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Computation Application: Techno-Economic Analysis on the Production of Magnesium Oxide Nanoparticles by Precipitation Method

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ABSTRACTS

This study aims to analyze the feasibility of a project for the production of magnesium oxide nanoparticles using precipitation methods on a large scale. The feasibility analysis of this project was determined using an evaluation from an economic and engineering perspective. Evaluation from an engineering perspective is determined by the evaluation of the initial factory design and stoichiometric calculations. Meanwhile, the evaluation from an economic perspective is determined by several parameters, such as Payback Period, Gross Profit Margin, Cumulative Net Present Value, etc. The analysis results show that the production of magnesium oxide nanoparticles using the precipitation method can be carried out on an industrial scale. In this project, 11,250 kg of magnesium oxide nanoparticles were obtained per day, and the total profit earned was 1,881,184,752.91 USD in 10 years. Payback Period analysis shows that the investment will be profitable after more than three years. To ensure project feasibility, projects are estimated from ideal to worst-case conditions in production, including salary, sales, raw materials, utilities, and external conditions such as taxes.

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I. INTRODUCTION

Magnesium oxide (MgO) is one of the most useful ceramic materials because it has a high melting temperature (around 2800oC) (Tai *et al.*, 2007). Magnesium oxide is commonly used for catalysis and remediation of toxic wastes or as an additive in paints (Ding *et al.*, 2001). Magnesium oxide also has good additive properties, which can be applied to high fuel oils (Agrawal *et al.*, 2015). Magnesium oxide is needed in industrial, environmental, and health products. Magnesium oxide is used industrially as a catalyst in many applications includes organic carbonate synthesis catalysts (Kantam *et al.*, 2007). Another application of magnesium oxide is in steel manufacture because it is highly corrosion-resistant (Z Zhang *et al.*, 2015).

Magnesium oxide nanoparticles can be produced through several synthesis methods. Synthetic methods that can be used in the synthesis of magnesium oxide nanoparticles include combustion (Balakrishan *et al.*, 2020), synthesis of plant extracts (Essien *et al.*, 2020), sonochemical synthesis (Yunita *et al.*, 2020), solid-state synthesis (Zhang *et al.*, 2019), sol-gel synthesis (Taghavi *et al.*, 2018), and precipitation (Alvionita and Astuti, 2017). Of the several methods, the precipitation method is one of the most preferred methods for the synthesis of magnesium oxide nanoparticles because it allows control over the particle size so that the time required is relatively short and can be carried out at low temperatures (Alvionita and Astuti, 2017). Therefore, the precipitation method was chosen as the method to be analyzed through economic evaluation in producing magnesium oxide on an industrial scale. Fig. 1 shows a diagram of the manufacture of magnesium oxide using the precipitation method.

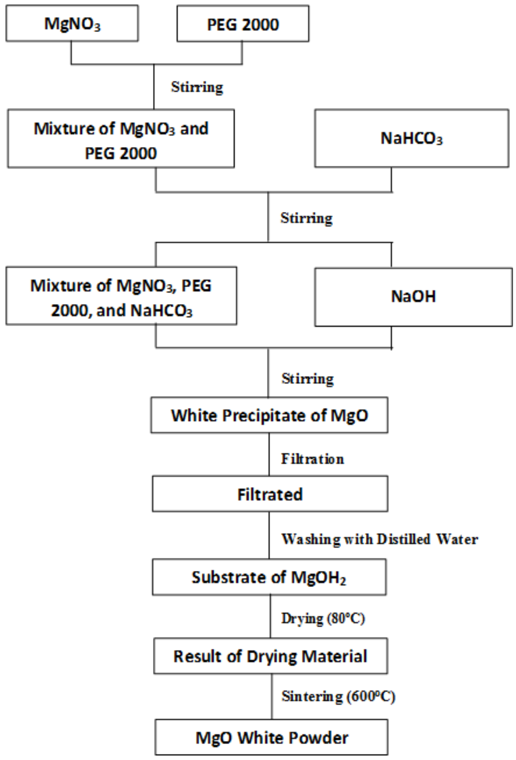

Fig. 1. Schematic of the process of making magnesium oxide nanoparticles using the precipitation method.

Previously, there have been many studies describing the process of synthesizing magnesium oxide nanoparticles using the precipitation method. However, there is no study that examines the economic evaluation of the synthesis of magnesium oxide nanoparticles using precipitation methods on an industrial scale. Therefore, the aim of this study is to analyze the economic evaluation in the project of manufacturing magnesium oxide nanoparticles using precipitation methods on an industrial scale. This evaluation is carried out from two perspectives, namely the engineering perspective and an economic perspective.

From the engineering perspective, it can be determined using stoichiometric calculations and evaluation of the initial factory design. Meanwhile, from the economic perspective it is determined by several parameters to determine the benefits of the project to be established, namely Gross Profit Margin, Payback Period, and Cumulative Net Present Value under certain conditions (Nandiyanto et al., 2018).

2. METHODOLOGY

In this study, selected research on the manufacture of magnesium oxide nanoparticles was conducted as the main reference (Alvionita and Astuti, 2017). In the economic evaluation, an analysis of the prices of equipment, utilities, and available raw materials for the manufacture of magnesium oxide nanoparticles was obtained from the online shopping site Alibaba. The price of electricity per kWh is obtained based on data on electricity costs from the State Electricity Company. Then, the data is calculated using Microsoft Excel with reference to several parameters, such as Gross Profit Margin, Payback Period, and Cumulative Net Present Value of various cost variables. Calculations were carried out based on the literature (Nandiyanto *et al.*, 2018; Ragathita *et al.*, 2019; Nassar *et al.*, 2017; Garret, 2012). To obtain the results of this study, calculations were carried out using several formulas such as:

- Gross Profit Margin (GPM) is the first analysis to determine the level of profitability of a project. This analysis is estimated by reducing the cost of selling the product with the cost of raw materials.

$$GPM = \Sigma_{tr=1}^{tr} (S \cdot \eta - RM) PC \cdot Q \cdot t \quad (1)$$

  S is total sales, RM is total raw materials, PC is production capacity, Q is capacity of raw materials included and used in the process (kg/hour), and t is production time.

- Payback Period (PBP) is a calculation to predict the length of time required for an investment to return the initial capital expenditure. In short, the Payback Period is calculated when the Cumulative Net Present Value reaches zero.
- Cumulative Net Present Value (CNPV) is the total value of Net Present Value (NPV) from the beginning of the factory construction until the end of the factory operation.

$$NPV = \Sigma_{tr=1}^{tr} \left(\frac{R_t}{(1+i)^{tr}}\right) \quad (2)$$

  Rt is the net cash inflows minus outflows over a period of tr, i is the discount rate that can be obtained in alternative investments, tr is the project time (in a year), and Tr is the last year of the project.

3. RESULTS AND DISCUSSION

3.1. ENGINEERING PERSPECTIVE

In this study, several assumptions were used based on the illustration of the process of making magnesium oxide nanoparticles shown in Fig. 2. Based on these assumptions, it shows that by increasing the project through stoichiometric calculations, the production of magnesium oxide nanoparticles is approximately 1,500 kg in one cycle. The assumptions are: (1) all raw materials are upgraded to 10,000 times the laboratory scale in the literature. (2) The materials used are of high purity. (3) PEG 2000, magnesium nitrate, sodium bicarbonate, and sodium hydroxide were reacted and produced magnesium oxide nanoparticles with a purity of 98%. (4) Loss during the process of moving, drying, and collecting products is 2%.

There are several assumptions used to ensure economic analysis. This assumption is needed to analyze and predict several possibilities that occur during the project. These assumptions are: (1) All analyzes use USD (1 USD = 14,312 rupiah); (2) Based on commercially available prices, the prices of PEG 2000, magnesium nitrate, sodium bicarbonate, and sodium hydroxide are 2.00 USD/kg, 2.00 USD/kg, 0.25 USD/kg, and 0 ,90 USD/kg. All materials are estimated based on stoichiometric calculations; (3) When project land has been purchased, land costs are added at the beginning year of the factory construction and recovered at the end of the project; (4) Total Investment Cost (TIC) is calculated based on Lang Factor (Garret, 2012); (5) Total Investment Cost is prepared in at least two steps. The first step is 40% in the first year and the second step is the remainder (during project development); (6) Depreciation is estimated using direct calculation [15]; (7) One cycle of magnesium oxide nanoparticle manufacturing process takes 7.1 hours; (8) Magnesium oxide nanoparticles are priced at 2 USD/pack (1 kg); (9) A one-year project is 300 days (and the remaining days are used to clean and organize the process); (10) To simplify utility, utility units can be described and converted into electrical units, such as kWh. Then, the unit of electricity is converted into charge. The unit of electricity (kWh) is multiplied by the cost of electricity. The assumed annual utility cost is 41,271 USD/kWh; (12) Total salary/labor is assumed to be at a fixed value of 10 USD/day; (13) Discount rate 15% per year; (14) Income tax is 10% per year; (15) The duration of the project operation is 10 years.

Economic evaluation is carried out to test the feasibility of a project. This economic evaluation is done by varying the value of raw materials, utilities, sales, salaries, and taxes under several conditions. Variations in raw materials, utilities, sales, and salaries are carried out at 50, 75, 100, 125, 150, 175, and 200%, while tax variations are carried out at 10, 25, 50, 75, and 100%.

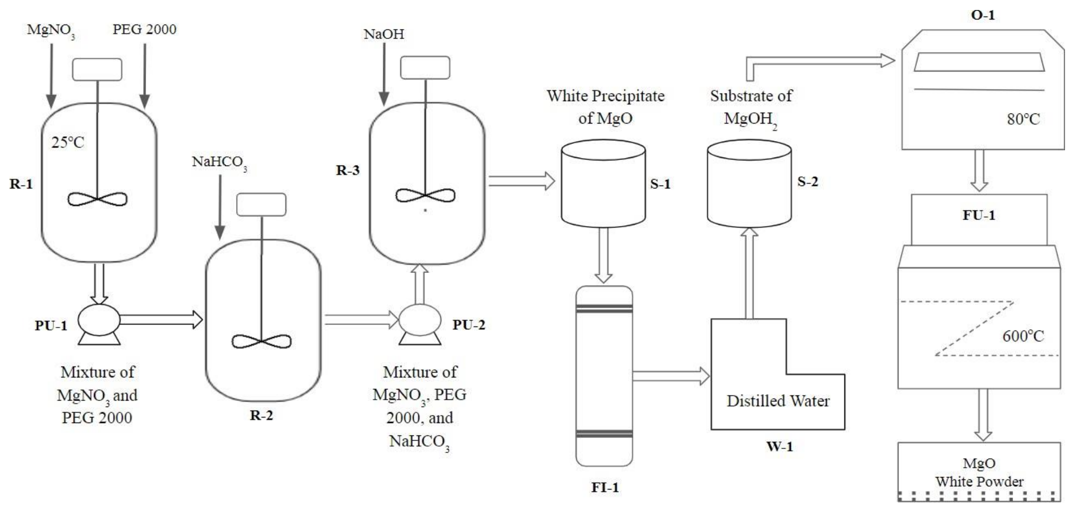

Fig. 2. Illustration of a flow chart for the manufacture of magnesium oxide nanoparticles

Table 1. Table of process flow diagrams for the manufacture of magnesium oxide nanoparticles.

No	Symbol	Information
1	R-1	*Reactor-1*
2	R-2	*Reactor-2*
3	R-3	*Reactor-3*
4	PU-1	*Pump-1*
5	PU-2	*Pump-2*
6	S-1	*Storage-1*
7	S-2	*Storage-2*
8	FI-1	*Filtration-1*
9	W-1	*Washer-1*
10	O-1	*Oven-1*
11	FU-1	*Furnace-1*

Fig. 2 shows the process of making magnesium oxide nanoparticles using the precipitation method based on the literature study (Alvionita and Astuti, 2017). All symbols are shown in Fig. 2 are presented in Table 1. MgO nanoparticles were synthesized using the precipitation method with the addition of PEG, namely PEG 2000 1 M MgNO3 was mixed with PEG and then stirred in the reactor for 10 minutes at room temperature. Next, 1 M NaHCO3 solution was added to the previously mixed MgNO3, and PEG was stirred at a constant speed 1 M NaOH solution was added to the previous solution mixture and stirred in the reactor for 3 hours without changing any parameters. From this process, a white precipitate of magnesium oxide is produced. After that, the white precipitated powder of magnesium oxide was filtered using a filtration machine. The filter results were washed with double distilled water to make a precipitate free from foreign elements and produce a substrate of Mg(OH)2. Then Mg(OH)2 was dried using an oven for 1 hour at 80oC and sintered for 3 hours at 600oC using a furnace (Alvionita and Astuti, 2017; Meenakshi *et al.*, 2012).

In this process, one cycle produces 11,250 kg of magnesium oxide nanoparticles. In one month, the project can produce 281,250 kg, and in one year, the project can produce 3,375,000 kg magnesium oxide nanoparticles.

From an engineering point of view, the total cost for purchasing raw materials for one year is 483,750 USD, while the total sales in one year are 2,025,000,000 USD. The profit for one year is 1,881,184,752 USD. The price for the equipment cost analysis is 44,943 USD. Total Investment Cost must be less than 190,558 USD. Project life is 10 years. In 10 years, it produces magnesium oxide nanoparticles with a Cumulative Net Present Value/Total Investment Cost reaching 30,140.28%. In the tenth year and the third year, the Payback Period has been successfully achieved.

3.2. Economic Evaluation

Ideal Condition

The ideal condition from an economic perspective is shown in Fig. 3. Fig. 3 shows a graph of the relationship between Cumulative Net Present Value/Total Investment Cost over 10 years. The y-axis is the Cumulative Net Present Value/Total Investment Cost, and the x-axis is the lifetime (years). The curve shows that there is a negative value from Cumulative Net Present Value/Total Investment Cost (%), which is a value below 0 in the first year to the third year which indicates a decrease in income in that year due to initial capital costs for the production of magnesium oxide nanoparticles. In the third year, there is an increase in the movement of the curve that indicates an increase in income; this condition is called the Payback Period (PBP). Profits can cover the initial capital that has been issued and continues to increase thereafter until the tenth year. In Table 2 Cumulative Net Present Value/Total Investment Cost, there is a negative value from the first year to the second year. Then the value of Cumulative Net Present Value/Total Investment Cost began to return to a positive value in the third year. Thus, the production of magnesium oxide nanoparticles can be considered a profitable project because it requires a short time to recover the investment costs.

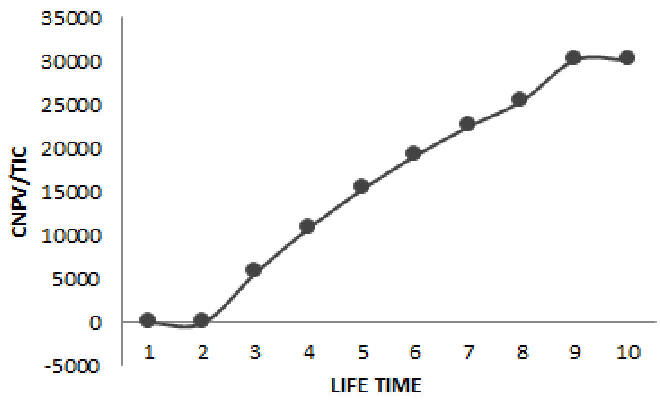

Fig. 3. Ideal conditions for Net Present Value/Total Investment Cost for life time (years)

Table 2. Table of process flow diagrams for the manufacture of magnesium oxide nanoparticles.

CNPV/TIC	**Year**
0	0
-0,409351928	1
-0,845204551	2
5841,0101357171	3
10920,8843446460	4
15338,1662654538	5
19179,2809791997	6
22519,3807302830	7
25423,8152964425	8
30145,5803756431	9
30145,5803756431	10

Effect of External Conditions

The success of a project can be influenced by external factors. One of the factors is the taxes levied on projects by the state to finance various public expenditures. Fig. 4 shows a graph of Cumulative Net Present Value with various tax variations for ten years. The y-axis is Cumulative Net Present Value/Total Investment Cost (%), and the x-axis is the lifetime (years). Fig. 4 shows that the conditions from the beginning of the year to the second year show the same results because the Cumulative Net Present Value is under tax variations and due to project development. In addition, from the beginning of the year until the second year, there was no income, and there was a decrease by the ideal condition graph. Profits continue to increase after reaching the Payback Period (PBP) up to the tenth year. Cumulative Net Present Value/Total Investment Cost in the tenth year for each variation of 10, 25, 50, 75, and 100% is 301.46; 251.21; 167.47; 83.72, and -0.01%. Therefore, the maximum tax to earn a Break-Even Point (the point where there is profit and loss in the project) is 75%. Changes in tax up to more than 75%, which lead to failure in the project.

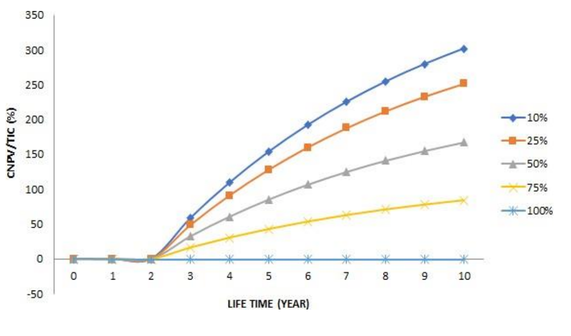

Fig. 4. Cumulative Net Present Value curve of tax variations.

Change in Sales

The graph of the relationship between Cumulative Net Present Value and various sales variations is shown in Fig. 5. The y-axis is Cumulative Net Present Value/Total Investment Cost, and the x-axis is the lifetime (years). Fig. 5 is shown the results of the Payback Period. The conditions from the beginning of the year to the second year of the project, the Cumulative Net Present Value in various variations are the same. This happened because of the project development. The effect of sales on Cumulative Net Present Value can be obtained after the project is made for two years from the initial conditions. The greater the sales value, the more profits will be obtained from the project being implemented. However, if there are conditions that cause product sales to decline, then the project's profits will fall from ideal conditions.

Based on Payback Period (PBP) analysis, the Payback Period for sales variations of 50, 75, 100, 125, 150, 175, and 200% can be achieved in the third year. Profit continues to increase after reaching the Payback Period. The profit margin generated every year increases as sales increase from ideal conditions. Cumulative Net Present Value/Total Investment Cost in the tenth year for each variation of 50, 75, 100, 125, 150, 175, and 200% is 15055, 76; 22600.67; 30145.58; 37690.49; 45235.40; 52780.31; and 60325.22%. The minimum sales to get the Break-Even Point (the point at which the project's profit or loss) is 50%, so the sale of magnesium oxide nanoparticles will be more profitable if the sales increase by more than 50% because the graph shows a higher Cumulative Net Present

Value/Total Investment Cost positive value, it means the project is feasible.

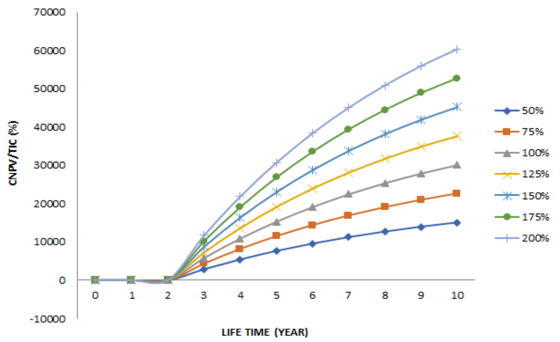

Fig. 5. Cumulative Net Present Value curve of sales variation.

Variable Cost Changes (Raw Material Costs, Salaries, Utilities)

The condition of the cost of raw materials, salaries, and utilities are some of the internal factors that can affect the success of a project. Fig. 6 shows a graph of Cumulative Net Present Value with various variable costs of raw materials for 10 years. The y-axis is the Cumulative Net Present Value/Total Investment Cost, and the x-axis is the lifetime (years). The analysis is carried out by decreasing and increasing the cost of raw materials by 25, 50, 75, and 100%. The ideal raw material cost is 100%. When 25 and 50% reduce the cost of raw materials, the cost of raw materials becomes 75 and 50%, respectively. When 25, 50, 75, and 100% increase the raw material cost, the raw material cost will be 125, 150, 175, and 200%.

The payback period is obtained from the variable cost of raw materials. The results of the Payback Period are shown in Fig. 6. The conditions from the beginning of the year to the second year of the Cumulative Net Present Value project at various raw material variable costs are the same. This is due to the development of the project. The effect of raw material costs on the Cumulative Net Present Value can be obtained after the project is made for two years from the initial conditions. The lower the cost of raw materials, the higher the project profit will be. However, if there are circumstances that cause the cost of raw materials to increase, then the project's profits will fall from the ideal state.

Based on Payback Period analysis, profits continue to increase after reaching the Payback Period (PBP) until the tenth year. However, the profit margin earned every year is getting smaller in line with the increase in raw material costs from ideal conditions. On the other hand, the annual profit margin increases with the decrease in raw material costs from ideal conditions. Cumulative Net Present Value/Total Investment Cost in the tenth year for each variation of 50, 75, 100, 125, 150, 175, and 200% is 30149.46; 30147.52; 30145.58; 30143.64; 30141.70; 30139.77; and 30137.83%. From the variable costs of raw materials, the project can still run and generate profits.

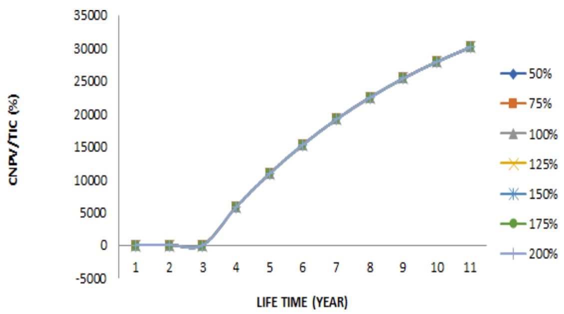

Fig. 6. Cumulative Net Present Value curve of sales variation.

Fig. 7 shows a graph of Cumulative Net Present Value with various salary variations. The y-axis is the Cumulative Net Present Value/Total Investment Cost, and the x-axis is the lifetime (years).

Increasing and decreasing salaries carried out the analysis by 25, 50, 75, and 100%. The ideal salary is 100%. When 25 and 50% reduce the salary, the salary will be 75 and 50%, respectively. When 25, 50, 75, and 100% increase the salary, the salary becomes 125, 150, 175, and 200%, respectively. The Payback Period is obtained from the results of salary variations. The results of the Payback Period are shown in Fig. 7. The conditions from the beginning of the year to the second year of the Cumulative Net Present Value project from various salary variations are the same. It happened because of the project development. The effect of salary on Cumulative Net Present Value can be obtained after the project is made for two years from the initial conditions. There is no significant change from the salary variation curve to the Cumulative Net Present Value graph. The payback period for each variation in salary is still achieved in the third year. However, the Cumulative Net Present Value/Total Investment Cost in the tenth year is different for each variation. The difference in values for each variation of 50, 75, 100, 125, 150, 175, and 200% is 30157.62; 30151.60; 30145.58; 30139.56; 30133.54; 30127.52; and 30121.49%. From the salary variations, it can be concluded that the project can still run and generate profits.

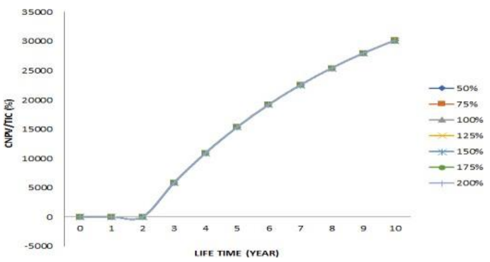

Fig. 7. Cumulative Net Present Value curve of salary variation.

Fig. 8 shows the Cumulative Net Present Value graph with various utility variations. The y-axis is the Cumulative Net Present Value/Total Investment Cost, and the x-axis is the lifetime (years). The analysis is done by increasing and decreasing the utility by 25, 50, 75, and 100%. The ideal utility is 100%, when 25 and 50% reduce the utility; the utility becomes 75 and 50%, respectively. When 25, 50, 75, and 100% increase utility, the utility becomes 125, 150, 175, and 200%, respectively. The Payback Period is obtained from the results of utility variations. The results of the Payback Period are shown in Fig. 8. The conditions from the beginning of the year to the second year from the Cumulative Net Present Value to the Cumulative Net Present Value can be obtained after the project is made for two years from the initial conditions. From the utility variation to the Cumulative Net Present Value graph, there is no significant change.

However, the Cumulative Net Present Value/Total Investment Cost differs in the tenth year in each variation. The difference in values for each variation of 50, 75, 100, 125, 150, 175, and 200% is 30145.91; 30145.75; 30145.58; 30145.42; 30145.25; 30145.08; and 301344.92%. The payback period for each utility variation is still achieved in the third year. From the utility variation, it can be concluded that the project can still run and generate profits.

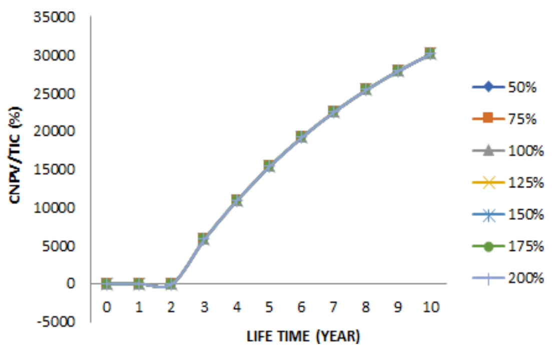

Fig. 8. Cumulative Net Present Value curve of utility variations.

4. CONSLUSION

Based on the techno-economic analysis that has been carried out, the project of manufacturing magnesium oxide nanoparticles from an engineering point of view shows that scale-up of the project can be carried out using currently available tools and relatively low cost. The Payback Period analysis shows that the investment will experience a profit after more than three years. This happens because the use of raw materials in the synthesis process of magnesium oxide nanoparticles with the precipitation method is cheap and requires a short time to produce magnesium oxide. From this economic evaluation analysis, it can be concluded that this project is feasible to run.

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