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Computation in the Analysis of Techno-Economic of the Production of Al_2O_3 (Aluminum Oxide) Nanoparticles through Precipitation Method

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A B S T R A C T S

This study aims to demonstrate computation in the techno-economic analysis of the production of aluminum oxide (Al_2O_3) using the precipitation method on an industrial scale. This evaluation is based on the perspective of technical and economic evaluation. Several economic evaluation parameters were analyzed to obtain potential information from the manufacture of Al_2O_3 nanoparticles based on gross profit margin, payback period, and cumulative net present value. The results of this study identified that the manufacture of Al_2O_3 nanoparticles using the precipitation method could be done industrially. Based on the engineering perspective, Al_2O_3 nanoparticles can be produced as much as 6.9 tons and earn an annual profit of 144,635.69 USD with a period of 20 years. To ensure that this project can be carried out, an economic evaluation is made based on estimates of ideal and non-ideal conditions, including tax increases, sales changes, raw material prices, utility prices, and labor's salary. This study is expected to provide information for the manufacture of Al_2O_3 nanoparticles using the precipitation method on an industrial scale.

A R T I C L E I N F O

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1. INTRODUCTION

Nanoparticles are microscopic particles. The properties of nanoparticles with a diameter less than 100 nm differ from their bulk form (Parast & Morsali, 2011). Nanoparticles have several uses, including catalysts (Parast & Morsali, 2011), anti-bacterial agents (Prashant *et al.*, 2011), anti-cancer and cell imaging (Parast & Morsali, 2011; Prashant *et al.*, 2011), nuclear coolant (Syarif *et al.*, 2018), and can be used in radiators or sandpaper (Zhu *et al.*, 2020)

Synthesis of Al_2O_3 nanoparticles can be carried out by various methods such as sol-gel (Mohammed *et al.*, 2020; Li *et al.*, 2000); precipitation (Ali *et al.*, 2019; Wang *et al.*, 2008; Hassanzadeh-Tabrizi & Taheri-Nassaj, 2009); hydrolysis (Sharifi *et al.*, 2013); synthesis under supercritical water conditions (Noguchi *et al.*, 2008); wet chemical (Lu et al., 2005; López-Juárez et al., 2018); combustion (Syarif *et al.*, 2019; Afruz & Tafreshi, 2014); mechanochemical (Gao *et al.*, 2018; Bodaghi *et al.*, 2009); and microwave (Hasanpoor *et al.*, 2017). Precipitation is the most efficient method for synthesizing Al_2O_3. It is because the simplest method compared to other methods, has low raw material costs, does not pollute the environment, and has several advantages such as high purity products, high thermal stability, and the ability to control desired particle size.

There are still few studies that discuss the economic evaluation of Al_2O_3, and there is no economic evaluation based on the precipitation method. Thus, the purpose of this study is to demonstrate the economic evaluation of the synthesis of Al_2O_3 nanoparticles using the precipitation method on an industrial scale. This study contains several variations of raw materials, taxes, utilities, labor, and sales.

2. METHOD

2.1. Synthesis of Al_2O_3 Nanoparticles using the precipitation method

The synthesis of Al_2O_3 nanoparticles can be selected and improvised from the literature (Ali *et al.*, 2019; Wang *et al.*, 2008; Hassanzadeh-Tabrizi & Taheri-Nassaj, 2009). The materials used were $AlCl_3.6H_2O$, Tween-80, ammonium hydroxide solution, water, and ethanol. First, $AlCl_3.6H_2O$ was dissolved in water to obtain a concentration of 0.4 M, and then Tween-80 was added to the reactor. Then, ammonium hydroxide is added periodically using an injector and stirred in the reactor to produce a precipitate. After that, the precipitate was filtered, washed with water and ethanol, and the residue was taken. The residue $Al(OH)_3$ was dried in an oven at 100°C for 2 hours and then calcined using a furnace at 550°C for 5 hours to obtain γ-Al_2O_3. Then, the γ-Al_2O_3 nanoparticles were ground in a ball mill to produce a homogeneous nano size of γ-Al_2O_3. The process scheme of this precipitation method is shown in Fig. 1.

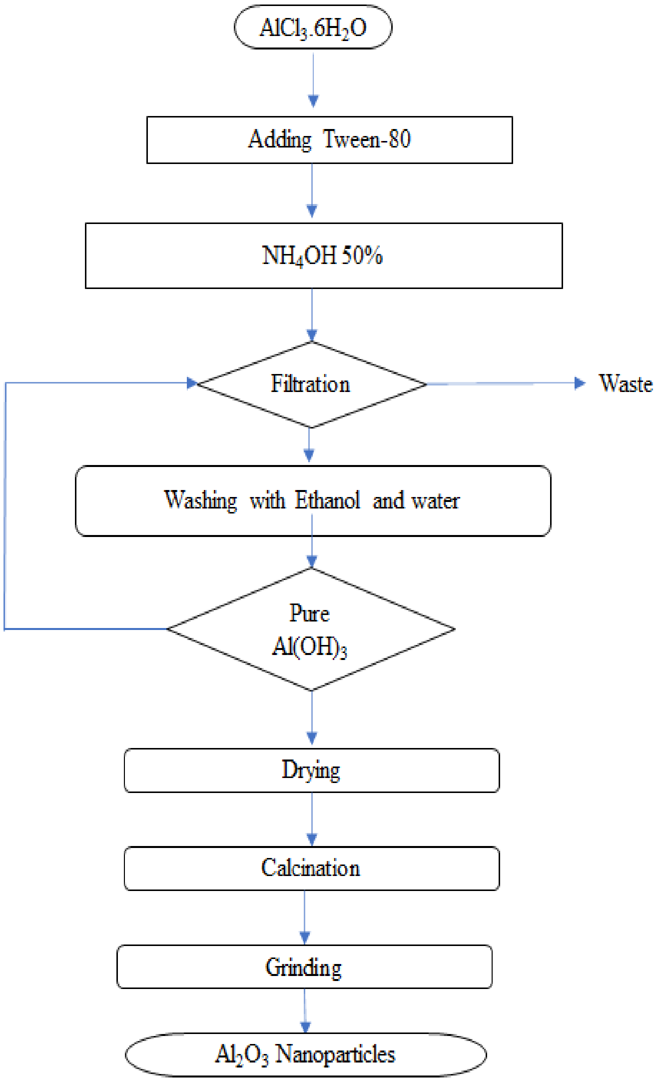

Fig. 1. **Al_2O_3 Nanoparticles Synthesis Scheme Using Precipitation Method**

2.2 Analysis Method

The feasibility of establishing a factory is investigated in this study from a technical and economic perspective. Engineering and economic perspectives were used to evaluate the manufacture of Al_2O_3 nanoparticles using the precipitation method by adopting references (Ali *et al*., 2019; Wang *et al*., 2008; Hassanzadeh-Tabrizi & Taheri-Nassaj, 2009). The method is carried out from an engineering perspective by simulating the production process on a large scale using commercially available equipment and raw materials. This process is then simulated by the mass balance that occurs during the production process. In addition, we also consider the use of raw materials and equipment to support and minimize investment costs. Data evaluation is carried out from an economic perspective. It is included all equipment specifications, equipment costs, raw material prices, and utility systems. The information was gathered from online web stores such as Alibaba.com. Then, the data is processed using simple mathematical calculations in the Microsoft Excel application. The economic evaluation was calculated using several economic feasibility parameters (Ragadhita et al., 2019). The economic evaluation parameters are explained briefly as follows:

- Gross Profit Margin (GPM) is the first analysis to predict a rough analysis of the profitability level of this project. GPM is calculated by subtracting the cost of selling the product and the price of raw materials.
- Cumulative Net Present Value (CNPV) is a value that predicts project conditions as a function of production in years. CNPV is calculated by adding up the Net Present Value (NPV) at a particular time from the start of the project. NPV is a value that expresses business expenses and income. NPV itself can be calculated by multiplying the cash flow by the discount factor.
- The profitability index (PI) identifies the relationship between project investment costs and the impact on business continuity or profitability. PI is calculated by dividing the CNPV by the total investment cost (TIC). If the PI is less than one, then the project can be classified as unprofitable. However, if the PI is more than one, the project can be classified as a good project.
- Break-Even Point (BEP) is the minimum amount of product that must be sold at a certain price to cover the total cost of production. BEP is calculated by dividing fixed costs value and profits (total selling price minus total variable costs).
- Payback Period (PBP) is a calculation to estimate the time required to return the initial capital through profits. The payback period is calculated when the CNPV/TIC is at zero for the first time.

The synthesis method of Al_2O_3 nanopowder, as shown in Fig. 2, is the basis for some engineering assumptions. All symbols that are shown in **Fig. 2** will be described in Table 1. These assumptions are based on stoichiometric calculations after the project was upgraded to produce around 7 kg of Al_2O_3 nanoparticles per cycle. The assumptions are:

1. All the chemical compositions in the reaction, such as aluminum chloride hexahydrate, surfactant Tween 80, ammonium hydroxide solution, ethanol, and distilled water were used for the production of Al_2O_3 nanoparticles. These materials are of high purity.
2. The quantity of chemicals is calculated based on the literature.
3. The scale of the chemicals is increased by up to 3000 times.
4. Aluminum chloride and ammonium hydroxide are reacted in a ratio of 1: 3.
5. The Al_2O_3 nanoparticle production process has a conversion rate of 100%.

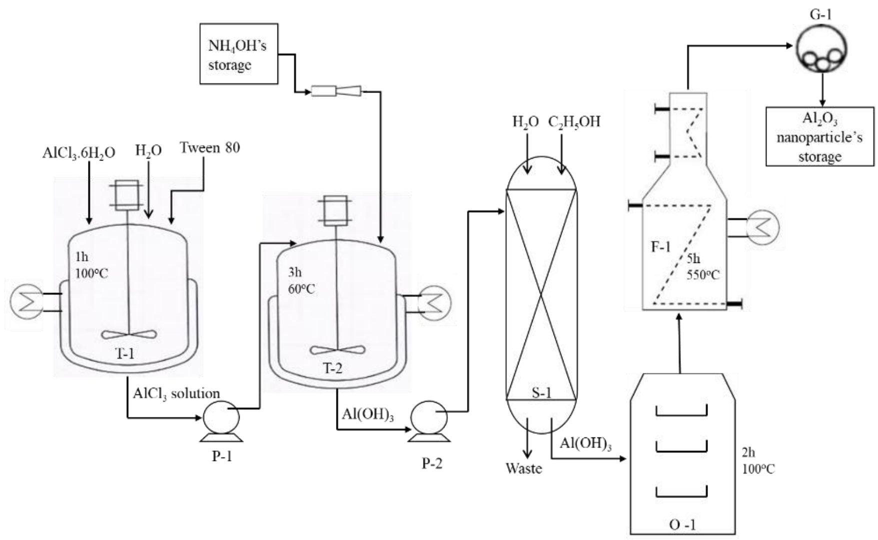

Fig. 2. Process Flow Diagram of Alumina Nanoparticles.

Table 1. Process Flow Diagram Flow of Alumina Nanoparticles.

No.	Symbol	Information
1	T-1	Tank-1
2	P-1	Pump-1
3	T-2	Tank-2
4	P-2	Pump-2
5	S-1	Separator-1
6	O-1	Oven-1
7	F-1	Furnace-1
8	G-1	Grinding-1

To analyze the economic perspective in this study, several assumptions are made:

1. All analysis is in USD. 1 USD = 14,500 IDR.
2. The project is not supported by a bank loan.
3. All raw material prices are based on those found in the online shop (Alibaba.com). Aluminum chloride hexahydrate, Tween 80 surfactant, ammonium hydroxide solution, and ethanol are priced at 0.4 USD/kg, 2.2 USD/kg, 1.5 USD/kg, and 0.79 USD/kg, respectively.
4. All materials used in the production process are calculated based on stoichiometric calculations.
5. The water source is free of charge because the project is located near a river.

6. The total investment cost (TIC) is calculated based on the Lang Factor (Nandiyanto, 2018).

7. Land purchased. Therefore, the land is considered as part of the plant's initial cost and is recouped at the end of the project.

8. One cycle of making Al_2O_3 nanoparticles takes 15 hours.

9. In a one-day process, the estimated total processing cycle is 4 cycles, assuming all tools work for continuous production based on time considerations. Al_2O_3 nanoparticles produce as much as 29 kg per day.

10. All products are sold in full and no products are lost.

11. The Al_2O_3 nanoparticles sell for 50 USD/kg.

12. Shipping costs are borne by the buyer.

13. One year project is 240 days (the remaining days are used to clean and repair tools).

14. To simplify utility, utility units are described as units of electricity such as kWh. Then, the unit of electricity is considered as a cost. Assuming a utility cost of 0.099 USD/kWh.

15. Total wages/labor is assumed to be fixed at 120 USD/day for 20 laborers.

16. The discount rate and annual income tax rate are 15% and 10% per year, respectively.

17. The project operation length is 20 years.

An economic evaluation is carried out for a feasibility test project. This economic evaluation is done by varying the value of taxes, sales, raw materials, labor, and utilities under several conditions. Tax variations are carried out at 10, 25, 50, 75, and 100%. Meanwhile, variations in sales, raw materials, labor, and utilities were carried out at 80, 90, 100, 110, and 120%.

3. RESULTS AND DISCUSSION

3.1. Engineering Perspective

The process of producing Al2O3 nanoparticles using the precipitation method is carried out with several instruments using industrial scales that can be obtained commercially and economically. Suppose the production is carried out 960 times a year. In that case, 6.9 tons of Al_2O_3 nanoparticles will be produced, requiring 33.00 tons of aluminum chloride hexahydrate, 60.48 tons of ammonium hydroxide, 12.21 tons of Tween-80, and 200 tons of ethanol. The total price required in a year for production is 203,364.31 USD with annual sales of 348,000.00 USD, resulting in a profit of 144,635.69 USD per year. These advantages will be shown in an economic evaluation, and the value of the project will be shown over 20 years

3.2. Economic Evaluation

3.2.1 Ideal Conditions

The ideal condition is shown by the analysis of the relationship between CNPV/TIC and lifetime (year). CNPV/TIC is on the y-axis, and lifetime (year) is on the x-axis. In the first to second year, there is a negative CNPV/TIC number that is less than zero. This indicates that due to the initial cost of the production of Al_2O_3 nanoparticles, there was a decrease in income in that year. The lowest CNPV/TIC value was -

0.9746 in the second year. However, in the third year, the value increased to 3.8652. This point is referred to as the payback point, and the increase shown on the graph is called the Payback Period (PBP). The profit to cover the initial expenses increased until it reached 33.1325 in the 21st year. Moreover, the project of making Al2O3 nanoparticles with the precipitation method can be considered profitable because it requires a short time to recover the investment cost, which is only 3 years. Fig. 3 shows the ideal condition of the CNPV/TIC graph on lifetime.

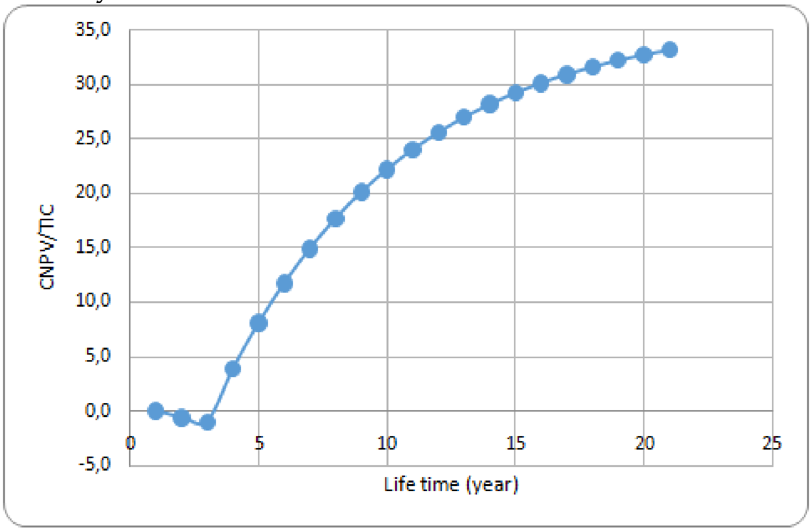

Fig. 3. Graph of CNPV/TIC on Lifetime (year) Under Ideal Conditions.

3.2.2. The Effect of External Conditions

The external conditions of the economic evaluation influence the success of a project. The most influential external factor on the success of a project is the country's economic condition where the project is established. These factors, such as taxes levied on projects by the state to finance public spending. Fig. 4 shows a graph of CNPV/TIC with various tax variations over 20 years. The y-axis is CNPV/TIC, and the x-axis is a lifetime (years). The PBP obtained from the tax variations of 10, 25, 50, 75, and 100% is shown in Fig. 4. In the initial conditions of up to two years, the CNPV project shows negative results in various tax variations. However, in the third year, the results start to be positive, and there is a difference in the payback point of this tax variation. The payback points obtained for variations of 10, 25, 50, 75, and 100% respectively are 3.87, 3.06, 1.72, 0.38, and for 100% tax, there is no payback point because it continues to decrease every year. So, it can be concluded that the lower the tax obtained, the higher the profit obtained, and the higher the tax obtained, the lower the profit obtained.

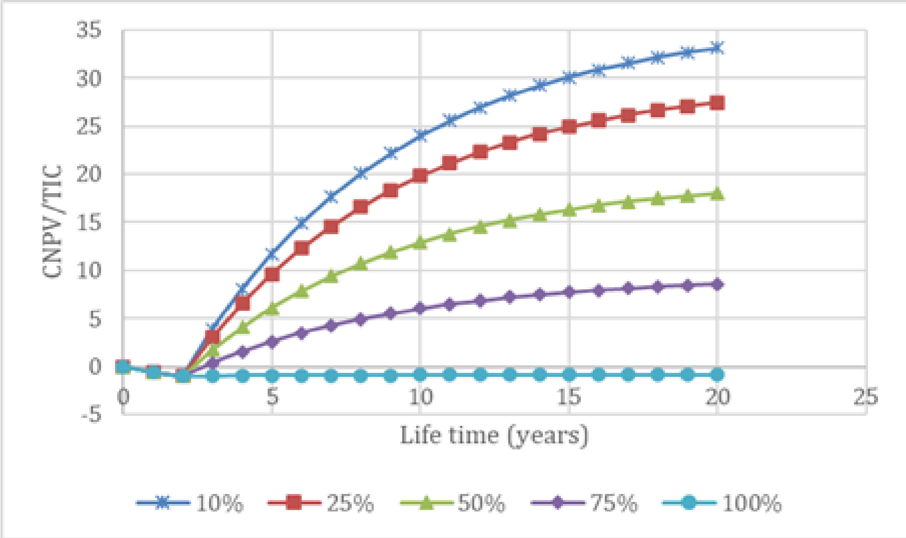

Fig. 4. Graph of CNPV/TIC on Lifetime (year) for Tax Variation.

3.2.3 Change in Sales

Fig. 5 shows a graph of CNPV/TIC against various sales variations. The y-axis is CNPV/TIC, and the x-axis is a lifetime (year). The analysis is done by increasing and decreasing the sales value by 10 and 20%, with an ideal sales value of 100%. Thus, the 10 and 20% decrease is 80% and 90%, while the increase of 10 and 20% is 110% and 120%, respectively. The initial phase is in the first and second years, where sales variation is still the same because it is still in the development phase. In the third year, the effects of the project are starting to show. This can be seen from the payback points in the third year, which have positive values for variations of 80, 90, 100, 110, and 120%, namely 1.69, 2.78, 3.87, 4.95, and 6.04. A higher sales value indicates a more significant profit, and a low sales value indicates a lower profit. Based on the PBP analysis, the return on investment will be obtained in 3 years when there are variations in sales of 80, 90, 100, 110, and 120%.

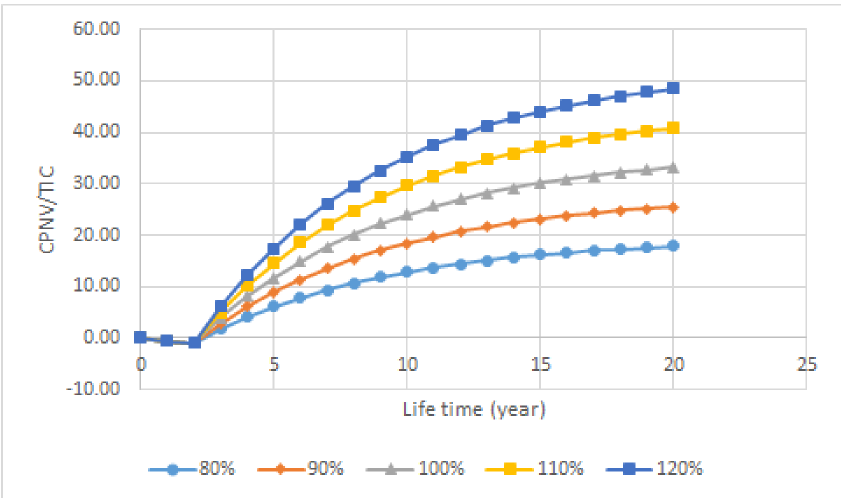

Fig. 5. Graph of CNPV/TIC on Lifetime for Sales Variations

3.2.4. Change in Variable Cost (Raw Material, Utility, Labor)

Changes in variable costs are caused by the prices of raw materials, utilities, and labor. Fig. 6 shows the variation in raw material prices. The y-axis is CNPV/TIC, and the x-axis is a lifetime (year). This analysis is done by increasing and decreasing the price of raw materials starting from 10 and 20%. When the price of raw materials is lowered, the percentages obtained are 80 and 90%. The price of raw materials is increased, the percentages obtained are 110 and 120%, and the ideal price is 100%. In the first to second years, there has been no difference in the variation in the price of this raw material. This is because the project is still in its infancy. Starting to see the effect of this variation in raw material prices when entering the third year. The highest payback point is in the third year with a variation of 80%, which is 4.54, and the lowest is in the 120% variation, which is 3.19. The lower the value of the variation, the higher the profit. The higher the value of the variation will result in a lower profit.

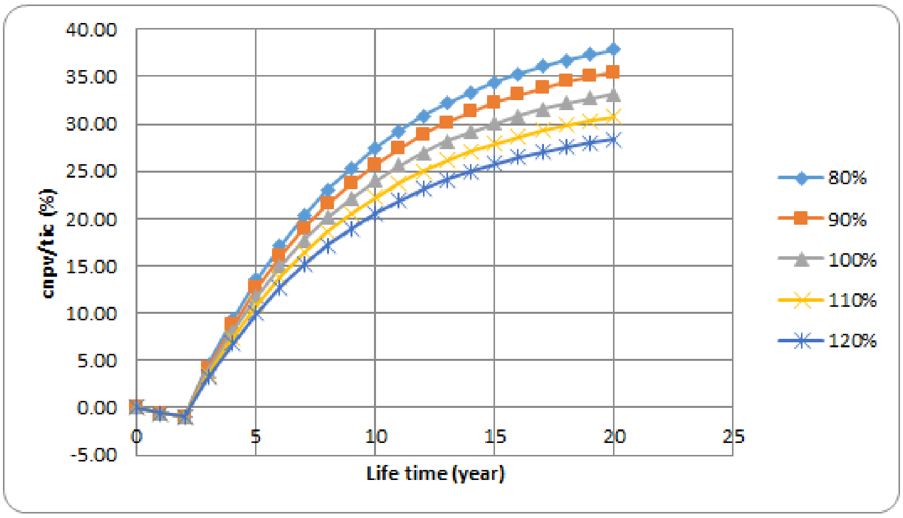

Fig. 6. Graph of CPNV/TIC on Lifetime (year) for Raw Material Variations.

Fig. 7 shows the relationship of CPNV/TIC to a lifetime (year) if the utility price is varied. The y-axis is CPNV/TIC, and the x-axis is a lifetime (year). Variations are made by adding and subtracting utility prices by 10 and 20% with a utility price value of 100%. Thus, the variations obtained are 80, 90, 100, 110, and 120%. The payback points obtained in the third year are 4.1, 4, 3.9, 3.8, and 3.7. Based on **Fig. 7**, this variation in utility prices does not show a significant effect because, for 20 years, the value of CNPV/TIC on the variation in utility prices is not much different. In the 20th year, the highest CNPV/TIC value was shown by a variation of 80%, namely 34.5, and the lowest CNPV/TIC value was indicated by a variation of 120%, which was 31.8.

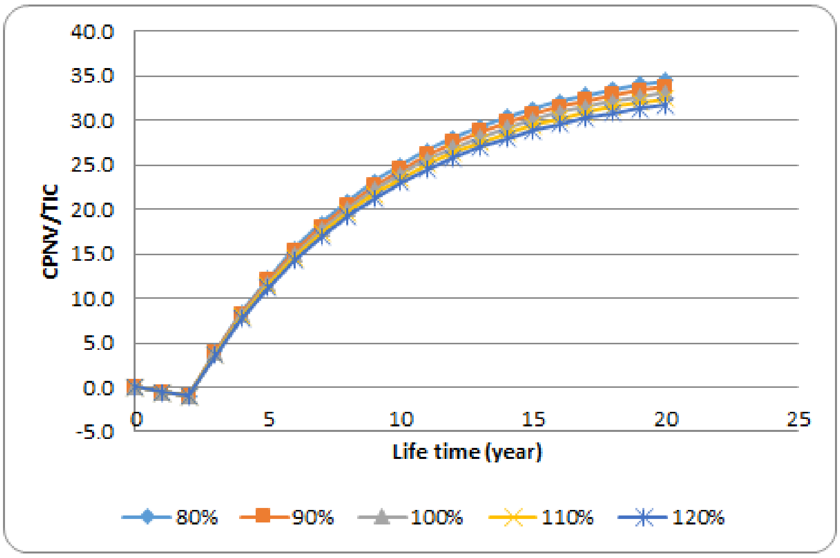

Fig. 7. Graph of CPNV/TIC on Lifetime (year) for Utility Prices Variations

Fig. 8 shows the relationship of CPNV/TIC to a lifetime (year) if variations are made on employee salaries. Variations are made by adding and subtracting 10 and 20% salaries with an ideal salary value of 100%. Thus, the variations obtained are 80, 90, 100, 110, and 120%. In the first and second years, there has been no difference in the variation in labor salary caused by the development period of the company. In the third year, the difference in the salary variations of these laborers began to be seen. The payback points obtained for CNPV/TIC values with variations in employee salaries of 80, 90, 100, 110, and 120% are 4.2, 4.0, 3.9, 3.7, and 3.5. This utility price variation does not show a significant effect. This is indicated by the value of the variation in labor salary who are not much different. The highest CNPV/TIC value in the 20th year, at 80% variation, is 35.4. Meanwhile, the lowest CPNV/TIC value in the 20th year, at 120% variation, is 30.9.

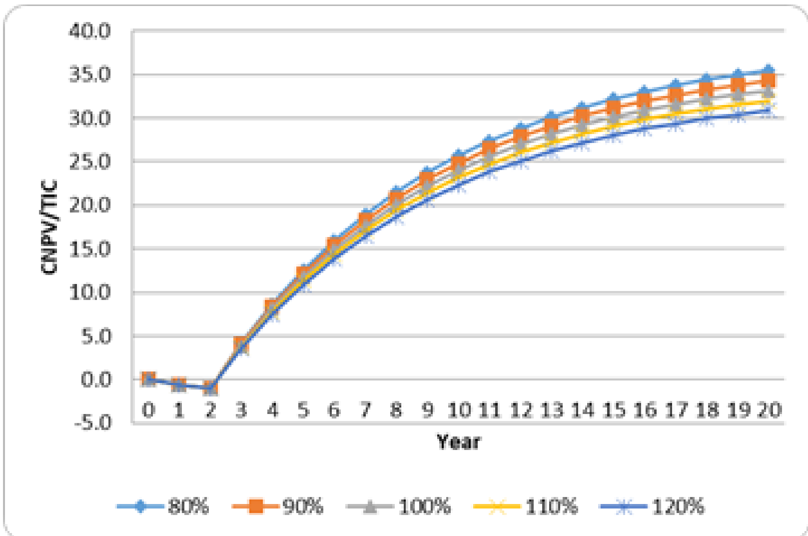

Fig. 8. Graph of CPNV/TIC on Lifetime (year) for Variations in Labor Salary Conditions

4. CONCLUSION

Based on the analysis results, the production project of Al_2O_3 nanoparticles using the precipitation method with aluminum chloride as the main raw material shows a prospective project from an engineering and economic perspective. The precipitation method has the advantages of a simple method used, low raw material costs, and produces a high purity product. PBP analysis shows that the project can compete with the standard market because the return on investment is profitable in a short time, after about three years. From the economic evaluation analysis results, it can be concluded that this project is feasible to run. Further research is needed to find ways to process waste to be reused and become environmentally friendly.

5. ACKNOWLEDGEMENTS

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