan Tol Yang Memadai Di Indonesia. Jurnal Economia, 2012. 8(1): p. 65-77..

[2] Junoasmono, T., INDONESIA ROAD SECTOR DEVELOPMENT, in On the 31st Japan Road Congress, D.G.O.H.M.O.P.W.A.H.R.O. INDONESIA, Editor. 2015, Dinas PU: Japan.

[3] BPJT-PU. Tahapan Makro Pengusahaan Jalan Tol. [cited 2020 02-08]; Available from: http://bpjt.pu.go.id/konten/investasi/tahapan-makro-pengusahaan-jalan-tol..

[4] Almeida, M.V. and A.W.C. Oreta, A risk assessment model for high-rise school building project in Metro Manila, Philippines. GEOMATE Journal, 2020. 18(69): p. 30-37.

[5] Toan, N. and K. Ozawa. Stakeholders' perception on risks of BOT infrastructure projects in Vietnam. in CIB W107 Construction in Developing Countries International Symposium. 2008.

[6] Mochamad, A.W., Risk Management in Indonesia Construction Project: A Case Study of a Toll Road Project. 2018

[7] Wirahadikusumah, R.D., B. Susanti, and B.W. Soemardi, Risk in government's estimate for toll road: based on investors' perspective. International Journal on Advanced Science, Engineering and Information Technology, 2018. 8(2): p. 475-482.

[8] Valipour, A., et al., A fuzzy analytic network process method for risk prioritization in freeway PPP projects: an Iranian case study. Journal of Civil Engineering and Management, 2015. 21(7): p. 933-947.

[9] Jiang, X., et al., Identifying significant risks and analyzing risk relationship for construction PPP projects in China using integrated FISM-MICMAC approach. Sustainability, 2019. 11(19): p. 5206.

[10] Yuan, J., et al., Modelling residual value risk through ontology to address vulnerability of PPP project system. Advanced Engineering Informatics, 2018. 38: p. 776-793.

[11] Choudhry, R.M. and K. Iqbal, Identification of risk management system in construction industry in Pakistan. Journal of Management in Engineering, 2013. 29(1): p. 42-49.

[12] Jokar, E., B. Aminnejad, and A. Lorak, Risk prioritization and selection of contractor participating in Public-Private Partnership (PPP) infrastructure project using Hybrid Fuzzy AHP and Fuzzy TOPSIS (Case Study: Saveh-Salafchegan Freeway Project). Journal of Construction Engineering, Management & Innovation, 2020. 3(1): p. 1-16.
[13] Castelblanco, G., et al., Risk allocation in unsolicited and solicited road public-private partnerships: Sustainability and management implications. Sustainability, 2020. 12(11): p. 4478.
[14] Do Tien Sy, V.L., M. Onishi, and P.T. Nguyen, Impacts of risk factors on the performance of public-private partnership transportation projects in Vietnam.
[15] Karamoozian, A., et al., An approach for risk prioritization in construction projects using analytic network process and decision making trial and evaluation laboratory. IEEE Access, 2019. 7: p. 159842-159854.
[16] BPJT-PU, Analisis resiko investasi jalan tol, D.P. UMUM, Editor. 2005, Kementerian Pekerjaan Umum: Jakarta.
[17] Stević, Ž., G. Petrović, and D. Stanujkic. Novel Rough Delphi Method for Determination Weights of Criteria. in Proceedings of the 2nd International Conference on Management, Engineering and Environment (ICMNEE 2018), Belgrade, Serbia. 2018.
[18] Chen, Z., et al., A rough-fuzzy DEMATEL-ANP method for evaluating sustainable value requirement of product service system. Journal of Cleaner Production, 2019. 228: p. 485-508.
[19] Zadeh, L.A., Fuzzy sets. Information and control, 1965. 8(3): p. 338-353.
[20] Akyuz, E. and E. Celik, A fuzzy DEMATEL method to evaluate critical operational hazards during gas freeing process in crude oil tankers. Journal of Loss Prevention in the Process Industries, 2015. 38: p. 243-253.
[21] Sun, C.-C., A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods. Expert systems with applications, 2010. 37(12): p. 7745-7754.
[22] Habibi, A., F.F. Jahantigh, and A. Sarafrazi, Fuzzy Delphi technique for forecasting and screening items. Asian Journal of Research in Business Economics and Management, 2015. 5(2): p. 130-143
[23] Song, W. and J. Cao, A rough DEMATEL-based approach for evaluating interaction between requirements of product-service system. Computers & Industrial Engineering, 2017. 110: p. 353-363.
[24] Mohd-Rahim, F., et al., Project life cycle risk of public-private partnership (PPP) projects for construction sustainability. Journal of Design and Built Environment, 2018: p. 39-53.
[25] Pai, S., et al., Identification of risks causing time and cost overrun in roads and highway projects in India. International Journal of Civil Engineering and Technology, 2018. 9(3): p. 683-697.
[26] Likhitruangsilp, V., S.T. Do, and M. Onishi, A comparative study on the risk perceptions of the public and private sectors in public-private partnership (PPP) transportation projects in Vietnam. Engineering Journal, 2017. 21(7): p. 213-231.
[27] Patel, T.D., T.C. Haupt, and T. Bhatt, Fuzzy probabilistic approach for risk assessment of BOT toll roads in Indian context. Journal of Engineering, Design and Technology, 2019.
[28] Ahmadabadi, A.A. and G. Heravi, Risk assessment framework of PPP-megaprojects focusing on risk interaction and project success. Transportation research part a: policy and practice, 2019. 124: p. 169-188.
[29] Deshpande, P. and S. Rokade, Prioritization and assessment of critical risks of public private partnership highway projects in India using analytical hierarchical process. International Journal of Civil Engineering and Technology, 2017. 8(6): p. 605-620.
[30] Suseno, Y.H., M.A. Wibowo, and B.H. Setiadji, Risk analysis of BOT scheme on post-construction toll road. Procedia Engineering, 2015. 125: p. 117-123.
[31] Johnston, J. and A. Kouzmin, Addressing governance, accountability and performance monitoring issues in partnerships: can'infrastructure Australia'provide a strategic response? Public administration quarterly, 2010: p. 513-551.
[32] De Schepper, S., M. Dooms, and E. Haezendonck, Stakeholder dynamics and responsibilities in Public–Private Partnerships: A mixed experience. International Journal of Project Management, 2014. 32(7): p. 1210-1222.
[33] Fakhrin, M.R., L.S. Riantini, and Y. Latief. Risk-Based Institutional Evaluation of Trans Sumatera Toll Road Infrastructure Development to Improve Time Performance. in International Conference on Global Optimization and Its Applications 2021. 2021.