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Techno-Economic Analysis of the Production of Magnesium Oxide Nanoparticles Using Sol-Gel Method

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Abstract

The purpose of this research is to determine the feasibility of a project in producing magnesium oxide (MgO) nanoparticles using the sol-gel method and to evaluate it from a technical and economic point of view. The sol-gel method is a method that is often used by industry because the process is simpler. Assessment from a specialized point of see is done by calculating the stoichiometry, whereas assessment from a financial viewpoint is decided by a few parameters, such as deciding Gross Profit Margin (GPM), predicting Payback Period (PBP), predicting Cumulative Net Present Value (CNPV), etc. The results of the technical analysis appear that the overall fetched of the gear to create 1,875 kg of MgO nanoparticles per day is 45,373 USD. Payback Period analysis appears that the venture pays off after more than three a long time. This venture is able to compete with PBP capital advertise measures since the venture will return in a brief time. Based on the economic evaluation, it can be concluded that this project is very promising if it is anticipated that losses will occur due to changes in several ideal conditions. The result of this study about are anticipated to be a reference for building more economical, efficient and high-demand MgO nanoparticle production projects.

Keywords: *MgO nanoparticles, sol-gel method, economic evaluation, feasibility study*

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INTRODUCTION

Magnesium oxide (MgO) is one of the functional metal oxides and has been widely used in various fields. MgO can be utilized for ceramic materials since it contains a high melting point that makes it fire resistant, has a strong surface, is water resistant, soundproof, resistant to attack by mold, mildew and decay [1]. MgO has excellent optical, electrical, thermodynamic, electronic and mechanical properties. In the industrial world, MgO is usually used to make materials that function as heat-resistant walls in furnaces, electrical insulators, food packaging, cosmetics, pharmaceutical manufacturing [2], catalysts [3], bactericidal properties [4], photocatalytic [5], adsorbents [6], optical properties [7], electrochemical biosensors [8], refractory materials, paints, and superconductors [9].

Magnesium oxide nanoparticles are metal oxide nanoparticles which are exceedingly ionic in nature with an awfully tall surface region and an abnormal precious stone morphology [9]. Magnesium oxide nanoparticles have been used widely because of their attractive properties, especially their wide bandgap, ability to maintain thermodynamic density, low dielectric stability, and low refractive index [10]. A few strategies can be utilized within the synthesis of magnesium oxide nanoparticles, including combustion [11], synthesis of plant extricates [12], sonochemical synthesis [13], solid-state synthesis [14], and sol-gel synthesis [15]. In this research, synthesis of magnesium oxide by sol-gel method was utilized. The sol-gel strategy is a broadly utilized method for synthesizing magnesium oxide nanoparticles since the method is straightforward, the item abdicate is very tall, and the response temperature is low. In expansion, the sol-gel strategy is moderately reasonable to get magnesium oxide nanoparticles with a contract measure dissemination and bigger surface range which is exceptionally critical to overcome the issue of low reactivity and catalytic capacity [16]. This study examines the generation of magnesium oxide nanoparticles utilizing magnesium acetic acid derivation tetrahydrate ($Mg(CH_3COO)_2.4H_2O$) and oxalic acid dehydrate ($C_2O_4.2H_2O$) raw materials. The production prepare can be seen within the stream chart appeared in Figure 1.

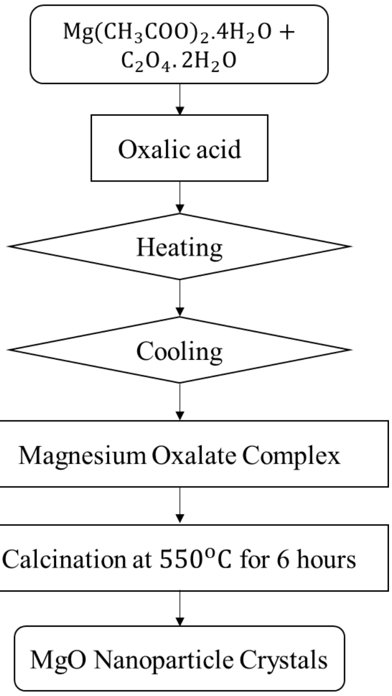

Figure 1. Schematic diagram of the MgO nanoparticles production process using the sol-gel method.

Until now, many studies have explained how magnesium oxide nanoparticles are synthesized, but the financial assessment of the amalgamation of magnesium oxide nanoparticles by the sol-gel strategy on a mechanical scale has not been broadly considered. In this manner, the point of this inquire about is to analyze the economic evaluation of a extend that produces magnesium oxide nanoparticles utilizing the sol-gel strategy on a mechanical scale. This evaluation can be done from two sides, namely the technical and economic sides. From a technical point of view, it can be determined by calculating stoichiometry, mass balance, and evaluating the initial plant design. Meanwhile, evaluation from an economic point of view can be determined by several parameters including the value of Gross ProfitMargin, Internal Rate of Return, Break Even Point, Payback Period, and Cumulative Net Present Value which will determine the benefits of the project to be established under various conditions [17].

METHODS

In this ponder, we chose a investigate method for the synthesis of MgO nanoparticles utilized magnesium acetic acid derivation tetrahydrate ($Mg(CH_3COO)_2.4H_2O$) and oxalic acid dehydrate ($C_2O_4.2H_2O$) as raw materials [18]. Financial assessment is carried out by implies of cost investigation of gear, utilities, and raw materials utilized for the generation of magnesium oxide nanoparticles. The information is at that point calculated utilizing Microsoft Excel expectations with a few parameters such as Gross Profit Margin, Internal Rate Return, Break Even Point, Payback Period, and Cumulative Net Present Value of various variable costs. Calculations are based on literature [17]. To urge the comes about of this ponder, calculations were carried out utilizing a few equations, such as:

- Gross Profit Margin (GPM) is the primary examination that can decide the level of productivity of a extend. This investigation can be assessed by lessening deals costs with raw materials costs [17].

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

  S is the amount of sales, η is efficiency, RM is the amount of raw materials, PC is generation capacity, Q is raw materials capacity included and utilized within the prepare (kg/hour), and t is generation time.

- Internal Rate Return (IRR) could be a representation that appears the normal intrigued wage per year for all costs and salary within the same sum. On the off chance that the Internal Rate Return is higher than the winning genuine intrigued rate (current bank lending rates), at that point the production line is considered beneficial, but on the other hand in case the Internal Rate of Return is lower than the winning genuine intrigued rate, then the factory is considered to be in deficit [17].

$$IRR = i_1 + \frac{NPV_1}{NPV_1 - NPV_2} \times (i_1 - i_2) \quad (2)$$

  i_1 is the small (low) interest rate, i_2 is the large (high) interest rate, NPV_1 i is the NPV using the lower discount rate, and NPV_2 is the NPV using the higher discount rate.

- Break Even Point (BEP) is the least add up to item esteem that must be sold at a certain cost to cover production costs. Break Even Point can be calculated by separating fixed costs by benefits [17].

$$BEP = \frac{FC}{P - VC} \quad (3)$$

  FC is the fixed cost, P is the price per unit, and VC is the variable cost.

- Payback Period (PBP) could be a calculation that can be utilized to anticipate the time required for an venture to return its beginning speculation (introductory capital). In brief, the Payback Period is calculated when the Cumulative Net Present Value (CNPV) reaches zero [17].

$$PBP = \frac{n+(a-b)}{(c-b)}\ x\ 1\ year \quad (4)$$

n is the most recent year for which the sum of cash stream was not adequate to cover the introductory speculation, a is the sum of beginning speculation, b is the total sum of cash stream in year -n, and c is the aggregate sum of cash stream in year n+1.

- Cumulative Net Present Value (CPNV) is the total net present value from the start of the production line development to the conclusion of the plant's operation [17].

$$\text{NPV} = \Sigma_{tr=1}^{tr} \left(\frac{Rt}{(1+i)^{tr}}\right. \quad (5)$$

Rt is the net cash inflow less cash outflow during a period tr, i is the markdown rate that can be gotten from elective speculations, and tr is the term of the extend per year.

RESULTS AND DISCUSSIONS

Engineering Perspective

Several assumptions were used in this study based on the representation in Figure 2 which shows the production process of magnesium oxide nanoparticles and the flow diagram for the manufacture of magnesium oxide nanoparticles appeared in Table 1. These assumptions are shown by stoichiometric calculations which will increase the yield of magnesium oxide production if the project is scaled up. In this study, the production output after increasing the project resulted in around 1,875 kg of magnesium oxide nanoparticles in one production cycle (per day). Assumptions that need to be improved include: (1) All raw materials are increased up to 2,000 times compared to lab scale in the literature. (2) The materials utilized are of tall immaculateness. (3) Magnesium acetate derivation tetrahydrate and oxalic acid dehydrate respond to create magnesium oxide with a virtue of 98%. (4) There's a misfortune of 2% amid the method of decantation, drying and item collection.

In industrial projects, assumptions are needed to ensure economic evaluation analysis and anticipate different conceivable outcomes that will happen amid the extend. The assumptions are: (1) All analyzes utilize USD. 1 USD = 15,628 rupiah [19]; (2) Based on commercially accessible costs, the costs for magnesium acetic acid derivation tetrahydrate and oxalic acid dehydrate are 2.025 USD/kg and 0.6 USD/kg. All materials are assessed based on stoichiometric calculations; (3) Have obtained the venture location (land). Thus, land costs can be included at the starting of the plant development year and can be recouped after the venture closes (4) Total Investment Cost (TIC) can be calculated using the Lang Factor [20]; (5) Total Investment Cost is made in at slightest two stages. The primary phase is 40% within the to begin with year and the moment stage is the leftover portion (amid the venture development stage); (6) Depreciation is estimated by direct calculation [20]; (7) In each one cycle of magnesium oxide nanoparticle generation takes 16 hours; (8) Shipping costs are charged to the customer; (9) Magnesium oxide nanoparticles are sold at 2 USD/pack (1 kg); (10) The yearly extend will final 300 days (the remaining days are utilized for cleaning and prepare administration); (11) To encourage supply, utility units can be broken down and changed over into power units, for case kWh [17]. Then, electricity units can be converted into payments (fees). The unit of power (kWh) increased by the taken a toll of power. The operating cost assumption is 0.071 USD/kWh; (12) The full wage/labor is assumed to be a settled esteem of 62.91 USD/day; (13) Markdown rate of 15% per year; (14) Income tax of 10% per year; (15) When the project carried out for 10 years.

A project can be tested for its feasibility by conducting an economic evaluation analysis. The analysis is carried out by changing or varying the values of several important parameters in a project. In this case, the parameters of raw materials, equipment, and labor are varied by 50%, 75%, 100%, 125%, 150%, 175% and 200%, while the tax parameters are varied by 10%, 25%, 50%, 75%, and 100%.

Figure 2 appears the processing conditions for producing magnesium oxide (MgO) nanoparticles utilizing the sol-gel method. The synthesis procedure for MgO nanoparticles analyzed in this study used magnesium acetate derivation tetrahydrate ($Mg(CH_3COO)_2.4H_2O$) and oxalic acid dehydrate ($C_2O_4.2H_2O$) as raw materials. First of all, the raw material is dissolved with methanol in the reactor for 120 minutes and the heating process is carried out at 110^oC. The consistent warming prepare will deliver a clear colored blend. The blend gotten was balanced to pH 5 by including oxalic corrosive to the arrangement and taken after by a blending prepare until a white gel was gotten. Then the resulting gel was transferred to the next reactor for the cooling process at room temperature and left for 12 hours so that the gelation process was complete. The gel is at that point sifted to isolated the gel and the arrangement. The strong gotten was warmed at 110°C for 24 hours to evacuate water and acetic acid derivation caught within the strong shaped, at that point cooled to room temperature. Furthermore, the dry product was refined using a special mechanical refiner to create a magnesium oxalate complex which capacities as a forerunner for the fabricate of MgO nanoparticles. The complex formed is then calcined at certain temperatures: 400; 450; 500; 550°C, but in this study, the temperature for the calcination process can be carried out at 550°C with a pressure of 1 atm for 6 hours [18]. This process will produce MgO nanoparticle crystals. Each production cycle produces 1,875 kg of magnesium oxide nanoparticles. In one month, the project can produce 46,875 kg and in one year produce 562,500 kg of magnesium oxide nanoparticles.

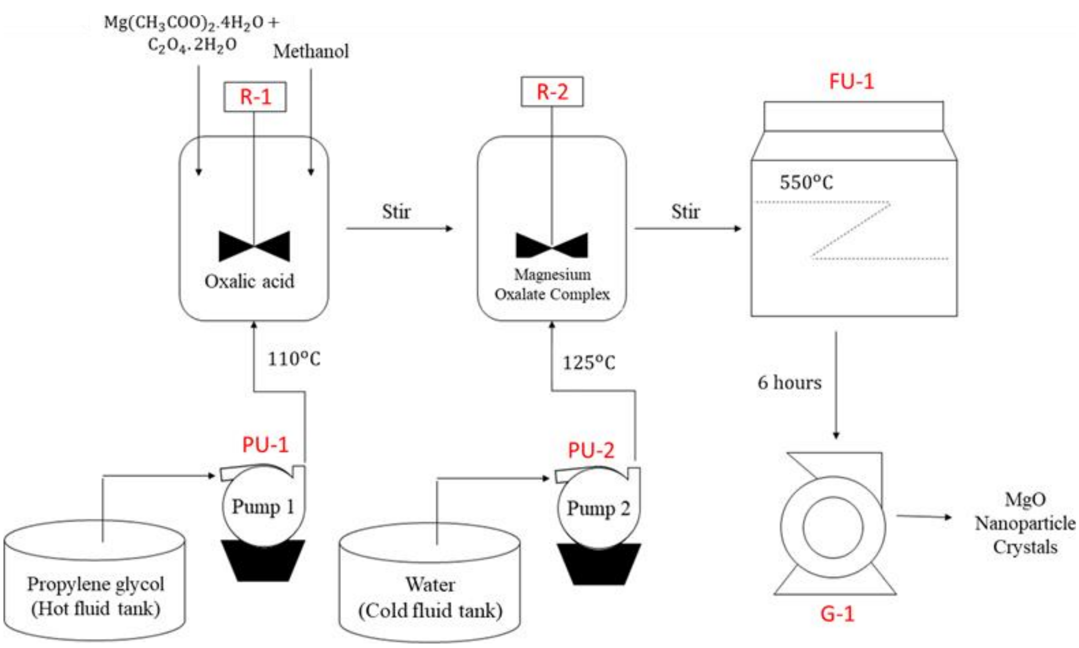

Figure 2. PFD on the synthesis of MgO nanoparticles

Table 1. Table of the method stream chart for the fabricate of MgO nanoparticles

No.	Symbol	Information
1.	R-1	Reactor-1
2.	R-2	Reactor-2
3.	PU-1	Pump-1
4.	PU-2	Pump-2
5.	FU-1	Furnace-1
6.	G-1	Grinding-1

Table 2. Annual cumulative net present value under ideal conditions.

CNPV/TIC	Year
0	0
-0,409351928	1
-0,845204551	2
963,8091576966	3
1802,6390379121	4
2532,0563250560	5
3166,3322269202	6
3717,8764894109	7
4197,4801959245	8
4977,1762027330	9
4977,1762027330	10

From a designing viewpoint, the whole taken a toll brought about by a project to purchase MgO raw material for one year is 78,750 USD, whereas the whole sales gotten in one year is 337,500,000 USD. The profit earned for one year is 337,421,250 USD. The costs incurred to purchase the equipment amounted to 45,373 USD. Total Investment Cost

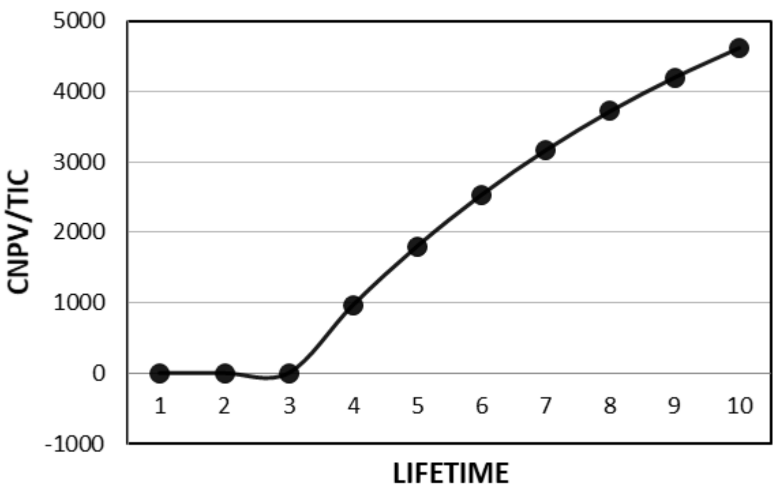

Figure 3. Ideal conditions *Cumulative Net Present Value/Total Investment Cost* for *life time (year)*

(TIC) must be less than 192,381.52 USD. This project will be implemented for 10 years and will produce magnesium oxide nanoparticles with a Cumulative Net Present Value/Total Investment Cost reaching 4977.176% within the tenth year and the Payback Period has been successfully accomplished within the third year.

Economic Evaluation

Ideal Conditions

The graph of the relationship between Cumulative Net Present Value/Total Investment Cost to time can be seen in Figure 3. In the graph, the y-axis shows Cumulative Net Present Value/Total Investment Cost, while the x-axis shows life time(year). From the graph it can be seen that the cumulative value of the Cumulative NetPresent Value/Total Investment Cost is negative (%), which is less than from the primary year to the third year, which shows a diminish in salary in that year due to the beginning capital outlay to produce magnesium nanoparticles oxide. Within the third year, the chart appears an increment in income, where this condition is the Payback Period (PBP). The benefits earned can be utilized to cover the beginning capital that has been issued and benefits will proceed to extend from that point until the tenth year. The negative esteem of the Cumulative Net Present Value/Total Investment Cost from the primary year to the moment year can be seen in Table 2. At that point the esteem of the Cumulative Net Present Value/Total Investment Cost a toll begins to return to positive within the third year. In this manner, the generation of magnesium oxide nanoparticles can be respected as a productive commerce since the generation of magnesium oxide nanoparticles requires a brief time to cover venture costs.

Influence of External Conditions

A few components of outside conditions can influence the victory of a extend. One figure is the charges exacted by the government to back different open uses. The graph of Cumulative Net Present Value with various tax variations can be seen inFigure 4. In the graph, the y-axis shows Cumulative Net Present Value/Total Investment Cost (%) while the x-axis shows life time (years). Figure 4 appears that the conditions from the starting of the year to two a long time appear the same comes about, typically since the Cumulative Net Present Value is beneath varieties in charges and there's extend advancement. In expansion, in that year there was no income and deductions were made according to the graph of ideal conditions. Profits proceed to extend after coming to the Payback Period (PBP) point until the tenth year. The cumulative net present value/total investment cost within the tenth year for each variety of 10%, 25%, 50%, 75%, and 100% is 9.57; 23.94;

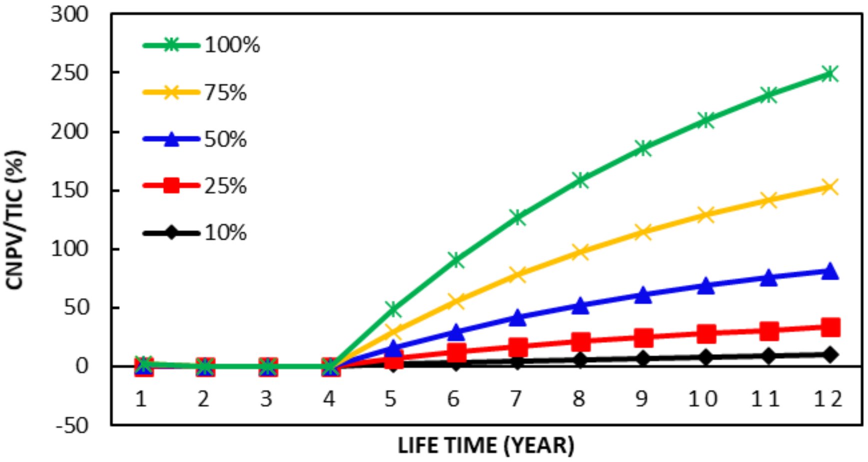

Figure 4. Cumulative Net Present Value curve for tax variations

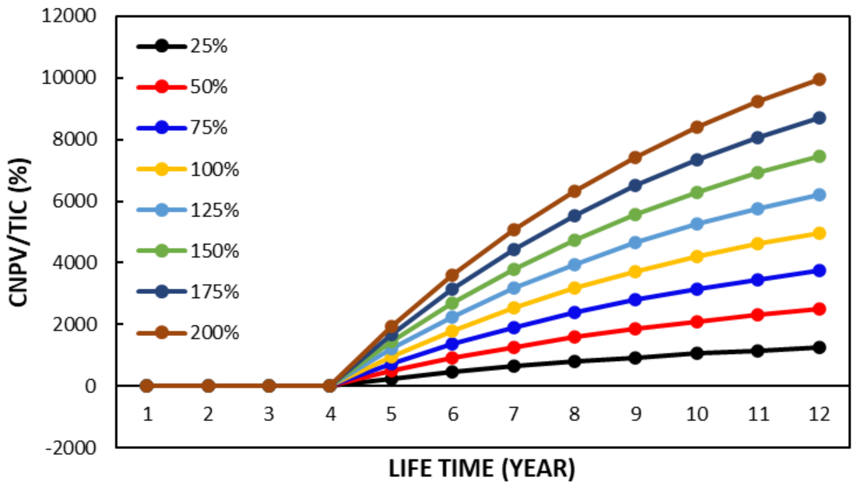

Figure 5. Cumulative Net Present Value curve for variations in sales

47.87; 71.81; and 95.751%. So, the most extreme assess to urge the Break Even Point (the point where both picks up and misfortunes within the venture) is 75%. Changes in taxes to more than 75% make the project fail.

Sales Changes

The graph of Cumulative Net Present Value with different sales variations and Payback Period results can be seen in Figure 5. In the graph, the y-axis showsCumulative Net Present Value/Total Investment Cost while the x-axis shows life time(year). Project provisions for Cumulative Net Present Value from the primary year to the moment year are the same in different variations. This happened since of the advancement venture. The impact of deals on the Cumulative Net Present Value can be decided after the usage of the venture for 2 a long time. The higher the sales value, the higher the profit from the realized project. However, if conditions occur that cause a decrease in product sales, the venture income will diminish from ideal conditions.

Based on Payback Period analysis, return on investment can be achieved with sales fluctuations of 25%, 50%, 75%, 100%, 125%, 150%, 175% and 200% in the third year. Profits will proceed to extend after coming to the Payback Period (PBP) until the third year when the total benefit edge for the year increments as deals increment from perfect conditions. Cumulative Net Present Value/Total Investment Costin the tenth year for each variation of 25%, 50%, 75%, 100%, 125%, 150%, 175%, and 200% is 1244.29; 2488.58; 3732.88; 4977.17; 6211.47; 7465.76; 8710.06; and 9954.35%. Therefore, the least income to reach the Break Even Point (the point at which the venture picks up or loses) is 50%. Deals of magnesium oxide nanoparticles will be more productive when turnover increments by more than 50% since the chart appears a positive Cumulative Net Present Value/Total Investment Cost, which suggests the extend is doable to run [21].

Changes in variable costs (raw materials, labor wages, utilities)

The success of a project can be influenced by several internal factors, includingthe condition of raw materials, labor and utilities. Analysis can be done by evaluatingthe project with Gross Profit Margin (GPM) analysis in various conditions of raw materials and sales as shown in Figure 6. This analysis is evaluated by subtracting thecost of goods sold from the cost of raw materials [22]. The results of the analysis showa positive correlation between sales and GPM, while raw materials show a negative (opposite) correlation. In this case, the increase in sales will directly impact the success of the project (profitability), whereas the cost of raw materials will have an affect on the maintainability of the extend. Based on the examination, the two crude materials utilized, namely magnesium acetate and oxalic acid, have an effect similar to GPM. If seen from the graph in Figure 6, the raw material parameter that has the mostinfluence is oxalic acid because it shows a steeper curve compared to magnesium acetate.

Apart from raw materials and sales, project financial conditions can also be affected by the amount of labor and utilities which can be seen in Figure 7 and Figure 8. The figures shown in the graph explain the estimated Profitability Index (PI) as a function of sales, raw materials, labor , and utilities. Sales factors are positively correlated with GPM, while raw materials, labor, and utilities are negatively correlated with GPM. Based on the PI profit-to-sales chart shown in Figure 7, sales have an exponential curve effect on the PI value. The PI value changed from 0.926 to 0.930. These results are consistent with the fact that declining sales have a direct impact onrevenue, especially when the sensitivity fluctuates between -50 and 0%. But the increase in sales does not affect the results because the increase in sales is associatedwith changes in variable costs. Therefore, sales must be carried out optimally in orderto obtain optimal profits as well. The next effect is raw materials that produce a linearcurve, meaning that an increase in raw materials directly affects the success (profitability) of the project. For labor, this cost increase has a smaller impact compared to sales and raw materials, i.e. the PI varies between -50 and 150%. Meanwhile utility shows the smallest impact, namely PI only varies between 0 to 50%.

Based on the profit-to-investment PI chart shown in Figure 8, a relativelystraight linear curve for sales parameters is obtained. This indicates that sales growthdirectly affects the success (profitability) of the project. For raw material and utility parameters, a horizontal curve is obtained indicating that sales growth does not affectthe success (profitability) of the project. The last is the labor parameter which showsa curve with a PI varying between -50 to 100%.

The results of the analysis of the profitability index (PI) graph, the most relevant graph is chart 7, because the results are consistent with the fact that a decrease in sales has a direct impact on income and an increase in raw material prices can directly affect the success (profitability) of the project. Whereas in graph 8 there is something that is less relevant, namely that raw materials and utilities do not affect the success (profitability) of the project even though they should be able to affect the success (profitability) of the project as well.

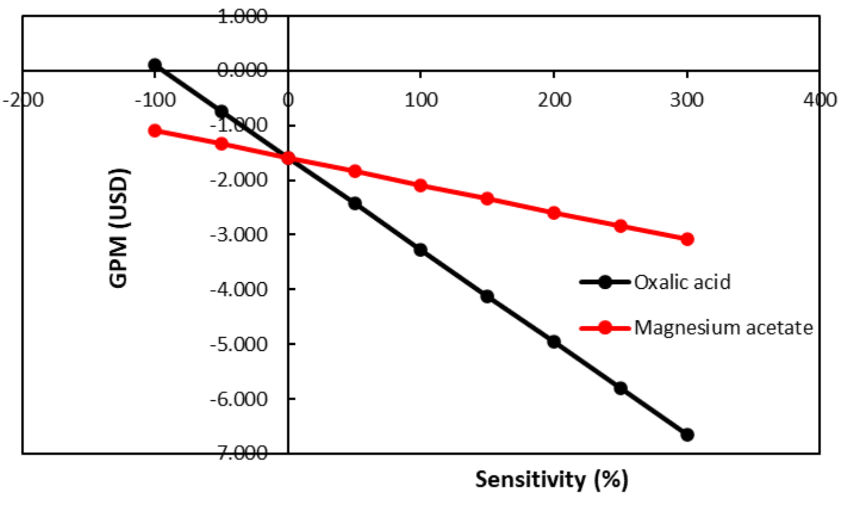

Figure 6. Effect of changes in raw material cost to Gross Profit Margin (GPM).

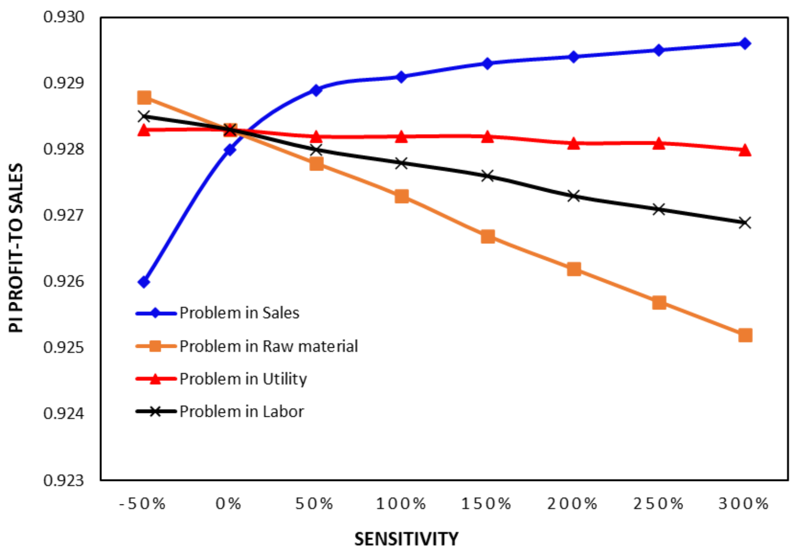

Figure 7. Analysis of Profitability Index (PI) profit to sales as a function of sales, raw material, utility, and labor

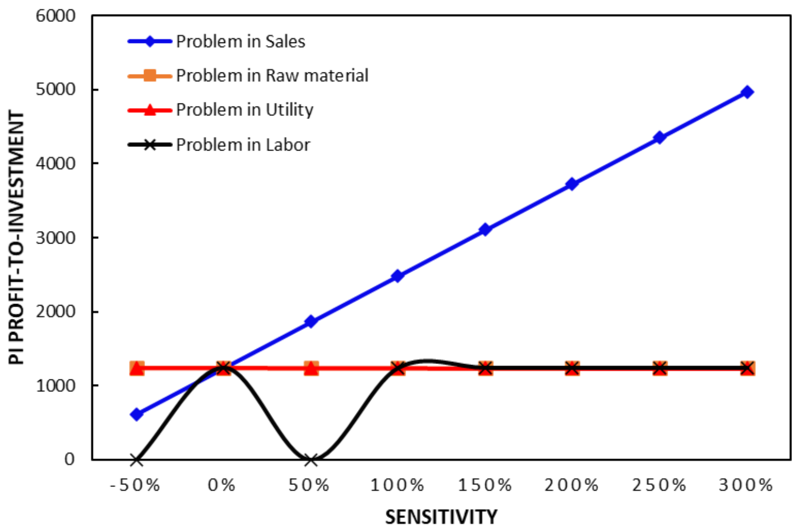

Figure 8. Analysis of Profitability Index (PI) profit to investment as a function ofsales, raw material, utility, and labor.

Based on the analysis that has been done, the project to manufacture magnesium oxide nanoparticles is feasible to run under ideal conditions. This project will only be profitable under certain economic conditions and will suffer losses if the project is implemented under certain economic conditions. Below is an explanation of the provisions of these economic conditions: (1) Taxes affect project profits. Taxes must be clearly estimated, because the maximum tax to sustain the project must be less than 75%. (2) Conversion must be maintained in the range of more than 90%. If conversion is less than 90%, the project is considered a failure. (3) Changes in raw material prices with fluctuations of 50, 75, 100, 125, 150, 175 and 200% will affect annual profits.

Although the project is still operational, it will generate little profit if the commodity price exceeds 100%. (4) Labor costs with fluctuations of 50, 75, 100, 125, 150, 175 and 200% do not affect the profit generated. This is because labor costs account for about 0.02% of profits. (5) User fees (electricity costs) do not affect the profits generated. This is because labor costs account for about 0.02% of profits. (6) Variable cost variation analysis was carried out by Nandiyanto, A., [23] and Nandatamadini, F., et al [24]. They stated that the results of the analysis of variable costs with various variations played an important role in profits and reduced variable costs could affect the final high value of CNPV. An increase in variable costs on a project will lead to reduced profits or it could lead to losses. But when using a lower variable cost value, the project will be more effective in generating more profit. In the results of this study the most influential variable cost is the cost of raw materials and the level of sales. This can be seenfrom the changes in each curve on the GPM chart. In addition to the economic prospects, this project must be analyzed for its attractiveness to investors, but this project is a less attractive perspective for industrial investors. This perspective refers to the standard Indonesian capital market [23]. In addition, this study does not demonstrate a newly designed process. However, the new idea in this research can provide knowledge and information about the feasibility of making MgO nanoparticles.

CONCLUSIONS

Based on the techno-economic studies that have been carried out, the business of making magnesium oxide nanoparticles using the sol-gel method from a building perspective shows that expanding the business scale can be carried out by utilizing existing facility equipment and combining the costs incurred so that expenses are reduced. Payback Period investigation appears that the venture is productive after more than three a long time. This is often because the utilize of raw materials within the prepare of synthesizing magnesium oxide nanoparticles utilizing the sol-gel strategy is cheap and requires a brief time to create magnesium oxide. From the results of the economic evaluation analysis it can be concluded that this venture is attainable to run.

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