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Techno-Economic Evaluation of The Production of Resin-Based Brake Pads using Agricultural Wastes: Comparison of Eggshells/Banana Peels Brake Pads and Commercial Asbestos Brake Pads

Risti Ragadhita [1], Dwi Fitria Al Husaeni [2], Asep Bayu Dani Nandiyanto [1,]*

[1] Departemen Pendidikan Kimia, Universitas Pendidikan Indonesia, Bandung, Indonesia
[2] Departemen Pendidikan Ilmu Komputer, Universitas Pendidikan Indonesia, Bandung, Indonesia
Correspondence: E-mail: nandiyanto@upi.edu

ABSTRACT

The purpose of this study was to analyze, evaluate, and compare the results of the feasibility analysis of producing egg shells/banana peels brake pads and commercial asbestos brake pads based on engineering and economic perspectives. Mass balance and several economic parameters (i.e., gross profit margin (GPM), payback period (PBP), break-even point (BEP), cumulative net present value (CNPV), and profitability index (PI)) are calculated to analyze the feasibility projects based on engineering and economic perspectives, respectively. The process of analyzing the economic feasibility of the project is assumed to be in ideal conditions. The engineering perspective shows that the project of banana peels/egg shells brake pads and commercial asbestos brake pads are prospective if the fabrication uses simple apparatus on a large scale. Economic evaluations such as GPM, PBP, BEP, CNPV, and PI all returned positive results, indicating that the project has the potential for large-scale production. It is hoped that the research could well demonstrate the project's importance for future development and serve as a model for future production of brake pads made from agricultural waste.

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1. INTRODUCTION

The brake system is a system on the vehicle that is very important to the vehicle. The brake system's function is to control the vehicle's speed by utilizing the deceleration of the vehicle's wheels. Aside from regulating the vehicle's speed, the brake system also controls the vehicle's speed and stops it, so the driver can control where and when the vehicle stops using the brake (Nandiyanto *et al*., 2021a; Nandiyanto *et al*., 2021b; *Sukrawan et al., 2019*). On the market, the automotive brake pads market is expected to exceed 3 billion USD in 2021 and grow at a compounded annual growth rate (CAGR) of 4.3% between 2022 and 2028. In 2028, this industry's shipments are expected to exceed 728,625.8 thousand units. Demand for automotive brake pads is expected to rise due to increased vehicle sales and the availability of sophisticated and lightweight friction materials (see https://www.gminsights.com/industry-analysis/automotive-brake-pads-market).

Analyzing the techno economy is an important part of understanding the production of brake pads. This techno-economic analysis seeks to comprehend current market conditions thus the strategies implemented to market products run smoothly and profitably. Several studies have now reported on the economic analysis of several products which are summarized in **Table 1**.

According to the preceding explanation, data for large-scale production from all perspectives and parameters are critical. As a result, the primary goal of this research is to identify the best and most optimal engineering and economic conditions for the fabrication of banana peels/eggshells brake pads and commercial asbestos brake pads. Several economic parameters, such as gross profit margin (GPM), payback period (PBP), break-even point (BEP), cumulative net present value (CNPV), profitability index (PI), and internal rate of return (IRR), are calculated to support the analysis.

Table 1. Current research on techno-economic analysis.

Material	Product	Economic Analysis Results	Refs
Rice straw, NaOH, and HCl	Silica Particles	• The total purchased equipment cost for converting 20 kg of rice straw waste per batch is USD 4,900. • The total investment is less than USD 20,000 thus this value is relatively economical	(Nandiyanto, 2018)
Titanyl isopropoxide, nitric acid, titanyl hydroxide, and glycine	Titanium Dioxide Nanoparticles	• The engineering analysis revealed the possibility of large-scale production because the process can be carried out with currently available technology and low-cost apparatus. • The economic evaluation revealed the project's potential profitability.	(Ragadhita, *et al*., 2019)
Rice husk, corn cob, bagasse, sugarcane	Silica Particles	• Agricultural wastes (i.e., rice husk, rice straw, bagasse, and corn cob) are perspective as silica raw material. • The project is simple to operate, improve, and develop by utilizing readily available and inexpensive technologies and apparatuses.	(Nandiyanto, *et al*., 2020a)
Zinc nitrate hexahydrate, methyl imidazole, methanol	Zinc imidazole framework (MOF) Particles	• Analysis of several sensitivity parameters is also performed, with several condition boundaries shown to be profitable.	(Nandiyanto & Ragadhita, 2019)

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Table 1 (continue). Current research on techno-economic analysis.

Material	Product	Economic Analysis Results	Refs
		• Economic analysis generates the opposite conclusion. The process of converting rice straw waste is unappealing to industrial investors.	
Rice husk, Bisphenol A-epichlorohydrin, and Cycloaliphatic amine	Brake Pad from Rice Husk	• The resin-based brake pad project is prospective based on an engineering perspective. • From economic evaluation showed positive results, indicating that the project is potential for the large-scale production.	(Nandiyanto, *et al*., 2021c)
Lanthanum (III), nickel (II) nitrate hexahydrate, glycine, CaH_2, and LiCl	$LaNi_5$ Particles	• The engineering analysis revealed that $LaNi_5$ production projects are reliable using commercial apparatuses. • The economic parameters generate positive results, indicating that the projects are suitable for large-scale production.	(Nandiyanto *et al*., 2020b)

2. METHODS

Based on previous research, brake pads were mass-produced at room temperature without the use of additional heat using commercially available equipment. Raw materials during processing follow the mass balance calculation. In the economic evaluation, several assumptions were used based on equipment specifications, prices of raw materials/chemicals, utility systems, and equipment costs, where these prices were seen from several e-commerce sites, such as Alibaba, Amazon, Tokopedia, etc. The data was then processed, used, inputted, and computerized in the calculation of the economic feasibility analysis. Here, the results of the economic analysis of eggshells/banana peel brake pads and commercial asbestos brake pads were compared. Economic evaluation analysis was carried out by applying ideal conditions. Then, the calculations used for the economic feasibility analysis were adopted from our previous studies (Nandiyanto, 2018; Ragadhita et al., 2019; Nandiyanto et al., 2020a; Nandiyanto & Ragadhita, 2019; Nandiyanto et al., 2021c; Nandiyanto et al., 2020b).

3. RESULTS AND DISCUSSION

Here, the techno-economic analysis is performed under ideal conditions. The economic feasibility analysis calculations were based on the literature (Nandiyanto, 2018; Ragadhita, et al., 2019; Nandiyanto, et al., 2020a; Nandiyanto & Ragadhita, 2019; Nandiyanto, et al., 2021c; Nandiyanto et al., 2020b). The mass balance in the large-scale production of resin-based brake pads ware calculated using several assumptions. The assumptions are as follows:

(i) The prices of the equipment and raw materials used were obtained from commercially available online markets such as alibaba.com, tokopedia.com, and bukalapak.com.
(ii) For banana peels/egg shells brake pads, the raw materials needed are egg shells, banana peels, bisphenol A-epichlorohydrin, and aliphatic cyclic amine with the composition were 140, 47, 100, and 100 kg/cycle, respectively.

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(iii) For commercial asbestos brake pads, the raw materials needed were asbestos, barium sulfate ($BaSO_4$), bisphenol A-epichlorohydrin, and aliphatic cyclic amine with the composition are 140, 47, 100, and 100 kg/cycle, respectively.
(iv) No byproduct during the production process, the room temperature was used during the production process, and the final product consisted solely of resin-based brake pad material.
(v) The production of resin-based brake pads requires one cycle per day.

According to the mass balance analysis, one producing cycle for one day produces 18,750 pieces of brake pads with dimensions of 4 x 1 x 3 cm in length, height, and weight. Under ideal conditions, the project could be scaled up to 264 cycles per year. As a result, the project's production capacity is 4,950,000 units.

To determine the economic feasibility of the resin-based brake pad project, the following assumptions were used:

(i) The unit price is in USD. The USD to Rupiah conversion rate is 1 USD = 15000.
(ii) Banana peels/egg shells and commercial asbestos brake pad costs are two USD per piece.
(iii) Stoichiometry calculations are used to calculate all raw materials used during production.
(iv) There is no charge for the egg shells and banana peels.
(v) The discount rate is 15% and income taxes is 10%.
(vi) A utility system costs 0.10 USD/kWh.
(vii) The number of productive days of labor in a year is 264.
(viii) The labor force is composed of 15 people, with each worker earning 8 USD per day.
(ix) The project takes place in the newly acquired underground. As a result, the land is calculated as the initial cost of project development, which will be recovered once the project is operational.
(x) The project has been running for 20 years.

Total production costs (TMC) are calculated by taking into account the costs of raw materials, utilities, loan interest, operating labor, labor-related costs, capital-related costs, depreciation, and sales-related costs as shown in **Table 2**. These costs are calculated in advance based on their annual characteristics. Based on **Table 2**, all prices are the same because the price of equipment for production for both brake pads production (banana peels/egg shells and commercial asbestos brake pads) are the same. However, there are differences in prices for raw materials because there are different materials. In banana peels/eggshells-based brake pads, the main raw materials are egg shells and banana peels which can be obtained free of charge. Meanwhile, in commercial asbestos brake pads, the main materials are asbestos and $BaSO_4$ which are not obtained for free. Thus, in the production of commercial asbestos brake pads, there is an additional cost of asbestos and $BaSO_4$ raw materials.

The TMC value was calculated using the above-mentioned cost data, as shown in **Table 3**. The TMC value is the sum of the following costs: raw materials, utilities, loan interest, labor, and labor-related costs, capital-related costs, depreciation, and sales-related costs**. Tables 4 and 5** provide detailed information on raw materials and utilities. **Table 6** contains detailed information on the fixed cost. Variable cost information is also used, as shown in **Table 7**.

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Table 2. The costs of raw materials, utilities, loan interest, operating labor, labor-related costs, capital-related costs, depreciation, and sales-related costs for both brake pad production.

Cost Type	Brake Pad based Non-Asbestos Material	Brake Pad based Asbestos Material
Plant Cost (PC)	64,400 USD	64,400 USD
Total Plant Cost (TPC)-Land	11,466 USD	11,466 USD
Total Investment	20,447 USD	20,447 USD
Raw Material	722,938 USD	847,660 USD
Utilities	984 USD	984 USD
Loan Interest	-	-
Operating Labor	31,680	31,680 USD
Selling Price per Year	9,900,000	9,900,000 USD

Table 3. TMC calculation for banana peels/egg shells and asbestos commercial brake pads production.

Component	Factor	Cost for non-asbestos-based brake pad production (USD)	Cost for asbestos-based brake pad production (USD)
Raw Materials		722,938	847,660
Utilities		984.24	984.24
Loan Interest	7% of loan	-	-
Operating Labor		31,680	31,680
Labor-related Cost		21,225	21,225
Capital-related cost		2,396	2,396
Depreciation		544	544
Sales-related cost		693,000	693,000
Total of TMC		**1,472,224**	**1,596,946**

Table 4. Detail of the price of raw material used per year for both banana peels/egg shells and asbestos commercial brake pad production.

Raw Materials	Unit (tons) per year	Cost per year (USD)
Egg Shell	47	0
Banana Peel	140	0
Bisphenol A-epichlohydrin	100	428,076
Aliphatic cyclo amine (epoxy hardener EPH 555)	100	291,456
Asbestos	140	103,488
$BaSO_4$	40	24,640

Table 5. Detailed price of utilities used per year for both banana peels/egg shells and asbestos commercial brake pad production.

Items	kWh	Cost per year
Grinding	9765	973.56
Sieve Shaker	105.6	10.65
Total		**984.24**

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Table 6. Detailed price for fixed cost for both banana peels/egg shells and asbestos commercial brake pad production.

Items	Units	Cost (USD)
Digital Balance	5	50
Automatic Sieve Shaker	5	2,500
Silicon Moulding	200	200
Pressing Apparatus	50	15,000
Mixing Reactor	2	1,360
Total		**19,100**

Table 7. Detailed information for variable cost of both banana peels/egg shells and asbestos commercial brake pad production.

Components	Cost per year for non-asbestos brake pad production (USD)	Cost per year for asbestos brake pad production (USD)
Raw Material	722, 938	847,660
Utilities	984.24	984.24
Labor	31,680	31,680
Sales	9,900,000	9,900,000

Figure 1 depicts the CNPV/TIC versus lifetime curve for the eggshells/banana peels brake pads and commercial asbestos brake pads project. Based on the ideal curve, the CNPV/TIC parameter remains negative for the first three years of the project. The project's first two years are still under construction. Variable costs, fixed costs, sales, depreciation, pre-tax profits, and income taxes were all factors influencing this result, which began to be considered in the third year. The production process has only just begun in the third year, and there is no profit. The project begins to profit in the fourth year and can be profitable for up to 20 years. According to the economic analysis, the resin-based brake pad project is profitable and promising under ideal conditions. Based on **Figure 1**, the economic value of banana peels/egg shell-based brake pads is greater than that of asbestos-based commercial brake pads. This is because the production cost of banana peels/egg shells brake pads is lower than the production costs of commercial asbestos brake pads. These costs can be lower because the raw material costs of banana peels and egg shells are free compared to the costs of asbestos and $BaSO_4$ which are relatively expensive in the production of commercial asbestos brake pads.

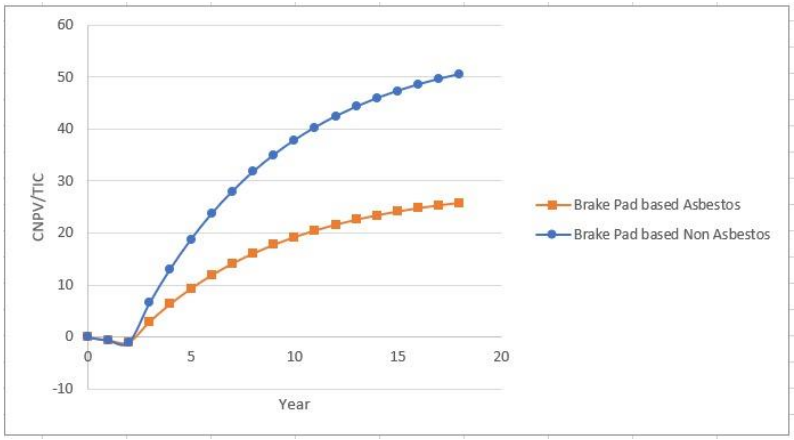

Figure 1. CNPV/TIC versus lifetime curve for the eggshell/banana peels brake pads and commercial asbestos brake pads project.

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Table 8 is the results of the economic evaluation parameters. According to the economic evaluation parameters, all parameters have positive values. Although this project has its advantages. In short, GPM determines the profitability of the project. However, based on the IRR parameter, the project does not appear to be attractive to industrial investors. According to PBP's analysis, the project can return the initial capital in 3 years. The project is competitive because the time frame is very short. The BEP value is the minimum product that must be sold to cover the total cost of production (Alnasser *et al*., 2014). IRR analysis revealed an IRR value greater than 2.5% for both asbestos-based and non-asbestos-based brake pad products for 20 years, indicating a very low level of investment for investors and not promising. The final CNPV/TIC analysis shows a relatively high positive yield over the 20-year project life. The profit-to-sale analysis revealed some encouraging results, indicating that the project is profitable. The minimum number of products that must be sold to earn a profit in this project is 55,423 pieces and 105,531 pieces for non-asbestos and asbestos brake pads.

Table 8. The economic evaluation parameter value for both brake pad production (non-asbestos and asbestos brake pad).

Economic Evaluation Parameter	Economic value for non-asbestos brake pad	Economic value for asbestos brake pad
GPM (USD/Year)	9,177,061	9,052,340
PBP (Years)	3	3
BEP (Pieces)	55,423	105,531
IRR (%)	3.32	2.21
Final CNPV/TIC (%)	51	26
PI-to-sales (%)	0.15	0.08

4. CONCLUSION

According to the findings, this study was successful in analyzing the techno-economic of producing resin-based brake pads from banana peels/egg shells and asbestos. According to the economic parameters in the economic evaluation, all economic parameters had positive values. However, because of the low IRR value, the project is less appealing to investors. As a result, government funding must be considered to ensure the project's long-term viability. When compared to commercial asbestos brake pads, the production process of resin-based brake pads involves the use of agro-industrial waste materials, which can be a solution to agro-industrial waste processing problems and become an alternative to producing low-cost brake pads.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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