Plant Design for a Production Process of Nanoasphalt Emulsion from Asbuton Rock

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***Abstract*—The largest deposit of natural asphalt in the world is located on Buton Island, Indonesia, which is around 677 million tons. With such abundance, Indonesia should be able to supply domestic asphalt needs, even has the potential to export abroad. However, the asphalt industries in Indonesia have not been able to process effectively the natural asphalt from Asbuton rock into a better quality of asphalt. Generally, they only focuses on resizing and separating the Asbuton rock according to the specifications of filler. This situation causes Indonesia has to import asphalt from abroad. Several studies and experiments have been done previously in lab-scale to produce high yield of nanoasphalt from Asbuton by combining microemulsion technique and Ultrasonication. Here we present a conceptual plant design of nanoasphalt production to process 121.8 tons/day of Asbuton rock as the raw material and produce 190 ton/day of nanoasphalt. The economic feasibility of processes of the Plant Design is analyzed. The economic evaluation in this work involves analyzing the capital and operating costs of the process to determine the return on investment (ROI), Break Even Point (BEP), Payback Period (PP), Internal Rate of Return (IRR). The result shows that the production of nanoasphalt is relative economical with ROI, BEP, PP and IRR are 31.54%, 24.5%, 2.47%, 35.46%, respectively.**

***Keywords*—Asbuton, nanoasphalt, microemulsion, ultra-sonication**

I. Introduction

In recent years, Indonesian government has been stepping up development road infrastructure to build connectivity according to the Nawacita program and it needs the supply of asphalt about 1.3 million tons/year. On the other hand, Pertamina as the supplier of oil asphalt only be able to meet 30% of domestic asphalt needs. Even according to the estimation from Binamarga, it is likely that in year 2025, Pertamina will no longer be producing petroleum asphalt. Also, based on foreign trade data compiled by UN Comtrade, it is recorded that Indonesia is one of the 10th largest asphalt importers in the world which worth of US $ 371 million.

One way to overcome this, is to use natural asphalt from rocks found on the Buton Island and its surroundings as known as Asbuton. The amount of asphalt deposits on Buton Island are very large, that is 650 million tons. In fact, it is the greatest deposit in the world. With such abundance, Indonesia should be able to supply domestic asphalt needs, even has the potential to export abroad. However, currently, Indonesia is still unable to utilize effectively the abundance of the natural asphalt. This is indicated by the fact that Indonesia still has to import asphalt from neighboring countries. Singapore is the country of source for Indonesia's main asphalt. One of the State-Owned Enterprises (BUMN), PT Wijaya Karya Tbk (WIKA), is currently able to produce Asphalt Buton (Asbuton) but its production is still limited and relatively small compared to the amount imported.

In general, compare to petroleum asphalt, Asbuton has better characteristics such as: higher stability of marshall, higher dynamic stability of asphalt mix, better construction life, and more resistant to temperature changes. In addition, because Asbuton contains high aromatic and resinous ingredients, it has high adhesion and flexibility. Therefore, with those characteristics, Asbuton is suitable to be applied in high temperature locations (tropical) and for heavy loaded highway. Therefore, several researchers have attempted to extract asphalt from Asbuton. However, so far the process being implemented is still relatively expensive and involves hazardous solvents.

Nanotechnology has been increasingly intruded into the field of asphalt modification. Nanomaterial exhibits specific features novel properties compared to the bulk material due to its large surface area. Properties of nanomaterials can be changed through controlling the size, regulating chemical composition, surface modification and controlling interactions between particles. Outstanding effects of nanomaterials are being brought to improve the performance of asphalt. Several nanomaterials used in asphalt modification have been studied by some researchers. Adding nanomaterials such as nanoclay, nanosilica, and nanotubes in asphalts will increase the viscosity of asphalt binders and improves the rutting and fatigue resistance of asphalt mixtures [1], [2]. Researchers anticipate nanotechnology to provide great potential in advancing asphalt pavement technology in the fields of materials design, manufacturing, properties, testing, monitoring and modeling [3], [4]. Specifically, focus areas in asphalt pavement analysis should include the bonds between aggregate, bonds between layers, properties of the mastic, self-repair and rejuvenation of binder, ageing (oxidation) effects and improvements in surface to tire properties [5], [6]. Nanoparticles for pavement materials is required to be non-hazardous low-cost products, due to them being spread over large volumes of material and being in almost direct contact with human activities. The reduction of energy requirements during construction of asphalt pavements through development of improved emulsions and reduction in binder viscosity at ambient temperatures through the introduction of micro-bubbles will not only lead to a potential energy cost saving, but also assist in the lowering of emissions during construction. The typical bitumen binder thickness coating around aggregate is in the order of a few microns [7], [8]. However, most studies on binder properties do not focus on this small dimension.

Nanoclays have very large aspect ratio with non-uniform size and shape. Adding 6% of nanoclays improves the permanent deformation or rutting behavior and enhance the resistance to aging of asphalt. Using nano calcium carbonate in asphalt mixtures can reduce the permanent deformation on asphalt pavement. The optimum performance is reached by adding 5% of these nanomaterials to the asphalt mixture [9], [10]. In Asbuton rock, there are naturally occurring minerals and subjected to natural variation in their formation. Various physical properties (such as stiffness and tensile strength, tensile modulus, flexural strength and modulus thermal stability) of the bitumen can be enhanced when it is modified with small amounts of nano-clay, on condition that the clay is dispersed at nano-scopic level. Generally, the elasticity of the nanoclay modified bitumen is much higher and the dissipation of mechanical energy much lower than in the case of unmodified bitumen [11], [12].

The mineral composition of Asbuton rock containing bitumen (~30%) found in Lawele are following: $CaCO_3$ 72.90 % SiO_2 17.06%, Fe_2O_3 2.31%, Al_2O_3 1.94%, $MgCO_3$ 1.28% and the total other minerals about 5%[13] . This shows that the mineral in Asbuton rock can be made as the nanoparticles. Instead of buying the expensive nanoparticles and added to the asphalt, the nanoparticles can be produced in-situ during the process. Moreover, adding nanoparticles to the very viscous material such as asphalt needs a very high energy and time to mix and make nanoparticles to be well dispersed in the asphalt mixture[1], [14], [15] . This method can anticipate all those disadvantages, because the nanoparticles are not added from outside but inside, thus they can be well mixed easily.

In this work, we present a Plant Design of nanoasphalt production from Asbuton rock based on our experimental results in lab-scale. Several studies and experiments have been done previously in lab-scale to produce high yield of nanoasphalt from Asbuton by combining microemulsion technique and Ultrasonication.

II. MATERIAL AND PROCESS DESCRIPTION

A. *Material*

The raw materials used in the production of nanoasphalt include Asbuton rock, diesel oil as the solvent and sorbitan monooleate as the surfactant. The sorbitan monooleate surfactant required was produced in this plant, meanwhile the necessary Asbuton and diesel oil are obtained from other parties.

Asbuton contains high aromatic and resinous ingredients, so that asbuton has high adhesion and flexibility in the mixture. Another advantage is that the crack resistance due to weather and environmental consequences of asbuton is very high [16], [17]. The Asbuton needed is obtained from PT Wijaya Karya Bitumen which has a capacity of 66,000 tons/year at a price of IDR 270/ton.

Diesel oil (namely solar) is a fraction of clear brown yellow petroleum with a boiling point range between 250˚C to 350˚C which is also called the middle distillate. Diesel oil is chosen as a solvent in the nanoasphalt production process because of its abundant availability in Indonesia and its relatively cheap price. In addition, diesel fuel contains aromatic compounds which make diesel fuel very easy to extract asphalt solids. Diesel oil is also not reactive so that the extraction process avoids unexpected side reactions. The need for diesel for the nanoasphalt production process is obtained from PT Pertamina RU IV Cilacap with a capacity of 348,000 barrels per day at a price of IDR 9400/liter.

Surfactant is a substance that has the ability to reduce the surface tension of a medium and reduce the interfacial tension between two phases with different degrees of polarity. The term interface refers to the side between two phases which do not dissolve each other, while the term surface refers to the interface where one of the phases is air (gas). The surfactant structure can be described as a tadpole that has a head and tail. The head part of the surfactant is hydrophilic or polar and compatible with water, while the tail is hydrophobic or non-polar and is more attracted to oil/fat). The surfactant used in this nanoasphalt production process is sorbitan monooleate which has commercial name of Span 80. The raw materials for making Sorbitan monooleate include sorbitol, oleic acid, and both NaOH and H_3PO_3 solutions which function as catalysts.

Sorbitol ($C_6H_{14}O_6$) is a sugar alcohol which is a reduction product of glucose. In Indonesia, sorbitol is commonly produced from cassava root flour. In addition, sorbitol can also be found in red algae which contain 13.6% sorbitol [18]. This sorbitol was obtained from PT Sorini Argo Corporation Pasuruan which has a capacity of 120,000 tons/year at a price of IDR 16,200/kg.

Oleic acid is a fatty acid found in animal and vegetable oils. Oleic acid is also called unsaturated fatty acids because it has double bonds in its C atomic chain. In its pure state, this acid is liquid with a light yellow or brownish color. The required oleic acid is obtained from PT Aneka Kimia Inti at a price of IDR 13,700/kg. PT Aneka Kimia Inti has a capacity of 182,000 tons/ year.

Sodium hydroxide (NaOH) also known as caustic soda is a type of caustic metal base. Sodium hydroxide is very soluble in water and will give off heat when dissolved. The required NaOH is obtained from PT Asahimas Chemical Cilegon at a price of IDR 4,500/kg. PT Asahimas Chemical has a capacity of 700,000 tons/year.

Phosphoric acid or orthophosphoric acid is an inorganic mineral acid which has the chemical formula H_3PO_3. Phosphoric acid is a solid substance which at high temperatures will undergo dissociation. The H_3PO_3 required was obtained from PT Pradana Chemindo Perkasa at a price of IDR 13,700/kg.

Tires are a composite material of isoprene natural rubber. Tires consist of rubber or polymer materials reinforced with synthetic fibers and steel which can produce a material with very high tensile strength, flexibility and high shear resistance. The used tire powder needed as an additive in the manufacture of surfactants was obtained from CV Gemilang RnP Jaya Makmur Bekasi at a price of IDR 2,700/kg.

B. Process Description

The process of making nanoasphalt from Asbuton is carried out using a microemulsion extraction method with the help of solvents and surfactants. The solvent used is diesel oil and the surfactant used is sorbitan monooleate. The production process begins with the manufacture of surfactants and continues with the extraction of nanoasphalt as shown in the process flow diagram (PFD) in Fig. 1. The list of equipment in the PFD is given in Table 1. The process of making sorbitan monooleate surfactant is carried out in a packed bed reactor with a temperature of 170˚C and a pressure of 1 atm. The process of making sorbitan monooleate is an esterification reaction using an acid-base catalyst, namely a mixture of NaOH and H_3PO_3. First, sorbitol powder, liquid oleic acid and NaOH crystals are mixed in the M-001 mixer at a temperature of 170˚C. On the other hand, mixing H_3PO_3 with water was carried out in the M-002 mixer which was also heated to 170˚C to form a gas-phase 85% H_3PO_3 solution. A mixture of sorbitol, oleic acid and NaOH enters the top of reactor R-001 while H_3PO_3 gas and water enters the bottom of reactor R-001. The reaction that occurs in R-001 is as follows.

$$C_6H_{14}O_6 + C_{18}H_{34}O_2 \longrightarrow C_{24}H_{44}O_6 + 2H_2O$$

The gas-phase reaction product, namely water and H_3PO_3 then exits through the top of the reactor, then enters C-001 to be condensed. The H_3PO_3 gas and water which has been condensed are then cooled to a temperature of 30˚C and enter the storage tank. The results of the search phase reaction include the sorbitan monooleate product, the unreacted reactants, namely sorbitol and oleic acid, and the NaOH catalyst then pumped by P-005 to the distillation column D-001 to be separated.

In the distillation column D-001, the reaction product is heated at a pressure of 1 atm until the boiling point of oleic acid is 360 ˚C. This causes the oleic acid and sorbitol to evaporate into a distillate while the sorbitan monooleate and NaOH products are left as the bottom. The resulting distillate then passes through C-002 to be condensed and cooled before entering the storage tank. Meanwhile, the bottom consisting of the sorbitan monooleate tie and NaOH is pumped into the microemulsion extraction process that occurs in the Sonifier SF-001.

Sonifier SF-001 works at a pressure of 1 atm and a temperature of 60˚C. The bait that enters sonifier SF-001 is asbuton rock which is crushed to 200 μm using Ball Mill BM-001. The crushed Asbuton rock then enters screen S-001 to be filtered from rocks that are still large in size. Large rocks are returned to BM-001 via belt conveyor BC-005, while rocks that pass the screening then enter the sonifier. Apart from Asbuton rock and sorbitan monooleate, solvent is simultaneously pumped to the sonifier. The nanoasphalt production process also uses a 40 mesh rubber additive.

The result of the sonification process on SF-001 in the form of a slurry is then pumped by P-010 to the M-003 mixer. The mixture in the M-003 mixer is heated to 150˚C where the rubber additive is melted so that it is mixed more homogeneously. From the M-003 mixer, the extracted product is then pumped into the SP-001 separator and allowed to stand for some time until two layers are formed. The top layer is the nanoasphalt that is formed while the lower layer is the residue of Asbuton rock. The nanoasphalt product or top layer is cooled by cooler C-004 to a temperature of 30˚C and stored in storage tank T-012. Meanwhile, the lower layer, namely the Asbuton rock residue, still contains quite a lot of bitumen and minerals, so it is washed in two stages. This washing is done by adding diesel solvent to the residue in the M-004 mixer (first stage). This mixer works at a pressure of 1 atm and a temperature of 150˚C. The washing product from the mixer then enters the separator SP-002 for separation as before until two phases are formed. The top layer in the form of nanoasphalt is then pumped into the distillation column D-002 while the lower layer residue enters the M-005 mixer and SP-003 separator for the second washing process. The top layer obtained from the two washing processes then goes into the D-002 distillation column to be separated between the nanoasphalt and solar solvent. The distillation column D-002 operates at a pressure of 1 atm and a temperature of 250˚C, which is at the boiling point of diesel so that the diesel is evaporated into a distillate and the nanoasphalt product is left as the bottom. The distillate is then condensed and cooled before entering the storage tank.

The washed nanoasphalt product will certainly have less nanoparticle composition when compared to the main nanoasphalt product. Therefore, the washed nanoasphalt product that comes out of D-002 then enters the M-006 mixer at a pressure of 1 atm and a temperature of 150˚C. In this mixer, the washed nanoasphalt product is mixed with the Asbuton rock residue which still has remaining mineral content. The Asbuton rock residue is of course crushed first to nano-sized at BM-002. The mixing between the residue and the nanoasphalt will make the washed nanoasphalt product have a nanoparticle composition that is equivalent to the main nanoasphalt product.

III. ECONOMIC EVALUATION

The calculation in economic evaluation is based on the following assumptions:

- the bank interest rate of 12%
- the CE-Index 2020 is 597.05
- the tax applied is 25% on gross profit
- the loan is10% from the total capital investment (TCI)

- the plant's life is 20 years

A. Total Capital Investment (TCI)

Capital investment is required for any industrial process, therefore classifying the required investment is an important part of a plant design project. The total investment for a process consists of physical equipment, plant equipment and facilities, as well as the working capital required to pay salaries, store raw materials and products, and manage other special items [19].

Total Capital Investment (TCI) is the sum of the Total Plant Cost (TPC) and Other Capital Requirements (OCR). The Total Plant Cost (TPC) is presented in the Table II.

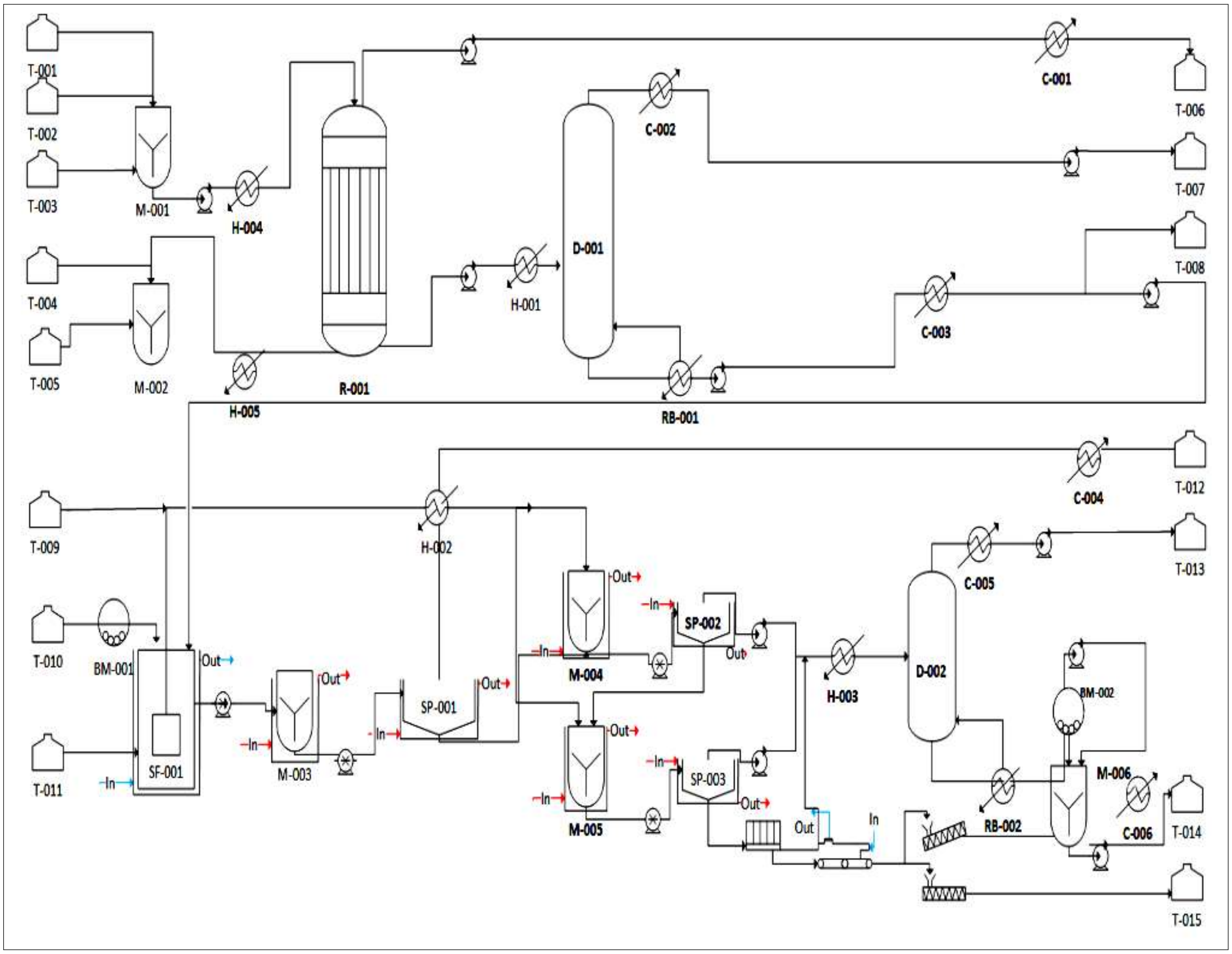

Fig. 1. Process Flow Diagram of Nanoasphalt Prodcution

TABLE I. EQUIPMENT IN THE PLANT

Unit Code	Unit Operation	Unit Code	Unit Operation
T-001	Oleic Acid Tank	C-001	Cooler 1
T-002	Sorbitol Silo	C-002	Cooler 2
T-003	NaOH Silo	C-003	Cooler 3
T-004	Water Tank	C-004	Cooler 4
T-005	H_3PO_3 Silo	C-005	Cooler 5
T-006	H_3PO_3 Tank	C-006	Cooler 6
T-007	Distillate I Tank	H-001	Heater 1
T-008	SPAN 80 Tank	H-002	Heater 2
T-009	Solar Tank	R-001	Reactor
T-010	Landfill Asbuton	BM-001	Ball Mill 1
T-011	Rubber Silo	BM-002	Ball Mill 2
T-012	Nanoasphalt I Tank	D-001	Distillation Column 1
T-013	Distillate II Tank	D-002	Distillation Column 2
T-014	Nanoasphalt II Tank	SP-001	Separator 1
T-015	Residue Silo	SP-002	Separator 2
M-001	Mixer 1	SP-003	Separator 3
M-002	Mixer 2	H-003	Heater 3
M-003	Mixer 3	H-004	Heater 4
M-004	Mixer 4	H-005	Heater 5
M-005	Mixer 5	RB-001	Reboiler 1
M-006	Mixer 6	RB-002	Reboler 2

The total cost for OCR is Rp. 580.626.482.799, which comprises of:

- Off-site facilities such as the cost of packaging, warehouse, transportation and offices which is 0.15*TPC = IDR 193.542.160.933
- Plant Start-up which is 0.1*TPC = IDR 129.028.107.288
- Working capital such as the cost of raw material, salaries and others during the factory operation which is 0.2*TPC = IDR 258.056.214.577

Therefore, to produce nanoasphalt of 68000 tons/year and sorbitan monooleate of 5000 tons/year, PT Hay Asphalt requires investment costs in the form of Total Capital Investment (TCI) of IDR 1.870,907,555,6877.

A. Production Cost Estimation

Production cost estimation is divided into calculation of total sales, itemized cost, labor related cost, capital related cost and sales related cost, manufacturing cost and interest. Sales calculation is made by multiplying the number of products produced per year with the estimated selling price of the product on the market. Total sales of the plant is presented in Table III.

TABLE II. PLANT COST ESTIMATION

Component	Value (IDR)	Assumption
Purchased Equipment	256,772,352,813	The costs of all the equipment include process equipment and auxiliary equipment
Piping	109,128,249,945	The plant process mostly involves solid and liquid, therefore it does not need too much piping
Electrical	25,667,235,281	All of the plant's electricity needs are supplied by PLTU.
Instrumentation	89,870,323,484	All the unit process are equipped with an instrumentation system and this unit is managed as well as possible so that the production process is more effective.
Utilities	134,805,485,227	The utilities that required in the plant are steam, water and compressed air.
Insulation	20,541,788,225	The plant involves thermal energy in many process equipment where this energy must not be wasted so that it can be utilized.
Painting, Fireproofing, Safety	25,677,235,281	Plant safety and robustness must be properly maintained so that no undesirable things happen.
Yard Improvements	12,838,617,640	The plant will be built on the green land in industrial areas, therefore the construction of sidewalks, parks, drainage, etc. does not require large costs.
Environmental	51,354,470,562	The plant produced only a small amount of waste, therefore the waste treatment costs are not too large.
Buildings	134,805,485,227	The production of sorbitan monooleate is carried out indoors to maintain the purity and minimize the contamination of the product.
Land	12,836,617,640	The plant will be built in an industrial area so that land costs are not too large.
Construction, Engineering	192,579,264,610	Good construction and techniques are used to minimize problems during the production process.
Contractors fee	70,612,397,023	The plant construction are handled by the local contractors (Indonesia) so the fee is not too costly.
Contingency	21,966,667,586	The nanoasphalt production process is a process that is still rarely encountered so it requires a large amount of unexpected funds.
Total Plant Cost (TPC)	**IDR 1,290,281,072,887**	

The production cost is the cost required by the plant during the production process. The production costs required consists of variable cost and fixed cost

Variable costs are costs required by the plant which depend on the amount of plant production capacity and other costs that support the production process. Variable cost is composed of itemized cost, labor related cost, capital related cost, and sales related cost, as presented in Table IV.

TABLE III. TOTAL SALES

Product	Production (ton/year)	Price (IDR/ton)	Total Price (IDR/year)
Nanoasphalt (high quality)	64680	23,920,224	1,547,149,049,806
Nanoasphalt (grade B)	2950	23,000,000	67,856,949,864
Sorbitan monooleate	2074	88,142,080	182,844,530,286
Residue (nanoparticle)	2401	4,131,660	9,921,990,589
		Total (IDR)	**1,807,772,520,546**

Itemized cost calculations include the calculation of the cost of purchasing raw materials, utilities and operating labor salaries. The raw material includes Asbuton, sorbitol, oleic acid, H_3PO_3, NaOH, and rubber crumbs, whereas the utility comprises of electricity and boiler fuel. The operating labor costs is obtained from the number of operating employees multiplied by the annual salary. The costs of other components in Table IV is calculated based on the factors whose values are estimated based on the rule of thumb [20].

TABLE IV. VARIABLE COST

Variable Cost	Cost (IDR)
a. Itemized Cost	
Raw Material	378,340,366,312
Utility	13,650,450,853
Operating Labor	12,000,000,000
b. Labor Related Cost	
Payroll Overhead	2,640,000,000
Supervisory, Misc. Labor	2,400,000,000
Laboratory Charge	1,800,000,000
c. Capital Related Cost	
Maintenance	96,771,080,466
Operating Supplies	28,224,896,469
Environmental	44,353,411,880
d. Sales Related Cost	
Packaging, storage	63,272,038,219
Distribution and sales	108,466,351,232
R&D	9,038,862,602
Total Variable Cost	**IDR 749,179,592,743**

Fixed costs are costs that are incurred regularly every time which not depend on the plant production capacity. Fixed costs are presented in the Table V below.

TABLE V. FIXED COST

Variable Cost	Cost (IDR)
a. Labor Related Cost	
Payroll Overhead	2,640,000,000
b. Capital Related Cost	
Local Taxes, Insurance	64,514,053,644
Plant Overhead Cost	48,385,540,233
c. Sales Related Cost	
Patent & Royalties	45,194,313,013
Administrative Cost	36,155,450,410
Total Fixed Cost	**IDR 193,905,107,327**

In the calculation of production cost, there is a component called depreciation. Depreciation is a systematic depreciable allocation cost of an asset over its useful life. These costs affect the financial statements, including the company's net profits. There are three methods to determine depreciation, namely straight line, double declining balance and sum of year digits. It is assumed that the plant life is 20 years without salvage value, and the land cost is IDR 12,838,617,640. The calculation result for depreciation value using the straight line method in 20 years is IDR 63,872,122,762/year.

IV. FEASIBILITY ANALYSIS

Project feasibility analysis is useful for avoiding the worst prospect of the plant. The following method used for this analysis are Return on Investment (ROI), Break Even Point (BEP), Payback Period (PP), Internal Rate of Return (IRR), and Present Value (NPV). The analysis method is calculated from the cash flow data during the plant's establishment.

A. Return on Investment (ROI)

Return on Investment (ROI) is a profitability ratio that measures the efficiency of an investment by comparing net income to the total cost or capital invested. ROI shows the rate of return on capital or investment per year. The ROI value, which is getting bigger each year, shows that the plant is more feasible to build (Table VI). The plant is considered to be feasible if the ROI > MARR. The MARR (Minimum Acceptable Rate of Return) is calculated by the net-profit average divided by TCI, which is equal to 20.75%. Because ROI > MARR, the project is feasible.

TABLE VI. RETURN ON INVESTMENT (ROI)

Year	ROI before Tax	ROI after Tax
1	11,28%	15,05%
2	14,62%	19,49%
3 – 20	21,24%	28,31%

B. Break Even Point (BEP)

Break Even Point (BEP) is a point where the resulting production capacity can cover all production costs without any profit or loss or Cash Flow is zero. The smaller the BEP value indicates the more feasible the factory is to build. The BEP value of the plant before depreciation and after depreciation is shown in Table VII below.

TABLE VII. BREAK EVEN PONT (BEP)

Year	BEP before Depreciation	BEP after Depreciation
1	45,43%	34,30%
2	39,75%	30,01%
3 – 20	31,80%	24,01%

C. Payback Periode (PP)

Payback period is time required after startup to recover the total capital investment. Here, the payback period since the plant started operating to pay off the initial investment from the earned revenue is calculated by dividing Total Cost Investment (TCI) with the cash flow. The MARR (Minimum Acceptable Rate of Return) is calculated by the net-profit average divided by TCI, which is equal to 20.75%. The PP acceptable which is calculated by the Total Plant Cost/((MARR * TCI) + Depreciation), which is equal to 3.5 years.

D. Internal Rate of Return (IRR)

Internal Rate of Return (IRR) is the highest discount rate by calculating the nominal discounted rate (interest rate) which equates the present value of an investment with the present value of future net cash receipts at the time of the NPV value = 0. The plant is considered to be feasible if IRR> deposit interest rate. This plant has an IRR value of 37.04% which is higher than the deposit interest rate (7.31%)

E. Present Value (PV)

A plant can be considered to be feasible if the Present Value (NPV) is greater than zero at the end of the plant's life. The income from the plant after discounted (minus IRR) is presented in Table VI. Because the PV > 0 at the end of the plant's life, then the plant is considered to be feasible. Fig.2 shows that the depreciation allowance ceases in 7.5 years.

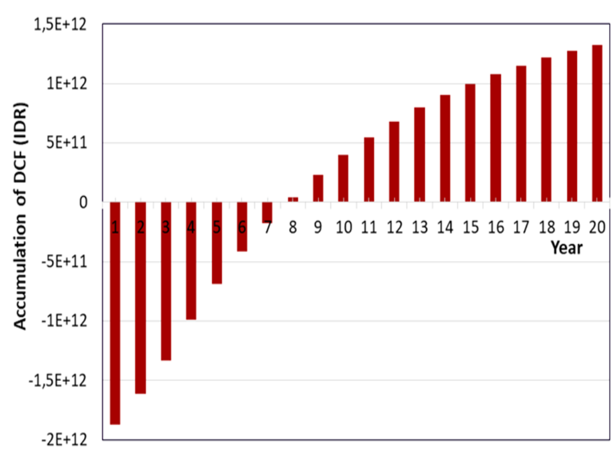

Fig. 2. Cummulative Cash Flow Diagram for the evaluation of the project

F. Sensitivity Analysis

Sensitivity analysis is a method that aims to determine the level of sensitivity of the plant's feasibility to changes in factors that are considered in economic analysis. These factors include sales, production costs, raw materials, and utilities. The sensitivity analysis is depicted as a spider web curve in Fig. 3.

As can be seen from Fig. 3, the four factors that influence the profits earned by the plant. If sales increase, the profits will also increase. Meanwhile, if raw materials, utilities and production costs increase, then the profits will decrease. The Sales Curve has a sharp increase which makes this factor have a big influence on the continuity of the plant if there is an increase or decrease. In addition, the three other factors, namely raw materials, costs and utility, have a sloping curve, even very gentle for the factor of complexity. This means that these three factors have a lower influence than the sales factor.

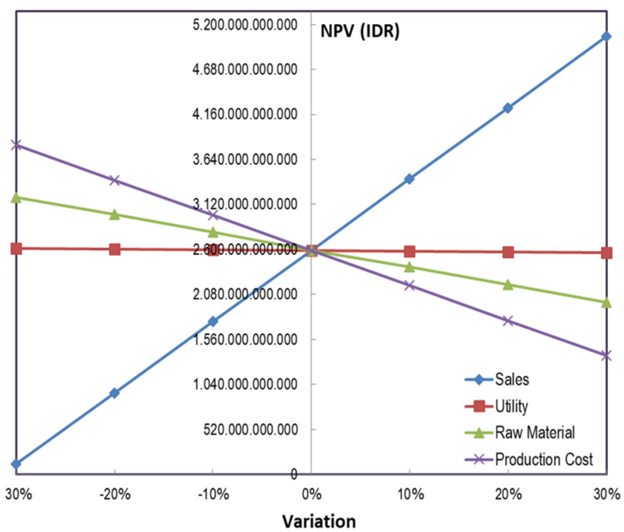

Fig. 3. Sensitivity analysis which shows the change in the NPV of the project cash flow at 20 years of production

However, if these three factors experience an increase that occurs simultaneously or continuously, then the factory will also experience losses. In other words, it can be said in total that the plant can be established.

V. CONCLUSION

The plant economic analysis determines whether a plant is feasible to be established or not. The analysis result shows that the plant is commendable to be founded, because it fulfils the feasibility criteria, such as:

1. ROI (21.24%) > MARR (20.75%)

2. PP (3.50 years) < PPacceptable (3.57 years)

3. IRR (28.97%) > Interest Rate (12%)

4. PV (IDR 2,931,836,681) > 0 at the end of factory life

The plant's sensitivity shows that if the sales value has decreased by 30%, the factory will experience a loss. However, the plant economic is sensitive to utility and raw material is also insensitive to changes in raw material price increases and also prices for utilities, this explains that this factory has a low sensitivity level. With the establishment of this plant, it will certainly have a good and beneficial impact on Indonesia because it can reduce the need for asphalt and surfactant imports, increase employment, improve the welfare of the surrounding community, and also increase the country's foreign exchange by having the opportunity to export abroad.

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