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Multi-Scenario Optimization of Fuel Distribution Transportation Using Goal Programming

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Abstract: Inefficient distribution routes of oil could lead to supply deficits and increased costs. Several goal programming models were developed in this study to determine an optimal distribution model for fuel oil transportation using goal programming that meets target demand while optimizing capacity, time, and cost. Data were obtained through sources directly involved in operational performance. A total of four scenarios reflecting variations in demand and route use were evaluated. The optimization results showed increased fuel fulfilment by 1,033 KL; 2,533 KL; 1,378 KL; 3,973 KL for Scenario 1 to 4, respectively. Also, the average travel time and distribution cost per litre were significantly reduced across all scenarios. The findings demonstrate that multi objective goal programming models enable in providing strategic allocation of transport resources in the networks of fuel-distribution. Moreover, implications for logistics managers include prioritizing route efficiency and modelling trade-offs between fulfilment, time, and cost in dynamic supply-chain nature.

Keywords: energy allocation; oil distribution; operational efficiency; optimization; supply chain

1 INTRODUCTION

The need for fuel oil has grown significantly over the last few decades due to several factors, including ongoing economic expansion, expanded access to personal vehicles, and global integration, which has raised transportation demands. Despite the recent rise in electric vehicles, conventional fuels are predicted to continue to be used at least until 2050 [1], which will have an impact on the environment. Even though the industrial sector uses a substantial quantity of energy globally, there are very few economic research on industrial energy demand [2]. Industries operating in hard-to-reach areas, such as Industrial Plantation Forests, face unique challenges in addressing this issue. Common problems include long distribution processes, high costs, limited access, and the socio-economic conditions of the surrounding communities.

Harvesting [3] is a production process that consists of a series of activities including Felling, Skidding, Transporting, and Loading/Unloading. The expense of fuel is the most expensive aspect of these activities. In Fig. 1, the fuel costs are as follows: 34% for felling, 36.9% for skidding, 39.3% for transporting (Pompong), 48.6% for transporting (Tronton), 54.3% for loading/unloading at TPn or Forest Landing Site, 54.3% for loading/unloading at TPK or Log Yard, and 45.3% for loading/unloading at the logpond. This suggests that the expense of fuel throughout the harvesting process needs to be given careful consideration.

All operational activities, including nursery, planting, and road construction, would be impacted by the up to 31% increase in the harvesting target, according to the company's report data. This will also affect the company's operations, which would require more gasoline. The goal planting numbers, the standard age of the plants during harvest, and the age of the standing trees in the field are used to calculate the expected increase in the Wood Delivery goal.

There would be a sharp rise in fuel consumption, especially in a few key operational and supporting activities including road construction and plantation operations. According to the Standard Calculation of Estimated Fuel Consumption in harvesting, the company's fuel consumption for harvesting activities is 8 Liters for every ton of wood harvested. For planting activities, fuel consumption is assumed to be 74% of the harvesting consumption, as shown in Tab. 1. Furthermore, weekly and annual fuel use will undoubtedly be impacted by road construction fuel consumption.

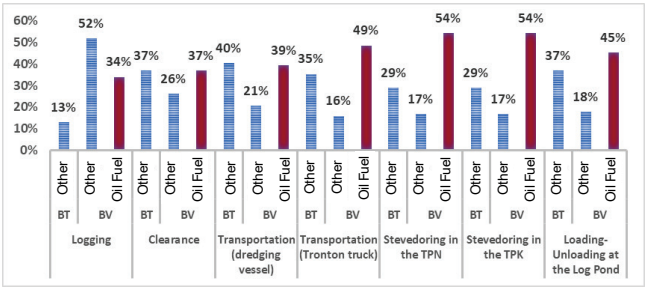


Figure 1 The percentage of fuel costs compared to other costs in each operational activity

Table 1 Monthly fuel needs for the years 2021-2025 (Tons)

No.	Business Unit	2021	2022	2023	2024	2025
1	Harvesting	3,733,333	3,993,246	4,052,060	4,463,665	5,167,424
2	Plantation	2,758,750	2,954,325	2,998,524	3,302,554	3,822,860
3	Road construction	222,917	396,250	449,110	476,770	504,430
	Total	6,715,000	7,343,821	7,499,694	8,242,989	9,494,714

Table 2 Number of non-productive heavy equipment and potential loss

No.	Date	Total unproductive heavy equipment (units)	Potential losses (tons)
1	09/22/2022	11	440
2	09/23/2022	22	880
3	09/28/2022	3	120
4	10/02/2022	10	400
5	10/13/2022	5	200
	Total	51	2,040

Based on data and reports collected over a two-month period, from September to October 2022, some operational harvesting regions have had substantial challenges hurting Wood Shipping production. According to statistics from two districts, a total of 28 heavy equipment units had their production impeded while on standby for fuel delivery. The company will undoubtedly lose opportunities because of

heavy equipment's inefficiency. Based on the results of the time study conducted by the Harvest Management team, the productivity of one heavy equipment unit is approximately 40 tons per day, thus the company's expected losses, as summarized in Tab. 2.

The data on unproductive heavy machinery is merely a sample of operational data collected from two districts over a two-month period. Given the comparatively lower fuel production and consumption targets in 2022 compared to subsequent years, the corporation is likely to face more potential challenges if changes are not implemented quickly. These enhancements are designed to optimize fuel delivery, both in terms of timing and prices. The many distribution channels and hard-to-reach places will undoubtedly affect access time and distribution costs, therefore the option of using multimodal transportation in its distribution is critical.

Furthermore, in the plantation operations, fuel oil distribution is a crucial factor in the supply chain, where inefficiencies in routing, scheduling and resource allocation could lead to significant deficits and cost inefficiency. Although optimization techniques in the logistics and supply chain area have advanced considerably, many existing studies focus on single objective models, such as minimizing cost or delivery time alone. For example, [4] used a single objective Mixed-Integer Linear Programming (MILP) model to minimize total costs in solving closed-loop supply chain, location-allocation, transportation, and supplier selection problems.

Although many studies investigate logistics and supply chain optimization, a gap remains in models that integrate multiple fuel distribution scenarios such as varying demand, route cycles with simultaneous objectives of fulfilment, time, and cost. The objective of this study is to find optimal scenarios for petroleum distribution routes using goal programming mathematical models to meet target demands, as well as to generate distribution route scenarios using existing resources to optimize time, costs, and available transport capacity. This paper contributes by 1) developing a goal programming model for multi-scenario fuel distribution, 2) analyzing trade-offs between three key objectives, and 3) applying the model to real plantation data to provide practical decision-support for route and resource allocation.

2 LITERATURE REVIEW

2.1 Concept of Optimization

An action or activity that aims to produce the best or most ideal results is called optimization. The goal of optimization is to minimize the amount of work or resources needed, while they can also be used to maximize the desired outcomes [5]. When something is accomplished as efficiently and maximally as possible, it is said to be optimized. Optimization can also be interpreted as a standard by which to measure whether the actions taken satisfy the criteria and needs [6]. There must be a declaration about the purpose of the choice variables used in the optimization procedure. This is used to define or explain the procedure for determining the function's maximum or minimum value. Investigating operations is one of the steps or procedures that must be followed when performing optimization activities to solve an optimization problem [7].

2.2 Distribution

Distribution is the process of delivering goods or products to customers after the sales process [8]. Distribution is the transfer of commodities or products from the manufacturer to consumers or users via distribution channels, as well as the reverse flow of payments between buyers and sellers or back to the original provider [9]. Distribution is defined as marketing operations that facilitate the distribution of goods or products from sellers to customers [10]. Thus, the distribution procedure refers to the steps or series of marketing activities for products to customers that are repeated.

The implementation method of distribution contains numerous alternatives or types of channels that can be used, and these possibilities can be classified as consumer goods and industrial goods. First, consumer goods are items or objects purchased by consumers for use or consumption. Customer products are acquired based on the preferences or needs of the user or end customer, not the manufacturer, because the purchased commodities are no longer goods to be produced. Second, industrial goods are those that, once purchased, will be further processed with the intention of fulfilling the interests and demands of the relevant industry. Buyers of industrial commodities include businesses, institutions, and organizations.

2.3 Oil Fuel

Fuel is a type of material that can be transformed into energy. Fuel contains thermal energy that can be converted into energy for specialized applications, such as those used in automobiles or engines. Fuel types are classified according to their content or octane rating, which is divided into solid fuel and liquid fuel. Solid fuels are employed during combustion operations. Examples of solid fuels include wood, coal, and uranium. Liquid fuel is a mixture of hydrocarbon compounds acquired naturally or through artificial means, typically from petroleum. Oil fuel is one type of fuel, specifically a liquid fuel with a looser structure than solid fuel. Its molecules move freely. Liquid fuels include gasoline, kerosene, and diesel. Liquid fuels are commonly used in industrial sector [11].

2.4 Transportation

In industrial activities, Operations and Supply Chain Management (OSCM) continues to evolve by adopting various strategies, frameworks, and technologies to address increasingly complex challenges across industries [12–14]. It plays a vital role for all companies and influences many areas of their activities [15]. As one of the important aspects in OSCM, transportation positioned as an important role in ensuring the smooth flow of goods, services, and information throughout the supply chain.

Transportation is the movement of commodities or persons from one location to another. Transportation begins at the origin (where the initial activity occurs) and ends at the destination. Transportation is critical in locations that supply raw materials, market, and produce goods [16]. The transportation system can be defined as a system that

provides facilities and infrastructure, as well as services that enable activities throughout the region, allowing for effective movement and mobility from one location to another [17].

Transportation services are one of the systems that make up transportation. Transportation companies produce transportation services such as shipping, airline, and bus transportation, among other things. Transportation services are one of the input variables for operations such as manufacturing, trading, and others. Transportation services are closely related to the transportation process [18]. Transportation promotes and stimulates development while also contributing to a country's economic growth. As a result, transportation infrastructure is created before any other development projects. Transportation works best when journey time is kept to a minimum, accidents are minimized, service frequency is acceptable, and passengers are comfortable.

Existing study in transportation and logistics have adopted quantitative modelling approaches to optimise cost, time and fulfilment objectives as [19] for an example in short-haul airfare markets. Our study extends the optimisation framework to fuel distribution in the plantation sector.

2.5 Goal Programming Method

Goal programming extends the linear programming technique [20]. It is one of many mathematical methods used in decision-making to analyze and develop optimal solutions or resolutions incorporating numerous objectives, with the goal of obtaining the most optimal solution [21, 22]. The basic approach used in the goal programming process is to determine and set goals expressed numerically or, in other words, mathematically, to compile and formulate a function that becomes the objective function of the optimization problem, and to seek a solution or solutions by minimizing or optimizing the amount of deviation from the objective function [23].

2.6 Related Works

A number of scholars, particularly those working with optimization models, have expressed serious concerns about the distribution problem. Aside from the type of goods, this literature review identifies several distribution objectives in optimizing the distribution process, including maximizing profits [24, 25], supplier selection and allocation [26], fairness and effectiveness in fulfilling demand [27], multi-objective green logistics optimization [28], and maximizing distance and modes of transportation [29]. In addition, a study of [30] applied a multi-criteria approach to optimise last-mile distribution networks by considering cost, time, and resource utility. However, because distribution optimization has numerous objectives, goal programming optimization models are widely utilized.

The study [31] compared the optimization methodologies of Analytical Hierarchy Process (AHP) and goal programming, with a particular emphasis on supplier selection and evaluation processes aimed at attaining an optimal order quantity. The findings showed that using the interactive model method, namely the goal programming method, yields the best outcomes. Similar results were found in a study [32] comparing goal programming and AHP approaches for identifying optimal solutions in bank asset liability management. The study's findings revealed that the goal programming model is an effective and simple way for setting targets and limits to produce optimal solutions.

According to this literature review, the following trends could be found. First, several researches have proven that goal programming optimization models are effective in achieving various objectives of the problem. This is supported by the improved results gained as well as the overview provided by this strategy. Second, no researchers (to the best of our knowledge) have developed goal programming models for the problem of distributing fuel via intermodal transportation. As a result, the research described in this paper represents a novel contribution in a topic with important economic contributions and repercussions for the Industrial Plantation Forest Company.

3 METHODS

The purpose of this study was to develop an optimization model for the distribution of fuel oil using goal programming to attain multiple objectives. The research methodology is designed to systematically determine the most optimal distribution scenarios by considering the scientific principles and addressing the previously defined problem. Data collected from the Industrial Plantation Forest Company were processed and analyzed based on established theoretical foundations.

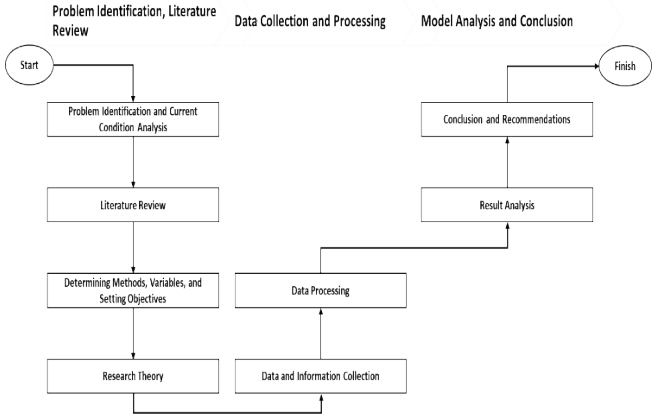


Figure 2 Illustration of the research flowchart

3.1 Research Flowchart

The research flowchart of this study consisted of three main phases as illustrated in Fig. 2. First, we performed problem identification and literature review. This stage provides a foundation for the research direction, where the research methods and variables were determined based on a reliable and compatible theoretical basis. Consequently, in the subsequent stages, the collected data must support the chosen research methods. Second, data collection was carried out. The collected data was ensured to support the research methods. Once the data was obtained, it was processed according to the mathematical model of the chosen research method. Lastly, the model resulting from data processing was

then analyzed to determine whether it surpassed the current conditions. If the model proved to be superior, the research has achieved its objectives.

3.2 Optimization Model using Goal Programming

The constraints and parameters used in the problem analysis process were expressed into mathematical models. The objective of this data modeling was to define the decision variables, the objective function, and the constraints of the identified problem. In this study, the initial model was Linear programming model, which was later converted into a goal programming model. There are some fundamental concepts of goal programming including [33]:

1) In a goal programming model, different objectives are expressed as goals. Thus, there will be multiple goals.
2) All goal constraints are expressed as equations that contain deviation variables: d^+ and d^-.
3) Positive deviation variable: d^+, represents the surplus value over the target level of the goal.
4) Negative deviation variable: d^-, represents the deficit value against the target level of the goal.
5) At least one (or both) of the deviation variables of the goal constraint must have a value of zero.
6) Deviation variables cannot be negative.
7) The objective function of all goal programming models is to minimize the deviations from all goal constraints levels.

In this study, several key assumptions underpin the goal-programming model. The decision variables were variables with unknown values. The decision variables were the West distribution route, which requires intermodal transportation, and the East distribution route, which uses a single mode of transportation. The objective function defined the goals to be achieved, which include fulfilling the monthly fuel needs, optimizing the distribution time, minimizing distribution costs, and maximizing carrying capacity of the fuel distribution transportation. Meanwhile, constraints were variables that serve as limits in achieving the objective function. The constraints in this study were the types of transportation used for fuel distribution. In addition, to ensure validity of the model, the model structure, parameter values, and decision rules were discussed by domain experts of the company who operate the fuel distribution system. In addition, the results from the goal programming model were also compared against historical distribution data.

The general steps of goal programming used in this study [34]:

1) Determination of the decision variables

There are seven parameters, including:

X_1 = West Route (Intermodal); X_2 = East Route (Direct/sea route only); P_1 = First Priority; P_2 = Second Priority; P_3 = Third Priority; d^- = Negative Deviation; d^+ = Positive Deviation.

2) Definition of the objectives and deviation variables for each goal

There were two objectives for fulfilling fuel needs, with two scenarios each being presented. However, in general, this scenario was used to compare two distribution routes in four different conditions. This was conducted to prove whether we must choose one distribution route or must use both routes on several trips. Scenario 1 was the fulfillment of the east demand target in 2023. Scenario 2 was the fulfillment of the highest east demand target in 2025. Furthermore, Scenarios 3 and 4 were the fulfillment of the west and east demand targets in 2023 and 2025, respectively.

a) Goals and priorities of Scenario 1:

1) Allocating 2 units of 500 KL Pontoons to pass through 2 routes (East and West) with priority to meet the minimum fuel needs of the East Area by at least 500,000 liters.
2) The company aims to distribute as quickly as possible given the absence of safety stock in each area. The maximum distribution time within 1 month is 28 days.
3) The company strives to minimize Distribution costs as much as possible.

b) Objective and priority of Scenario 2:

1) Allocating 2 units of 250 KL Pontoons to pass through 2 Routes (East and West), and 1 pontoon of 500 KL through the East route, with the priority to fulfill the minimum fuel needs of the East Area by at least 750,000 liters.
2) The company aims to distribute goods as quickly as possible considering the absence of safety stock in each area. The maximum distribution time within 1 month is 28 days.
3) The company aims to minimize Distribution costs as much as possible

c) Objective and priority of Scenario 3:

1) Allocating all available units to compare 2 Routes (East and West), with priority for fulfilling the fuel needs of the entire Area (West and East) minimally by 7,499,694 liters.
2) The company aims to distribute goods as quickly as possible given the absence of safety stock in each area. The maximum distribution time within 1 month is 28 days.
3) The company strives to minimize distribution costs as much as possible

d) Objective and priority of Scenario 4:

1) Allocating all available units to compare 2 Routes (East and West), with priority for fulfilling the fuel needs of the entire Area (West and East) minimally by 9,494,714 liters.
2) The company aims to distribute goods as quickly as possible given the absence of safety stock in each area. The maximum distribution time within 1 month is 28 days.
3) The company strives to minimize distribution costs as much as possible.

3) Formulation of the goal programming models

$$Z = X_1 + X_2 + d^- - d^+ \tag{1}$$

Minimize: $P_1 d_1^-$, $P_2 d_2^+$, and $P_3 d_3^+$

a) Scenario 1

1) Carrying Capacity

$$500{,}000X_1 + 500{,}000X_2 + d_1^- - d_1^+ = 1{,}286{,}609 \tag{2}$$

2) Time

$$7X_1 + 15X_2 + d_2^- - d_2^+ = 28 \tag{3}$$

3) Cost

$$103{,}900{,}000X_1 + 231{,}000{,}000X_2 + d_3^- - d_3^+ = 0 \tag{4}$$

b) Scenario 2

1) Carrying Capacity

$$750{,}000X_1 + 750{,}000X_2 + d_1^- - d_1^+ = 2{,}292{,}828 \tag{5}$$

2) Time

$$7X_1 + 15X_2 + d_2^- - d_2^+ = 28 \quad (6)$$

3) Cost

$$153,740,000X_1 + 346,500,000X_2 + d_3^- - d_3^+ = 0 \quad (7)$$

c) Scenario 3

1) Carrying Capacity

$$2,595,000X_1 + 2,595,000X_2 + d_1^- - d_1^+ = 7,499,604 \quad (8)$$

2) Time

$$7X_1 + 15X_2 + d_2^- - d_2^+ = 28 \quad (9)$$

3) Cost

$$501,950,000X_1 + 1,198,890X_2 + d_3^- - d_3^+ = 0 \quad (10)$$

d) Scenario 4

1) Carrying Capacity

$$2,595,000X_1 + 2,595,000X_2 + d_1^- - d_1^+ = 9,494,714 \quad (11)$$

2) Time

$$7X_1 + 15X_2 + d_2^- - d_2^+ = 28 \quad (12)$$

3) Cost

$$504,290,000X_1 + 1,198,890X_2 + d_3^- - d_3^+ = 0 \quad (13)$$

3.3 Data Collection

The data collection process was conducted to obtain information regarding the distribution process of fuel at PT EFG in South Sumatra Province. As a result, this research utilized secondary data. The collected data included fuel distribution from January to February 2023. Data collection began by gathering information about the background information through field observations, case studies, and data related to the fuel distribution process. The data to be processed in this study were those related to transport capacity (Tab. 4), distribution time (Tab. 5), and distribution costs (Tabs. 6-8).

Table 3 The indicator of research variable used in this study

Variables	Definition	Indicator
Transportation capacity (X_1)	The capacity of a facility or medium to transport people or products from origin to destination	1) Load quantity 2) Duration of travel 3) Trips 4) Target within one period
Delivery time (X_2)	The series of processes from the ongoing and future conditions, in this case, the process referred to is the distribution process of fuel	1) Distribution location 2) Quantity of shipments 3) Total cycle time
Distribution costs (X_3)	Sacrifices that are economic in nature measured in monetary units	1) Distance travel 2) Weighted of the load 3) Price calibration

Table 4 Transport capacity data

No.	Capacity (KL)	Quantity (units)
1	500	4
2	250	2
3	95	1
4	10	1
5	20	1

Table 5 Travel time data in one trip cycle

No.	Track	Time (days)	Description
1	West	7	Total cycle time
2	East	15	

Table 6 Transportation cost

No.	Track	Pontoon cost
1	West	IDR 190/Liter (Fuel Range 10.001-15.000)
2	East	IDR 462/Liter (Fuel Range 10.001-15.000)

Table 7 Calculation of freight costs from West to East (1/2)

Truck capacity	Fuel consumption		Rental truck (IDR)	Freight			Distance (km)
	Liter/km	Fuel price (IDR)		KL/month	Trip/week	KL/week	
	(a)	(b)	(c)	(d)	(e) = (d) : 4	(f) = (d) : (e)	(g)
10 KL	6.25	13,000	18,000,000	150	4	40	80
20 KL	10	13,000	20,000,000	288	4	77	80

Table 8 Calculation of freight costs from West to East (2/2)

Truck capacity	Round-trip fuel costs (IDR)	Total units per Target		Total weekly cost (IDR)	
		322	573	250	573(h)
	(h) = (a) × (b) × (g) × 2 × (e)	(i) = 322 : (f)	(j) = 573 : (f)	(k) = [(h) × (i)] + [(c) : 4]	(l) = [(h) × (j)] + [(c) : 4]
10 KL	1,248,000	9	15	15,732,000	23,220,000
20 KL	780,000	5	8	8,900,000	11,240,000

4 RESULTS AND DISCUSSION

4.1 Data Processing and Analysis

The data obtained in this study were analyzed using LINGO software. The data processing steps were divided into two steps: 1) formulating mathematical equations and entering the mathematical model into the LINGO, and 2) interpreting the output generated by LINGO.

In our study, four scenario models were examined to achieve optimal objectives by considering three key criteria (fuel fulfillment, travel time, and transportation costs) that minimize deviations from each criterion. The results of these models were expected to provide an optimal solution based on the priority scale stated in the minimization objectives.

The instructions @GIN(X1) and @GIN(X2) in LINGO output indicate that the variables X1 and X2 must be treated as integer variables. By defining X1 and X2 as integer variables, the model guarantee that the generated solutions were applicable in real-world scenarios, where distribution trips must be in whole numbers. Goal programming serves as a tool for making optimal decisions in situations with various priorities and complex constraints.

It should be noted that the finding from the four scenarios was the absence of a company-designated budget for distribution costs (D3_PLUS). Therefore, we decided to set the distribution cost target at 0 Rupiah indicating that any additional costs incurred were considered insignificant in affecting the final decision. This nominal value represents the optimal and reasonable budget recommended for expenditure which is aligned with the priorities established in the goal programming model.

a) Scenario 1. In Scenario 1, we analyzed the fuel fulfillment targets in the East region in 2023 using goal programming analysis in LINGO. The main objectives were to minimize the negative deviation from the fuel fulfillment target (D1_MIN), minimize the positive deviation from the

number of travel days (D2_PLUS), and minimize the positive deviation from the required costs (D3_PLUS) as shown in Fig. 3.

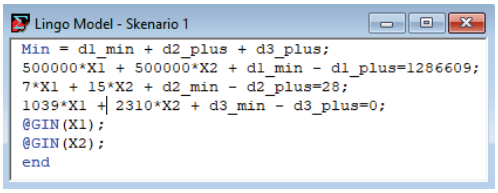


Figure 3 Mathematical equations for Scenario 1

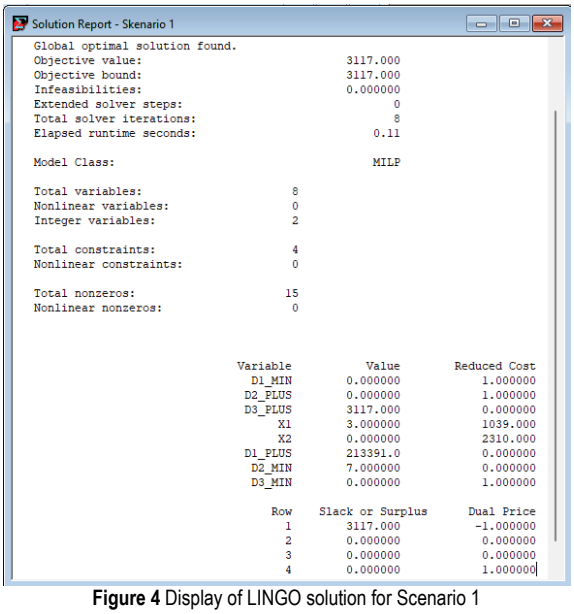


Figure 4 Display of LINGO solution for Scenario 1

The optimization results as shown in Fig. 4 revealed that:

1) Fuel Fulfillment Target. The fuel fulfillment target for the East region in 2023 is 1,286,609 liters. To achieve this target, three trips were planned in the West area (X1 = 3) and no trips were scheduled in the East area (X2 = 0).

2) Deviation from the Target. D1_MIN (negative deviation from the fuel fulfillment target) was 0, which means that the fuel fulfillment target was fully met. Next, D2_PLUS (positive deviation from the number of travel days) was 0, which indicates that there was no excess in the planned travel days. Lastly, D3_PLUS (positive deviation from the required costs) was 3117, which shows that the planned distribution cost is optimal and reasonable.

3) Distribution Costs. Although there was no budget that specifically allocated for distribution costs by the company, this study set the target cost at 0 to minimize D3_PLUS. This means that the calculated cost of Rp. 311,700,000 is considered optimal for achieving the best solution in the optimization scenario. Thus, the results of the goal programming model using LINGO showed an optimal distribution strategy that successfully met the fuel fulfillment target with high efficiency and minimize the deviations from the priority targets.

b) Scenario 2. In Scenario 2, we analyzed the fuel fulfillment targets in the East region in 2025. The main objectives of this model were to minimize the negative deviation from fuel fulfillment (D1_MIN), minimize the positive deviation from travel time (D2_PLUS), and minimize the positive deviation from transportation costs (D3_PLUS) as shown in Fig. 5.

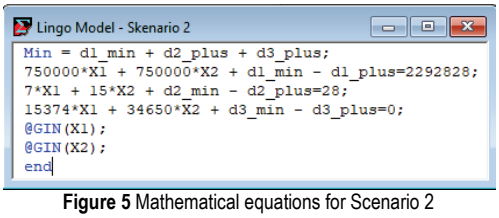


Figure 5 Mathematical equations for Scenario 2

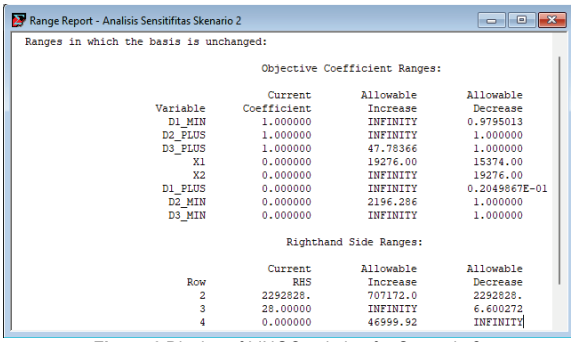


Figure 6 Display of LINGO solution for Scenario 2

Based on the LINGO output (Fig. 6), the optimal distribution strategy was to conduct four trips using the West area (X1 = 4) and no trips via the East area (X2 = 0). This strategy showed minimal deviation from the fuel fulfillment target (D1_MIN = 0) that indicates fuel needs were fully met. Minimal deviation in travel time (D2_PLUS = 0), which means the planned trips align well with the target schedule. Lastly, a positive deviation in transportation costs of Rp. 614,960,000 (D3_PLUS = 61,496), which represents the estimated optimal cost.

In addition, setting the distribution cost budget at 0 Rupiah as a target to minimize D3_PLUS guarantees that the results are both optimal and reasonable. This indicates that the estimated cost in the model already covers all relevant needs without requiring additional allocation from the company. Thus, the company could make efficient fuel distribution decisions based on this goal programming analysis to achieve the 2025 target with minimal costs and maximum fulfillment of fuel demand.

c) Scenario 3. In Scenario 3, we analyzed the fuel fulfillment targets in the East and West region in 2023. The main objectives of this model were to minimize the negative deviation from fuel fulfillment needs (D1_MIN), minimize the positive deviation from travel time (D2_PLUS), and minimize the positive deviation from transportation costs (D3_PLUS) as shown in Fig. 7.

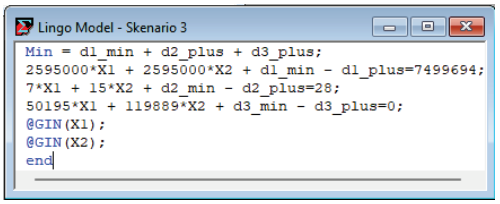


Figure 7 Mathematical equations for Scenario 3

The results showed that the optimal distribution strategy was to carry out three trips through the West area (X1 = 3) and no trips through the East area (X2 = 0). Deviation from the fuel fulfillment target (D1_MIN) was zero which means that fuel needs were met precisely as planned. Travel time was also optimal (D2_PLUS = 0) which indicates there was no excess travel time. In addition, there was a positive deviation in transportation costs of 150,585 or Rp. 1,505,850,000 (D3_PLUS) which indicates the cost exceeded the initial target (Fig. 8).

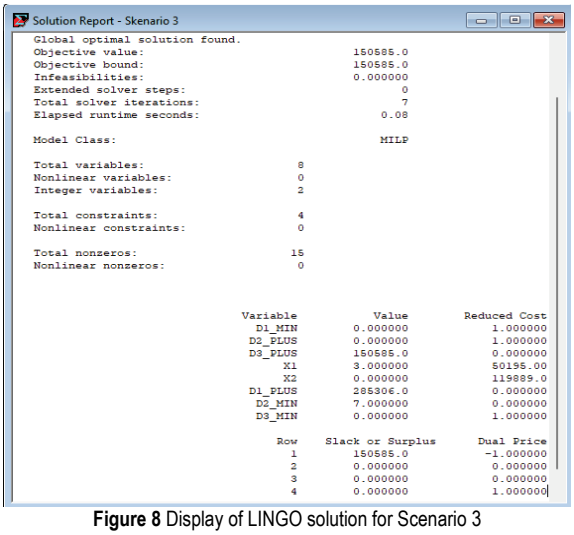


Figure 8 Display of LINGO solution for Scenario 3

With the distribution budget set at 0 Rupiah to minimize D3_PLUS, the costs incurred in this model were considered both optimal and reasonable. The company could use these findings to formulate efficient fuel distribution decisions that allows fuel needs to be met without excessive travel time, despite a slight deviation in transportation costs. This model served as a valuable guide for more effective resource allocation in 2023.

d) Scenario 4. In Scenario 4, we analyzed the fuel fulfillment targets in the East and West region in 2025. The main objectives of this model were to minimize the negative deviation from the fuel fulfillment target (D1_MIN), minimize the positive deviation in travel time (D2_PLUS), and minimize the positive deviation in transportation costs (D3_PLUS) as shown in Fig. 9.

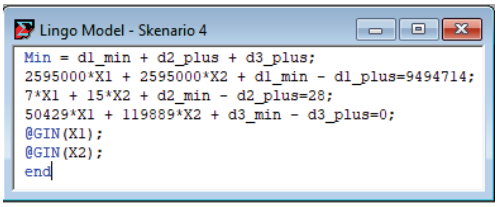


Figure 9 Mathematical equations for Scenario 4

The LINGO output (Fig. 10) displayed two decision variables, X1 and X2 represent the number of distribution trips through the West and East areas, respectively. The optimal results indicated that to efficiently meet the fuel distribution target, the best strategy was to conduct four trips through the West area and no trips via the East area were optimal.

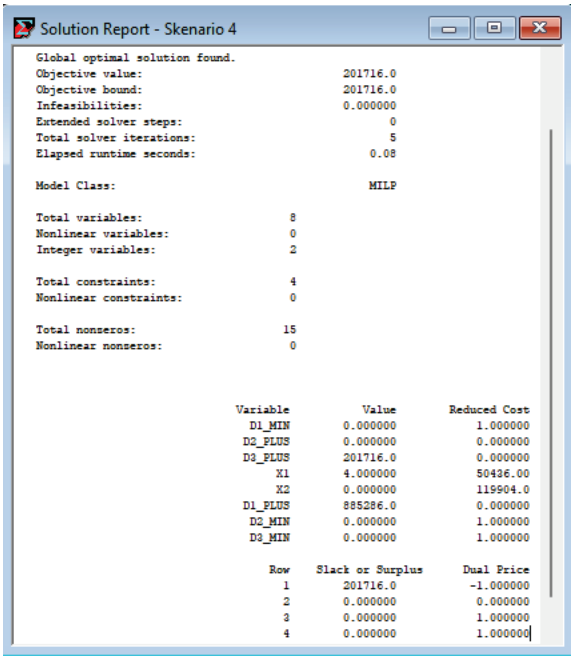


Figure 10 Display of LINGO solution for Scenario 4

A positive deviation in transportation costs (D3_PLUS) of Rp. 2,017,160,000 was identified, which indicates an increase in costs that should be considered in optimizing distribution trips. Meanwhile, the negative deviation from the fuel fulfillment target (D1_MIN) and the positive deviation in travel time (D2_PLUS) have been successfully minimized based on the established priorities. Thus, the goal programming results provide insights into how distribution trips should be allocated to minimize deviations from the set targets, with a focus on cost efficiency and optimal travel time.

4.2 Comparison of Proposed Models with Current Conditions

In this study, a comparison was also made between proposed models and current fuel distribution conditions. The planning and formulation of distribution routes were performed manually based on demand and utilize only one type of transportation. Fuel distribution was divided according to the same area within a single route; thus, time and cost aspects were not considered. The current distribution conditions could be observed in Tab. 9, which illustrates the fuel distribution allocation based on the area.

Tab. 9 summarized the fuel distribution using several pontoons in the West and East areas. In the West area, there were seven pontoons with various capacities and different departure schedules. For example, Pontoon 2 starts the first trip, followed by the other pontoons with a one-day gap from the previous one. Each pontoon has a total travel time of 7 days (including loading-unloading and round trips). The total fuel transported per month in the West area was 5,940 KL. Meanwhile, in the East area, there was only one pontoon (Pontoon 1) with a capacity of 250 KL and a total travel time of 15 days that allows it to transport 467 KL of fuel per

month. In total, the combined fuel transported from both areas per month was 6,407 KL.

Table 9 Current Condition of Fuel Distribution

Area	Poonton	Capacity (KL)	Travel duration*	Departure schedule	Trip	Date	Total transported per month
West	Poonton 2	250	7	0	3	3	750
	Poonton 3	500	7	+2 from Poonton 2	3	5	1,500
	Poonton 4	500	7	+2 from Poonton 3	3	7	1,500
	Poonton 5	500	7	+2 from Poonton 4	2	9	1,000
	Poonton 6	500	7	+2 from Poonton 5	2	11	1,000
	Poonton 7	95	7	+2 from Poonton 6	2	13	190
						Total:	**5,940**
East	Poonton 1	250	15	0	1.87	3	467
						Grand total:	**6,407**

*Total loading-unloading + Round trip travel

There was a distribution issue on the East Area route, which takes 15 days (round trip), with a time constraint that must not exceed 28 days per period. The pontoon used has a capacity of 250 KL. Meanwhile, the fuel demand in the East Area in 2023 on average was 1,287 KL per month out of a total demand of 7,500 KL per month across all areas. Due to the high demand in the West area, most of the pontoons were directed to support the West region more extensively. This concern was further provoked by the unproductivity of some heavy equipment since the fuel distribution delays. The problem worsened with the projected increase in monthly demand, which was expected to reach 9,495 KL per month by 2025.

Given these challenges, a proposal has emerged to add more distribution pontoon units. However, this solution must be supported by data to convince management. In addition, the company encounters difficulties in finding vendors capable of providing pontoons in the future. Meanwhile, the addition of new units requires a significant increase in storage capacity in each area. This process was not only time-consuming but also requires a substantial financial investment.

To solve this problem, the company intended to evaluate the optimization of available resources. The goal was to improve the efficiency of fuel distribution to the West and East Areas by considering target fulfillment, optimal distribution time to reduce the need for large safety stock, and minimizing additional operational costs. The company was limited to two main distribution routes: West and East. However, if the West route is used to support the needs of the East, the company must consider the use of intermodal transportation, which could potentially increase additional costs.

Tab. 10 summarized the fuel distribution solution based on the scenario models that have been developed by referring to the current target and future highest projections. The objective was to optimize the needs of both the East and West Areas simultaneously. The comparison highlights differences before and after the implementation of the proposed model. Each scenario has a specific fuel target and considers various factors such as the number of trips, fuel consumption, time, and cost.

Table 10 Comparison between current conditions and proposed model

Scenario	Target	Route	Current condition				Proposed model				Comparison of current conditions vs proposed model	
			Trip	Fuel (KL)	Time (days)	Cost (Rp/ltr)	Trip	Fuel (KL)	Time (days)	Cost (Rp/ltr)	Fuel (KL)	Time (days)
1	1,286,609	West	-	-	-	-	3	1,500	7	207.80	–1,033	8
		East	1.87	467	15	462	-	-	-	-		
2	2,292,828	West	-	-	-	-	4	3,000	7	204,99	–2,533	8
		East	1.87	467	15	462	-	-	-	-		
3	7,499,694	West	2-3	6,407	$\bar{x} = 7.58$	209,83		7,785	7	193,43	–1,378	0.58
		East	1.87					-	-	-		
4	9,494,714	West	2-3	6,407	$\bar{x} = 7.58$	209,83		10,380	7	193,33	–3,973	0.58
		East	1.87					-	-	-		

1) Scenario 1: With a target of 1,286,609 liters, the current conditions for the East route included 1.87 trips, 467 KL of fuel, 15 days, and a cost of Rp 462 per liter. In the proposed model, for the West route, 3 trips were required, carrying 1,500 KL of fuel, with a travel duration of 7 days and a cost of Rp 207.8 per liter. The comparison showed an increase in time by 8 days and a cost adjustment to Rp 254.2 per liter, with an achievement percentage of 221% for fuel, 53% for time, and 55% for cost.

2) Scenario 2: With a target of 2,292,828 liters, the current conditions for the East route remained the same as in the first scenario. The proposed model for the West route required 4 trips, carrying 3,000 KL of fuel, with a travel duration of 7 days and a cost of Rp 204.99 per liter. The comparison showed an increase in time by 8 days and a cost adjustment to Rp 257.01 per liter, with an achievement percentage of 542% for fuel, 53% for time, and 56% for cost.

3) Scenario 3: With a target of 7,499,694 liters, the current conditions for the West route included 3-2 trips, 6,407 KL of fuel, 7.58 days, and a cost of Rp 209.83 per liter. In the proposed model, 3 trips were required, carrying 7,785 KL of fuel, with a travel duration of 7 days and a cost of Rp 193.43 per liter. The comparison showed an increase in time by 0.58 days and an adjusted cost of Rp 16.4 per liter, with an achievement percentage of 22% for fuel, 8% for time, and 8% for cost.

4) Scenario 4: With a target of 9,494,714 liters, the current conditions for the West route remained the same as in the third scenario. The proposed model required 4 trips, carrying 10,380 KL of fuel, with a travel duration of 7 days and a cost of Rp 193.33 per liter. The comparison showed an increase in time by 0.58 days and an adjusted cost of Rp 16.5 per liter, with an achievement percentage of 62% for fuel, 8% for time, and 8% for cost.

Fig. 11 listed a comparison of fuel demand fulfillment capability between the current conditions and the proposed model across four different scenarios.

1) Scenario 1: With a fuel fulfillment target of 1,286,609 liters, the current conditions showed a deficit of 820 KL. Meanwhile, the proposed model achieved an improvement of 213 KL. This indicated that the proposed model could reduce the existing deficit and improved fuel fulfillment capability.

2) Scenario 2: At a target of 2,292,828 liters, the current conditions showed a larger deficit of 1,826 KL; however, the proposed model demonstrated an increase of 707 KL in fulfillment capability. This showed that the proposed model not only reduced the deficit but also enhanced the fuel demand fulfillment.

3) Scenario 3: For a target of 7,499,694 liters, the current conditions showed a deficit of 1,093 KL, while the proposed model showed an increase of 285 KL in fulfillment capability. This indicated that the proposed model contributed to improving fuel fulfillment efficiency, even for high targets.

4) Scenario 4: At a target of 9,494,714 liters, the current conditions showed a deficit of 3,088 KL. The proposed model achieved an increase of 885 KL in fulfillment capability. This suggested that the proposed model reduced the deficit in fuel fulfillment for scenarios with very high targets.

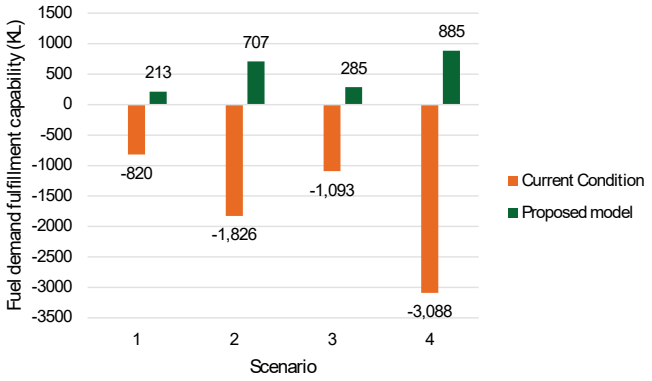


Figure 11 Comparison between current conditions and proposed model

The proposed model in this study demonstrated its effectiveness in improving fuel demand fulfillment capability compared to current conditions. These findings indicated that applying goal programming to optimize fuel distribution provided valuable benefits to the industry by reducing deficits and improving overall operational efficiency.

4.3 Analysis of Constraints in Implementing the Proposed Model

This study determined an optimal scenario for fuel oil distribution routes using goal programming mathematical models to fulfill target demands. The proposed goal programming model offers several noteworthy benefits. It enables simultaneous optimization of multiple objectives such as fuel demand fulfilment, transport time, and cost, rather than focusing on a single criterion. Thus, it reflects real-world trade-offs more accurately. Existing study of [35] pointed out that goal programming models were highly effective for transportation problems involving conflicting objectives, but their performance depends sensitively on weights and scenario definitions. Similarly, [36] demonstrated a goal programming strategy for fuel distribution routing in Indonesia and aligned with our model's focus. In addition, [37] highlighted that while multi objective frameworks provide rich trade-off insights, they require significant data, computational effort, and careful interpretation of results.

The implementation of the new model to optimize fuel distribution might face several challenges that need to be solved as summarized in Tab. 11. For example, the complexity of scheduling and route coordination requires an integrated scheduling system to optimize travel time. In addition, extra costs and additional workforce must be well-prepared to secure sustainability in operation [35–37].

Table 11 Challenges and proactive plans in implementing the proposed model

No.	Challenges	Proactive plans to solve challenges
1	Scheduling and route coordination complexity	Implementing an integrated scheduling system to maximize time efficiency and vehicle route coordination
2	Cost and workforce enlargement	Estimating additional costs and preparing an sufficient budget plan as well as a recruitment strategy to solve increased workload
3	Provide appropriate infrastructure	Developing a plan for the maintenance and development of crucial infrastructure to support optimal fuel distribution operations
4	Fuel loss risk management	Developing methods and procedures to minimize fuel loss risks during transportation, such as strict management and supervision
5	Development of training and human resource competency	Conduction training on the use of the new system and developing human resource competencies in understanding and managing change
6	System integration and data security	Providing smooth and secure system integration for managing sensitive data related to fuel distribution

Furthermore, the company must also consider sufficient infrastructure to support optimal distribution operations, including necessary maintenance and infrastructure development. The other key focus is to manage the risk of fuel loss during transportation that required the development of methods to minimize risks and strict supervision. Proper training activities to enhance human resource competencies are also crucial to provide that the team could understand and manage changes that come from the implementation of this new model. Moreover, effortless system integration and tolerable data security must be prioritized to protect information regarding the fuel distribution. By implementing these proactive plans into action, the company could guarantee that the necessary changes in fuel distribution operations will be carried out effectively and sustainably in the future. Thus, it was expected that these plans would aid in obtaining the goals of optimizing time, cost, and transport capacity.

Although the scope of this study is on fuel distribution in plantation operations, the proposed model framework has the potential to be adapted to other industries that involve

bulk transport and distribution. For example, chemical product delivery, cold chain logistics, mining supply bases, or remote infrastructure support services that face similar challenges of fulfilling demand, optimizing time, and controlling cost under constrained networks. The future studies need to reformulate the scenario sets, goal programming targets. It is expected the same approach could support organization management to allocate transport resources more strategically, simulate future scenarios, and balance operational trade-offs effectively.

5 CONCLUSIONS

The present study aimed to determine an optimal scenario for fuel oil distribution routes by utilizing goal programming mathematical models to fulfill target demands. This study investigated four different scenarios. Based on a comparison of present conditions and the proposed model, the results revealed that the suggested model greatly reduced the gap in fuel demand fulfillment across all scenarios. The proposed model indicated a greater ability to achieve fuel demand requirements, with increases of 1,033 KL (Scenario 1), 2,533 KL (Scenario 2), 1,378 KL (Scenario 3), and 3,973 KL (Scenario 4). These findings showed the goal programming model's efficiency in optimizing distribution routes to meet fuel demand. The data showed that the proposed strategy not only enhanced fuel demand fulfillment, but it also increased time and cost efficiency. In each scenario, the proposed model's travel time and fuel cost per liter were more efficient than the current conditions. In Scenario 1, travel time and cost were optimized, with a 221% increase in fuel, 53% in time, and 55% in cost. Scenarios 2, 3, and 4 also result in considerable time and cost savings. The proposed approach improved resource use by optimizing time, cost, and transport capacity for fuel distribution routes.

For the practical implications of this study, manager of logistics could use the models in prioritizing route options, allocating tanker, and pontoon resources more effectively, and simulating future demand scenarios for strategic decision-making. The model serves as a tool to support decision making in balancing fulfilment, time and cost in fuel-distribution operations. However, several limitations also need to be addressed. The model assumes constant route capacities, deterministic demand forecasts, and without any disruption events (e.g., breakdowns or weather delays) that may not fully capture the real-world process. In addition, the study case application of this study is specific to a fuel distribution for plantation that may need to be adjusted for other industries. Several recommendations were also made for future investigation. First, building upon this work, future research should focus on developing models with additional extensions, such as scheduling and vehicle route integration, to improve loading and unloading process efficiency. Second, it is proposed to take into account other objective functions, such as limiting handling loss or depreciation during transportation. Finally, using data mining or machine learning approaches to discover patterns, predict future demand, and improve decision-making in fuel distribution could result in additional cost, time, and resource savings.

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