INVESTIGATING THE COST EFFECTIVENESS OF BIODIESEL DISTRIBUTION IN INDONESIA

Herbert Wibert Victor Hasudungan*, Elis Heviati **, Sulthon Sjahril Sabaruddin***, Sigit Hargiyanto****

DOI: 10.51558/2303-680X.2023.21.1.71

Abstract

The implementation of biodiesel in Indonesia has been regarded as one of the main strategies to improve country's energy security equally and equitably. However, as the largest archipelago country in the world, the activity in distributing their biodiesel production bears a key problem. The complexity of delivering biodiesel from the supply point to the blending terminal of gasoil might result in cost inefficiency, which in turn will escalate the government funding of biodiesel incentives. This paper aims to both evaluate and formulate the Indonesian biodiesel transportation costs in all routes using either trucking or shipping mode. Based on primary data and information obtained from experts, we found that the most dominant factors that affect the shipping distribution cost are the size of the ship and its activities (such as voyage, ballast, loading, discharge, waiting, and buffer), whilst for the trucking mode, the dominant factors are both its corresponding operational costs and investment costs. Given that fuel prices fluctuate periodically, we also argue that the cost differences between the regulated and formulated reference may arise due to i) the data inaccuracy of the diesel fuel consumption and ii) specific terms outlined in the agreement between the corresponding transporters and suppliers.

Keywords: biodiesel, Indonesia, Transportation Cost, renewable energy, energy distribution

JEL: M11, O21, Q21, Q42, R40, R41, R42

1. Introduction

The utilization of renewable (clean) energy sources has been regarded as one of the global key priorities to address the issue of climate change and to substitute fossil fuels (Hasudungan, 2016; Masripatin, 2017). Since 2021, energy transition has been regulated as one of the cores of Indonesia's energy policies to achieve an equal and equitable energy security (Kuntjoro *et al.*, 2021). Biodiesel, as one of the biofuel types of products, is known as a renewable source of diesel engine fuel made from biomass resources (Silalahi and Simatupang, 2020; Valizadeh *et al.*, 2014). Based on the Indonesian energy transition road map released by the Ministry of Energy and Mineral Resources (MEMR) of the Republic of Indonesia in 2022 (IEA, 2022), biofuel expansion has been one of the key strategies to achieve a 23% mixture of renewable energy in 2025 and 31% in 2050. In its biofuel roadmap, biodiesel blending in the diesel fuel mix is targeted to reach 40% in 2035.

The large implementation of biodiesel contributes greatly to Indonesia's economy (Harahap *et al.*, 2018). Firstly, the mandate requires a large feedstock of crude palm oil (CPO) which, in turn, improves economic activities due to the increasing production and demand of the agricultural sector as well as job opportunities. Secondly, biodiesel mandatory also stabilizes the market price of palm oil because it can be applied to set the shifting of CPO demand and supply domestically. Thirdly, under the biodiesel mixture policy, the total consumption of Indonesian diesel fuel has significantly declined each year. In 2022, the total domestic demand for biodiesel – a substitution for gasoil demand, was about 10.5 million kilo litter (KL) (Directorate of Bioenergy, 2022). In other words, the biodiesel program equally cuts the gasoil import, which in turn will reduce the Indonesian trade deficit. Finally, the implementation of a clean source of biodiesel contributes significantly to mitigate its national GHG emissions (Directorate of Bioenergy, 2022).

Petterson *et al.* (2015) argued that compared to all cost components, the level of transportation costs can significantly affect the product competitiveness in the marketplace (Petterson *et al.*, 2015). As the largest archipelago country globally, the large distribution of Indonesian

* Universitas Islam Internasional Indonesia and Ministry of Energy and Mineral Resources of Republic of Indonesia, Indonesia, herbert.hasudungan@uiii.ac.id
** Ministry of Energy and Mineral Resources of Republic of Indonesia, Indonesia, elis.heviati@esdm.go.id
*** Ministry of Foreign Affairs of the Republic of Indonesia, Indonesia, ssabaruddin@yahoo.com
**** Ministry of Energy and Mineral Resources of Republic of Indonesia, Indonesia, sigit.hargiyanto@esdm.go.id

biodiesel mandatory has encountered several obstacles that are mostly related to the complexity of delivering the Fatty Acid Methyl Ester (FAME) production from the supply point to the blending point. At the blending point, the biodiesel product will then be mixed with gasoil (30% biodiesel and 70% gasoil), and hence shall be distributed to final consumers (Silalahi and Simatupang, 2020).

Rahman (2019) argued that the distribution routes of Indonesian fuel oil products have been regarded as the most complex transportation routes in the world. This is because biodiesel producers in the country are mostly located in the western region of Indonesia, scattered in the area of Sumatra and Java islands. On the other hand, biodiesel demand is located throughout Indonesian islands. Figure 1 presents the complexity of biodiesel distribution throughout Indonesian regions. To overcome this complexity, a well-integrated distribution system is required to maintain the sustainability of biodiesel product throughout Indonesia's regions.

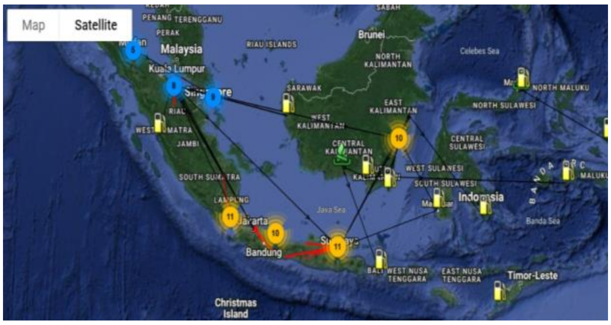

Figure 1. *The Indonesian biodiesel distribution*

Source: BPDPKS, 2023

Furthermore, the implementation of biodiesel is regulated in the Government Regulation No. 79/2014 regarding National Energy Policy. Among others, this policy aims to ensure Indonesia's energy security domestically (Directorate Bioenergy, 2022). Under its derivative regulation, the biodiesel mandatory program is given in the Regulation of MEMR No. 32/2008 regarding the Provision, Utilization, and Trading System of Biofuels as Other Fuels. All activities that are regulated include the minimum percentage of biodiesel blending, pricing mechanism, quality standard, and administration process (Directorate Bioenergy, 2022).

Starting from January 1st, 2020, the mandatory of 30% biodiesel (B30) mixture in gasoil fuel has been mandated as a diesel-engine fuel in Indonesia. The successful provision and utilization of B30 has put Indonesia at the world's first position in terms of biodiesel implementation. In 2022, biodiesel consumption used for B35 implementation reached about 10.5 million KL (Directorate Bioenergy, 2022). Under the Decree of the MEMR Number 205.K/EK.05/DJE/2022, at this period, there were 70 blending locations which were supplied by 21 biodiesel factories spreading throughout Indonesia regions. Figure 2 shows the increasing consumption of biodiesel from 2009 until 2022. The blending mixture of biodiesel is expected to further increase by approximately 35% (B35) in 2023 and 40% (B40) mixture of biodiesel in the future. The Indonesian biodiesel program has significantly improved its economy growth, i.e., it emits fewer pollutants; and reduces the volume of gasoil imports – which in turn, improves the national trade balance (Halimatussadiah *et al.*, 2021).

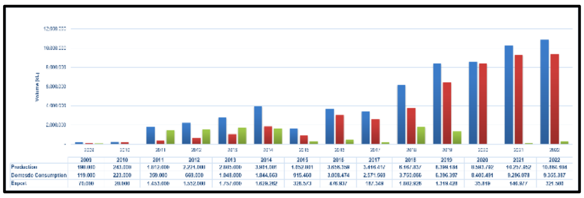

Figure 2. *The biodiesel production, domestic consumption, and export in the eriod 2009 – 2022*

Source: Directorate General of New and Renewable Energy and Energy Conservation (DGNREEC), MEMR (2022)

The distribution of the biodiesel product throughout all Indonesia's regions uses several types of freight modes such as shipping, trucking, and piping from the supply points of biodiesel factories to the blending points, which are located at the chosen fossil fuel stations. The expenses generated to deliver the biodiesel product are paid by the government through the incentive schemes given by the Palm Oil Plantation Fund Management Agency (BPDPKS). The total incentives are accounted in terms of cost per litter multiplied by total volumes of biodiesel delivered per trip (MEMR Regulation No. 24/2021).

In terms of the pricing scheme, the Indonesian market price of domestic biodiesel is officially determined by i) the total price of domestic CPO[1], ii) conversion costs[2], and iii) transportation costs (DGNREEC, 2023). According to the MEMR Regulation Number 24/2021 regarding the Supply and Demand of Biodiesel in the funding framework of the Oil Palm Plantation Fund Management Agency, the incentive covers the price difference between the Index Price of Biodiesel and the Index Price of Gasoil. This incentive is funded from the levies of CPO export. Nevertheles, on the condition where the Index Price of Biodiesel is cheaper than that of the Index Price of Gasoil, the incentive funding is not given.

Until date, the determination of biodiesel freight costs is simply based on auction submission proposed by transporters for the chosen route(s). The government will then officially investigate and choose the lowest offer of the corresponding freight costs per unit; and finally set the maximum ceiling price at its 15% higher than that of its corresponding offer (BPDPKS, 2022). This procedure, however, has raised some unclear estimation. This is because the regulated transportation costs of biodiesel might generate an inefficient rate due to unclear references of cost components of both trucking and shipping modes offered by the chosen transporters.

Based on the literature, the level of biodiesel transportation costs is influenced by several main factors, namely i) transportation mode types; ii) point-to-point distances; and iii) biodiesel volume delivered per trip. For the trucking transportation mode, the expenses must be ideally estimated from their total cost function of all expenses and margin which are derived into marginal and average costs. Therefore, the unit freight costs using trucking areleast when the marginal costs equal its average cost.

Each type of expense can be categorized into certain and uncertain types of costs. This information is obtained from transporter interviews as well as the literature reviews related to that of fixed and variable costs of transportation. The fixed costs include all expenses generated which are not affected by all conditions faced, i.e., legal and liaisons, insurance, and depreciation costs. On the other hand, variable costs include those expenses that are varied dynamically and flexibly. The cost components for both fixed costs and variable costs for the trucking mode are commonly classified in Table 1.

Table 1. *Fixed and variable cost components for trucking mode transportation*

Fix Cost	Variable Cost
1. Legal & Liaisons Cost	1. Fuel Cost
2. Insurance Cost	2. Operational Cost (Driver Wage)
3. Investment Cost (Cost of Money)	3. Other Operational Cost
4. Overhead Cost	4. Maintenance Cost
5. Depreciation	5. Tires Cost

Source: Authors' own work

On the other hand, for shipping transportation, the expenses on fixed and variable costs are more complex than those of the trucking transportation mode. Among others, one of the most significant differences is related to the type of shipping itself – i.e., shipping types of Self-Propelled Oil Barge (SPOB), Tanker Vessel, or Barge. The other difference is mainly associated to that type of shipping charter or rent – *i.e.*, based on bareboat, time, voyage, or contract of affreightment type of charter.

In general, shipping costs are usually proxied to the total days of delivery. In overall, it can be inferred that the cost level using shipping transportation is influenced by internal and external factors. The internal factors include i) type and year of the ship construction, ii) ship capacity; and iii) speed of the ship.

The external factors include i) weather and climate conditions; ii) harbor capacity as well as its onshore tank pump power; and iii) type of water areas. The differences in these categories, in turn, shall specifically determine their total bunker consumption.

This paper aims to estimate the model for biodiesel transportation costs in Indonesia. The complexity of biodiesel distribution in Indonesia can be optimized through a well-designed model to improve the cost competitiveness of its biodiesel production (Silalahi and Simatupang, 2020; and Harahap *et al.*, 2018). To do so, we assess the least costs of biodiesel distribution from its supply point to the end user (blending terminal) point at the gasoil fuel station using the optimization model. Based on both questionnaires and secondary type of data sources, we take into account all expenses related to either the trucking or shipping transportation mode. Furthermore, by considering the existing spread of biodiesel supply and demand, we also pay attention to the highest possibility of the shortest route of biodiesel distribution. For example, biodiesel distribution around Java-island will use only the trucking mode of transportation. On the other hand, the shipping mode will be prioritized for the biodiesel distribution between Indonesian islands. To our knowledge, this research contributes a significant novelty to the biodiesel development program, to some extent, in how to address optimal distribution costs of biofuel usage globally. The assessment of factors that influence the costs of distributing biodiesel, in a type of transportation mode, throughout Indonesia is important for policymakers and stakeholders in order to maintain its long-term sustainability

2. Literature review

The literature related to the assessment of biodiesel distribution costs is still lacking. Therefore, in this section, we briefly summarize the literature sources that also discussed the assessment of optimal transportation costs in distributing the oil-type products.

The level of transportation costs is mainly influenced by several factors, namely: the type of transportation mode used, distances, and biodiesel volumes which must be delivered. Sadewo (2012) estimated the transportation costs of biodiesel in terms of uniform costs per km-litter for the trucking mode. The author found that the transportation costs for trucking are uniformly about Rp. 1.25/km-litter. Therefore, when the distribution distance between the biodiesel supply and blending station is about 240 km, the unit costs of transportation (Rp/litter) will be approximately Rp. 300/litter. This assessment, however, did not involve the geographical and traffic condition in each routing area. Therefore, the uniform unit costs might give an underestimated expense for those route conditions which have a situational condition, i.e., tend to have more road damage, winding routes or heavy road congestion.

Hadiguna and Putra (2015) assessed the transportation costs for distributing biodiesel products from unused cooking oil (UCO) using the trucking mode. The authors assumed that the product is delivered from the producer's factory to both, the distribution center and Pertamina's gas and oil terminal station using the Distribution Storage Carrier Delivery concept. The biodiesel product is then distributed to final consumers from these agents. By using the 16 KL trucking mode, the total distances are approximately 99.2 km and the total delivery time is about 139 minutes assuming the speed of the truck by around 40-45 km/hour, while the time needed for loading and unloading is about 15 minutes for each agent. Overall, the total unit costs of transporting biodiesel products to these agents are about Rp. 32.13/litter.

Alhamda (2016) optimized the costs of transporting oil products in the West Nusa Tenggara region, Indonesia by using tanker shipping and container shipping. The author classified the cost components into the fixed and variable costs. The ffixed costs were further classified into ship costs and port costs while variable costs were split into three components, namely: ship operational costs; ship voyage costs; and port operational costs. The results indicated that the least costs of shipping were obtained for the following terms. A unit tanker type of shipping with a capacity of 7.992 Dead Weight Tonnage (DWT) is used to deliver the oil products to multiports (three locations) – from the transit terminal of oil and gas in Manggis (Bali) to the Ampenan, Badas, and Bima's depot. The total days (return) needed for delivery are 4.47 days and the total unit costs of delivery (one to multiports based) are about Rp. 203,587.70 per KL – which consists of Rp. 46.15 billion for shipping maintenance and operations; and about Rp. 68.50 billion for the port's maintenance and operation. At an equal volume delivered, the total unit costs using the container type of shipping are 12% higher compared with the tanker type of shipping. For instance, by using container shipping with a payload of about 322 TEUs, the total unit costs of delivery are about Rp. 231,998.28 per KLr. However, the total trips (return) required for delivery are much faster, about 4.2 days. The total costs for both shipping and the port's maintenance and operation are Rp. 33.14 billion and Rp. 96.91 billion, respectively.

By comparing the transportation costs in countries, Maryam and Syafie (2014) found that distance and quantity have become the main factors that influence the distribution costs of palm oil liquid product. Thus, they are regarded as the keys in optimizing the production and supply chain system.

Valizadeh *et al.* (2014) investigated the optimal planning of biodiesel supply chain in Malaysia under the Linear Programming Model. Based on the transportation model, the authors presumed the uses of the trucking mode in the western part and the shipping mode in both east and western parts of Malaysia. The secondary data for transportation costs were obtained from Kim *et al.* (2011) which are generated from the optimization Mixed Integer Linear Programming (MILP) modeling framework. The costs for road transportation (truck) are approximately 0.19 Malaysian Ringgit (MYR)/ton.km; while shipping costs from Port Klang to Kota Kinabalu and from Port Klang to Kuching are approximately 230 MYR/ton and 220 MYR/ton, respectively. It was concluded that the total transportation cost covered about 10% of the total biodiesel production costs.

To estimate a more accurate biofuel (biomass) supply chain, Kim *et al.* (2011) applied the Geographical Information Systems (GIS) to assess the transportation distances and their related costs. The costs for logistic transportation are accounted from delivering the biomass resources to the processing point and then to the final markets. The results presented that the unit costs of transportation for biodiesel was approximately US$ 0.1/ton-miles. However, the information of how to calculate each cost component to form the transportation costs was not identified in their research work.

3. Transportation Cost Model and Findings

3.1. Trucking Mode

The trucking mode is used typically in shorter distances, smaller quantities of fuel delivered, and applied only in the land channeled distribution. Based on in-depth interviews with practitioners and transporters, the cost components of fixed (UFC_{truck}) and variable costs (UVC_{truck}) are classified as follows. The fixed costs consist of i) legal and liaison expenses; ii) cost of money; iii) overhead; iv) depreciation; and v) insurances. Variable costs consist of i) fuel consumption; ii) operational expenses for the driver; iii) other operational expenses; iv) maintenance; and v) tires.

Thus, the unit costs (IDR/litter) of trucking mode can be expressed as follows:

$$TC_{truck} = (UFC_{truck} + UVC_{truck})D_{truck} \quad 1)$$

Where UFC_{truck} and UVC_{truck} represent the unit costs of fixed and variable expenses (IDR/km-litter) and D_{truck} represents the route distance (return).

By allowing the return for transporter (π) and taking into account the risk factor adjustment geographically (α), eq. (1) is extended as follows:

$$TC_{truck} = (UFC_{truck} + UVC_{truck}) D_{truck}(1+\pi)(1+\alpha) \quad 2)$$

Risk adjustment (α), in terms of percentage index, is important to weigh the route conditions during delivery, especially for those cases regarding i) congestion intensity and ii) road terrain complexity. In turn, these factors will affect the level of expenses of fuel consumption, operations and maintenance, and depreciation. Based on expert justification, it is assumed that the route with heavy congestion compared to that of light congestion conditions, will require a higher fuel consumption by about 0.5 km/litter. Table 2 presents the statistics of risk factors in delivering biodiesel products through the trucking mode over a distance of about 602 km.

Table 2. *Risk factors of biodiesel distribution using trucking mode*

No.	Risk Type	Low Risk	Medium Risk	High Risk
1.	Fuel Consumption (km/litter)	2,5	2.3	2.0
2.	Delivery time (hours)	60	66	72
3.	Additional maintenance Cost (%)	0	5	10
4.	Additional depreciation cost (%)	0	5	10
Risk adjustment (α)		0	10	22

Source: Authors' own work

3.1.1. Trucking Fixed Costs

The components that are included in the trucking fixed costs are described as follows. The expenses for Legal and Liaisons are required for numerous obligatory checking and business licenses such as: i) technical viability checking for vehicles ("Keur" Checking); ii) business licenses; iii) hazardous and toxic materials checking; iv) terra and calibration checking; v) oil and gas checking; v) vehicle registration letter; vi) retribution and dispensation; and vii) other licenses required for transporter operational.

Based on the interviews with experts and transporters, the expenses for both "Keur" checking and business license are around Rp 1 - 2 million, depending on the type of truck used. The expenses for hazardous and toxic materials checking; terra and calibration checking; oil and gas checking, as well as vehicle registration letter are all around Rp. 4 million.

Insurance costs are around 2% of the total investment costs – consisting of truck and stainless-steel tank purchase, which is between Rp. 1.3 and 2.2 billion depending on the size and the type of truck as showed in Table 3. The costs of money are assumed at about 12% of the total investment costs, which are between Rp. 156 million and Rp. 264 million, with the assumption of 5 years instalment. The overhead costs are accounted from the total of employees' wages (excluding driver); capital rent; electricity consumption; communication, and other appliances. Based on expertise adjustment, it is assumed that these costs cover around 10% of the total operational costs. Finally, by using a straight-line method for 60 months, the asset values are about 80% of the book value of the purchase.

Table 3. *The Indonesian trailer types for biodiesel distribution*

Type of Truck	Capacity (kL)	Description
Standard Trailer	16	too small, thus uneconomical
Trailer 20 feet	24	ideal and quite economical
Trailer 40 feet	32	ideal and quite economical
trailer 40 feet	40	maximum, thus it is the most economical

Source: In-depth interviews with biodiesel experts and transporters (2021)

3.1.2. Trucking Variable Costs

The components that are included in trucking variable costs are given as follows. Fuel consumption (IDR/litter) is estimated from the distribution distance and fuel price (about IDR 12,500 per litter). Based on the intervies with experts, the fuel consumption ratio is assumed to be in the range of 2 – 3.5 km/liter, of which the highest magnitude is given to that of smaller capacity of truck.

The operational costs are generated from driver's wages and daily food multiplied by the total days of delivery. We assume that these expenditures are around Rp. 150,000-200,000 per day and IDR 75,000 per day, respectively. The total trips for one delivery are about 2.5 days (return) – including the queue time at both, thesupply and blending terminal points. For other operational costs, we also include additional expenses that might be incurred during delivery trip, i.e., toll fees, inter-island crossing fees, parking fees, and others. It is suggested that the total costs for these are around Rp. 600,000 – 700,000 for each delivery.

The maintenance costs are related to those expenses on trucking observances such as i) preventive maintenance, ii) regular maintenance, and iii) breakdown maintenance. These costs depend on the distance (IDR/km), which is assumed between Rp. 150,000 and 180,000 per trip at a distance of about 602 km. Finally, the costs for the total tire replacement (or treatment) are estimated from the unit costs of each tire maintenance multiplied by the total tires per distance (km). Based on expert justification, the total tires of each truck are varied between 10 and 22 tires, which require about Rp. 50 million.

3.2. Shipping mode

Compared to that of the trucking mode, the shipping mode has an advantage of delivering large volumes of biodiesel within a wider range of inter-provincial and inter-island routes. Types of vessels commonly used in transporting biodiesel are tankers, although several transporters (or ship charter companies) also use other types of vessels such as Self-Propelled Oil Barge (SPOB).

The framework to calculate the freight costs using the shipping mode is different from those of the trucking mode. For example, the total expenses of fixed and variable costs are commonly aggregated into the unit rental costs per day. Nevertheless, apart from their rental fees, another essential expenses that charterers require to pay are bunker fees or fuel costs which are considered as other expenses. Hence, by assessing the nature schemes of shipping charter, we propose the structural framework of expenses using the shipping mode as presented in Figure 2.

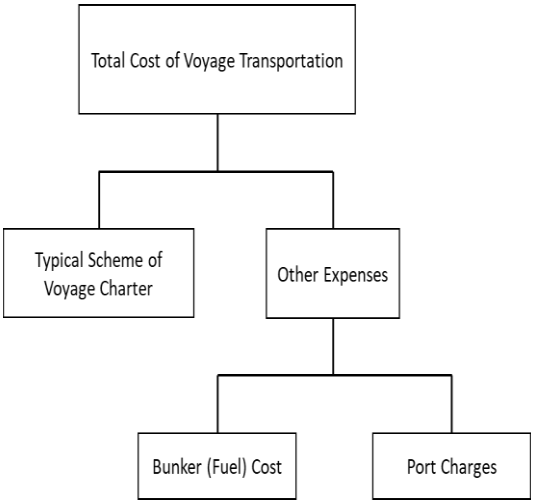

Figure 2. *Framework of distribution costs using shipping mode*

Source: Authors' own work

3.2.1. Costs of Voyage Charter

In general, the vessel charter fees paid by the charterer – in this case biodiesel producer – include the fixed and variable costs, excluding fuel expenses and profit margin. The breakdown of these costs consists of several components, i.e., crew salaries; ship maintenance; and ship components (such as spare parts, and expenses on ship lubricant uses). We adjust the unit costs (IDR/litter) of this ship charter fee per day to the tanker rate offered by the Indonesian State-Owned Company of Oil and Gas (*Pertamina*) at a rental scheme, namely, voyage charter. For example, in a voyage charter scheme, the destination points and sailing path will be pre-determined. The use of the ship will start from the supply point to the blending terminal point (return).

There are several options that are commonly offered for shipping charters:

– Bareboat Charter is the scheme where the charterer only rents the vessel without the crew and route distance calculation. In other words, the charterer must find and equip its own crew. The fees will be given on a daily basis, excluding expenses on fuel and clean water on board.

– Time Charter is the scheme where the charterer will hire the vessel within a certain period. Within the renting period, the charterer can use the vessel to several destinations. In contrast to that of the bareboat charter, the expenses for a time charter include the crew and other costs, i.e., fuel or bunker costs and port fees (Coghlin *et al.*, 2014).

– Voyage Charter is the scheme given only to the charterer with a determined sailing path. When the destination changes, the contract needs to be renewed. Similar to that of the time charter scheme, a ship rental using a voyage charter scheme is also equipped with the crew.

– Contract of Affreightment (CoA) is a type of maritime contract that is used for a specific vessel (or group of vessels) to deliver specific cargo from one (or multi-ports) of loading to one (or multi-ports) of discharging over a period of time. It is a binding agreement between the shipowner and the charterer that outlines the terms and conditions of carrying the goods. A CoA typically specifies, among others, the cargo types to be delivered; the quantities; the location ports of loading and discharging; delivery date; and freight rates. The latter may be fixed or based on a market rate index. The CoA may also include provisions regarding insurance, liabilities, responsibilities, and dispute resolution. CoA contracts are usually classified into three types, namely, i) Bill of Lading Contract; ii) Charter Party Contract; and iii) Negotiation Charter Party Terms (UiO, 2014).

3.2.2. Other Expenses

Other essential expenses that charterers are required to pay are bunker fees or fuel costs. The price of fuel used is weighted to that of the average price of industrial fuel, which is around IDR 12,000/liter. In addition, in terms of specific fleet expenses on daily fuel consumption, we classify them according to the activity types that are undertaken by the ship during the voyage activity. For example, fuel consumption (kL/day) while traveling will definitely be greater than that of the docking ship at the port. Thus, it can be concluded that the total days of voyage will significantly affect the expenses for bunker consumption. Additionally, there are also port charges, which vary from port-to-port trip. However, based on in-depth interviews with transporters, for all voyages, the port charges given in the unit costs of shipping transportation, are fixed at average values.

3.2.3. Influenced Factors and Costliness Parameters

Unlike the trucking mode, the estimation of the ship's freight costs is based on the total days required to deliver the biodiesel product. In addition, several factors may also influence the fleet's voyage, which in turn, would affect the corresponding total costs of shipping. For simplification, we group these factors into internal and external leverage as follows. The internal factor is related to those parameters of i) the type and year of shipbuilding; ii) ship capacity; and iii) ship speed, while the external factor is associated with those parameters of i) weather and climate; ii) port capacity including the onshore tank pump power; and iii) type of waters.

These factors would affect the distribution cost level that is reflected in the total days of delivery and fuel consumption. We then disaggregate the number of days of delivery into their specific activities. Thus, the adjustment level of fuel consumption costs can be assessed carefully according to these activities.

To accurately estimate the shipping freight costs, we account the days required for each activity. This is aimed to capture not only the risks of shipping but also fuel consumption efficiency. Table 4 shows the period shares of the biodiesel cargo shipping activities.

Table 4. *Shipping distribution activity and its fuel consumption*

Shipping Activity Status	Number of Days	Fuel Consumption (KL/day)	Description
Voyage	depending on the distance and the ship's speed	6.5	Total sailing days from the supply point to the blending terminal point (total distance divided by the shipping speed).
Ballast	depending on the distance and the ship's speed	6.5	Total sailing days of returning in empty vessel condition (total distance divided by the shipping speed).
Loading	1	1.5	Total days required to load the biodiesel product from storage tank to the shipping tank (at the supply point)
Discharge	1	2.0	Total days required to unload the biodiesel product from the shipping tank to the storage tank (at the blending terminal point)
Waiting	4	1.2	Total days required for port queuing (in both supply's port and blending terminal's port)
Buffer	1	6.5	Total days required for anticipating all risks during the travel

Source: Own calculation based on transporter interviews

To calculate the distribution costs of shipping, we apply some assumptions and statistics as follows. The total days of the voyage (return) and ballast are estimated by dividing the port-to-port distances by the ship speed. Each distance is obtained from the Netpass website (https://www.netpas.net/) in terms of Nautical Miles (NM); while the ship speed is assumed equal to the standard speed of tanker type owned by Pertamina which is 8 knots. However, in shallow waters, we assume that the ship size is smaller and thus its speed is lower, which is about 6 knots. In terms of port queuing, because each port has a different capacity of tank and pumping rate, we consider an average of two days awaiting in both the supply port and blending terminal port.

Apart from the influenced factors, costliness parameter is also essential to accurately estimate biodiesel distribution cost using the shipping mode. As known, regionally, each province of Indonesia may have different conditions in terms of macroeconomic indicators, i.e., regional inflation, GDP, consumer purchasing power, and so on. In turn, these indicators would indirectly influence the expense level in each region such as employee salary, insurance, and crews' food allowance. However, for simplification, we estimate the region based on the costliness parameter (β) only in those of Indonesia's largest islands as showed in Table 5. This parameter will then be added to the shipping costs of biodiesel distribution.

Table 5. *The estimation of the regional costliness parameter*

Regional	Description	β Value
Sumatera	Baseline: crew salary, assurance, and food allowance	0
Java and Bali	Baseline: crew salary, assurance, and food allowance	0
Kalimantan	Baseline + 20%	0.2
Sulawesi	Baseline + 50%	0.5
Papua, Molucca and Nusa Tenggara	Baseline + 80%	0.8

Source: Own calculation based on transporter interviews

3.2.4. Cost components for shipping mode

Based on the above frameworks, we formulate the estimation of biodiesel distribution costs using the shipping mode as follows. The delivery costs (IDR/liter) of the sipping mode (TC_{ship}) for each route is determined by 3 variables, namely: i) type of shipping charter (RC_{ship}); ii) diesel fuel consumption (DC_{ship}); and iii) port charges (POC_{ship}) as given in Eq. (3).

$$TC_{ship} = RC_{ship} + DC_{ship} + POC_{ship} \quad (3)$$

The expenses for diesel consumption (DC_{ship}) are obtained from the diesel (bunker) price (PD_{ship}) multiplied by its volume (VD_{ship}), while the shipping charter is estimated from the delivery days required (T_{ship}) and the unit shipping rent per day (URC_{ship}). Thus, Eq. 3 is re-expressed to become Eq. 4 as follows.

$$TC_{ship} = (T_{ship} * URC_{ship}) + (PD_{ship} * VD_{ship}) + POC_{ship} \quad (4)$$

We then add β parameter (%) in the model; and weighting TC_{ship} by the shipping capacity (KL) (SC_{ship}) to obtain the unit delivery costs of the shipping mode (UTC_{ship}) (IDR/liter) expressed in Eq. 5.

$$TC_{ship} = \frac{\left(T_{ship} * URC_{ship}(1+\beta)\right)}{SC_{ship} * 1000} + \frac{\left(PD_{ship} * VD_{ship}\right) + POC_{ship}}{SC_{ship} * 1000} \quad (5)$$

4. Optimizing the biodiesel transportation costs

By applying the software of the General Algebraic Modelling System (GAMS) with Linear Programming solver (LP), we optimize the total least cost of delivering the biodiesel product. The transportation model is specified into the trucking and shipping mode, whilst the piping mode is excluded due to its given installation attached into each supply and blending terminal point.

In general, assuming the same number of items delivered, transportation costs mostly depend on the distance and route condition of delivery. However, in the case of biodiesel mandatory program, both volumes of the j-th production supply and its i-th demand of biodiesel throughout Indonesia's regions become the main constraints in the optimization model. In this regard, we apply the data of the total domestic demand of biodiesel in Indonesia in 2022 released by MEMR (2023). The model specification to optimize the biodiesel transportation costs is given as follows.

Optimize:

$$TV = \sum_i \sum_j VTruck_{i,j} DTruck_{i,j} + \sum_i \sum_j VShip_{i,j} DShip_{i,j} \quad (5)$$

Constraint:

$$VS_i = \sum_j VTruck_{i,j} + \sum_j VShip_{i,j} \quad (6)$$

$$VD_j = \sum_i VTruck_{i,j} + \sum_i VShip_{i,j} \quad (7)$$

$$VS_i \le S_i;\ VD_j = D_j \quad (8)$$

Where TV is the total volume by distance of biodiesel delivered (KL Meter); $VTruck_{i,j}$ is the total volume of biodiesel delivered by the trucking mode from the i-th supply to the j-th blending terminal point of biodiesel (KL); $VShip_{i,j}$ is the total volume of biodiesel delivered by the shipping mode from the i-th supplier to the j-th blending terminal point of biodiesel (KL); $DTruck_{i,j}$ is the total distance of delivering biodiesel by trucking (Meter); and $DShip_{i,j}$ is the total distance of delivering biodiesel by shipping (Meter); VS_i is the i-th total volume supply of biodiesel delivered by the trucking and shipping mode; and VD_j is the total volume biodiesel delivered by the trucking and shipping mode to the j-th terminal point of blending. Finally, the total transportation costs of biodiesel delivery at post optimization process are given as follows:

$$TC_j = TCTruck_j + TCShip_j \quad (9)$$

$$TCTruck_j = \sum_i \left(VTruck_{i,j} CTruck_{i,j}\right) \quad (10)$$

$$TCShip_j = \sum_i \left(VShip_{i,j} CShip_{i,j}\right) \quad (11)$$

Where TC_j is the total transportation costs of delivering biodiesel to all Indonesia's region in the j-th terminal point of blending (Rupiah); $TCTruck_j$ the total transportation costs using the trucking mode to the j-th terminal point of blending (Rupiah); $TCShip_j$ is the total transportation costs using shipping mode to the j-th terminal point of blending (Rupiah); $CTruck_{i,j}$ is the unit transportation costs of delivering biodiesel by trucking from the i-th supplier to the j-th terminal point of blending (Rupiah/liter); and $CShip_j$ is the unit transportation costs of delivering biodiesel by trucking from the i-th supplier to the j-th terminal point of blending (Rupiah/liter).

5. Results and discussions

By applying the above cost models for both trucking and shipping modes, we obtain the distribution costs for each route. We then compare these results with that of regulated transportation costs. The results indicate that some transportation costs given in the regulation may be either higher (or lower) compared to the models.

5.1. Transportation costs using trucking mode

We estimate the transportation costs for all 19 routes of biodiesel distribution using the trucking cost model. Table 6 presents the comparative results between formulated and regulated transportation costs of biodiesel. Both, truck routes and types are based on the existing data obtained from Decree of MEMR Number 146.K/HK.02/DJE/2023.

Table 6. *The regulated vs formulated transportation costs of trucking mode*

Trucking Route	Supplier Point	Trucking Type	Distance (km)	$TCTruck_j$ (Rupiah/L)	Regulated Transportation Cost (Rupiah/L)
Gresik (East Java)-Tuban (East Java)	Gresik	Trailer 40 KL	202	94	97 (+)
Bekasi (West Java)-Cikampek (West Java)	Bekasi	Trailer 40 KL	134	62	135 (+)
Bekasi (West Java)-Jakarta	Bekasi	Trailer 40 KL	42	20	350 (+)
Marunda (Jakarta)-Cikampek (West Java)	Marunda	Trailer 40 KL	162	75	135 (+)
Marunda (Jakarta)-Bandung Group (West Java)	Marunda	Trailer 40 KL	336	156	158 (+)
Marunda (Jakarta)-Merak (Banten)	Marunda	Trailer 40 KL	146	68	260 (+)
Marunda (Jakarta)-Cilegon (Banten)	Marunda	Trailer 40 KL	278	129	260 (+)
Marunda (Jakarta)-Jakarta	Marunda	Trailer 40 KL	64	30	168 (+)
Marunda (Jakarta)-Banten	Marunda	Trailer 40 KL	282	131	260 (+)
Panjang (South Sumatera)-Kertapati (South Sumatera)	Panjang	Trailer 32 KL	618	319	340 (+)
Dumai (Riau)-Dumai (Riau)	Dumai	Trailer 32 KL	68	35	52 (+)
Gresik (East Java)-Semarang Group (Middle Java)	Gresik	Trailer 32 KL	264	136	226 (+)
Gresik (East Java)-Surabaya (East Java)	Gresik	Trailer 32 KL	42	22	130 (+)
Panjang (South Sumatera)-Kertapati (South Sumatera)	Panjang	Trailer 32 KL	618	319	340 (+)
Batam (Riau Islands)-Batam (Riau Islands)	Batam	Trailer 32 KL	29	15	116 (+)

Source: Decree of MEMR Number 146.K/HK.02/DJE/2023 and Own Calculation

Table 6 indicates that the regulated costs tend to be overestimated. For examples, the costs from Batam to Batam and Gresik (East Java) to Surabaya (East Java) reached almost 9 folds and 6 folds, respectively, compared to that of formulated costs. Nevertheless, for several routes, i.e., from Gresik (East Java) to Tuban (East Java) and Dumai (Riau) to Dumai (Riau), its regulated costs are quite similar to that of formulated cost. On average, the regulated costs (IDR 167/liter) are higher than the formulated cost (IDR 114/liter), or about 68.26% higher. Although the estimation of the formulated distribution costs has considered risk regional factors (α), we argue that the cost gaps might be due to the chosen contract proposal in the regulated scheme. Thus, the regulated transportation costs could be randomly varied depending on the specific terms outlined in the agreement between the parties (biodiesel supplier and transporter) involved. Thus, it is important for the government to carefully review and understand the terms of the contract to ensure that both parties are aware of the transportation costs and any additional fees or charges that may be incurred. This intervention is essential for the sake of logistic efficiency since transportation costs are paid through incentive funding. In overall, we found that the cost components that would sequentially affect the total trucking unit costs are: i) operational costs (25%); ii) investment costs (20%); iii) driver salary; and iv) other factors – i.e., driver expenses, depreciation, and overhead (10% each); tires (8%), maintenance (3%), and licensing and insurance (2% each). Nevertheless, based on expert judgment (such as group interviews with shipping owners, transporters, shipping associations, and shipping experts), the α for Java-Bali and Sumatera regions are considered to be zero; whilst for east regions of Indonesia, the risk factor is customized depending on their geographical conditions and local characteristics.

5.2. Transportation Costs using Shipping Mode

The estimation of shipping costs is more complex than that of the trucking mode. This is because it delivers a large volume of biodiesel and requires information of specific days in all shipping activities such as ballast, waiting, loading, voyage, discharge, and buffer. Each activity will affect the use of bunker (fuel) consumption. Table 7 presents the days requirement in each shipping activity including its bunker fuel requirement.

Table 7. *The days requirement in shipping activity*

Vessel Status	Number of Days	Bunker Consumption (KL)	Total Bunker Consumption (KL)
Ballast	6.4	6.5	41.9
Waiting	2.0	1.2	2.4
Loading	1.0	1.5	1.5
Voyage	6.4	6.5	41.9
Waiting	2.0	1.2	2.4
Discharge	1.0	2.0	2.0
Buffer	1.0	6.5	6.5
Total	19.9		98.5

Source: Own calculation

We then multiply the fuel consumption by its price and add it to the port charges and ship charter (proxied to total voyage days) to obtain the total costs of the shipping mode. Table 8 presents the example of calculation of shipping costs from Dumai to Balikpapan.

Table 8. *The shipping costs from Dumai to Balikpapan*

Total Voyage Days	Rate per Day (US$)	Total US$
19.9	4,200	83,496
Total Bunker Consumption	**Bunker Price (Rupiah)**	**Total US$**
98,500	12,000	81,534
Total Freight Rate		165,039
Port Charges		11,637
Grand Total (US$)		176,667
Grand Total (IDR)		2,561,668,500
Total cost per tanker with capacity 4,000 KL		640,417
Unit Cost (IDR/L)		640.18

Source: Own calculation

This result shows that the regulated shipping costs also tend to be more expensive than the formulated costs. We found that the average formulated costs, including the costliness parameter (β), are 10% cheaper than that of regulated unit costs. Table 9 presents the comparative statistics between the formulated and regulated shipping costs in specific 74 available routes. Both, shipping routes and types are based on the existing data obtained in the Decree of MEMR Number 146.K/HK.02/DJE/2023.

Table 9. *The Regulated vs Formulated Shipping Costs*

No.	Shipping Route: Supply Port to Blending Port City (Province)	Ship Capacity (KL)	Distance (NM)	Speed (Knot)	Duration (Days)	$TCShip_j$ (Rupiah/L)	Regulated Transportation Cost (Rupiah/L)
1.	Bagendang (Middle Kalimantan)-Manggis (Bali)	4,000	410	8	11	313	315 (~)
2.	Bagendang (Middle Kalimantan)-Tanjung Wangi (East Java)	4,000	514	8	12	348	350 (~)
3.	Bagendang (Middle Kalimantan)-Kotabaru (South Kalimantan)	4,000	149	8	10	309	355 (+)
4.	Bagendang (Middle Kalimantan)-Banjarmasin (South Kalimantan)	2,500	144	8	9	358	550 (+)
5.	Batam (Riau Islands)-Tanjung Uban (Riau Islands)	4,000	378	8	7	178	215 (+)
6.	Batam (Riau Islands)-Sambu Island (Riau Islands)	4,000	353	8	11	294	275 (-)
7.	Batam (Riau Islands)-Jakarta (DKI Jakarta)	15,000	693	8	14	226	225 (~)
8.	Batam (Riau Islands)-Balikpapan (East Kalimantan)	4,000	1,410	8	22	703	850 (+)
9.	Batam (Riau Islands)-Balikpapan (Floating Storage, East Kalimantan)	4,000	1,410	8	22	703	850 (+)
10.	Batam (Riau Islands)-Tanjung Wangi (East Java)	4,000	1,064	8	18	532	350 (-)
11.	Balikpapan (East Kalimantan)-Balikpapan (Floating Storage, East Kalimantan)	4,000	127	8	7	195	240 (+)
12.	Balikpapan (East Kalimantan)-Palaran (East Kalimantan)	4,000	99	8	8	229	240 (+)
13.	Balikpapan (East Kalimantan)-Sangatta (East Kalimantan)	4,000	138	8	8	243	310 (+)
14.	Balikpapan (East Kalimantan)-Kotabaru (South Kalimantan)	4,000	144	8	9	245	330 (+)
15.	Balikpapan (East Kalimantan)-Manggis (Bali)	2,500	460	8	12	196	610 (+)
16.	Balikpapan (East Kalimantan)-Samarinda (East Kalimantan)	4,000	78	8	8	221	240 (+)
17.	Bayas (Riau)-Bau bau (South East Sulawesi)	4,000	1,214	8	20	632	644 (+)
18.	Bayas (Riau)-Wayame (Maluku)	4,000	1,584	8	24	766	803 (+)
19.	Bayas (Riau)-Belawan (North Sumatera)	4,000	600	8	13	377	275 (+)
20.	Bayas (Riau)-Labuhan Deli (North Sumatera)	4,000	886	8	16	472	275 (+)
21.	Belawan (North Sumatera)-Pontianak (West Kalimantan)	4,000	696	8	14	445	430 (-)
22.	Bitung (North Sulawesi)-Bitung (North Sulawesi)	4,000	3	8	7	176	125 (-)
23.	Bitung (North Sulawesi)-Kasim (West Papua)	4,000	429	8	11	348	1,095 (+)
24.	Bitung (North Sulawesi)-Kupang (East Nusa Tenggara)	4,000	755	8	15	466	395 (-)
25.	Bitung (North Sulawesi)-Wayame (Maluku)	4,000	385	8	11	332	534 (+)

Source: Decree of MEMR Number 146.K/HK.02/DJE/2023 and Owned Calculation

Table 9 shows that there are three routes of the regulated shipping costs which are consistent with the formulated costs. These routes are: from Bagendang to Manggis and Tanjung Wangi as well as from Batam to Jakarta. The remaining regulated routes have higher transportation costs. In addition, the highest difference of costs between the regulated and formulated costs is given from Bitung to Kasim.

Nevertheless, as explained previously, we argue that these cost differences might be caused by the following factors: the shipping size and activities used as well as the fixed shipping tariff given in the contract aggrement by the charterer. Therefore, similar to that of the trucking mode, we also suggest the establishment of a well-designed procedure such as the implementation of a publicly open and accountable auction process to obtain a realistic result of determining the official shipping costs on the chosen routes of delivery.

6. Total transportation costs

Finally, by using the optimization transportation cost model, we simulate the implementation of the Indonesian biodiesel mandatory program in the year 2022 – in terms of the trucking and shipping mode. We use the volume data of biodiesel consumption from 2020 to 2022. As showed in Table 10, the optimization model generates lower costs of transportation compared to that of the Business as Usual (BaU) scenario by around 3.2% to 7.7%. In other words, by applying the optimization model of transportation costs, the effectiveness of biodiesel distribution in the context of freight cost tends to be higher than only in the Business as Usual (BaU) scheme.

Table 10. *The cost effectiveness of biodiesel distribution using an optimization model*

Year	Total Cost (Trilion Rp.)					
	Trucking Mode			Shipping Mode		
	Optimization Model	BAU	% Change	Optimization Model	BAU	% Change
2020	0.26	0.28	-7.69	2.13	2.11	+0.94
2021	0.30	0.32	-3.23	2.42	2.56	-5.79
2022	0.35	0.37	-4.23	2.75	2.84	-3.27

Source: Own calculation

7. Conclusions and recommendations

Currently, the regulated distribution costs of biodiesel in Indonesia, i.e., by the trucking and shipping mode, have relied on the lowest auction offers from the corresponding transporters. This paper is aimed to propose a reference to establish the most effective cost formula for distributing biodiesel to all regions in Indonesia. The results show that some of its regulated transportation costs in certain routes might be either over- or underestimated.

For the trucking mode, we found that the most dominant factors which affect its transportation cost level, are i) operational costs, investment costs, and driver costs, while in the shipping mode, its size and its activities (i.e., voyage, ballast, loading, discharge, waiting, and buffer) have been regarded as the largest contribution to their level of distribution costs.

Based on the optimization cost model of transportation, we conclude that the formulated costs are more efficient than the regulated costs, which could reduce by about 3.2% to 7.7%. This result, however, does not take into account the return variations proposed by each transporter companies, i.e., the types of the shipping charter or rent given in the agreed contract.

Due to data limitation, this study does not take into account the cost components related to maintaining the storage quality of biodiesel product during delivery such as a nitrogen blanket requirement to prevent moisture contamination as well as oxygen degradation especially to that of long trip delivery. This is because biodiesel is a highly hygroscopic product, which could cause a degradation due to the contact with air and water during the transport and storage period (Botella *et al.*, 2014; Christensen and McCormick, 2014). Therefore, the additional costs for the expenses in protecting the storage stability of biodiesel during transportation are suggested as the topic for future research.

References

1. Alhamda, P. 2016. *Optimalisasi Sistem Pengiriman Product Oil Untuk Wilayah Kepulauan: Studi Kasus Nusa Tenggara Barat*. Doctoral dissertation, Institut Teknologi Sepuluh Nopember.

2. Botella L., Bimbela F., Martín L., Arauzo J., and Sánchez JL. 2014. Oxidation Stability of Biodiesel Fuels and Blends Using the Rancimat and PetroOXY Methods. Effect of 4-Allyl-2, 6-Dimethoxyphenol and Catechol as Biodiesel Additives on Oxidation Stability. Frontiers in Chemistry. Vol 2: 43. doi.org/10.3389/fchem.2014.00043.
3. BPDPKS (*Badan Pengelola Dana Perkebunan Kelapa Sawit*). 2023. *Sistem Informasi Program Biodiesel*. Retrieved from: https://program-biodiesel.bpdp.or.id/web/
4. BPDPKS (*Badan Pengelola Dana Perkebunan Kelapa Sawit*). 2022. *Penyusunan* Standard Operating Procedure (SOP) *Penetapan Ongkos Angkut dan Optimalisasi Distribusi FAME*. Final Research Report.
5. Christensen E, McCormick RL. 2014. Long-term storage stability of biodiesel and biodiesel blends. Fuel Processing Technology 128 (2014) 339-348. doi.org/10.1016/j.fuproc.2014.07.045.
6. Coghlin, T., Baker, Q.C., Kenny, J., Kimball, J.D., Belknap, T.H. 2014. Time Charters: Second Edition. Informa Law from Routledge.
7. Directorate of Bioenergy. 2022. *Buku Saku Pengembangan Bioenergy tahun 2022*. Directorate General of New and Renewable Energy and Energy Conservation (DGNREEC), the Ministry of Energy and Mineral Resources (MEMR) of the Republic of Indonesia.
8. Harahap, F., Silveira, S., Khawatiwada, D. 2018. Cost Competitiveness of Palm Oil Biodiesel Production in Indonesia. Energy (2018), doi: 10.1016/j.energy.2018.12.115.
9. Hadiguna, R. A., & Putra, D. 2015. *Dinamika Jaringan Rantai Pasok Biodiesel dari Minyak Goreng Bekas (Analisis, Pemodelan dan Kebijakan).*
10. Halimatussadiah, A., Nainggolan D., Yui, S., Moeis, F.R., Siregar, A.A. 2021. Progressive Biodiesel Policy in Indonesia: Does the Government's Economic Proposition Hold? *Renewable and Sustainable Energy Reviews* 150 (2021) 111431.
11. International Energy Agency (IEA). 2022. An Energy Sector Roadmap to Net Zero Emissions in Indonesia. International Energy Agency Special Report.
12. Kim, J., Realff, M.J., and Lee, J.H. 2011. Optimal Design and Global Sensitivity Analysis of Biomass Supply Chain Networks for Biofuels under Uncertainty. Computers and Chemical Engineering 35 (2011) 1738-1751.
13. Kuntjoro, Y.D., Khotimah, K., Rani, Agustiani. 2020. Indonesia Energy Security Concept to Improve Sustainability of New and Renewable Energy Utilization in Indonesia with Quintuple Helix Model: 4A+1S for National Defense. Mices 2020. IOP Conf. Series: Earth and Environmental Science 753 (2021) 012045. Doi: 10.1088/1755-1315/753/1/012045.
14. Sadewo, H. 2012. *Analisis Kebijakan Mandatory Pemanfaatan Biodiesel di Indonesia. Universitas Indonesia*.
15. Shalihah, A. H. 2017. *Model Sistem Dinamik untuk Meningkatkan Rasio Pemenuhan dan Efisiensi pada Manajemen Rantai Pasok Biodiesel Nasional*. Doctoral Dissertation, Institut Teknologi Sepuluh Nopember.
16. Silalahi, F.T.R., Simatupang, T. 2020. Biodiesel Produced form Palm Oil in Indonesia: Current Status and Opportunities. AIMS Energy, 8(1): 81-101. DOI: 10.3934/energy.2020.1.81.
17. Valizadeh, M., Syafiie, S., & Ahamad, I. S. 2014. Optimal planning of biodiesel supply chain using a linear programming model. 2014 IEEE International Conference on Industrial Engineering and Engineering Management, pp. 1280- 1284, IEEE.

[1] Indonesian domestic price of CPO is obtained to the *Kharisma Pemasaran Bersama Nusantara* (KPBN) reference.

[1] The conversion cost is fixed; that is approximately US$ 85/ton of biodiesel produced.