Risk and Uncertainty in the Medan-Binjai Toll Road Infrastructure Project, Indonesia Based on the Stochastic Analyzes

Ari Sandhyavitri, Alfian Malik, Imam Suprayogi, Manyuk Fauzi, Ridwan Rahman

***Abstract*—This paper demonstrates state of the arts stochastic risk analyzes in assisting decision-making processes in achieving the project objectives in terms of the estimating project costs under uncertainty. The objectives of this study were to; (i) analyze the feasibility of the Trans Sumatra toll road projects section of Medan-Binjai (25.46 km), Indonesia, and (ii) identify and quantify the toll road risk and uncertainty variables influencing the economic feasibility of the project using stochastic approach. This study identified that the risk variables in this study may include; Indonesia Certificate Bank (SBI), inflation, volume of traffic (vehicles), operation and maintenance (O&M) costs, construction costs, land accusation costs, Jakarta Inter-Bank Offer Rate (JIBOR), and design (EED/FED). The initial results of this study (Scenario 1), using concession period of a-35 years with an implementation of the initial tariff of class I vehicles (Rp. 750 / km) showed that the project was considered not financially feasible as 90% probability of the projected net present value (NPV) was negative at the range of Rp. -1.06 trillion to Rp. 2.57 trillion. The project would be financially feasibility after conducting mitigation processes for those the identified risks, such as; providing the government supports (GSs) as much as 40% of the total construction costs as well as land acquisition costs (Scenario 3). This scenario has resulted that there was 90% probability of the projected NPV would be positive at the range of Rp. 0.54 million to 1.894 million. The implementation of the stochastic risk analysis may assist the project managers comprehensively in developing decision-making processes in financing the toll road project.**

***Index Terms*—Risks; Uncertainty; Stochastic; NPV; Government Support; Construction Costs; Toll Road.**

I. Introduction

In order to encourage the development of transportation systems in Sumatra Island, Indonesia has sped up the construction of 24 toll roads with a high-grade highway (HGH) concept, including the construction of the main toll road of Bakauheni-Banda Aceh along 2.014 km, and establishing a highway feeder stretching 720 km lengths [1]-[3].

This paper investigated a toll road section of Medan-Binjai as a part of the Sumatra toll road project (Fig. 1).

The existing feasibility study of Medan-Binjai toll road project was conducted economic analyzes based on the deterministic approach. This study summarized that this project is classified as feasible economically project but not financially feasible [3]. This means that there was a need Government Supports (GSs) and additional duration to operate the project in order to ensure that the project becomes financially and economically feasible.

This paper explored the roles of the stochastic risk analyzes in assisting decision-making process for the development of toll-road in Sumatra, Indonesia.

According to [4]-[8], the government has promoted the public private partnership (PPP) scheme to build, operate, and operate (BOT) the strategic toll-road projects. The provision of infrastructure development will be supported in the form of financial and fiscal guarantees named viability gap fund (VGF). The VGF purposes were to shift the existing projected project economic performances to become economically and financially feasible.

The Medan-Binjai toll road project is divided into three sections, such as; Tanjung Mulia-Helvetia (Section 1), Helvetia-Semayang (Section 2), and Semayang-Binjai (Section 3) (Fig.1). The initial toll road investment cost was estimated at Rp. 1.604 trillion (the base year of 2015). It was identified the following toll road supporting infrastructures will be established such as four ramps, four overpasses, six underpasses, six bridges over the river, a single junction (JC), and three interchanges (IC), without viaduct (Fig. 1).

The construction of Medan-Binjai toll road was conducted over two years' period (2015 and 2016), and the project operations was started at early 2017. The volume of traffic was at the average of 13.771 vehicles/day (2017). The concession period is 35 years including construction period.

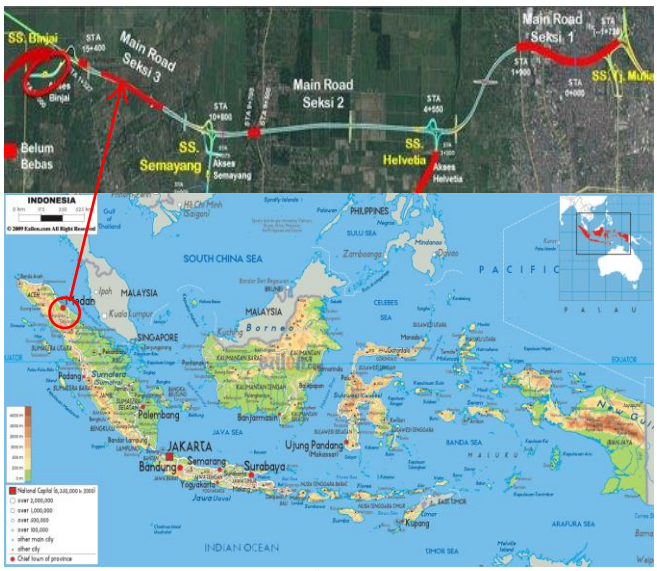

Fig. 1. The toll road of Medan-Binjai Indonesia

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The road was designed as a four - line road two-way split (MW 4/2D), which can be upgraded to a six-lines two-way (MW 6/2D). The construction of Medan-Binjai toll road was conducted over two years (2015 and 2016), and was planned starting operation in 2017. The initial average volume of the traffic is 15,301 vehicles/day with the initial tariff for vehicle type-1 is Rp.700/km. The concession period was set up to become 35 years including construction period [1].

The objective of this research is to analyze risk and uncertainty of the Trans Sumatra toll road projects section of Medan-Binjai using the stochastic analyzes approach. There were identified that various references related to project risk and uncertainty have been published, such as; a research study conducting in Saudi Arabia concerning the development of road construction identified that there were 41 risks affecting cost overrun, 2013 [9], a reviewed study conducting in Argentina, 2002 showed that there weresignificant three factors to manage the toll risk project e.g. tariffs collection, investment policy, and optimization of risk allocation between the road users and the project concessionaire in order to ensure project success [10], and it was also reviewed there were five major activities in developing of the toll project planning in Indonesia 2015 such as; obtaining project permission activities, developing project feasibility activities, developing detailed design, conducting land acquisition activities, and financing project investment, [11]. These previous studies were mostly based on the deterministic risk analyzes rather stochastic ones.

In addition, the objective of this study is also to identify and quantifythe risks inherent in the project construction and operation phases.

The results of the sensitivity analysis were conducted as a basis for the development of mitigation scenarios in order to reduce the negative risks and maximize the positive ones. This paper concerned in the investigating the projected net present value (NPV) of this toll road project construction and operation phases based on the probabilistic analyzes. Hence, more comprehensive information can be obtained in the decision support system (DSS) processes.

This study also discussed the proportional risk allocations between the government and Toll-road Enterprises (BUJT). This risk mitigation and risk allocation are intended to improve the project feasibility performances based on the economic and financial perspectives.

II. Research Methodology

This research developed a number of cash flow models of the identified risk and uncertainty encompassing inflation rate, traffic volume, operation and maintenance (O&M), and construction costs [8], [12].

In order to calculate and determine the components of costs, tariffs, and revenues the model simulated 10,000 iterations with 95% confidence level. The simulation processes conducted using software Microsoft Excel add-ins [12], [13]. Referring to [14] in order to modelling a future of the traffic volumes during ramp-up period (3 years), the calculation may use logarithm regression function as this function is more appropriate compared to the linear regression one [14],[15].

According to [6], risk and uncertainty were defined as an actual outcome for a particular activity deviates from an estimated value [16].

It is acknowledged that the risk will occur whenever there was uncertainty exist [17]. The risk is intrinsic in the development of decision-making process especially in the area of project financing for the toll road projects.

In this paper, an uncertainty is assumed inherent in predicting the future values of the toll project in the money terms. This is presented as random variables in the context of project investment. According to [8], risk and uncertainty can be expressed as follow [18]; a risk occurs when a decision is defined in term of probabilistic outcomes at a certain range of possibilities. An uncertainty is commonly expressed when there are more than one possible outcomes occur but there is no certain probability of each outcome could be quantified.

In this toll road projects, the difference between risk and uncertainty is considered have little significance, hence these terms have been used interchangeably in this paper [19].

It was identified that there were nine significant risks and uncertainties inherent in the project cash-flow, such as; the risk of inflation, Bank Indonesia (BI) interest rates during the operating and maintenance costs, depreciation, interest on loans, taxes, debt principal, land acquisition cost and duration, construction cost and duration (Table I).

This research obtained risks and uncertainties variable by conducting field surveys to several respondents including Indonesia Toll Road Authority (BPJT), PT Hutama Karya, Statistic Central Biro (BPS), Bank Indonesia, and the existing toll road operators.

This study conducted the stochastic risk analysis. The difference between deterministic and stochastic analyzes as follow; the deterministic risk analyzes may demonstrate that an activity is tolerant to the limit of a design basis and is presented in a single value, and the probabilistic risk analysis, provide a range of a realistic estimate of the risks. Hence, the stochastic analyze results may yield a relatively comprehensive range of information compared to those the deterministic one [20].

Normal distributions, lognormal and pert distributions were used to represent an uncertain event of random variables from the cost estimated activities [9].

III. Results and Discussion

This study was calculated at the base year 2015. According to the documents of Indonesia Toll Road Authority (BPJT), the total investment cost required to construct the toll road was Rp. 1.898 trillion (sum of Rp. 0.007 trillion (in phase 2014) + Rp. 1.123 trillion (in phase 2015)+Rp. 0.768 trillion (in phase 2016)), and the cost of land acquisition is Rp. 495 billion. The capital structure consists of debts and equity components within DER of 0.70. Loan interest rates during the construction phase (IDC) was 9.75% (by assuming the float of the interest rate was 300 basis points above JIBOR), while the loan interest rate for the duration of the operation is 6%. The average national economic growth indicators data were obtained from the historical data during the 2011-2015 period including SBI 6.78%, JIBOR 6.51%, and inflation rate 5.88%.

The technical and financial data of the project are presented as the following table:

TABLE I: TECHNICAL AND FINANCIAL DATA OF THE PROJECT

Types of Data and Information	**Road section Medan-Binjai**
Road length (km)	25.46
Construction duration (years)	2 (2015, 2016)
Initial year of project operation	2017
Concession period (construction + operation) (years)	35 (2 + 33)
Construction cost (Rp) trillion	1.898
Estimated traffic volumes of the first year (vehicle / day)	15,301
The composition of traffic (Class I : II : III : IV : : V), (%)	73.03 : 17.78 : 7.62 : 0.93 : 0.64
Initial tariff for class I (Rp/km)	750
The ratio of inter-group tariffs (I : II : III : IV : V)	1 : 1.5 : 2 : 2.5 : 3
Operating and maintenance cost (Rp)	20% of income
Traffic growth (%)	7.00
Income tax (%)	30

Source: BPJT [8], and Bank Indonesia [20]

The results of the traffic growth during the project assessment period (ramp-up period) indicated that the volume of traffic at the beginning of the project operation for low traffic risk was predicted as many as 13,771 vehicles/day (2017) to 98.729 vehicles/day in 2045 (the 29th of the concession period).

Medan-Binjai toll road line was designed to accommodate four-line two-way split (MW 4/2 D) which can be increased to MW 6 / 2D, with a line width of 3.60 meter [21]. The results showed that the capacity of the road would be 98.729 vehicles/day. This projection will be achieved by the year 2045 (year-to-29 of concession period) (Fig. 2).

Fig. 2 shows the forecasted volume of the traffic growth 2017-2047 (Fig. 2).

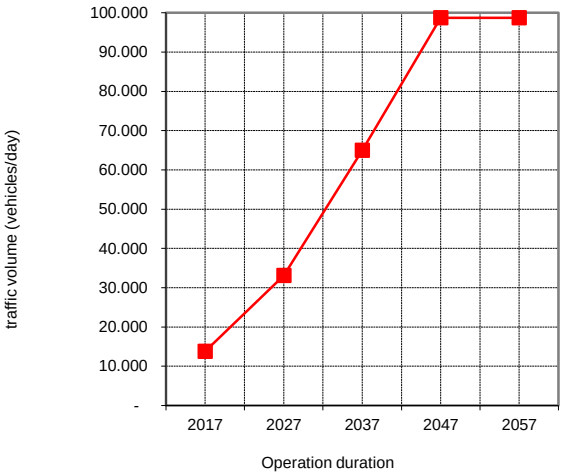

Fig. 2. Forecasted traffic volume 2017-2047.

This research also identified 7uncertain variables affecting the project cash flow such as; Inflation rate, Bank Indonesia Certificates (SBI), Jakarta Inter-Bank Offer Rate (JIBOR), the traffic volume, operational and maintenance costs, land acquisition cost and land acquisition duration, construction cost, and construction duration (Table II).

The existing risk variables and it's PDF were displayed in the following table:

TABLE II: UNCERTAIN VARIABLES AND PROBABILITY OF THE PROJECT

Uncertain variables	Probability Distribution Functions (PDF)	Parameter	Notes (data source)
BI Certificate (SBI)	Normal (empirical)	μ =6.78%, σ =0.77%	Bank Indonesia (2011-2015)
The national inflation (%)	Normal (empirical)	μ =5.88%, σ =1.54%	Bank Indonesia (2011-2015)
JIBOR	Normal (empirical)	μ =6.51%, σ =1.34%	Bank Indonesia (2011-2015)
Traffic volume at the beginning of operation (number of vehicles)	Lognormal (subjective)	μ : class I = 11.175 vehicle/day class II = 2.720 vehicle/day class III = 1.166 vehicle/day class IV = 142 vehicle/day class V = 98 vehicle/day COV = σ/μ = 10%	Mean (μ) from BPJT COV, subjective assumption by practitioner
Operating and maintenance costs (Rp)	Lognormal (subjective)	μ =20% of grass income per year (%) COV = σ/μ = 10%	Wibowo (2005a)
Land acquisition cost	Lognormal (subjective)	μ = Rp.495.000.000.000 COV = σ/μ = 20%	Mean (μ) from BPJT COV, subjective assumption
Uncertain variables	Probability Distribution Functions (PDF)	Parameter	Notes (data source)
Land acquisition duration	Normal (subjective)	μ = 1 year COV = σ/μ = 50%	Mean (μ) from BPJT COV, subjective assumption
Construction cost	Lognormal (subjective) Pert distribution	μ = Rp.1.294.486.000.000 COV = σ/μ = 20%	Mean (μ) from BPJT COV, subjective assumption
Construction duration	Normal (subjective) Pert distribution	-planning μ = 1 year COV = σ/μ = 5% -construction: μ = 2 year COV = σ/μ = 20%	Mean (μ) from BPJT COV, subjective assumption

The order of sensitivity variables inherent in the project cash was presented as the following spider diagram; 1) SBI, (2) inflation, (3) vehicle (type I), (4) operation and maintenance (O&M), (5) construction stage 1, (6) construction stage 2, (7) vehicle (type II), (8) land accusation, (9) JIBOR, (10) vehicle (type III) and (11) DED/FED. (Fig.3)

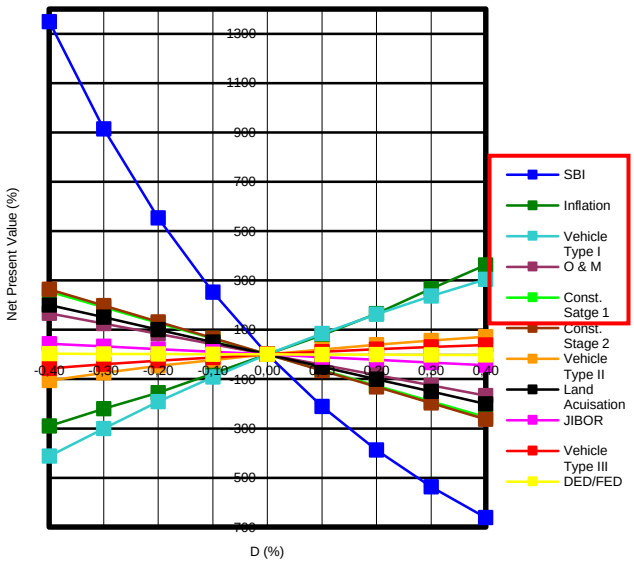

Fig. 3. Sensitivity analyzes of the risk variables.

Fig. 3 shows that the most sensitive risk variable is Jakarta Inter-Bank Offer Rate (JIBOR). The change of 10% of JIBOR may reduce predicted NPV up to 150%, and the change of 10% inflation rate may increase of NPV up to 100%.

These risk variables were then analyzed in a stochastic. For an example, a construction cost of an activity of stage 2 was estimated at Rp. 1.12 trillion (deterministic value). Then, the stochastic analyzes using a probability distribution function (PDF) of the Pert distribution was drawn as follow (Fig. .4).

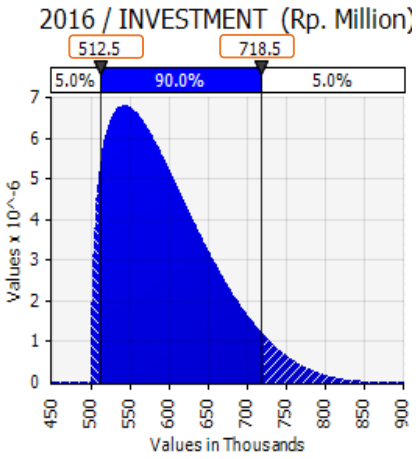

Fig. 4. The probability distribution function (PDF) of the construction cost for stage 2 (2015).

It was identified that there was a 90% probability of the construction activity was distributed at the minimum range of Rp. 512 million and maximum one Rp. 718 million (Fig. 4). Most of the project investment, the minimum value of projected project cost is closer to more-likely value, then the pert distribution is suitable for this project [13],[16].

The project cash flow components were discounted by leveraging the value of a risk-free rate (rf) with normal distribution density function of $\mu = 6.78\%$ and $\sigma = 0.77\%$.

This cash-flow was calculated using the Microsoft Excel add-ins software through the simulation of 10,000 iterations with Latin Hypercube Sampling (LHS) technique as this LHS is very common used in the risk analyzes.

This LHS generates statistical parameter Net Present Values for an initial (Base case) calculation, as follows (Table III and Fig. 5 and 6):

TABLE III: NPV STATISTICS AT THE LOW-RISK TRAFFIC LEVEL

Statistic Parameters	Low-risk NPV, Concession period 35 year (Rp. Million)			
	Year 10 project Operation	Year 20 project Operation	Year 30 project Operation	Year 33 project Operation
Minimum	2,197,001.80	1,608,229.84	1,211,104.85	1,066,007.17
Maximum	933,194.50	61,500.32	2,111,909.20	2,570,397.94
Mean	1,426,644.51	804,977.68	59,403.61	152,295.37
Standard Deviation	159,613.53	209,701.17	374,213.54	433,158.86
Median	1,419,410.33	802,944.11	86,272.84	111,290.03
Mode	1.429.268.98	763.378.52	33.723.01	139.191.19
Left X (P-5%)	1.702.758.16	1.146.628.82	617.541.58	481.967.93
Right X (P-95%)	1.179.845.81	461.127.55	586.91234	924.817.84

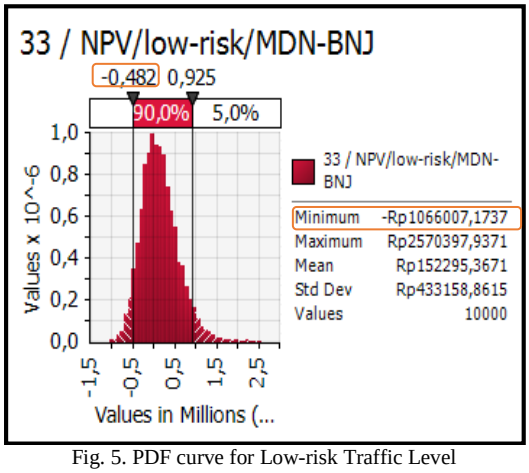

Fig. 5. PDF curve for Low-risk Traffic Level

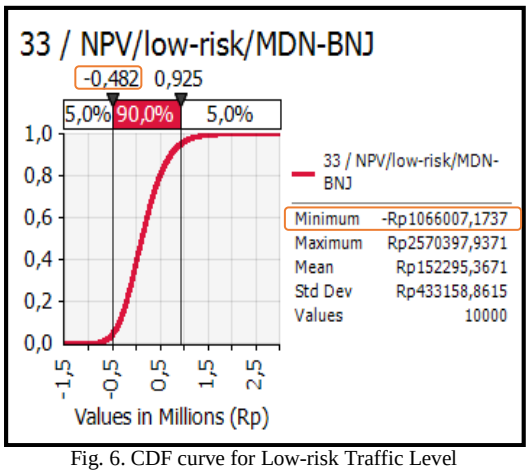

Fig. 6. CDF curve for Low-risk Traffic Level

Based on the simulation results (Fig. 5 and 6) there were identified that the concession period of 35 years, or the end of the operational period (year 33), would yield a negative NPV values (NPV33 minimum was Rp. -1.066 million). The confidence level of the NPV = 0 was 60.6%.There was also a probability of the NPV 39.4% will be less than zero (NPV<0) or negative. Hence, in the perspectives of the investors, this NPV is un-favorable [22], [23]. Thus, the investment of this Medan-Binjai toll road was not attractive and was considered risky.

In order to identify significant risks inherent in the toll road a sensitivity analysis of the project activities was conducted (Table V). However, there were identified 11 sensitive risk variables, this paper highlighted 5 major risks to be put into account (Table IV).

TABLE IV:RISK MITIGATION VARIABLES

No.	Influence variable	Risk Allocations
1	SBI (BI Certificate)	Determined by the market
2	Inflation	Determined by the market
3	Land acquisition	Can be mitigated trough out Local Government Land acquisition task force and community participation approach
4	Vehicle Class I	Determined by the market
5	Construction Cost	Can be mitigated trough out better risk allocation among main project stakeholders; project promoters, constructors, and consultants.

As there were 3 risk variables influenced in this toll-road project (SBI, inflation, and traffic volume) had been determined by the market and it was considered difficult to control, this paper investigated two controllable risks including; land acquisition and construction costs.

There were 3 scenarios developed in this paper (Table V).

TABLE V: SCENARIO FOR PROJECT FEASIBILITY IMPROVEMENT

Scenario	Concession (years)	Government Support and Warranty		Tariff (Rp/km)
		Land acquisition cost	Construction cost	
Base case	Existing duration 35 yrs	-	-	750
Scenario 1	Extended duration 40 yrs	-	-	750
Scenario 2	Existing duration 35 yrs	100%	35%-40%	750
Scenario 3	Extended duration 40 yrs	100%	35%-40%	750

Base case scenario has been presented (Fig. 5 and 6 and Table IV). The results have not attractive to the investor.

This paper developed 3 alternative scenarios as follow; scenario 1 (extended concession period), scenario 2(fully the government supports (GSs) for procuring land and 35%-40% the construction costs), and scenario 3 (extended the concession period up to 40 years with the government support of the land acquisition cost and 40% of the construction costs).

The discussion of these3 main scenarios was presented as follow.

A. Scenario 1

The first scenario (Scenario 1) was conducted to improve the financial feasibility of toll roads Medan-Binjai project by extending the concession period from 35 years to 40 years. The simulation results is tabulated as follow (Table VI):

TABLE VI: SIMULATION OF THE LOW-RISK (NPV) WITH AN EXTENDED CONCESSION PERIOD

Statistic Parameter	Low-risk NPV, Concession period 40 Years (Rp. Million)			
	Year 35 project operation	Year 36 project operation	Year 37 project operation	Year 38 project operation
Minimum	1,085,948.41	1,065,598.54	1,046,236.53	1,028,367.03
Maximum	3,338,008.77	3,578,375.20	3,831,293.44	4,073,088.55
Mean	282,023.83	342,638.26	403,076.70	459,797.01
Median	238,588.58	295,082.77	349,767.33	401,277.40
Left X (P-5%)	411,625.17	378,884.74	349,718.29	316,891.40
Right X (P-95%)	1,131,748.75	1,228,887.50	1,330,673.11	1,428,443.51

The projected NPV (scenario 1) indicated that the extension of the concession period from 35 years to 40 years have not been able to improve the financial feasibility of the Medan-Binjai project significantly.

This was showed that there was a negative NPV value (NPV<0) at 5%. This percentile shows that there was a probability of investment losses was at the level of 5%.

B. Scenario 2

The second scenario (Scenario 2) was conducted to improve the financial feasibility of toll road Medan-Binjai by obtaining government support in procuring land acquisition and sharing some construction costs. After conducting GSs in the form of financial support 35% and 40% of construction costs the project, the project NPV performances were even better (Table VII).

TABLE VII: NPV VALUES WITH THE GOVERNMENT SUPPORT

Statistic Parameter	NPV at low-risk traffic (Rp. Million)					
	40 years concession + 100% land acquisition cost		40 years concession + 100% land acquisition cost + 35% construction cost		40 years concession + 100% land acquisition cost + 40% construction cost	
	Year 33 project operation	Year 38 project operation	Year 33 project operation	Year 38 project operation	Year 33 project operation	Year 38 project operation
Minimum	(476,583)	(394,962)	(15,044)	81,934	36,625	112,170
Maximum	2,716,585	3,846,006	1,412,611	1990,225	3,655,444	4,833,272
Mean	648,452	954,428	1,066,227	1,370,739	1,126,280	1,430,484
Std. Dev	421,827	532,809	415,378	527,776	416,893	528,919
Median	600,452	887,732	1,018,216	1,300,961	1,073,745	1,358,448
Mode	596,794	771,532	1,081,171	1,047,252	1,051,124	1,363,477
Left X (P-5%)	37,781	200,953	485,524	642,113	539,896	699,949
Right X (P-95%)	1,407,029	1,924,340	1,824,788	2,345,285	1,894,495	2,412,185

Based on the Table VIII, it shows that the additional concession periods, combined with 100% of GSs for land acquisition cost and additional project finance form the Government (approximately 35% of the construction costs) may improve project's feasibility performance (NPV) to become financially feasible (Rp. 81.934 million).

C. Scenario 3

Scenario 3 was conducted by increasing the concession period to 40 years with the support about 100% of the land acquisition cost plus an additional 40% of the construction costs of Medan-Binjai toll road, this scenario becomes economically and financially feasible (Table VIII).

TABLE VIII: NPV VALUES WITH THE GOVERNMENT SUPPORT

Statistic Parameters	NPV at low-risk traffic (Rp. Million)
Minimum	112.170,31
Maximum	4.833.272,78
Mean	1.430.484,46
Std Dev	528.919,50
Median	1.358.448,45
Mode	1.363.477,47
Left X (P-5%)	699.949,37
Right X (P-95%)	2.412.185,91

There is no possibility (100%) of the projected NPV will be less than zero (NPV min was Rp. 112.17 million).

Fig. 8 shows that PDF and CDF simulation of 90% yield NPV positive at the range of Rp. 0.540 million to 1.894 million (Fig. 5). Thus, this project condition is considered acceptable for the investors.

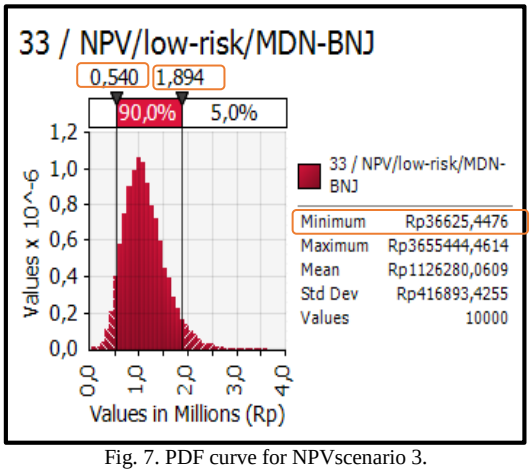

Fig. 7. PDF curve for NPVscenario 3.

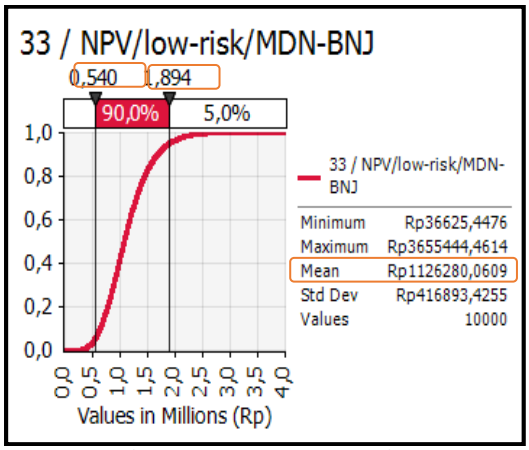

Fig. 8. CDF curve for NPV support about 40% of Construction Costs

Fig. 8 shows that there was 50% probability (more-likely NPV value) of the project would be Rp. 1.126 million.

The typical project cash-flow with pay-back period would be achieved at the year 2033 (Fig. 9).

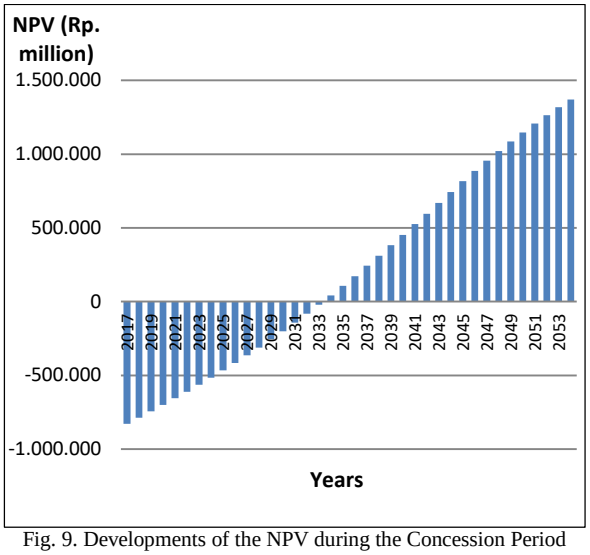

Fig. 9. Developments of the NPV during the Concession Period

The results of this research showed that under the base case condition and scenario 1, with a concession period of 35 years and the initial tariff for Class I vehicles of Rp. 750/km, the project was not financially feasible. The analysis showed that the scenarios 2 and 3 with the availability of the government supports (GSs) may change the feasibility of the projected investment from the condition of not financially feasible to become financially feasible.

Once the toll road construction project takes place and operate properly equipped with high-grade highway (HGH) standards, equipped with better traffic markings, smooth road pavement, there would be an improvement in the transportation system, road traffic safety, as the consequences, there would be a reduction of the number of the traffic accident, and ultimately saving the regional transportation costs [24]- [26].

IV. Conclusion

The base case conditions, with a concession period of 35 years with an initial tariff of class I vehicles Rp. 750 / km, showed that the project was considered not financially feasible as (95%) NPV at the range of Rp. Minus 1.066 trillion to Rp. 2.570 trillion. The sensitivity analyzes show that there were five main risks inherent in this toll project, such as; Certificate of Bank Indonesia (SBI), Inflation rates, Land acquisition, number of Vehicle Class I, and Construction costs for Medan – Binjai at the 2nd year. After conducting stochastic risk mitigation and control by providing the government supports (GSs) in the form of financial support of 35% of the total construction costs, and providing land acquisition costs. Then it is calculated that the projected NPV 90% was positive at the range of Rp. 0.326million to Rp. 1,637 million. It is confirmed that, by reducing risk and uncertainty, this project became financially feasible.

V. Nomenclature

SBI	Bank Indonesia certificate	Rp.
JIBOR	Jakarta Interchange Bank of Rate	point
PDF	probability density function	%
CPF	cumulative probability function	%
VGF	viability gap fund	
BPJT	Indonesia Toll Road Authority	
BUJT	Toll-road Enterprises	

Greek letters

μ	Mean/Average
σ	probability

VI. Acknowledgment

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