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Engineering and Economic Evaluation of Production of Al_2O_3 Nanopowder using a Sol-gel Method

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Abstract

The purpose of this study is to perform an engineering and economic evaluation of the synthesis of Alumina (Al_2O_3) nanopowder with the sol-gel method on an industrial scale. The evaluation is based on two main perspectives, namely the engineering perspective and the economic evaluation perspective. Several economic evaluation parameters are analyzed to provide information on the potential of Al_2O_3 nanopowder production which includes gross profit margin, payback period, and cumulative net present value. The results of this study indicate that the Al_2O_3 nanopowder industry project is feasible to run. Based on the results of the engineering perspective analysis, the Al_2O_3 nanopowder manufacturing project can be scaled up to 1.7 tons per year with annual profits reaching 865,774,580 IDR with a project life span of 20 years. To ensure the feasibility of the project, an economic evaluation analysis is carried out based on the estimation of ideal conditions and non-ideal conditions which include an increase in raw material prices, an increase in employee salaries, an increase in taxes, and a decrease in selling prices. This research is expected to provide information on prospective fabrication on the production of Al_2O_3 nanopowder on an industrial scale.

Keywords: Al_2O_3 nanopowder, sol-gel method, engineering and economic evaluation, feasibility study.

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1. Introduction

Lately, nano-sized Alumina (Al_2O_3) powder has been chosen for synthesis because of its ability to produce high-temperature, high-strength materials and use in a variety of applications, for example in

the fields of electronics, thermal, catalyst chemistry and mechanical such as materials in aircraft structures. Besides, the electrical conductivity is so low that it is suitable for use as an electrical isolator [1,2,3].

From previous studies, there have been several ways in synthesizing Alumina Powder such as the auto-ignition process [4], combustion [5], acid dissolution [6], precipitation [7], and sol-gel [8]. From these various methods, the sol-gel method was chosen with the consideration that this method is the most widely used method due to the high purity and high specific surface that generated from the solid particles produced, this method also contains materials that are easy to obtain economically to increase the production of large-scale alumina powder [8]. Although there is a lot of literature that discusses the synthesis of Al_2O_3 nanopowders with various methods, there is no literature that discusses the economic evaluation of the synthesis of Al_2O_3 nanopowders on an industrial scale. Whereas, this economic evaluation research needs to be done to determine the feasibility of a project on an industrial scale [9], as well as a key point in building a chemical industry business [10].

The purpose of this study is to perform an economic evaluation of the synthesis of Al_2O_3 nanopowder with the sol-gel method on an industrial scale. The evaluation is based on two main perspectives, namely the engineering perspective and the economic evaluation perspective. Several parameters are calculated to support economic evaluation based on the literature [11]:

- Gross Profit Margin (GPM) is the first analysis to determine the level of profitability of a project.
- Payback Period (PBP) is a prediction of the length of time an investment takes to be able to recover the total initial expense.
- Cumulative net present Value (CNPV) is the amount of cumulative financial flows each year.

To support the analysis both engineering and economically, various information obtained from the commercial web is included as a price reference and tool specifications. This study was calculated to estimate the feasibility and profitability of the synthesis of Al_2O_3 nanopowder by the sol-gel method applied on an industrial scale. Besides, this research can be used to suggest ways to optimize a project so that it can benefit economic growth.

2. Materials and methods

2.1. Synthesis of Al_2O_3 Nanopowder Using Sol-Gel Method

Synthesis of Al_2O_3 Nanopowder was taken and improvised from literature [6, 7, 8] Briefly, Aluminum Powder was dissolved in a 37% Hydrochloric Acid solution while stirring at 100°C. After the Aluminum powder is completely dissolved in Hydrochloric Acid a simple filtration is made to ensure that no aluminum powder remains. Then the mixture was added with a solution of Ammonium Hydroxide while

stirring at a temperature of 100°C. The resulting precipitate is then rinsed with distilled water, then dried on an 80°C heater for 48 hours. The dried precipitate was then calcined at 1100°C for 3 hours to produce α-Al_2O_3 which was then ground to a grinding ball mill to produce nano-sized Al_2O_3 powders. The process scheme of the sol-gel method is shown in **Fig 1**.

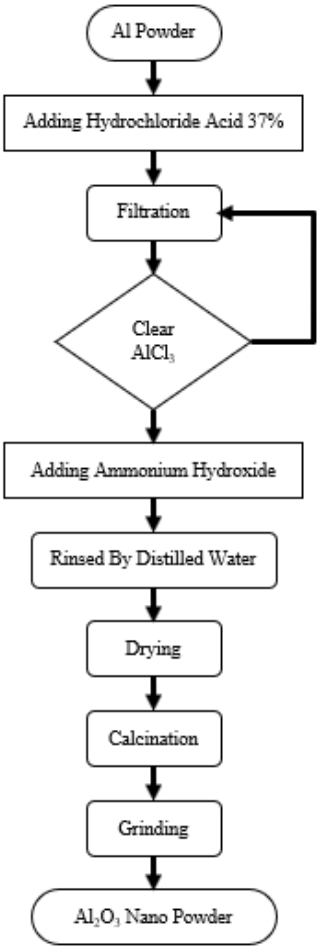

Fig 1. Al_2O_3 nanopowder synthesis scheme using sol-gel method

2.2. Experiment Method

The method used in this study is based on the analysis of the prices of materials and equipment, as well as the specifications of the equipment referred to online stores such as Alibaba.com. The analyzed data is processed in Microsoft Excel application to obtain economic evaluation parameters in the form of GPM, PBP, and CNPV. Calculation of the above parameters is based on literature [11] which is explained in the following formulation:

- The GPM parameter is obtained by subtracting the cost of the product sold with the cost of the raw material.
- PBP parameters are calculated based on when CNPV reaches zero point for the first time.
- CNPV parameters can be obtained as the sum of cumulative financial flows each year, calculated

from the total NPV value from the start of factory construction to the end of factory operations. Then an economic evaluation study to determine feasibility is performed by comparing PBP and CNPV parameters in ideal conditions and variations in conditions that are not ideal (i.e.: variations in the increase in raw material prices, variations in increases in employee salaries, variations in selling price decreases, and variations in tax increases).

2.3. Engineering Perspective Assumptions

Assuming an engineering perspective made based on the synthesis of Al_2O_3 nanopowder using the sol-gel method, stoichiometry calculations are shown after a project scaled up that produces about 17 kg of Al_2O_3 nanopowder every one cycle:

- All chemicals involved in production such as Aluminum powder, Hydrochloric acid, and ammonium hydroxide were scaled up and calculated based on the literature [7, 8].
- The conversion rate of all reactions is 100%.
- The amount of losses from the mechanical process is 5%.
- The level of production is carried out on a small industrial scale.

To ensure the processing steps, the process flow diagram for the production Al_2O_3 nanopowder using the sol-gel method is presented in **Fig 2**.

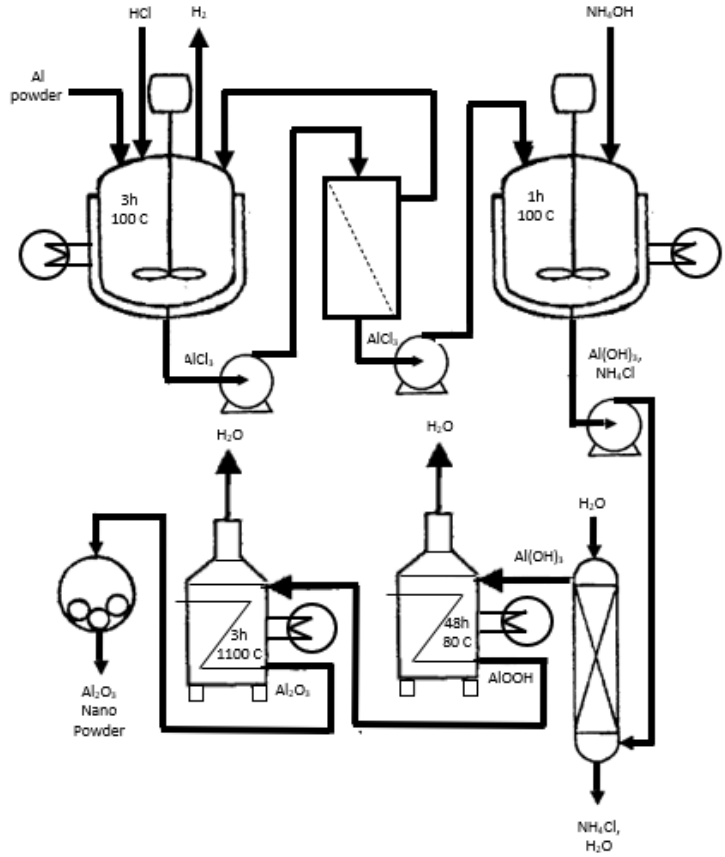

Fig 2. Process flow diagram for the production Al_2O_3 nanopowder using sol-gel method

2.4. Economic Evaluation Perspective Assumptions

To ensure economic evaluation analysis, several economic assumptions are used. This assumption was made to analyze and to predict several possibilities that occur during the project:

- All analyzes use the rupiah (IDR) currency.
- Prices of all raw materials are based on prices available in online stores (www.alibaba.com) with rounding decimals. The prices of aluminum powder, hydrochloric acid, ammonium hydroxide, and distilled water, respectively 82,000 IDR/kg, 54,000 IDR/L, 94,500 IDR/kg and 8000 IDR/L. All ingredients are calculated based on stoichiometric calculations.
- Equipment prices are set based on commercially available prices at online stores (www.alibaba.com).
- Lang Factor is used to analyze the total investment cost (TIC) based on the literature [11].
- Land bought. Thus, the cost of land is added at the beginning of the construction of the plant and recovered at the end of the project.
- The process to produce around 17 kg of Al_2O_3 nanopowder takes 3 days in one cycle.
- In one day, there is 1/3 production cycle.
- One-year project contains 300 days, so the maximum total production in one year is 100 times the processing cycle.
- Products are packaged in one pack per 1 kg.
- The basic electricity cost is assumed to be 15,000 IDR/kWh.
- The total salary of a day employees is 800,000 IDR / day.
- The discounted rate is 15% per year.
- Income tax is 10% per year.
- The project operation life span is 20 years.

3. Results and discussion

3.1. Engineering Perspective

Based on engineering perspective assumptions, scaling up can be used in manufacturing projects of Al_2O_3 nanopowder on an industrial scale with the availability of equipment that can be commercially and economically obtained. If every year a 100 production cycles were performed, then to produce 1.7 tons of Al_2O_3 nanopowder which consumes 1.08 tons of aluminum powder, 4.32 tons of hydrochloric acid, and 4.2 tons of ammonium hydroxide in one year under conditions ideal. Costs must be incurred annually for a total manufactory cost of 1,648,525,420 IDR with an annual selling price of 2,514,300,000

IDR so that the profit earned is 865,774,580 IDR each year. This profit figure shows the economic and convincing value for this project can be done with a project life span of 20 years.

3.2. Economic Evaluation

The results of the CNPV/TIC graph analysis from the calculation of several economic evaluation parameters in the industry of Al_2O_3 nanopowder over time (years) under ideal conditions can be seen in **Fig 3**. From the graph can be seen a decrease in the curve from the first year till the second year, which indicates the absence of income from the production of Al_2O_3 nanopowder. Because in the first two years there was an expense for the initial cost of the industrial process so that the value of the CNPV/TIC rate decreased. The curve indicates the payback period (PBP) around the 5th year which means the amount of the initial investment was recovered in that year. Then the following years showed an increase in the curve, which indicates an increase in income every year until the 20th year. An increase in profits could show the value of Gross Profit Margin (GPM) of this project is positive, which indicates good profitability from this project. From the results of this CNPV/TIC graph, it can be seen that the industry of the Al_2O_3 nanopowder project is feasible to run because it generates profits. These results are corresponding with the literature [9] where the increase of CNPV/TIC rate in ideal conditions becomes a benchmark for the feasibility of a project to be done.

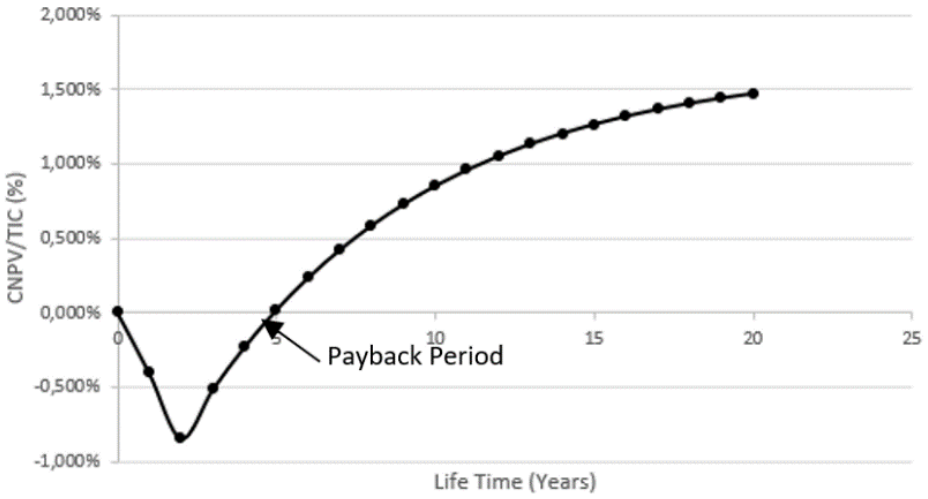

Fig 3. Graph of CNPV/TIC in ideal conditions for twenty years

Results of the analysis of CNPV/TIC graphs with variations in the increase of raw material prices for 20 years can be seen in **Fig 4**. From the Curves, it can be seen that there is an increase in CNPV/TIC rates from the 3rd to the 20th years which is different in each variation of the increase in raw material prices. The higher the increase in the price of raw material, the lower the increase of the CNPV/TIC rate. This

indicates that the increase in the price of raw materials can affect the decrease in GPM which results in a decrease in profitability of a project and the occurrence of PBP will also be longer if the price of raw material is higher. The industry of the Al_2O_3 nanopowder project will continue to decline due to the increase in raw material prices until it has not experienced PBP for 20 years when the increase in raw material prices reaches 70%. This result is corresponding with the literature [9] where variations in raw material prices can affect the GPM value of a project, the value of GPM will continue to decrease in line with the increase in raw material prices, and the increase in raw material prices will affect the decline in the CNPV / TIC rate shows a decrease in profitability of a project.

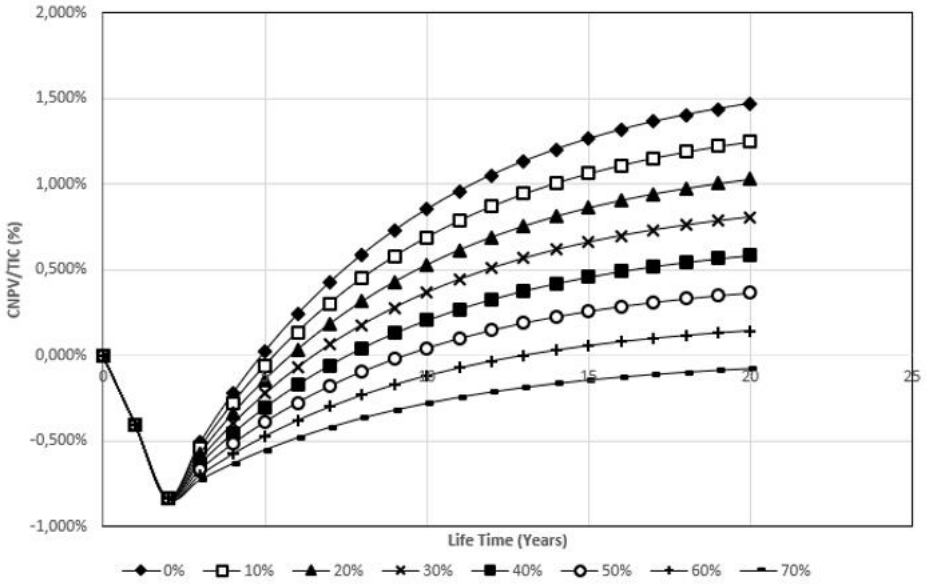

Fig 4. Graph of CNPV/TIC with variations in the increase of raw material prices for twenty years

The results of the analysis of the CNPV/TIC graph with variations in the increase of employee salary prices for 20 years can be seen in **Fig 5**. From the curve, it can be seen that there is an increase in CNPV/TIC rates from the 3rd to the 20th years which is different in each variation in the increase in employee salary prices. The higher the price of an employee's salary, the lower the increase in the CNPV/TIC rate. This indicates that the increase in the price of employee salary can affect the decrease in GPM, which results in a decrease in profitability of a project and the occurrence of PBP will also be longer if the price of employee salaries is higher. The industry of the Al_2O_3 nanopowder project will continue to decline due to the increase in the price of employee salary until it has not experienced PBP for 20 years when the increase in employee salary prices reaches 130%. These results are corresponding with the literature [9] where variations in employee salary prices can affect the variable cost price of a project, where an increase in variable cost prices can affect the decrease in the CNPV/TIC rate which indicates a decrease in profitability of a project.

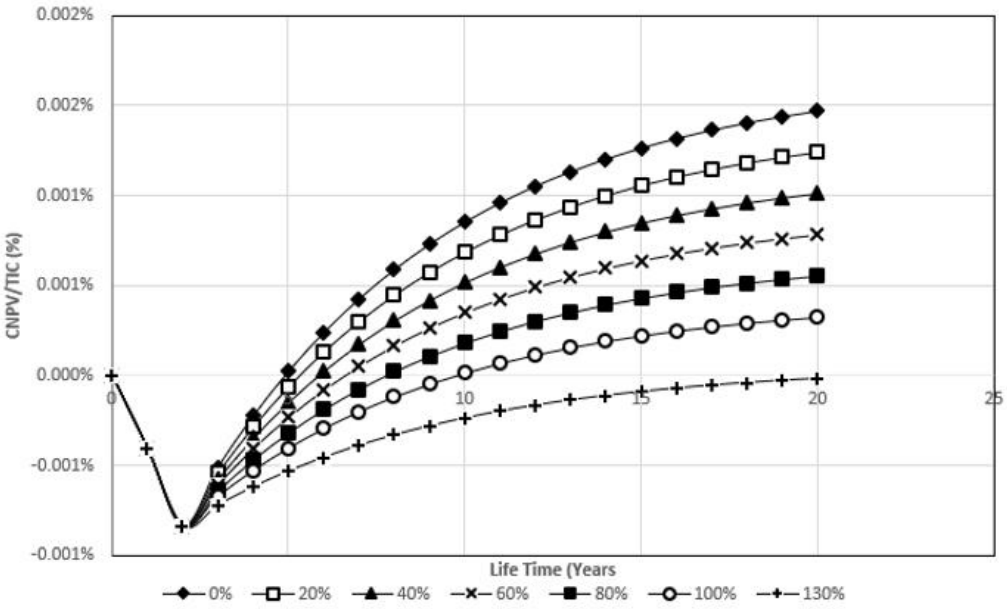

Fig 5. Graph of CNPV/TIC with variations in the increase of employee salary prices for twenty years

The results of the analysis of the CNPV/TIC graph with variations in the decrease in sales price for 20 years can be seen in **Fig 6**. The decrease of product selling prices will affect the value of GPM which can result in a decrease in profitability of the project. The lower the selling price, the smaller the profit obtained which has an impact on the smaller CNPV/TIC rate increase. It can be seen from the curve there is an increase in the CNPV/TIC rate from the 3rd to the 20th years which is different in each variation of the decrease in selling prices.

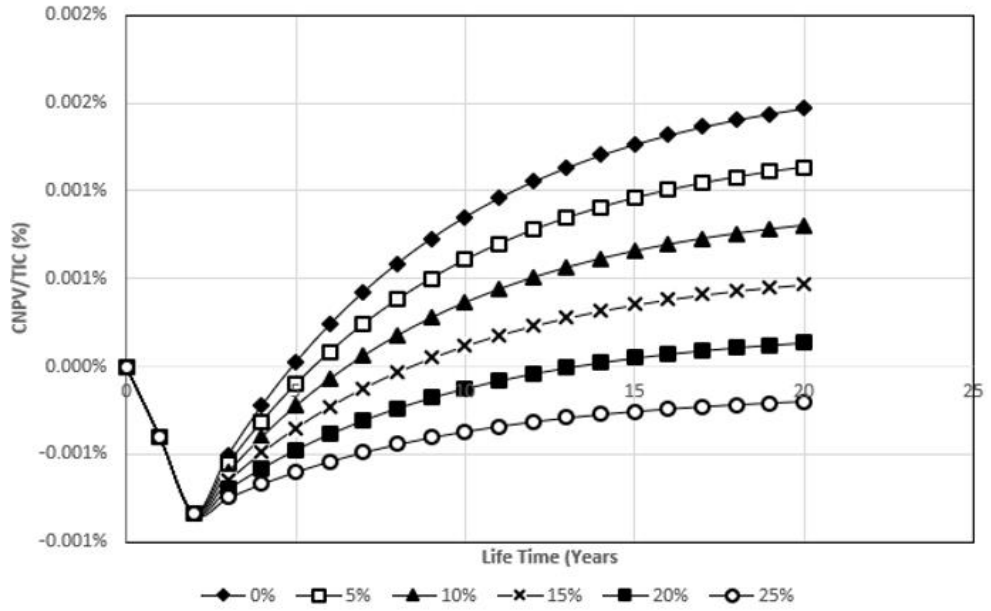

Fig 6. Graph of CNPV/TIC with variations in the decrease of sales prices for twenty years

If the CNPV/TIC rate decreases, the length of time to return the initial investment will increase resulting in the feasibility of the project will decrease. The industry of the Al_2O_3 nanopowder project will continue to decline due to the decreases in selling prices until it has not experienced PBP for 20 years when the sales price reduction has reached 25%. These results are corresponding with the literature [9] where variations in sales prices can affect the value of GPM of a project, where the value of GPM will continue to decline in line with the decreases in sales price which can affect the profitability of a project.

The results of the analysis of CNPV / TIC graphs with variations on tax increases for 20 years can be seen in **Fig 7**. From the curve can be seen the similarity between ideal conditions and variations where firstly there is a decrease until the second year due to the absence of incoming income from production Al_2O_3 nanopowder so no tax has been imposed. Furthermore, the curve shows an increase in the CNPV/TIC rate from the 3rd to the 20th years which is different in each variation of the tax increase. The higher the tax increase variation, the lower the CNPV/TIC rate increase. That is because the amount of tax value can affect the amount of profits obtained. This indicates that the increase in taxes can affect the decrease in GPM, which results in a decrease in the profitability of a project and the occurrence of PBP will also be longer if the tax is higher. The longer the return on the initial investment will affect the feasibility of the project. The industry Al_2O_3 nanopowder project will continue to decline due to the increase in tax value until it has not experience PBP for 20 years when the tax increase reaches 80%. These results are corresponding with the literature [9,12] where variations in taxes can affect the CNPV/TIC rate of a project, where an increase in the price of tax variations can affect the decrease in the CNPV/TIC rate which shows a decrease in profitability of a project.

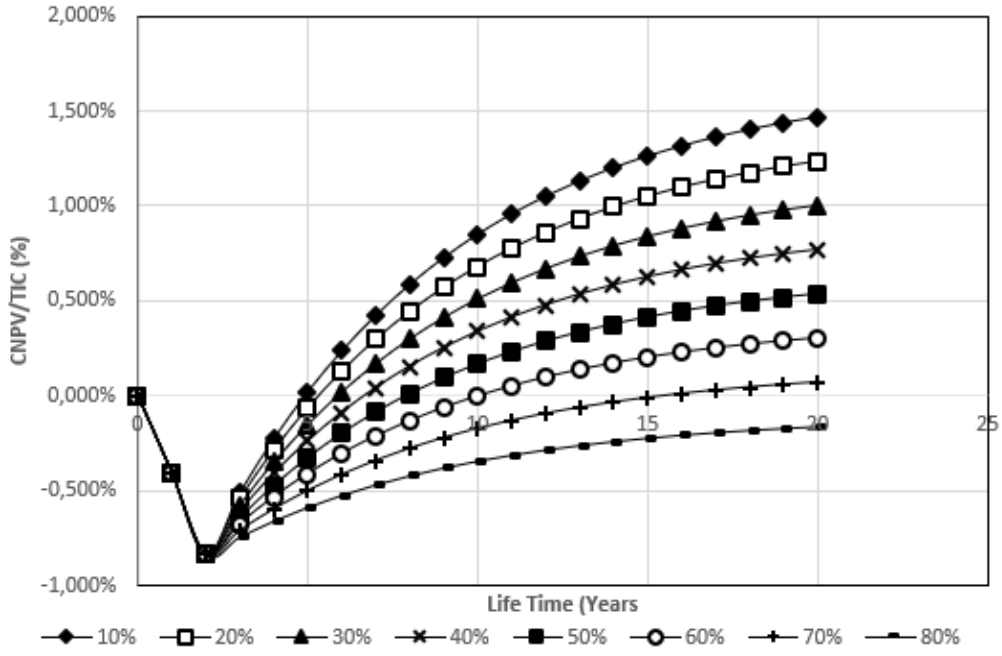

Fig 7. Graph of CNPV/TIC with variations in the increase of tax for twenty years

Conclusion

Based on the results of the analysis that has been performed, the production of the Al_2O_3 nanopowder project on an industrial scale is feasible because it can present profits from both an engineering perspective and an economic perspective. This analysis is supported by the results of the cost analysis on economic evaluation parameters that present positive numbers. An analysis of several conditions is also carried out which presents information on various boundary conditions to generate profit. The project is still considered feasible to make a profit if the increase in raw material prices is no more than 60%, the increase of employee's salary is no more than 100%, the tax increase is no more than 70%, and the selling price decreases no more than 20%.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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