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Risk mitigation of toll road development (a case study of trans-Sumatera toll road)

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Abstract. To achieve the level of infrastructure performance as a middle-income country by 2025, as well as to catch up with the backwardness of infrastructure, specifically for toll road projects, the government targets that by 2021 Indonesia will have 5200 km of toll roads. Hence, there is a significant increase of 3000 km. The government, especially in the development of toll road infrastructure, gives a more significant portion to the purely private sector, BUMN, and Public Private Partnership - Government Business Entity Cooperation. Risk analysis is carried out by structuring risk using the RBS (Risk Breakdown Structure) method and multiplying the impact value and frequency to get the risk level value for each risk factor. The results of the analysis obtained from RBS are further analyzed based on the practical experience of project implementers to determine their actions in overcoming risks, then analyzed and discussed again using a table comparing the amount of risk, comparison of the level of importance of risk (importance level) and the level of risk based on the payment system. The results obtained from this study can be seen as the most significant influence on the soil structure at the construction site. Soil structure is a serious concern at the project site, affecting the project's cost, quality, and time. Based on the analysis, the most effective handling of soft soil uses a piled slab with the highest score of 90.90, a Pile slab of 85.6, and a stone column of 81.9.

Keywords: construction, toll road, risk, soft soil.

1. Introduction

The government claims to have built 718 km of toll roads since 2014, so that in 2019 the length of toll roads owned by Indonesia will be 2200 km and added to 5200 km in 2024. In addition to increasing the budget for toll road construction, the government also has ambitions to increase the ranking of infrastructure development. From rank 82 in 2010 to 52 in 2018 and will continue to be improved. The construction of toll roads will be spread on the island of Java, connecting all provinces in Java, Sumatra Island as the artery of the Trans Sumatra route, and Kalimantan Island, which will be prepared to become the State Capital. In addition to increased development funds, the government has even issued supporting regulations. Amendments such as PP no 15 of 2005 on toll roads, [1] on changes to the previous regulation by adding two wheels may cross on toll roads or toll bridges, PP no 43 of 2013 on increasing the investment feasibility of toll roads built by the private sector and PP 30 of 2017 concerning the expiration of the concession period and the feasibility of the investment achieved.

The role of the private sector in the construction of toll roads in Indonesia was started in 1987 with the signing of the Concession Authorization Agreement (PKP) with PT. Jasa Marga, which at that time was the toll road authority in Indonesia, was 553 km long. The development of toll road construction in Indonesia was halted in 1998 due to the monetary crisis and continued until 2005. The development of toll roads in other countries with many similarities in geographical and demographic conditions with Indonesia, namely Malaysia. The construction of toll roads in Malaysia began in 1990 and currently has 3800 km. While Indonesia has been building since 1978 until now, it is still far behind.

Toll road infrastructure projects are perilous due to high initial investment costs, high construction risk, long concession terms, and high operating and maintenance costs. As a result, private partners must generate sufficient income to repay investment costs, interest, and corporate profits. With a normal license period (20-30 years).

Many factors influence the low capacity of toll road development in Indonesiaone of which is the risk factor in the implementation of toll road projects ([1]). The risks occur due to the following constraints:

1. Not all these projects interest investors, as not all toll road projects are economically viable. The government has undertaken initiatives such as the Infrastructure He Summit to make the projects offered economically viable and investable. The Indonesian government has introduced an infrastructure guarantee policy to increase the creditworthiness of infrastructure projects. To encourage private sector participation in infrastructure development in Indonesia, PT. Government Decree No. 35/2009 on State Equity Participation will increase creditworthiness and provide guarantees to reduce project risk, thereby attracting more private investment, enhancing bankability, and increasing the number of PPP projects in Indonesia. Facilitate competition among potential bidders in the bidding process. [2].
2. The land acquisition process dominates several toll road projects that have stalled. For example, the Bekasi-Cawang-Kampung Melayu (Becakayu) toll road has been delayed for ten years. Another toll road that stalled for 21 years is the Bociwi Ciawi-Cigombong toll road, whose construction began in 1997 [3].
3. Investors are concerned that investing during long concession periods is risky. It is described in [4] and identified 53 risks in full concession toll road projects. These risks include site risk, design risk, construction, operational testing, sponsorship risk, revenue risk, flexibility risk, interface risk, etc., during feasibility studies, implementation and operation.

The performance of toll road projects in Indonesia is strongly influenced by the risks borne by investors/private/state-owned enterprises. The risks in question are risks that have been prepared during the preparation of the feasibility study, including planning risk, implementation risk, operational risk, and the overall risk of the toll road investment project. The complexity of risk allocation requires different handling.

Other research from [5] said risk management and internal control over the procurement of construction services should be conducted by all parties interested in risk control. [6] describes the highest number of risks originate from project activities, which indicates that the risks, especially at the implementation stage, arise more because the technical work in the field is very close to the environment around the project and all its activities. The risk variable that has the most influence on the implementation of road construction projects, which are the top three average values (mean) in the results of the analysis of this study, is the contractual risk variable, with the sub-variable being unilateral termination by the owner if the contractor does not carry out the obligations according to the contract; technical risk variable with sub-variable of material availability that arrived in the field different from that ordered; natural/natural risk variable with erratic weather sub variable based on [7].

Risk analysis is carried out by structuring risk using the RBS (Risk Breakdown Structure) method and multiplying the impact value and frequency to get the risk level value for each risk factor. The results of the analysis obtained from the RBS were further analyzed based on the practical experience of project implementers to determine their actions in overcoming risks, then analyzed and discussed again using a table comparing the amount of risk, comparison of the level of importance of risk

(importance level) and the level of risk based on the payment system. The results obtained from this study are the type of risk. The level of risk at each stage of the project for a project with a combined lump sum contract system and unit price also depends on the type of work, project location, work complexity, and level of ability (experience) of the contractor, not only in the kind of contract used [8].

In a construction project, there must be risks. Risk is a consequence of uncertain conditions. In construction projects, the risk can not be predicted as well because there is a lot of uncertainty in predicting problems [8]–[10]. For example, the land acquisition process in the Indonesian toll road project has a high level of uncertainty. Land acquisition activities could be completed quickly, while some have been very slow for years. It depends on several problems in the field, such as the project's priority, the availability of compensation money, community participation, the limited resources of the National Land Agency, and the time to complete the land acquisition claims in the District Court and Supreme Court. The duration of a land acquisition depends on some main parties, i.e., the National Land Agency, the District Court or Supreme Court, and the Ministry of Public Works and Housing [9].

Another research regarding risk analysis at the toll road construction implementation stage uses descriptive methods and AHP (Analytical Hierarchy Process) to determine the most dominant risk from the multiplication between likelihood and consequence. Then the most prevalent risk is mitigated [11]. In the analysis of business assessment and risk management on investment feasibility decisions by considering uncertainty, it is obtained that risk variables that affect the feasibility study results include the inflation rate, forecast error of LHR volume, initial LHR volume, construction costs, and O&M costs. [12].

2. Material and Methods

2.1. Project Management Body of Knowledge

Most PMBOK guidelines, such as the Critical Path Method (CRM) and Work Breakdown Structure (WBS), are unique to project management. Project management knowledge includes 9 (nine) knowledge areas, namely:

1. Project Integration Management
2. Project Scope Management
3. Project Time Management
4. Project Cost Management
5. Project Quality Management
6. Project Human Resource Management
7. Project Communications Management
8. Project Risk Management
9. Project Procurement Management

As well as 4 (four) additional knowledge areas for construction management projects, namely:

1. Project Safety Management
2. Project Environment Management
3. Project Investment Management
4. Project Claim Management

Specifically, project financing is crucial because the government has a shortage of the financing, so it requires cooperation and support from various parties. Project financing, commonly known as project financing, is a type of large-scale financing scheme generally for the long term. In a project financing scheme, there is usually a group of investors who then act as shareholders of a newly formed company which is then known as a unique purpose entity or special purpose vehicle, abbreviated as SPV. The SPV company is then expected to design, build, and manage an infrastructure project.

2.2. Project Management Body of Knowledge

Risk mitigation is an action or response to risks that occur during the project cycle. The countermeasures are not meant to eliminate the risks that occur but to minimize the frequency and consequences of the risks that occur (residual risk). According to Flanagan and Norman, in Norken et al. [4], risk mitigation is carried out in several stages: holding, reducing, transferring, and avoiding risks. Risk ownership is determined based on the party considered responsible and able to control and provide treatment for risks that arise during the project cycle. Once the risk has been allocated, the less likely it is that disputes will arise between the parties involved.

2.3. Toll Road Investment Risk

A risk is a situation that an individual or business faces with potential harm. Below are some of the definitions proposed in the literature that are expected later to better understand the concept of risk. [13] proposed some risk definitions as follows:

1. Risk is the chance of loss.
2. Chance of loss is usually used to indicate a situation with an openness to loss or a possible loss.
3. Risk is the possibility of loss.
4. Possibility means the probability of an event being between zero and one.
5. Risk is uncertainly

The definition of risk conveys an understanding that risk is related to uncertainty. Two types of uncertainty can be categorized as natural or accidental uncertainty and uncertainty due to human behavior or technology. Natural or random uncertainties are caused by natural phenomena such as earthquakes, heavy rains, strong winds, and other natural disasters, which are difficult to predict due to their random nature. Approaches can be statistical or probabilistic (including random elements). At the same time, technical uncertainty stems from human behavior caused by uncertainty in sampling, measurements, limited data, data analysis, or inadequate models and estimates [13]. [14] explained that in the risk analysis of the Pekanbaru-Dumai toll road construction, four main risks were identified, namely:

1. Financing risk
2. Development Risk
3. Equipment Risk
4. Force Majeure Risk

2.4. Risk mitigation

Construction projects are unique, limited by cost, quality, and time. When carrying out construction projects, issues often arise that affect cost, quality, and time. Therefore, according to this case, there is a very high need to research risk management [15]. The construction of toll roads can improve transportation efficiency and the economy of a region. However, t implementation of toll road construction will not be free from risks [8].

Risk mitigation is an action or response to risks that occur during the project cycle. The countermeasures are not meant to eliminate the risks that occur but to minimize the frequency and consequences of the risks that occur (residual risk). According to Flanagan and Norman (in [16]) risk mitigation is carried out in several stages, namely, by holding, reducing, transferring, and avoiding risks [16]. Risk ownership is determined based on the party considered responsible and able to control and provide treatment for risks that arise during the project cycle. Once the risk has been allocated, the less likely it is that disputes will arise between the parties involved.
Several things can be done in dealing with risks, namely:

2.4.1. Retaining Risk (Risk Retention)

Risk-taking attitudes are closely related to the rewards involved in risk. Measures are taken to accept/mitigate this risk, as the effects of the adverse event are still tolerable.

2.4.2. Reducing Risk (Risk Reduction)

Risks are mitigated by examining the risks themselves, implementing preventative measures at the source of the risks, and combining measures to prevent them from collapsing. However, this measurement may leave residual risk that needs to be evaluated.

2.4.3. Transfer of Risk (Risk Transfer).

Suspension of risk transfer is through insurance of the risk arising from the transfer of part or all of the risk to another party. Risky businesses and jobs are delegated to those who can manage and control them.

2.4.4. Avoiding Risk (Risk Avoidance)

A risk-averse attitude is a way of avoiding losses by avoiding lossy activities. Risk aversion can be done through denial. An example of risk aversion in construction projects is the termination of a contractual relationship (breach of contract).

2.5. Soft Soil in Sumatra Toll Road Construction

Soil always has an essential role in a construction work site. Soil is the supporting foundation of a building, the construction material, or sometimes the cause of external forces on the building. The land has 3 (three) leading roles in transportation infrastructure buildings, namely as support, material, and load for transportation infrastructure buildings. As a supporting role, the land must have a carrying capacity that can support transportation infrastructure buildings that are on it. If the soil is compressed, the resulting subsidence of the building does not cause the transportation infrastructure to be damaged.

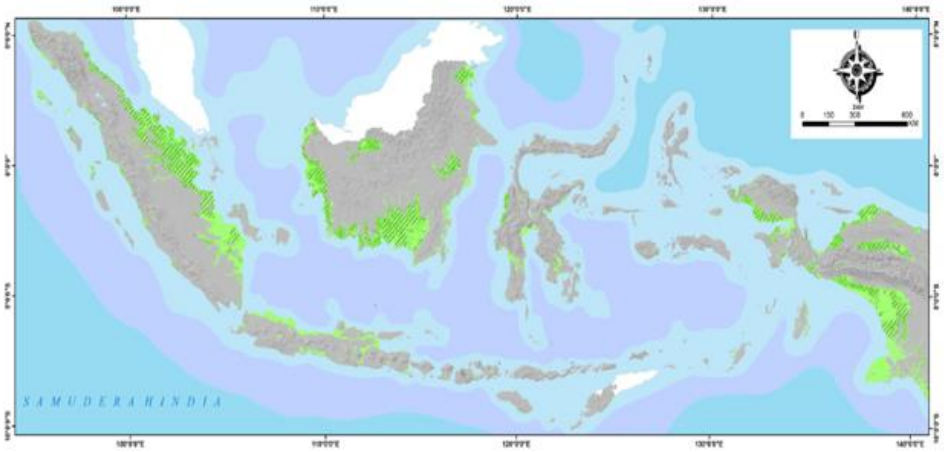

Figure 1. Distribution Map of Indonesian Soft Soil (Green Color) [16]

The main problems in constructing roads on soft clay are the subgrade's relatively low bearing capacity and relatively significant and long-lasting compression, as shown in Figure 1. The distribution of soft soil is found in several areas in Indonesia. If the subgrade is not repaired first, the infrastructure built on it will potentially be damaged before reaching the planned age.

2.6. Soil Improvement

According to [17] about soil improvement is a process of improving the characteristics of compressibility, bearing capacity, permeability, and resistance to liquefaction of the soil in situ where the foundation of a building or infrastructure will be erected, so that the characteristics of the soil change permanently and have compressibility, bearing capacity, permeability, and stability or adequate liquefaction resistance and reach a safe level. The purpose of soil improvement is to increase density,

soil stiffness, and liquefaction resistance to avoid excessive settlement, significant consolidation, and risky embankment stability.

There are nine ways to improve soil, namely:

1. Soil repair with cement (soil cement)
2. Soil improvement with lime (soil lime)
3. Soil improvement with ash (soil ash)
4. Soil improvement with a chemical solution (solvent stabilization)
5. Soil improvement by compaction
6. Soil improvement with consolidation
7. Soil improvement using the dewatering technique
8. Soil improvement with land replacement (replacement)
9. Soil improvement with permeation resin

2.7. Expert Test With Delphi Method

The Delphi method is a systematic method of collecting opinions from a panel of experts through a series of questionnaires, with a feedback mechanism through "rounds" of questions while maintaining the anonymity of the respondents' (experts') answers. The Delphi method is a modification of the brainwriting and questioning methods. Brainwriting is similar to brainstorming. It can generate new ideas, encourage creative problem-solving, and develop innovative solutions. But instead of discussing ideas out loud, brainwriting allows people to write down ideas and share them anonymously [18]. This method uses panels in a communication exercise through several written questionnaires. The Delphi method was developed in the early 1950s to seek expert opinion [19]. Most Delphi policies relate to statements, arguments, comments, and discussions. We establish multiple methods of evaluating ideas expressed by groups of respondents and a rating scale for selecting these guidelines. B. Ideas, Interests, Desirability, Beliefs, and Appropriateness of Various Policies and Topics [20].

2.8. Research flow

The research process begins with compiling a frame of mind in the form of a flow chart sequentially, starting from the search for data, the analysis process, and ending with the results of the study in the form of conclusions, as shown in Figure 2.

Based on Figure 2, the first step is conducting literature studies, selecting risk variables. And continued with the Delphi method & risk assessment using experts' opinions, and continued with selecting the most influential risk and then choosing the method of handling.

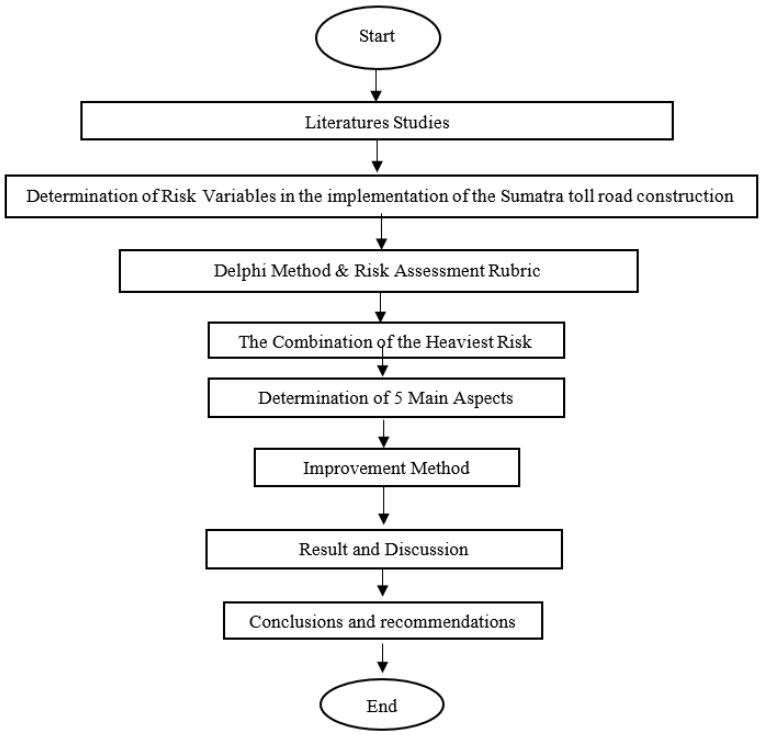

Figure 2. Research Flowchart

3. Result and Discussion

3.1. Research Variables and Instruments

A variable is a concept that can be assumed as a range of values. A variable is a measurable amount that can vary or change easily, as seen in Table 1.

Table 1. Sources of construction risk for Sumatra toll road construction [21]

Variable	Indicator	Number
Matrix Toll Road Sector Construction Risk Full Concession	Soil structure risk	1
	Contamination/pollution to the site environment	2
	Disruption of biodiversity in forest areas/conservation areas	3
	Barriers to public transportation access	4
	Disruption of the comfort of the community around the project area	5
	Unclear output specifications	6
	Failed to maintain security and safety on site	7
	Increase in construction costs	8
	Poor contractor/subcontractor performance	9
	Default contractor/sub-contractor	10
	Design error	11
	Late completion construction	12

Variable	Indicator	Number
	Operational test risk (testing & commissioning)	13
	Changes in the scope of work	14

3.2. Identification and Risk Analysis of Sumatra Toll Road Project Implementation

Risk identification is an analysis process to systematically and continuously find risks (potential losses) that challenge the company. Risks can be identified based on risk sources, events, and impacts. A source of risk is a condition that may increase the likelihood that the risk will materialize. An event is an occurrence that produces an influence or effect that can be either adverse or beneficial.

Risk identification is the initial stage of risk management which aims to describe and detail the types of risks that may occur from the activities or activities we will continue. Each activity will identify uncertainties (potential losses, errors, discrepancies) that may occur, guided by "What can go wrong" from what will be done. Risk identification can be carried out from the description of the planned activities to be carried out and guided by changes/uncertainties from various existing risk sources.

Identification of construction risks on toll roads by PT.PII. Based on the risk identification carried out previously, an analytical risk rubric was created, which will later be given to experts in determining the most significant risks that occur in the construction of the Sumatra toll road. This study uses the Delphi method involving eight respondents. The results of this study have a range of values from 1 to 5. A value of 5 is for a very appropriate answer, a value of 4 is for an appropriate answer, a value of 3 is for a reasonably appropriate answer, a value of 2 is for a wrong answer, and a value of 1 is for a highly inappropriate answer.

3.2.1. Stage 1 Questionnaire

In stage 1, there are 14 questions. From the results obtained, it can be seen that most of the respondents agree and even strongly agree that the risk of soil structure is the heaviest in the construction of the Trans Sumatra toll road. Furthermore, the lowest risk is a design error can be seen in Figure 3.

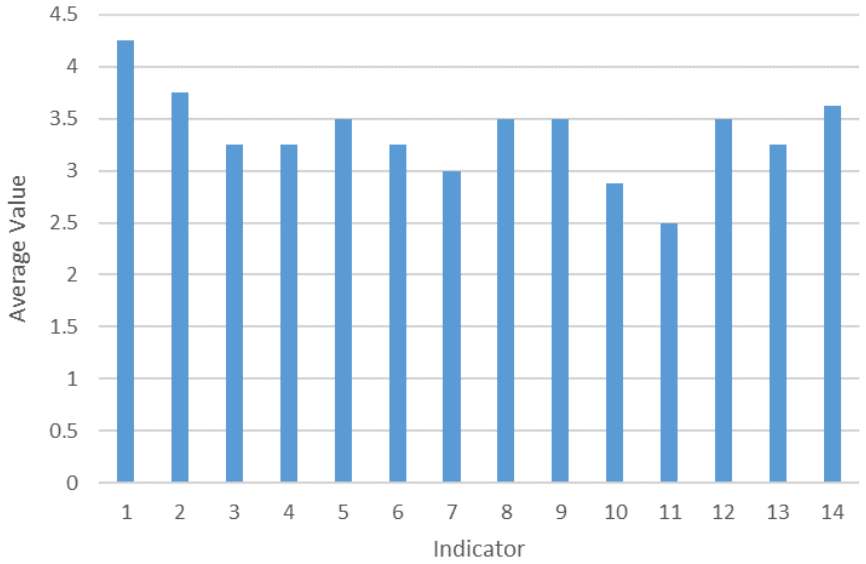

Figure 3. Analysis of the biggest risks of toll road construction stage 1 expert test (research result)

3.2.2. Stage 2 Questionnaire

The lowest result is that design errors can be eliminated when compiling the phase 2 questionnaire. So there are 13 questions at the time of the expert test with the phase 2 questionnaire. Trans Sumatra

toll road. Furthermore, the lowest risk is increased construction costs and failures due to contractor/sub-contractor defaults can be seen in Figure 4.

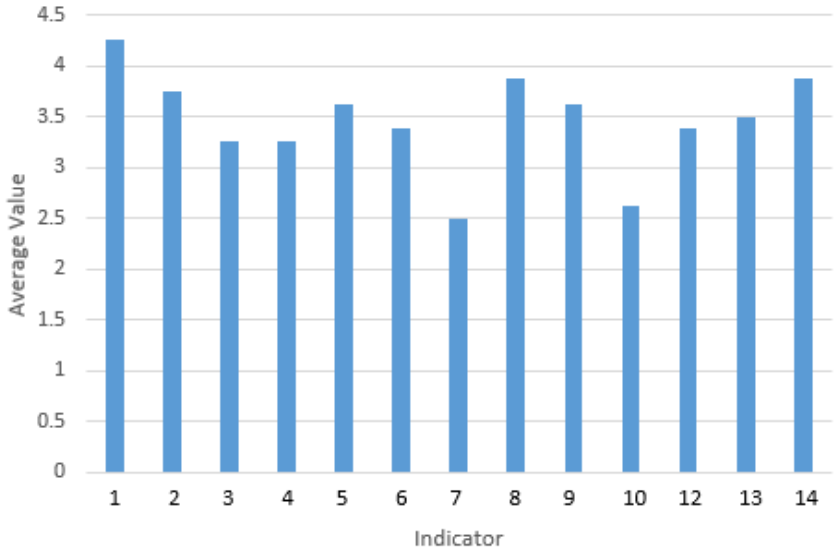

Figure 4. Analysis of the biggest risks of toll road construction stage 2 expert test (research result)

3.2.3. Stage 3 Questionnaire

The two lowest results from the questionnaire phase 2, namely the increase in construction costs and construction failures due to contractor/sub-contractor defaults, can be eliminated so that 11 final questions will be analyzed again using the Delphi method. The expert test results show that the Soil Structure Risk is the most challenging in implementing the Sumatra toll road construction project, as seen in Figure 5.

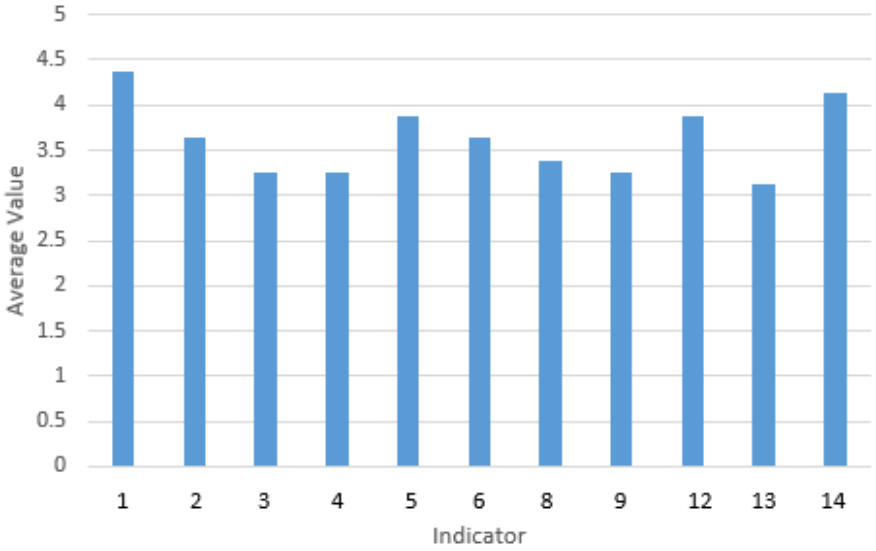

Figure 5. Analysis of the biggest risks of toll road construction stage 1 expert test (research result)

3.3. Result of Data Processing

All civil engineering buildings stand on the ground. Soil is the foundation for civil engineering buildings. The crucial thing in the soil is the presence of loading either by the construction itself or by

traffic and other forces due to shear or earthquake. The type of soil and the consolidation behaviour of each of these types significantly affect the settlement of the construction. Construction subsidence that occurs during construction is above the ground, and if it is not planned or calculated in the construction calculations, it will result in construction damage. The handling of soft soil is crucial in the trans-Sumatra toll road project because most of the soil types in the project are soft soil.

Based on expert testing that has been carried out in stages, it can be seen that the most significant influence is on the soil structure at the construction site. Soil structure is a serious concern at the project site, affecting the project's cost, quality, and time. Furthermore, it is discussed in detail regarding handling the soil structure at the research site.

3.4. Improvement Method

Based on the literature study, it is stated that the soft soil problem can be solved by several methods, including PVD Preloading, Stone Column, and Pile Slab.

3.4.1. PVD Preloading.

Prefabricated Vertical Drain (PVD) is a soil improvement method that accelerates the consolidation process by shortening the drainage path of pore water in soft soil layers so that that water can be dissipated quickly. In addition, using PVD maximizes the radial direction's consolidation by placing high-permeability materials in the soil.

3.4.2. Stone Coumn

Column Stone or Stone Column is a type of deep soil improvement (deep replacement) where aggregate/mortar is used as a replacement material in the soft soil layer, which is then compacted by vibrating and formed in rows like columns.

3.4.3. Pile Slab

A Pile slab foundation is a foundation structure supported by a pile group system and tied by a pile cap which is used to hold and transmit the load from the superstructure into the soil with the bearing capacity to hold it.

3.5. Aspects of Assessment

According to [22], controlling cost-effective projects can be done in several ways, including:

1. Detailed and Completely Defined Scope of Work
2. Project Risk Analysis
3. Accurate Cost Estimation and Determination of Budget Guidelines
4. Cost Performance Analysis and Forecasting
5. Performance Measurement Analysis
6. Scope Change Control System
7. Checking and Correcting Action
8. Cost Control Procedure

Based on some of these treatments, simplification, and analysis of which method has the most positive impact on the construction of this toll road, the analysis is based on the assessment of work tools, resources, maintenance, implementation, time, technique, and cost. In addition, the analysis is based on experts' testing to provide the best assessment. In a construction project, several aspects that can be seen in Table 2.

Table 2. Analysis of the most influential aspects (research result)

No.	Aspect	Respondent											Final Score
		11	10	9	8	7	6	5	4	3	2	1	
1	Maintenance	11	14	14	17	15	17	15	17	10	20	15	15
2	Implementation	15	19	16	12	17	11	17	12	12	10	14	14
3	Time	10	12	10	12	10	8	6	10	12	13	10	10
4	Method	30	28	23	24	27	28	20	29	25	20	26	25
5	Cost	28	23	30	20	20	24	22	23	26	27	32	25
6	Working Equipment	3	2	5	7	8	5	7	0	5	0	3	4
7	Resource	2	2	2	5	2	3	7	5	5	5	0	4
8	Ease of Getting Material	1	0	0	3	1	4	6	4	5	5	0	3
		100	100	100	100	100	100	100	100	100	100	100	100

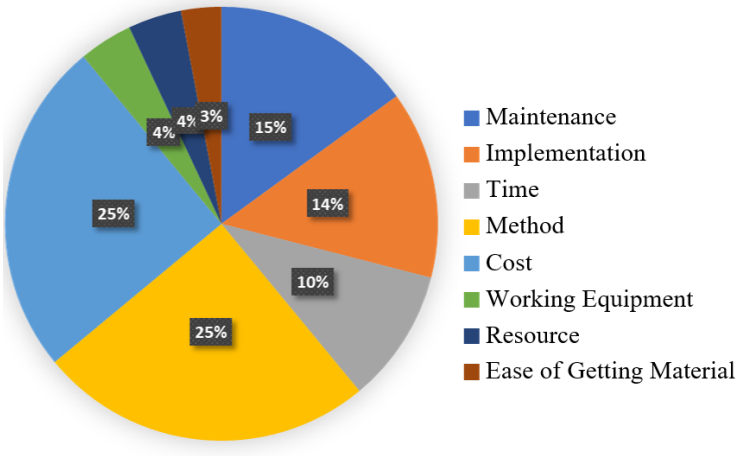

Figure 6. Influence analysis chart (research result)

Tools, resources, and ease of getting materials. These three aspects are further discussed as follows:

1. Work tools
   Work equipment has the most negligible weight of 3%, and the opinion of experts has the most negligible weight because the work tool has entered the implementation aspect. Hence, the non-specific aspect of the tool directly affects the construction of toll roads.
2. Resources
   Resources are included in the technical and implementation aspects, so the weight of resources is also tiny because other aspects represent them.
3. Ease of getting materials
   Materials have the most negligible aspect weight, similar to work tools, where materials are included in the implementation.

3.6. Field Analysis Results

Table 3. In-depth Study of Construction Method (research result)

No	Aspect	Weight	Value			Score		
			PVD + Preloading	Stone Column	Pile Slab	PVD + Preloading	Stone Column	Pile Slab
1	Maintenance	15%	80	90	100	12	13.5	15
2	Implementation	14%	80	70	95	11.2	9.8	13.3
3	Time	10%	80	70	100	8	7	10
4	Method	33%	80	80	100	26.4	26.4	33
5	Cost	28%	100	70	28	28	25.2	19.6
						85.6	81.9	90.9

Based on Table 3 regarding an in-depth study of the handling of soil structure, in this discussion, three methods of handling soft soils are taken, namely PVD Preloading, Stone Column, and Pile Slab. Tests are based on maintenance, Implementation, Time, Technique, and Cost. These parameters were obtained based on direct discussions with the resource persons. Furthermore, the weighting/assessment of each parameter is carried out for each improvement method used. Based on the assessment carried out, it was obtained that the highest value was obtained by the Pile Slab Method at 90.9, then by the PVD+Preloading method at 85.6, and the last was the stone column at 81.9, the most significant value indicating that this method is the best to be implemented in the field. However, it should be noted that this method may change at any time due to other unknown factors, so each development segment needs to be reviewed to adjust the method used.

4. Conclusions

From the results of the analysis and discussion conducted, the conclusions that can be drawn from this research are:

1. Based on expert tests, the soil condition is known that the biggest problem in the construction of the Indralaya-Prabumulih toll road.
2. An analysis of the factors that can increase costs during and after construction is carried out to determine the method. From this analysis, it is known that: construction costs with the selection of construction type have an effect of up to 25%, then the implementation method affects 25%, and maintenance affects 14%
3. In the selection of risk management, use the opinion of experts who already have experience in the related field
4. The most effective handling of soft soil based on the analysis uses a piled slab of 90.90. The Pile slab is 85.6, and the stone column is 81.9.

Based on the previous discussion, suggestions that can be given to improve further research are as follows:

1. Analysis should be added with comparisons in other areas.
2. Only three models were carried out in reviewing the handling model, and analysis with other handling models was needed to determine how far the boat was.

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