Valuation of Mini Hydropower Plant in Indonesia by Considering the Effect of Risk Factors using Value at Risk Approach

Armand Omar Moeis, Muhammad Fakhri Pratama, Andri Dwi Setiawan
Department of Industrial Engineering, Faculty of Engineering,
Universitas Indonesia
Depok, 16424, Indonesia
armand.omar@ui.ac.id, muhammad.fakhri95@ui.ac.id,
a.d.setiawan@ui.ac.id

Abstract

Energy plays a crucial role in developing a country and defining its' living standards though many still use non-renewable energy with high greenhouse gas emissions. Hence, there needs to be a change to new and renewable energy usage. In Indonesia, hydropower has huge potential as new and renewable energy. The government's support also follows in realizing potential. However, risks and uncertainties are involved when investing in new and renewable energy projects, particularly hydropower plants. Therefore, it's crucial to calculate the value of a project while considering the risks involved in the valuation model. The Value at Risk approach using Discounted Cash Flow and Monte Carlo Simulation is viable for calculating the value while accounting for risk. This study aims to discover the value of a mini hydropower plant facility while accounting for risks and uncertainties by discovering the Value at Risk with a 95% confidence level tested through two different scenarios. The results show that the value decreases when faced with risks at a determined confidence level. It also shows the most significant risk affecting the valuation is the water flow rate in the facility's production. Additionally, the significance of the risk and uncertainty factors can increase through different scenarios.

Keywords
Hydropower, Mini Hydropower Plant, Valuation, Risk, Discounted Cash Flow, Monte Carlo Simulation, Value at Risk

1. Introduction
Energy plays a crucial role in developing a country and defining its living standards. The ever-increasing population and industrialization demand for more energy to be used. This rise in demand is rapidly depleting the supply of conventional energy resources (Singh & Singal 2016). In Indonesia, electricity energy demand is showing an increase due to the push of Electric Vehicle adoption by the government according to the Institutes for Essential Services Reform (2021). This agenda increases the consumption for energy, specifically electricity in the country.

Along that line, the rapid growth of energy demand is accompanied by rising climate change issue. One of the factors of climate change issue is the rapid increase of greenhouse gas (GHG), specifically carbon dioxide (CO_2). The government of Indonesia has previously made efforts in increase new and renewable energy usage in the energy mix. However, as of November 2021, the usage of new and renewable energy in the energy mix is only at 11,50% (Agung 2022). This goes to show that there must be more efforts in realizing the potentials of new and renewable energy in Indonesia, such as hydropower energy.

In increasing new and renewable energy usage, hydropower offers a number of benefits and plays a crucial role against climate changes. As a clean and renewable energy, the sources are abundant due to the fact that our earth are made mostly out of water. Though, hydropower plants have large costs of establishing, maintaining and operating. For that reason, a small-scale hydropower plant is a suitable option for a relatively lower cost but powerful plant. A mini hydropower plant has advantages of lower costs than large-scale, power output of 1–10 MW, and the use of small water area that could supply electricity to regional grid.

Hydropower is one of the new and renewable energy that has a large energy potential in Indonesia at 75.091 MW (Prasetyo et al. 2022). This low realization of potential is caused by a major challenge that are slowing the development of the hydropower plant sector. According to Chairman of the Association of Micro Hydropower

Plant Developers Riza Husni, the uncertainty of new and renewable energy tariff and the risky operational costs on risky areas are the two major challenges that caused investors to be hesitant (Mudassir 2021).

High risk and uncertainty could result in unexpected cost overrun. Hence, companies and/or investors must be able to identify quantitative risk using financial modelling that registers and accounts risk factors in the valuation of a mini hydropower plant.

1.1. Objectives

This research aims to tackle the uncertainties of the risks affecting a valuation of a mini hydropower plant by identifying the risks and uncertainties factors that may influence the valuation and value the mini hydropower plant facility using financial modelling. Next, this research aims to value the mini hydropower plant while considering risk and uncertainties factor using Value at Risk approach. By doing this, it will identify the most influential risk and uncertainties factor in the valuation of the mini hydropower plant. It will also identify the financial performance of the mini hydropower plant when faced with risk and uncertainties factor.

2. Literature Review

By moving fresh water from lakes and rivers, hydroelectric power generates energy. Water flows downward due to gravity, and this motion contains kinetic energy. This kinetic energy can then be transformed into mechanical energy, which can subsequently be transformed into electrical energy in hydroelectric power plants (Rathore and Panwar 2021).

Hydropower plants are traditionally broken down into categories based on the capacity and type of schemes used in the facility. In Indonesia, Micro hydropower plants are the smallest plants, with outputs of between 1 and 100 kW. A plant is referred to as a mini hydropower plant if its output is between 100 kW and 1 MW. Mini hydropower plants typically have outputs of between 1 and 10 MW. However, in some nations, the maximum capacity may exceed 30 MW. Large hydropower plants are defined as those with capacity greater than 10 MW or up to 30 MW depending on the country (Badan Standarisasi Nasional 2019). Based on the plant schemes, the types of hydropower plant facilities are Dam and Reservoirs, Run-of-the-River, and Pumped Storage (Breeze 2019). According to Duivendijk (2014), the major components of a hydropower plant consist of forebay, intake structure, penstock, turbines, generator, and power house.

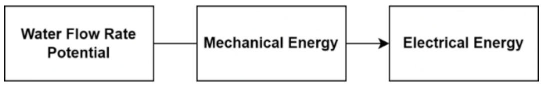

Figure 1. Basic Principle of Hydropower Plant Diagram

The fundamental basis of hydropower generation is the water potential is changed into mechanical energy by turning the turbine, and mechanical energy is then further transformed into electrical energy by employing generators. Figure 1 shows the basic principle of the production.

$$P = \rho \cdot g \cdot Q \cdot H_n \cdot \eta_T \cdot \eta_G \quad (1)$$

In the production of electricity power P (in Watt) in a hydropower plant, the height the water must fall, the net height H_n and the rate of flow Q (in m^3/s) are the two main factors that determine how much electrical energy may be produced from a water source. The production of electricity is also affected by the factor of turbine efficiency η_T, and the generator efficiency η_G. Lastly, the production is affected by the environmental factors of gravity of 9,8 m/s^2 and water density ρ of 1.000 kg/m^3 which generally turns the output in to kilowatt.

$$E = (P - Losses) \cdot t \quad (2)$$

Equation 2 shows the formula of the electricity generated E (in kWh) on a time period t (in hour) affected by production losses approximately 0.15% in losses for a mini hydropower plant facility. The calculation of electricity generated in a hydropower plant is usually calculated monthly with a yearly total recap of electricity generated (Duivendijk 2014).

According to Breeze (2019), small and mini hydropower plants are determined by regulatory frameworks as much as they are by inherent architectural attributes. In Indonesia, mini hydropower plants are those that fall under the category of new renewable generation and are under a specific size, usually 1-10 MW (Badan Standarisasi Nasional 2019). A mini hydropower scheme will result in a considerably simpler plant design.

In the valuation of an operating mini hydropower plant, there are risks that can affect the model. The risks consist of economic risk and electricity generation. According to Cunha and Ferreira (2014), the mini hydropower plant may see an increase in O&M costs as a result of changes in the market price and economic conditions. This kind of risk develops when there's a chance that the project won't perform well economically, even though it's supported by sound technology and carrying out its intended functions

In the electricity generation risk, the associated variable is the water flow rate (Q), a variable that affects the main production of the power plant (Roy et al. 2014). It determines how much electricity is produced during a set time period. Water flow rate (Q) is included as a risk due to the fact that a river flow rate is affected by environmental risk which includes both rain intensity and water elevation that has significant positive effect in the water flow rate (Rahardjo et al. 2021)

3. Methods

This research will be focusing on the techno-economic aspect of the facility. Techno-economic analysis (TEA) is a research technique that analyzes and assesses the economic implications and effects of technology on a subject. The general techno-economic model is a combination of integrated process and cost model that typically contains components of process design, process modeling, equipment size, capital cost estimation, and operating cost estimation (Burk 2018).

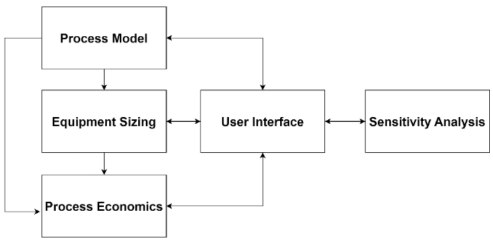

Figure 2. General Techno-Economic Framework

Figure 2 shows the general techno-economic framework. In a techno-economic valuation, an analysis on the economics of the project must be conducted. This analysis is used as the foundation of the decision-making process for stakeholders/investors to invest in the project. Traditional methods for investment appraisal are based on the DCF, as it is simple to use and understand. The value of the DCF method is based on the cash flow of the investment project where cash flows are discounted to the current value, and then converted into the present value (PV). Typically, the value is represented by the net present value (NPV). The DCF components consist of:

1. Cash Outflows
   The cash outflows consist of Capital Expenditure and the Operational and Maintenance Cost. For existing facilities, O&M cost are usually included in the financial statement.

2. Cash Inflows
   Cash inflow is the revenue generated. In Indonesia, the energy is priced using every kWh energy produced and it is sold to regulators or national electricity company (PLN). Usually, a company has made a Power Purchase Agreement (PPA) with the regulator, as in PT. PLN, the tariff will be based on the PPA. The revenue of the mini hydropower plant is calculated as in Equation 3.
   $$Revenue = Tariff\ x\ E_o \tag{3}$$
   E_o = energy output from the mini hydropower plant into PLN grid

3. Free Cash Flow
   Free cash flow (FCF) indicates if the operation results in a positive cash flow (surplus) or negative cash flow (deficit). To retrieve the net cash flow value, it is needed to calculate Earnings Before Interest, Depreciation, and Amortization (EBITDA), Earnings Before Interest (EBIT), Earning Before Tax (EBT), and Net Profit shown in Equation 4-8.
   $$EBITDA = Revenue - C_{OM} \tag{4}$$
   $$EBIT = EBITDA – Depreciation – Amortization \tag{5}$$
   $$EBT = EBIT – i \tag{6}$$
   $$Net\ Profit = EBT - Tax \tag{7}$$
   $$\boldsymbol{Free\ Cash\ Flow} = Net\ Profit + D\&A + C_i - \text{CAPEX} - \text{CWC} \tag{8}$$
   C_{OM} = Operation and Maintenance Cost $\quad i$ = Interest rate

CWC = Changes in Working Capital

4. Discount Rate

Discount rate is the rate that affects the cash flow with the effects of time value of money principle. The most traditional and widely used discount rate used for capital budgeting is the Weighted Average Cost of Capital (WACC) (Damodaran 2012).

$$WACC = \frac{E}{V} \cdot R_e + \frac{D}{V} \cdot R_d \cdot (1 - \tau) \tag{9}$$

$E = Equity$ $D = Debt$ $V = Total\ Equity\ and\ Debt$

$R_e = Cost\ of Equity$ $R_e = Cost\ of Debt$ $\tau = Corporate\ Tax\ (\%)$

$ROE_e = Expected\ Return\ on\ Equity\ (\%)$

The valuation from the financial modelling can be achieved by using DCF to obtain the Net Present Value. Net Present Value is a value retrieved from discounting the sum of the Free Cash Flow (FCF) for a time period using the stated discount rate i_d. In the valuation of a company, NPV can be used as a metrics of valuation. The NPV is calculated using Equation 10.

$$NPV = \sum_{i=1}^{n} \frac{FCF_t}{(1+i_d)^t} - FCF_0 \tag{10}$$

Approximations are used when an assumption must be made to complete the Discounted Cash Flow model. The most generally used approximation method are by looking at the previous historical data and using moving average. In this research, the weighted moving average will be used. A moving average is a method used to forecast values based on average of the data of previous n of periods. Since more recent data is more pertinent than older data, a weighted moving average gives more weight to more recent data points.

$$\frac{\sum_{i=1}^{n} W_i * D_i}{\sum_{i=1}^{n} W_i} \tag{11}$$

$W = Weighting\ Factor$ $D = Data\ Value$ $i = Period$

In calculating the effect of the risk factors into the model, the Value at Risk approach is used. VaR method purpose is the quantification of the potential losses under normal market conditions in the time horizon of the portfolio at a given confidence level (Dempster 2010). Generally, Value at Risk refers to the potential loss for a relatively short period of time and it is much used in the financial sectors. VaR analysis can be calculated with the formula below.

$$VaR = \inf\{z \in R : \Pr(X \geq x) \leq 1 - \propto\} \tag{12}$$

$\propto$ = *confidence level*
$\Pr(X \geq x)$ = *cumulative probability distribution function from X*

In this research, VaR is referred to the NPV affected by maximum potential loss in a long period of time. Ye et al. (2000) stated in their research that the goal of the NPV-at-risk method is the project's NPVs will exceed, with the probability corresponding to the specified confidence level. It entails calculating the discount rate and creating a cumulative distribution of potential NPVs. The following decision criteria can be derived from the definition of NPV-at-risk: If the NPV-at-risk at the provided confidence level is greater than zero, the project is acceptable with a confidence level of $1-\propto$; otherwise, it is unsuitable. (Ye et al. 2000). The NPV-at-risk for this research can be calculated using the equation below.

$$NPVaR = mean\ NPV - Z(\propto)\sigma \tag{13}$$

$Z(\propto)\sigma = number\ of\ units\ of\ standard\ deviation\ corresponding\ to$

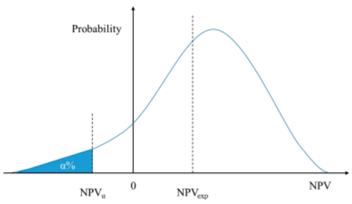

Figure 3. NPVaR Confidence Level

In applying the Value at Risk, one of the methods to input the risk factor as the variable is the Monte Carlo simulation method. Monte Carlo method defined the uncertain variables into random variables using random sampling that yields random outcomes (Thomopoulos 2013). In a Monte Carlo simulation, input variables are recognized as random variables with uncertain values that are independent of other input variables and unaffected by variations in time (Brandimarte 2014). The steps to conduct VaR in the Monte Carlo method are (Jorion 2007):

1. Mark the value of the base scenario by constructing a deterministic model with a time horizon
2. Define and measure the distribution of the risk factors
3. Set the confidence level prior to the simulation
4. Conduct the Monte Carlo simulation with *n* iterations
5. Conduct the sensitivity analysis and report the results

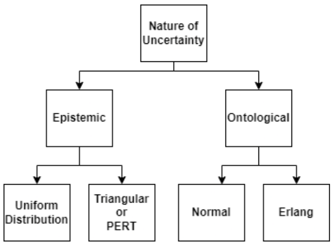

Figure 4. Nature of Uncertainty

The type of probability distribution for the random variable can obtained through expert judgement, literature review, or by conducting a fitting test from historical data (Brandimarte 2014). According to Salling and Leleur (2016), the nature of uncertainty is categorized into epistemic, where it caused by the lack of knowledge, and ontological, where it is caused by inherent variability within the system.

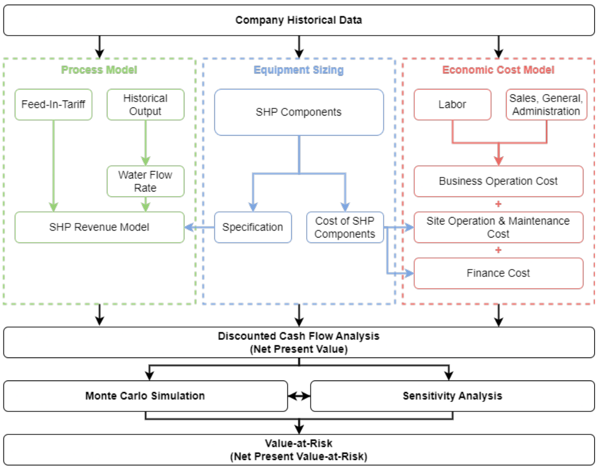

Figure 5. Techno-Economic Valuation Framework for SHP

Following the TEA framework, in Figure 5 the valuation will be conducted as an already operating mini hydropower plant is being analyzed. The risk will also be considered in the valuation.

Table 1. Mini hydropower Plant Specification

Facility Category	**Specification**
Type	Run-of-the-River
Capacity	<10 Megawatt (MW)
Location	Eastern Indonesia
Turbine	Francis Turbine
Turbine Efficiency	90%

Generator Efficiency	93%
Net Head (Hn)	94,5 m

The data obtained from the company historical data as a financial statement, specification, legality, and another supporting document. The specification of the facility can be seen in Table 1.

Table 2. Water Flow Rate Data (Q)

Description	**Value (m^3/s)**
Mean	1,13
Standard Deviation	0,48

From the previous electricity output data, the water flow rate (Q) data can be obtained by using Equation 1 and 2 to reverse-calculate the production model. The mean and standard deviation of the water flow rate is obtained as shown in Table 2. This shows a trend of the production for forecasting future cash flows.

Table 3. Historical Information of the Mini Hydropower Plant

Category	Component	**2019**	**2020**	**2021**
Free Cash Flow	-	**Rp 1.000.000.000**	**Rp 1.250.000.000**	**Rp 2.600.000.000**

Table 4. Tax Structure

Description	**Value**
Income Tax	2%
Tax from Operation	1,5%
Property Tax	10%

The financial information from previous periods is obtained directly from the company in a form of financial statement. The historical data that tracks back from 2019 until 2021 shown as free cash flow that will be used in the DCF model are stated in Table 3. The historical data is replaced with a dummy data close to the real data due to previous agreements. The list of the tax in the company are stated in Table 4.

Table 5. Feed-in-Tariff

Description	**Value (IDR/kWh)**
Feed-in-Tariff	1.100

The Power Purchase Agreement (PPA) is an agreement between the company that operates the facility and the company who will purchase the electricity generated, as in PT. PLN as the central supplier of electricity in Indonesia. According to the PPA of 2016, any amount of electricity generated at the facility will be purchased at a determined feed-in-tariff for each month. The determined feed-in-tariff are shown in Table 5.

Table 6. Production Assumption

Description	**Value**
Electricity Output	7.623.047 kWh on year 1
Growth	1%
Feed-in-tariff	1.100 IDR/kWh

By looking at the historical data of the financial statement, assumptions can be made by using approximation method of Weighted Moving Average. The assumptions in Table 6 are made for the electricity production. The feed-in-tariff of the electricity is based on the 'Power Purchase Agreement' previously made by the company with PT. PLN. The operational expenditure represents the cost it takes to produce electricity and keeping the facility up and running. Table 7 shows the value of the cost variable for each period.

Table 7. Detailed Cost Assumptions per Period

No	Site Operation (IDR/kWh)	Business Operation (IDR/kWh)	Depreciation (IDR/kWh)	Finance Cost (%)
1	187,87	561,44	321,09	32,05%
2	167,83	558,91	322,38	32,76%
3	168,74	553,80	316,85	33,10%
4	171,63	556,78	319,40	32,81%
5	170,03	556,14	319,05	32,90%
6	170,35	555,97	318,80	32,90%
7	170,46	556,16	318,98	32,89%
8	170,35	556,09	318,93	32,89%
9	170,38	556,09	318,93	32,89%
10	170,38	556,10	318,94	32,89%
11	170,38	556,10	318,93	32,89%
12	170,38	556,10	318,93	32,89%
13	170,38	556,10	318,94	32,89%
14	170,38	556,10	318,94	32,89%
15	170,38	556,10	318,94	32,89%

The operational expenditure represents the cost it takes to produce electricity and keeping the facility up and running. It consists of Site Operation and Business Operation that includes into the Operation and Maintenance Cost component. Depreciation must be included as the capital expenditure as it consists of fixed assets an intangible asset. As for finance cost, it must be included into the calculation of to complete the component of the model although it will be adjusted to obtain the Free Cash Flow. Table 7 shows the value of the cost variable for each period.

Table 8. WACC Component

Description	Value
WACC	7,01%

WACC is the most widely used discount rate for capital budgeting and DCF model as it accounts the company's debt equity, corporate tax rate, interest rate, and interest expenses shown in Table 8 and can be calculated by using the aforementioned Equation 9.

Table 9. DCF Parameter

Description	Parameter
Valuation Indicator	NPV
Time Period	15 Years
Discount Rate	WACC (7,01%)

In building the Discounted Cash Flow model, the parameter in Table 9 will be used along with the revenue and cost structure stated in Table 7. The Free Cash Flow, which will be used in calculating the Net Present Value of the mini hydropower plant, are shown in Table 10.

Table 10. Free Cash Flow and Cumulative of DCF Model

Period	Free Cash Flow	Cumulative
0	Rp 2.641.384.453	Rp 4.953.512.046
1	Rp 2.214.946.531	Rp 7.168.458.577
2	Rp 2.514.230.756	Rp 9.682.689.333
3	Rp 2.577.300.895	Rp 12.259.990.228
4	Rp 2.540.463.854	Rp 14.800.454.082
5	Rp 2.592.182.418	Rp 17.392.636.500
6	Rp 2.616.581.989	Rp 20.009.218.490
7	Rp 2.640.181.980	Rp 22.649.400.469
8	Rp 2.669.272.516	Rp 25.318.672.985
9	Rp 2.696.177.422	Rp 28.014.850.408
10	Rp 2.723.709.721	Rp 30.738.560.129
11	Rp 2.751.756.974	Rp 33.490.317.103
12	Rp 2.779.902.815	Rp 36.270.219.918
13	Rp 2.808.381.274	Rp 39.078.601.192
14	Rp 2.837.149.572	Rp 41.915.750.764
15	Rp 2.866.194.311	Rp 44.781.945.075

In conducting the Value at Risk, two scenarios will be used in the research, normal and adjusted inflation scenario. Normal scenario is a scenario where the condition of the economic simulation period is assumed to stay normal without influence of any other conditions and variables. The adjusted inflation scenario is a scenario where the value of O&M cost structure assumptions is adjusted considering 1,5% inflation condition. Scenarios are intended to show the effects of the risk factors in different situation.

Table 11. Risk and Uncertainty Registers

Risk and Uncertainty	**Distribution**	**Source**	**Assumption Scenario**			
			Normal Condition		**Adjusted 1.5% Inflation Rate**	
Financial						
O&M Cost						
Site Operation	Triangular	Cunha, J. et al 2014	Min =	167,83	Min =	171,33
			Most Likely =	171,33	Most Likely =	190,54
			Max =	187,87	Max =	211,03
Business Operation	Triangular	Cunha, J. et al 2014	Min =	553,80	Min =	556,53
			Most Likely =	556,53	Most Likely =	586,64
			Max =	561,44	Max =	617,66
Energy Output						

Water Current	Log-Normal	Roy, N. C. et al 2014	Mean=	1,13	Mean =	1,13
			Std. Dev=	0,48	Std. Dev =	0,48

Through expert and literature benchmark, risk registers variable is identified along with the distributions. The risk variables are divided into two categories, financial and engineering risk. Financial risk affects the cost factors of the cash flow and engineering risk affects the production of the mini hydropower plant facility. The risk and value in IDR/kWh are stated in Table 11.

Table 12. Confidence Level and Number of Iterations

Description	Value
Confidence Level	95%
Monte Carlo iterations	10.000

The Value at Risk (VaR) method includes the components of risk registers and a simulation method to calculate the potential losses when the model is affected by the risks. As aforementioned, the Monte Carlo Simulation will be used to calculate the Net Present Value at Risk where the confidence level and number of iterations are shown in Table 12. Along with the simulation, the Spearman Ranking Correlation Coefficient will be calculated to discover the sensitivity between the risk variables and output of NPV in the simulation. The ranking will be conducted accordingly together during the Monte Carlo Simulation.

4. Results and Discussion

Table 13. Net Present Value

Description	Value
Net Present Value	Rp 27.242.932.483

From the Discounted Cash Flow model, a Net Present Value is obtained using Equation 10. The Net Present Value represents the present value of the company's projected cash flow for a determined period of 15 years. Considering the model is in normal condition and follows the previously determined cost structure assumptions, Table 13 shows the NPV of the company.

The NPVaR is obtained after conducting Monte Carlo Simulation with 10.000 iterations inputting the risk registers one at a time and altogether on scenario 1 and scenario 2. The result of each simulation is shown in Figure 6, 7, 8 and 9 and in Table 14 and 16.

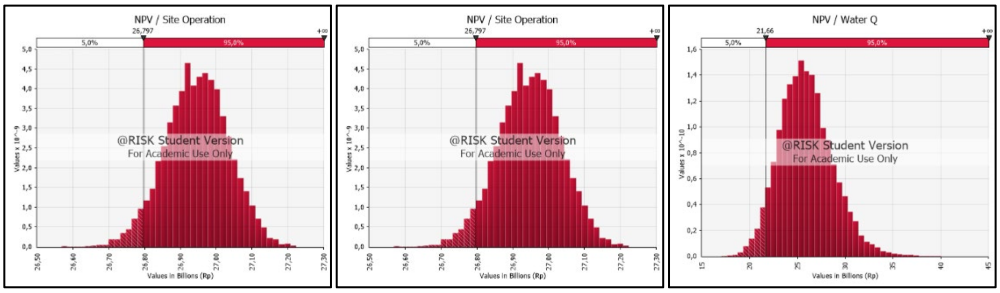

Figure 6. NPV affected by each Risk Factors in Scenario 1

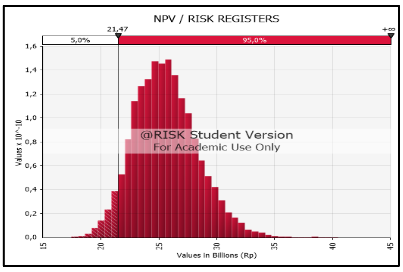

Figure 7. NPV affected by Combined Risk in Scenario 1

Table 14. NPVaR and Value Loss in Scenario 1

Description	**NPVaR**	**Value Loss**
Site Operation	Rp 26.797.443.766	1,64%
Business Operation	Rp 27.149.818.614	0,34%
Water Flow Rate	Rp 21.657.281.661	20,50%
Combined Risk	Rp 21.467.805.114	21,20%

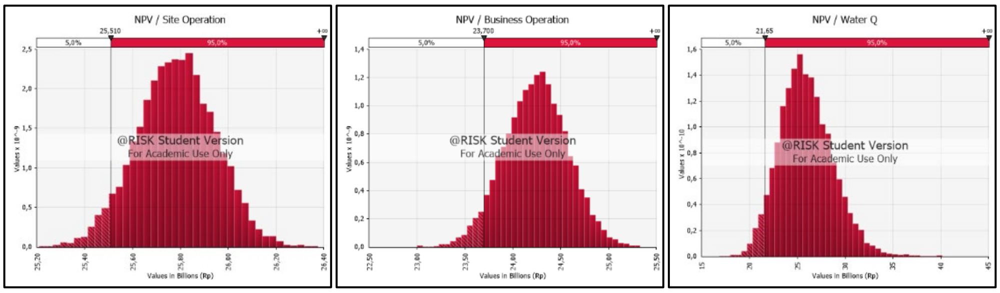

Figure 8. NPV affected by each Risk Factors in Scenario 2

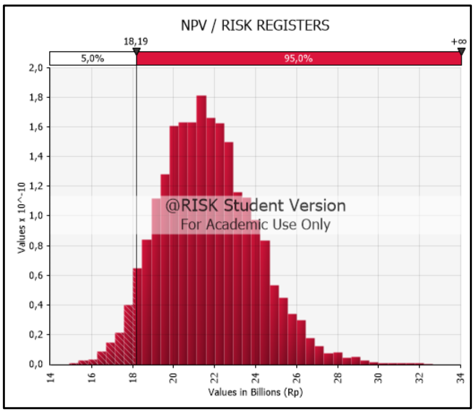

Figure 9. NPV affected by Combined Risk in Scenario 2

Table 15. NPVaR and Value Loss in Scenario 1

Description	**NPVaR**	**Value Loss**
Site Operation	Rp 25.509.525.479	6,36%
Business Operation	Rp 23.699.507.767	13,01%
Water Flow Rate	Rp 21.646.560.117	20,54%

Combined Risk	Rp 18.193.287.260	33,22%

Table 16. Comparison of Rank Correlation with NPVaR

Risk Registers	Normal Condition	Adjusted Inflation
Water Flow Rate	0,351	0,353
Business Operation	-0,011	-0,056
Site Operation	-0,025	-0,039

The Spearman's Rank Correlation Coefficients are also retrieved when conducting the simulation. Table 16 shows the rank value when related to the NPVaR.

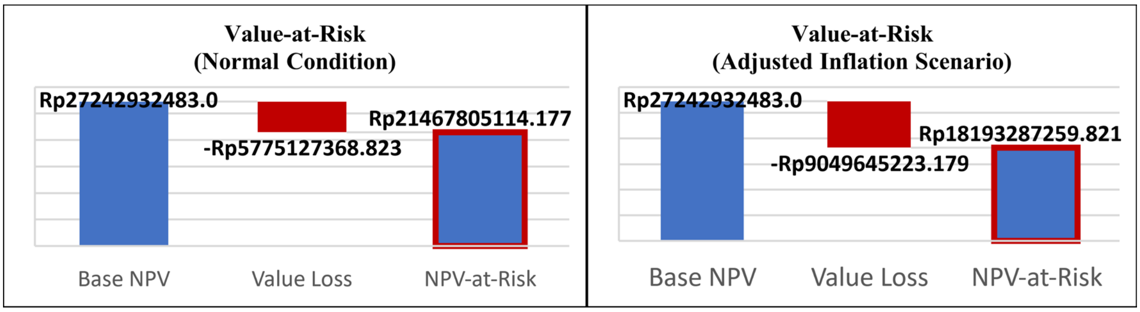

Figure 11. Total Value Loss and NPVaR of Each Scenario

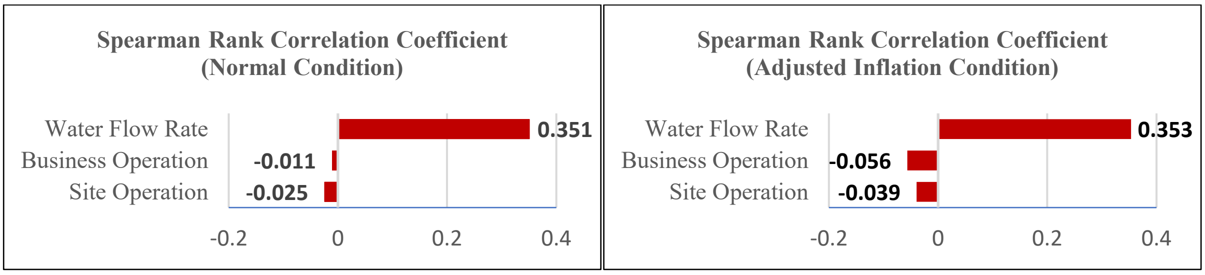

Figure 12. Correlation Coefficient for Risk Variables on Each Scenario

Figure 11 shows the difference between the NPV of the base model and the NPV-at-Risk. On normal condition, the Monte Carlo Simulation considering the risk registers on the financial model results in a value loss of Rp5.775.127.369 or 21,20%. On the second scenario, it results in a value loss of Rp9.049.645.223 or 33,22%. The Value at Risk analysis has shown that considering risks in a valuation will result in potential losses and lower valuation. From Figure 12, it revealed the most significant risk, the Water Flow Rate (Q). Additionally, there is a negligible increase on the coefficient in different scenario meaning that the result is concurrent between the two scenarios.

5. Conclusion and Recommendation

After conducting this research, the risk factors in the valuation of mini hydropower plants can be categorized into financial (O&M Cost) and production (Water Flow Rate) risks. The mini hydropower plant's base valuation using the Discounted Cash Flow method is Rp 27.242.932.483 and affected by risk the valuation is Rp 21.467.805.114, 21,20% lower in value on normal conditions, and Rp 18.193.287.260, 33,22% lower in value on adjusted inflation condition. The Water Flow Rate (Q) is the most significant risk factor in both scenarios. Lastly, faced with the risk factors, the valuation of the mini hydropower plant is lower than the base value, with a 95% confidence level on any scenario simulated in this research.

After conducting this research, the recommendation from the author includes more in-depth research using Value at Risk methodology on other mini hydropower plant facility to discover the potential loss in value when faced with risk factors. Furthermore, this research can be further developed to determine the mitigation step after retrieving the valuation when faced with risk factors in a mini hydropower plant facility. Lastly, the framework and methodology in this research can be used to develop a valuation of other projects and facilities.

References

Agung, F., Bauran EBT Pada tahun 2022 Bakal Menurun, Begini Penjelasan Kementerian ESDM, January 18, 2022, Available: https://industri.kontan.co.id/news/bauran-ebt-pada-tahun-2022-bakal-menurun-begini-penjelasan-kementerian-esdm, Accessed on October 4, 2022.

Badan Standarisasi Nasional, Klasifikasi pembangkit listrik tenaga air, *SNI 8396:2019,* Jakarta, Indonesia: Kantor Badan Standarisasi Nasional, December 17, 2019.

Brandimarte, P., *Handbook in Monte Carlo Simulation: Applications in Financial Engineering, Risk Management, and economics*, John Wiley & Sons, 2014

Breeze, P., *Power Generation Technologies*, Kidlington: Newnes an imprint of Elsevier, 2019

Burk, C., Techno-economic modeling for new technology development, July 17, 2018, Available: https://www.aiche.org/resources/publications/cep/2018/january/techno-economic-modeling-new-technology-development, Accessed on December 19, 2022.

Carrasco, J. L., Pain, A., & Spuhler, D., *Hydropower (small-scale)*, Available: https://sswm.info/water-nutrient-cycle/water-distribution/hardwares/water-network-distribution/hydropower-%28small-scale%29, Accessed on October 4, 2022.

Charnes, J. M., *Financial modeling with Crystal Ball and Excel*, John Wiley & Sons, Inc, 2012.

Cunha, J., & Ferreira, P. V., A Risk Analysis of Small-Hydro Power (SHP) Plants Investments, *International Journal of Sustainable Energy Planning and Management*, *2*, 47–62, 2014.

Damodaran, A., *Investment valuation: Tools and techniques for determining the value of any asset*, Wiley, 2012.

Dempster, M. A. H., *Risk management: Value at risk and beyond*, Cambridge University Press, 2010.

Duivendijk, J. V., *Water Power Engineering principles and characteristics*, Delft: Technische Universiteit, Faculty of Civil Engineering and Geosciences, 2004.

Indonesia, Enhanced Nationally Determined Contribution Republic of Indonesia 2022, *Nationally Determined* Contribution, 2022, Available: https://unfccc.int/documents/615084, Acessed on October 4, 2022.

Institute for Essential Services Reform, Indonesia Energy Transition Outlook 2022. Available: https://iesr.or.id/en/pustaka/indonesia-energy-transition-outlook-ieto-2022, Accessed on October 4, 2022.

Jorion, P., *Value at risk: The new benchmark for managing financial risk*, New York: McGraw-Hill, 2007.

Kim, Y., & Lee, E. B., A probabilistic alternative approach to optimal project profitability based on the Value at Risk, *Sustainability*, *10*(3), 747, 2018.

Mayes, T. R., *Financial Analysis with Microsoft Excel*, Cengage, 2021.

Mudassir, R., Kementerian ESDM target Pembangunan 31.859 stasiun pengisian Kendaraan Listrik Pada 2030, September 21, 2021, Available: https://ekonomi.bisnis.com/read/20210921/44/1444949/kementerian-esdm-target-pembangunan-31859-stasiun-pengisian-kendaraan-listrik-pada-2030, Accessed on October 4, 2022.

Prasetyo, A., Susanto, I., & Mada, K., *JEJAK DAN LANGKAH ENERGI TERBARUKAN INDONESIA,* Kompas, 2021.

Rahardjo, I. A., Suyitno, Subekti, M., Gunawan, W., Wijayanto, R. P., Mahir, I., & Sakirah., The effects of rain intensity and water elevation with energy productivity of Kracak Hydro Power Plant, bogor regency – west java, *Journal of Physics: Conference Series, 2111*(1), 012044, 2021.

Rathore, N. S., & Panwar, N. L. (2022). *Fundamentals of Renewable Energy*. Abingdon, Oxon: CRC Press.

Roy, C. N., Roy, N. G., Pandey, K. K., & Gupta, S., Risk Analysis for Operational Stage Small Hydro Power Projects of Uttarakhand: A Stochastic Approach Using Monte Carlo Simulation, July, 2014, Available: https://www.ijltemas.in/DigitalLibrary/Vol.3Issue7/243-250.pdf, Accessed on December 19, 2022,

Salling, K., & Leleur, S., Assessment of transport infrastructure projects by the use of Monte Carlo Simulation: The CBA-DK model, *Proceedings of the 2006 Winter Simulation Conference*, 2006.

Singh, V. K., & Singal, S. K., Operation of hydro power plants-A Review, *Renewable and Sustainable Energy Reviews*, *69*, 610–619, 2017.

Thomopoulos, N. T. (2013). Essentials of monte carlo simulation. https://doi.org/10.1007/978-1-4614-6022-0

Ye, S., & Tiong, R. L., NPV-at-risk method in Infrastructure Project Investment Evaluation, *Journal of Construction Engineering and Management*, *126*(3), 227–233, 2000.

Biographies

Armand Omar Moeis, Dr. is an assistant professor in the Industrial Engineering Department, Universitas Indonesia. His research focuses mainly on Maritime Logistics, with minor research focuses on Renewable Energy techno-economic policy. He especially deploys methods based on System Dynamics, Simulation Gaming, and Policy Analysis.

Muhammad Fakhri Pratama is an Industrial Engineering Department student at Universitas Indonesia. He is currently in the final year of his studies, using this research as a thesis for a requirement to receive a bachelor's degree in engineering. He is interested in Industrial Simulation, Engineering Economy, and Risk Management.

Andri Dwi Setiawan, Dr. is a lecturer at the University of Indonesia. His research interests are in decision under Uncertainty and Risk, Energy Management, Renewable and Sustainable Energy Systems, Systems Engineering, Support and Logistics for Systems Engineering, Technology Policy Modeling with System Dynamics.