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Practical Computation in the Techno-Economic Analysis of the Production of Magnesium Oxide Nanoparticles using Sol-gel Method

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ABSTRACTS

The purpose of this study was to determine the feasibility of a project for the manufacture of magnesium oxide nanoparticles using the sol-gel method by evaluating both technically and economically. Evaluation from the technical side is determined by stoichiometric calculations and evaluation of the initial factory design, while the evaluation from the economic side is determined by several parameters to determine the benefits of the project to be established (Gross Profit Margin, Internal Rate Return, Break-Even Point, Payback Period, and Cumulative Net Present Values). Some of these economic evaluation parameters were analyzed to inform the production potential of magnesium oxide nanoparticles, such as determining the level of profitability of a project (Gross Profit Margin), predicting the length of time required for an investment to return the initial capital expenditure (Payback Period), predicting the condition of a production project in the form of a production function in years (Cumulative Net Present Value), etc. The results of the technical analysis show that this project can produce 1,425 kg of magnesium oxide nanoparticles per day and the total cost of the equipment purchased is 45,243 USD. Payback Period analysis shows that the investment will be profitable after more than three years.

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1. INTRODUCTION

Magnesium oxide is an important functional metal oxide that has been widely used in various fields, such as catalysts, refractory materials, paints, and superconductors (Dobrucka, R. 2018). Magnesium oxide nanoparticles are highly ionic metal oxide nanoparticles with a very high surface area and unusual crystal morphology (Dobrucka, R. 2018). Magnesium oxide nanoparticles have been widely used because of their unique properties, such as large band gap, thermodynamic stability, low dielectric constant, and low refractive index (Prasanth, R., et al. 2019).

Several methods can be used in the synthesis of magnesium oxide nanoparticles, including combustion (Balakrishnan, G., et al. 2020), synthesis of plant extracts (Essien, E. R., et al. 2020), sonochemical synthesis (Yunita, F. E., et al. 2020), solid-state synthesis (Zhang, H., et al. 2019), and sol-gel synthesis (Taghavi Fardood, S., et al. 2018). Of these several methods, the most appropriate method for conducting economic evaluation analysis is the sol-gel synthesis method that has been carried out by Fardood, et al (Taghavi Fardood, S., et al. 2018). The sol-gel method is one of the most preferred methods for synthesizing magnesium oxide nanoparticles because of its simple process, high product yield, and low reaction temperature. In addition, sol-gel is an inexpensive method to get magnesium oxide nanoparticles with narrow size distribution and larger surface area which is very important to solve the problems of low reactivity and catalytic ability (Mguni, L. L., et al. 2013). Figure 1. shows a diagram of the manufacture of magnesium oxide nanoparticles using the sol-gel method with Arabic gum as the raw material.

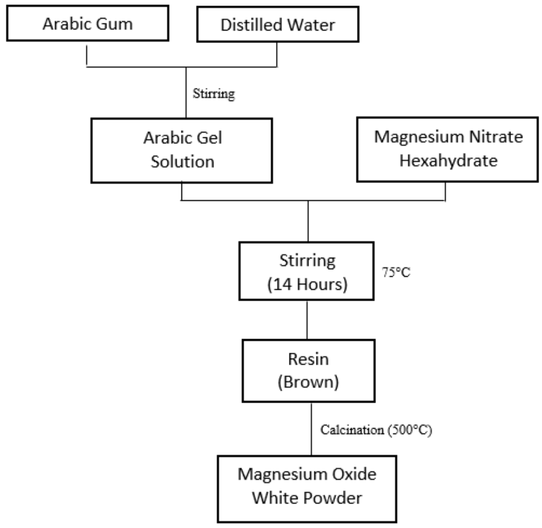

Fig. 1. Schematic of the sol-gel method of manufacturing magnesium oxide nanoparticles

Many studies have described various methods of synthesizing magnesium oxide nanoparticles, but there are no studies that have studied the economic evaluation of large-scale synthesis of magnesium oxide nanoparticles. Therefore, this study aimed to analyze the project economy of manufacturing magnesium oxide nanoparticles using the sol-gel method on an industrial scale. Evaluation is carried out from two sides, such as the technical side and the economic side. On the technical side, it can be determined by stoichiometric calculations and evaluation of the initial factory design, while the evaluation from the economic side is determined by several parameters to determine the benefits of the project to be established (Gross Profit Margin, Internal Rate Return, Break-Even Point, Payback Period, and Cumulative Net Present Value) under various conditions (Nandiyanto, A. B. D., 2018).

2. METHOD

In this study, we chose the research on the manufacture of magnesium oxide nanoparticles conducted by Fardood, et al (Taghavi Fardood, S., et al. 2018) as the main reference. In the economic evaluation, an analysis of the prices of equipment, utilities, and raw materials available for the manufacture of magnesium oxide nanoparticles was carried out on the Alibaba online shopping website. Then, the data is calculated using Microsoft Excel with several parameters, such as Gross Profit Margin, Internal Rate Return, Break-Even Point, Payback Period, and Cumulative Net Present Value of various cost variables. The calculations were carried out based on the literature (Nandiyanto, A. B. D., 2018), (Ragadhita, R., et al. 2019), (Nassar, M. Y., et al. 2017), (Garrett, D. E., 2012). To get the results of this study, calculations are 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.

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

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

- Internal Rate Return is a presentation that describes the average interest profit per year from all expenses and income of the same amount. If the Internal Rate Return is greater than the prevailing real interest (current bank loan interest), then the factory is considered profitable, but if the Internal Rate Return is less than the prevailing real interest (current bank loan interest), then the factory is considered a loss.

$$NPV = \Sigma_{tr=1}^{tr} \frac{C_o}{(1+i)^{tr}} - \mathrm{Co} \quad (2)$$

Co is the total investment cost, Ct is the net cash inflows during the period, tr is the project time (in years), and i is the discount rate that can be obtained in alternative investments.

- Break-Even Point (BEP) is the minimum amount of product value that must be sold at a certain price to cover the total cost of production. Break-Even Point can be calculated by dividing fixed costs by profit.
- 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 factory ends operation.

$$NPV = \Sigma_{tr=1}^{tr} \left(\frac{R_t}{(1+i)^{tr}} \right) \quad (3)$$

3. RESULTS AND DISCUSSION

3.1. Procedure

In this study, several assumptions were used based on the illustration of the process of making magnesium oxide nanoparticles shown in Figure 2. This assumption shows that by increasing the project through stoichiometric calculations, approximately 1,425 kg of magnesium oxide nanoparticles is produced in one cycle. The assumptions are: (1) All raw materials are upgraded to 500,000 times of the lab-scale in the literature. (2) The ingredients are of high purity. (3) Magnesium nitrate hexahydrate and Arabic gel solution are reacted and produce magnesium oxide with a purity of 98%. (4) The loss during the process of moving, drying, and collecting the product 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. The assumptions are:

(1) All analyzes use USD (1 USD = 14,383 rupiah) (Bank Indonesia, 2021); (2) Based on commercially available prices, the prices of Arabic gum and magnesium nitrate hexahydrate are 2.44 USD/kg and 0.26 USD/kg, respectively. All materials are estimated based on stoichiometric calculations; (3) When project land has been purchased, land costs are added at the beginning of the factory construction year and recovered at the end of the project; (4) Total Investment Cost (TIC) is calculated based on Lang Factor (Garrett, D. E., 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 (Garrett, D. E., 2012); (7) One cycle of the manufacturing process for magnesium oxide nanoparticles takes 16 hours; (8) The cost of postage shall be borne by the buyer; (9) Magnesium oxide nanoparticles are sold at 2 USD/pack (1 kg); (10) One year project is 300 days (and the remaining days are used to clean and organize the process); (11) To simplify utility, utility units can be described and converted as electrical units, such as kWh (Nandiyanto, A. B. D., 2018). Then, the unit of electricity is converted into charge. The unit of electricity (kWh) is multiplied by the cost of electricity. The assumed utility cost is 0.078 USD/kWh; (12) The total salary/labor is assumed to be at a fixed value of 68.36 USD/day; (13) The discount rate is 15% per year; (14) Income tax is 10% annually; (15) The length of operation of the project is 10 years.

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

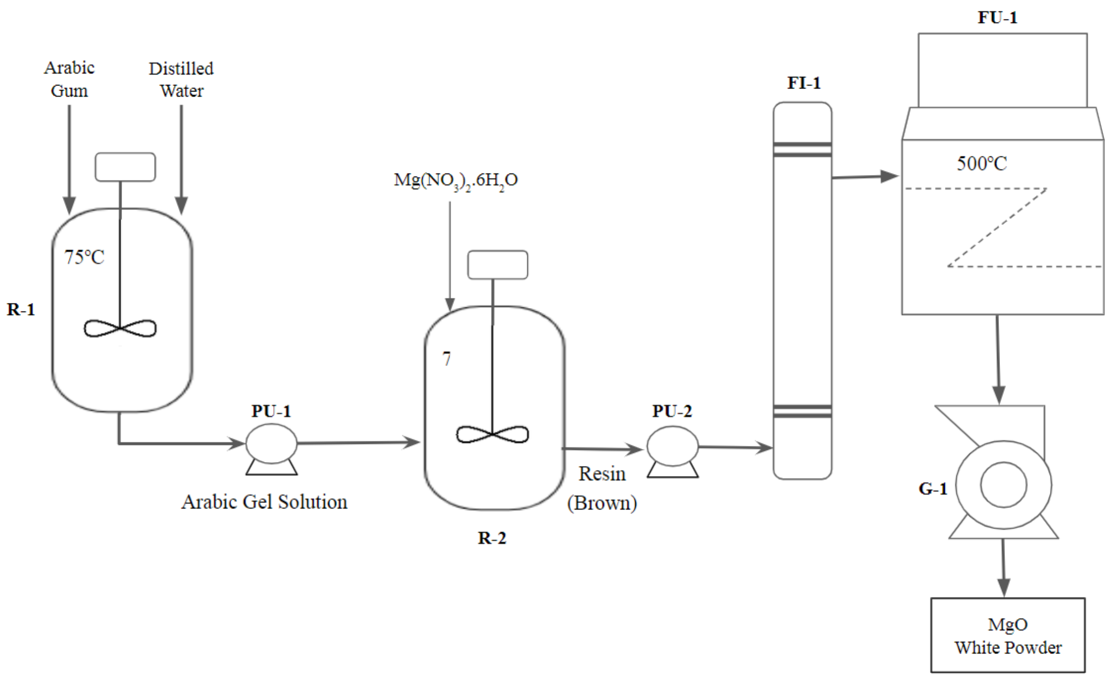

Fig. 2. Illustration of the flow diagram for the manufacture of magnesium oxide nanoparticles.

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

No	Symbol	Information
1	R-1	Reaktor-1
2	R-2	Reaktor-2
3	PU-1	Pump-1
4	PU-2	Pump-2
5	FI-1	Filtrasi-1
6	FU-2	Furnace-1
7	G-1	Grinding-1

Figure 2. shows the process of making magnesium oxide nanoparticles using the sol-gel method using Arabic gum as raw material based on the literature of Fardood, et al (Taghavi Fardood, S., et al. 2018). All the symbols in Figure 2 are informed in Table 1. First, Arabic gum was dissolved with distilled water in the

reactor for 120 minutes at 75°C to reach a clear Arabic gel solution and then transferred to the next reactor. After that, magnesium nitrate hexahydrate was added to the Arabic gel solution in the reactor, and stirring was continued for 14 hours to obtain a brown resin. The liquid was filtered, then continued into the furnace and the final product was calcined at 550°C for 4 hours. After that, the magnesium oxide sample was pulverized with a special mechanical powder smoothing tool to obtain the nanoparticle size (Taghavi Fardood, S., et al. 2018).

One cycle produces 1,425 kg of magnesium oxide nanoparticles. In one month, the project can produce 35,625 kg and in one year the project can produce 427,500 kg of magnesium oxide nanoparticles.

From an engineering perspective, the total cost for purchasing raw materials for one year is 263,674 USD, while the total sales in one year are 256,500,000 USD. The profit for one year was 256,236,325 USD. The price for the equipment cost analysis is 45,243 USD. Total Investment Cost must be less than 191,830 USD. The life of the project is 10 years, producing magnesium oxide nanoparticles with Cumulative Net Present Value/Total Investment Cost reaching 3,789.411%, in the tenth year and in the third year the Payback Period has been successfully achieved.

3.2. Economic Evaluation

3.2.1. Ideal Condition

Figure 3. shows a graph of the relationship between Cumulative Net Present Value/Total Investment Cost with respect to time. The y-axis is the Cumulative Net Present Value/Total Investment Cost and the x-axis is the lifetime (year). The curve shows a negative 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 revenue in that year due to the initial capital cost for the production of magnesium oxide nanoparticles. In the third year the graph shows an increase in income, this condition is the Payback Period (PBP). Profits can cover the initial capital that has been spent and continue to increase thereafter until the tenth year. In Table 2. the Cumulative Net Present Value/Total Investment Cost is negative from the first year to the second year. Then the value of Cumulative Net Present Value/Total Investment Cost began to return to positive 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.

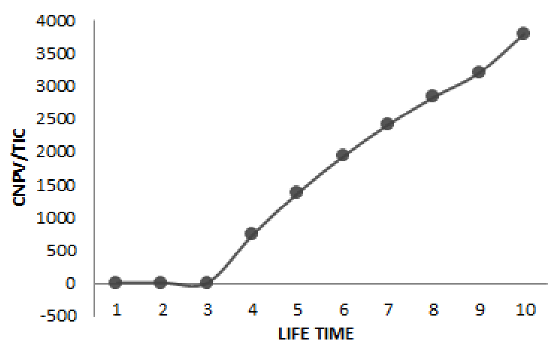

Fig. 3. The ideal condition for Cumulative Net Present Value/Total Investment Cost to a lifetime (year).

Table 2. Annual Cumulative Net Present Value under ideal conditions.

CNPV/TIC	Year
0	0
-0,4093519278	1
-0,8452045511	2
733,6408078950	3
1372,3242969786	4
1927,7012440078	5
2410,6377196854	6
2830,5824811441	7
3195,7518389344	8
3789,4109083098	9
3789,4109083098	10

3.2.2. The Effect of External Conditions

The success of a project can result from external factors. One factor is the taxes levied on projects by the state to finance various public expenditures. Figure 4. shows a graph of Cumulative Net Present Value with various tax variations. The y-axis is Cumulative Net Present Value/Total Investment Cost (%) and the x-axis is a lifetime (year). Figure 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 there is project development. In addition, in that year there was no income and there was a reduction in accordance with the graph of ideal conditions. Profits continue to increase after reaching the Payback Period (PBP) until the tenth year. Cumulative Net Present Value/Total Investment Cost in the tenth year for each variation of 50, 75, 100, 125, 150, 175 and 200% is 41.68; 41.05; 39.99; 38.94, and 37.89%. So, the maximum tax for earning a Break-Even Point (the point at which there is both profit and loss in the project) is 75%. Tax changes of up to more than 75% lead to failure in the project.

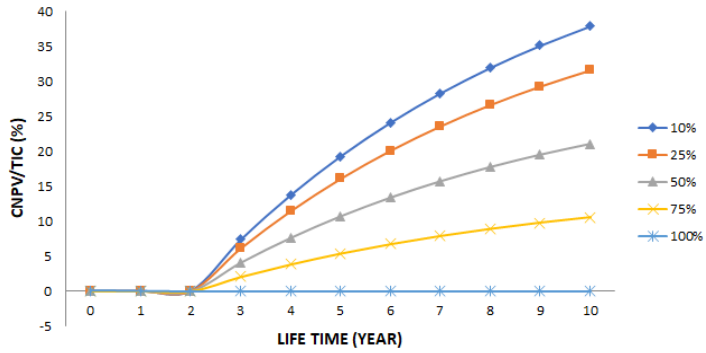

Fig. 4. Cumulative Net Present Value curve of tax variations.

3.2.3. Change in Sales

Figure 5. shows a graph of Cumulative Net Present Value with various sales variations. The y-axis is the Cumulative Net Present Value/Total Investment Cost and the x-axis is the lifetime (year). The results of the Payback Period are shown in Figure 5. The conditions from the beginning of the year to the second year of the Cumulative Net Present Value project 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 2 years from the initial conditions. The greater the value of the sale, the more the profits obtained from the project are carried out. However, if there are conditions that cause product sales to decline, the project's profits will decrease from ideal conditions.

Based on the 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. Profits continue to increase after reaching the Payback Period until the third year. The profit margin generated for each year increases with increasing sales 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 1890.71; 2840.06; 3789.41; 4738,77; 5688.11; 6637.47; and 7586.82%. So, the minimum sale to get the Break-Even Point (the point at which the project's profit or loss) is 50%. Sales of magnesium oxide nanoparticles will be more profitable if sales are increased by more than 50% because the graph shows a positive Cumulative Net Present Value/Total Investment Cost, this means the project is feasible (Nandatamadini, F., et al. 2019).

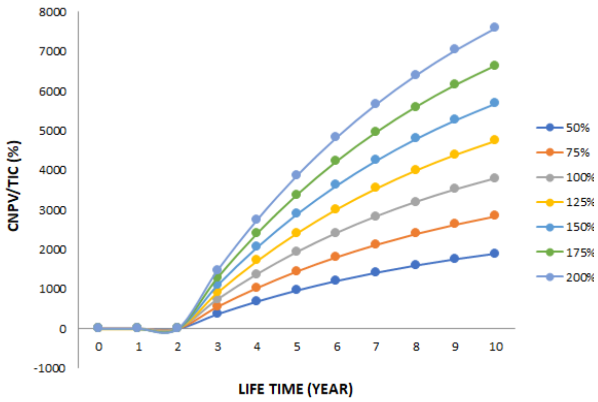

Fig. 5. Cumulative Net Present Value curve of sales variation

3.2.4. Change in variable cost (cost of raw material, salary, utility)

There are several internal factors such as the condition of the cost of raw materials, salary, and utilities that can affect the success of a project. Figure 6. shows a graph of Cumulative Net Present Value with various variable costs of raw materials. The y-axis is the Cumulative Net Present Value/Total Investment Cost and the x-axis is the lifetime (year). The analysis is done by lowering and increasing the cost of raw materials by 25, 50, 75, and 100%. The ideal cost of raw materials is 100% when the cost of raw materials is reduced by 25 and 50%, the cost of raw materials becomes 75 and 50%, respectively. When the cost of raw materials is increased by 25, 50, 75, and 100%, the cost of raw materials 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 Figure 6. The conditions from the beginning of the year to the second year of the Cumulative Net Present Value project in various variable costs of raw materials are the same. It is because of the project development. The effect of the cost of raw materials on the Cumulative Net Present Value can be obtained after the project is made for 2 years from the initial conditions. The lower the cost of raw materials, the higher the profit of the project. However, if there are circumstances that cause the cost of raw materials to increase, the project profit will decrease from the ideal situation.

Based on Payback Period analysis, profits continue to increase after reaching the Payback Period (PBP) until the tenth year. However, the profit margin obtained every year is getting smaller with the increase in the cost of raw materials from ideal conditions. On the other hand, the annual profit margin increases with a decrease in the cost of raw materials 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 3789.60; 3788.55; 3787.50; 3786.45; 3785.40; 3784.35; and 3783.30%. From the variable cost of raw materials, the project can still run and make a profit.

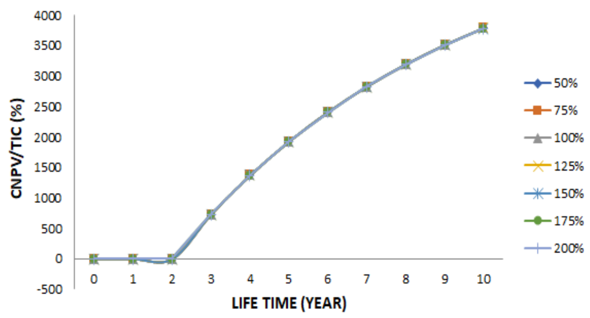

Fig. 6. Cumulative Net Present Value of the variable cost of raw materials.

Figure 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 (year). The analysis is done by increasing and decreasing salary by 25, 50, 75, and 100%. The ideal salary is 100%. When the salary is reduced by 25 and 50%, the salary will be 75 and 50% respectively. When the salary is increased by 25, 50, 75, and 100%, the salary will be 125, 150, 175, and 200%. The payback period is obtained from the results of salary variations. The results of the Payback Period are shown in Figure 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. This happened because of the project development. The effect of salary on Cumulative Net Present Value can be obtained after the project is made for 2 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 salary variation is still achieved in the third year. However, the Cumulative Net Present Value/Total Investment Cost differs in the tenth year for each variation. The difference in values for each variation of 50, 75, 100, 125, 150, 175, and 200% is 3790.37; 3789,89; 3789.41; 3788.93; 3788.45; 3787.98; 3787.50%. From the salary variations, the project can still run and make a profit.

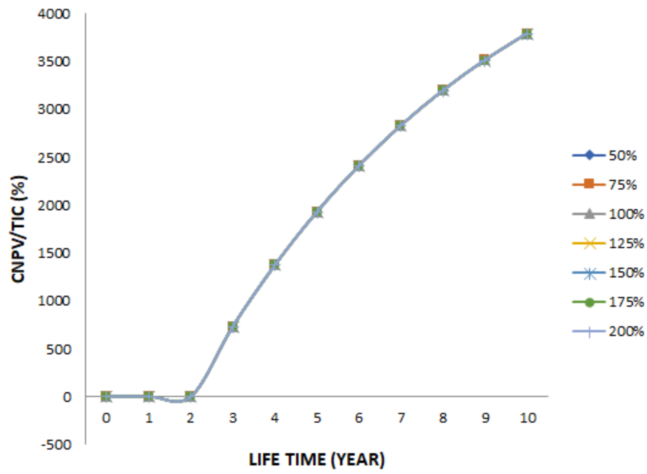

Fig. 7. Cumulative Net Present Value curve of salary variations

Figure 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 (year). The analysis is done by increasing and decreasing the utility by 25, 50, 75, and 100%. The ideal utility is 100%, when the utility is reduced by 25 and 50%, the utility becomes 75 and 50%, respectively. When the utility is increased by 25, 50, 75, and 100% then the utility becomes 125, 150, 175, and 200%. The Payback Period is obtained from the results of utility variations. The results of the Payback Period are shown in Figure 8. The conditions from the beginning of the year to the second year of the Cumulative Net Present Value of various utility variations are the same. This is because of the project development. The effect of utility on Cumulative Net Present Value can be obtained after the project is made for 2 years from the initial conditions. There is no significant change from the utility variation to the Cumulative Net Present

Value graph. 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 3789.57; 3789.49; 3789.41; 3789.33; 3789.25; 3789.17; and 3789.08%. The payback period for each utility variation is still achieved in the third year. From the utility variations, the project can still run and make a profit.

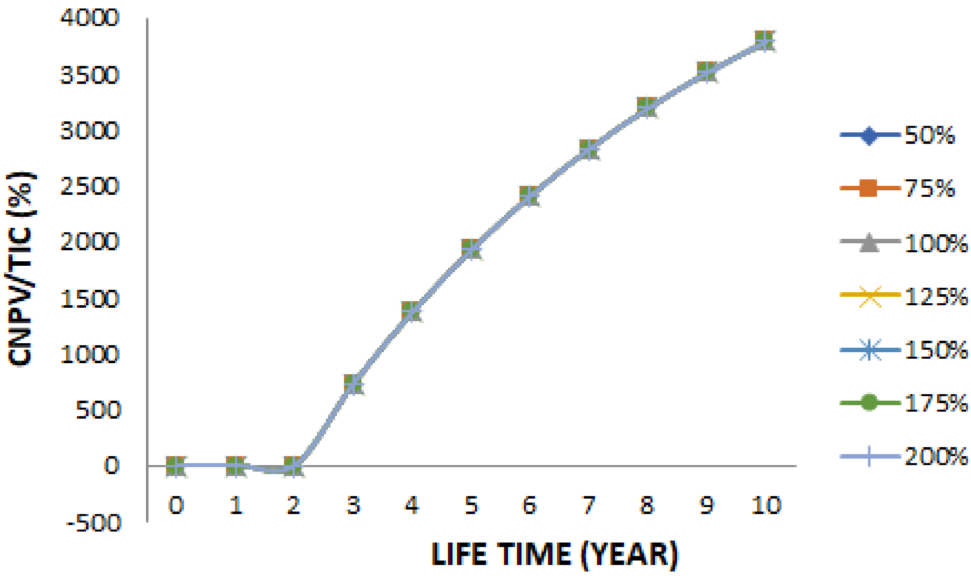

Fig. 8. Cumulative Net Present Value curve of utility variations

4. CONCLUSION

Based on the analysis that has been carried out, the project to manufacture magnesium oxide nanoparticles from an engineering point of view shows that the scale of the project can be scaled up using currently available tools and has a relatively low cost. Payback Period analysis shows that the investment is profitable after more than three years. This is because the use of Arabic gum as a raw material in the synthesis of magnesium oxide nanoparticles by the sol-gel method is cheap and environmentally friendly. From this economic evaluation analysis, it can be concluded that this project is feasible to run.

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