Research Paper

Optimization of Rice Distribution Network Based on Green Logistics Concept

Praftiwi Umitri*, Udisubakti Ciptomulyono

Department of Supply Chain Management, Interdisciplinary School of Management and Technology, Institut Teknologi Sepuluh Nopember Surabaya

ORCID
Praftiwi Umitri: https://orcid.org/0000-0002-8121-1592

Abstract.
SDGs or Sustainable Development Goals have become a global and national commitment. Greenhouse gases (GHG) are indicators of climate change which is one of the 17 SDG's goals. In the national food logistics system with rice as a staple food, there are some regions with surplus production and other deficits. Hence, the distribution involved the transportation activities that need to be carried out. In transportation, the carbon footprints are generated from exhaust gases as residue from the fuel combustion process. The carbon footprint efficiency is one of the indicators in green logistics. Green logistics for decarbonization in the transportation sector for a better environment has to start massively. Indonesia is committed to implementing the green logistics concept in logistics distribution. In this case, the author determined the surplus area and the deficit one based on statistical data on the production and consumption of each city in Java. Furthermore, a distribution network model is designed that involves emission level as a parameter in determining the route on the network. In the design, the selected mode of freight transportation was limited to land transportation modes besides trains. The design makes environmental aspects a major consideration in the distribution as well as the shipping costs.

Keywords: carbon footprint, emission factor, green logistics

Corresponding Author: Praftiwi Umitri; email: praftiwi.206032@mhs.its.ac.id

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1. Introduction

National and global are currently committed to realizing the SDGs or Sustainable Development Goals as the 2030 agenda, where the SDGs contain 17 goals and 169 targets. Indonesian Secretariat of the National Development Planning Agency issues 4 pillars of the SDGs: social development pillars, economic development pillars, environmental development pillars, and legal and governance development pillars. The environmental development pillar aims to reach sustainable natural resource management and the environment will support all life. The SDGs goal of this environmental development pillar are consisted of: clean water and proper sanitation, sustainable cities and settlements, responsible consumption and production, climate change management, ocean ecosystem, and land ecosystem.

Greenhouse gases (GHG) are indicators of climate change. The government targets annual GHG emission reductions through activities carried out based on activity plans under five priority sectors: forestry and peatland, agriculture, energy and transportation, industry, waste and coastal and marine ecosystems (blue carbon). Green logistics supports decarbonization of the energy and transportation sectors. The efficiency of the carbon footprint is one of the indicators in green logistics. Green logistic for decarbonization in the transportation sector for a better environment has to be massively started. According to the Minister of Transportation Budi Karya Sumadi in 2021, Indonesia is committed implementing the green logistics concept in logistics distribution.

In this study, the author intends to apply the green logistics concept to the distribution of staple foods for the Indonesian population. The agricultural sector is one of the vital sectors in human life. Rice, which is the result of rice farming, is the staple food for 97% of Indonesia's population. This indicates a very high dependence on rice (Louhenapessy, et al. 2010). As a staple food, rice is a functional product with low supply uncertainty. Rice demand tends to be stable.

In the food logistics system, transportation needs (to handle inter-regional logistics needs) and warehousing needs (to handle inter-time logistics needs) between surplus areas and shortage areas must be encouraged to fulfil. The following is a chart of problem of food fulfilment refer to Food Security and Nutrition Strategic Policy Report Year 2020-2024:

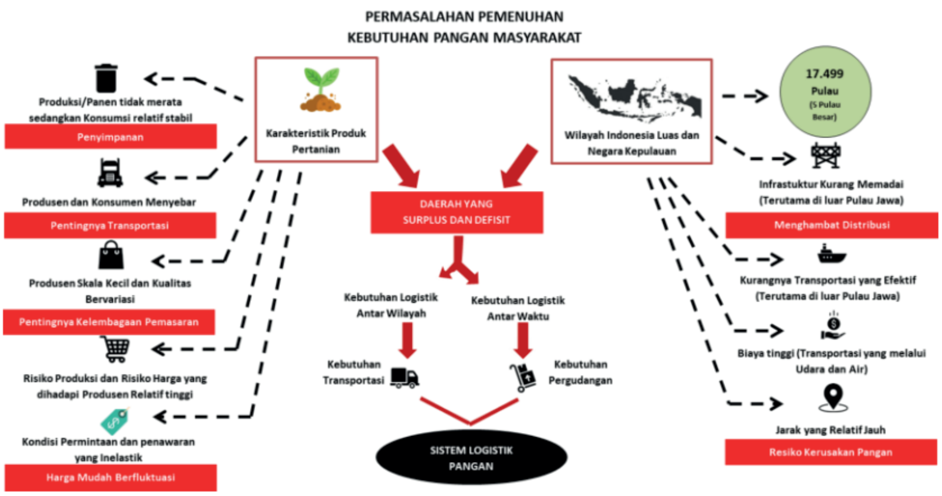

Figure 1: Problem of Food Fulfilment (Food Security Agency of the Indonesian Ministry of Agriculture).

In transportation aspects, the carbon footprints are generated from exhaust gases as remains of fuel combustion process and commonly called emissions. The resulting emission is a constituent of greenhouse gases (GHG). The characteristics and load of the vehicle will affect the ability of the vehicle to reduce the emissions. For similar modes of transportation and similar of vehicle characteristics, the total carbon footprint generated will be proportional or equal to the distance travelled by the transportation mode. Therefore, the mileage through will determine the carbon footprint generated during delivery of goods. Optimizing the route of delivery is expected to shorten the distance which will reduce the carbon footprint. The delivery route can be optimized if the overview of demand in several destination locations has already gotten.

2. Literature Review

2.1. Green Logistics

Logistics is management of flow of goods that involves the integration of information, transportation, inventory, warehouse, and material handling. According to Alan McKinnon (2010) logistics is a term commonly used to describe the transportation, storage, and handling of products in the flow of goods from the source of raw materials to be used in the production system to the point of sale until finally accepted by the final consumer. Green logistics includes all actions that involve, minimize, and measure the environmental impact of various supply chain activities.

2.2. Carbon Footprint

The carbon footprint can be defined as the amount of carbon dioxide and other greenhouse gas emissions (expressed in CO2 equivalents) generated either directly or indirectly from the entity of observation (Carbon Trust, 2007). According to Flores & Larsen (2010), the carbon footprint is equivalent amount of carbon dioxide and other greenhouse gases emitted during the life cycle of a product. Thus, the carbon footprint is a measure of the amount of CO2 converted from an activity.

According to Dhewantara (2010), there are two approaches in measuring carbon dioxide (CO2) emissions: through the approach of fuel used volume and through the mileage approach. The CO2 emissions are calculated by multiplying the volume of fuel consumed with emission factor of each type of fuel used, or by multiplying the distance traveled by emission factor per unit distance. Generally, the resulting emissions can be calculated by the following formulation:

CO_2 Emissions = Vehicle Activity Data x Emission Factor

Equation 1 -- Calculating CO_2 Emissions

The emission factor can be expressed in units of grams/kilometer (g/km), grams/kilogram (g/kg), or grams/Joule (g/J), depending on the unit of conversion of the calculated vehicle activity.

2.3. MILP for Network Model Optimization

The network model is usually designed to minimize costs or the objective in a period (days, weeks, years) by selecting the number of units to be shipped or delivered on different lines during the period to meet demand within capacity constraints. The prescriptive model optimization can be found by using deterministic demand.

Mixed Integer Linear Programming (MILP) is a model that can be used to solve optimization problems in distribution network design (Lwin, 2015). MILP is combination of Linear Programs (LP) and Integer Programs (IP). LP has objective and constraint functions that are linear but the variables can be continuous. IP has an integer decision variable that discontinuous number. Before formulating the MILP mathematical model, we must first define the objectives and the constraints that are flexible enough to find the optimal solution value (Lopez & Chaudhry, 2020). In general, the mathematical formula for MILP is written as follows:

Min atau max $Z = f(x)$

Equation 2 -- Objective Function to Find the Optimal Value (Maximum or Minimum)

This objective function has constraints that must be obeyed absolutely by the decision variable x, both the value of the left side and the right side, according to the relationship either equality (=) or inequality ($\geq$ or $\leq$).

Multi-objective optimization can solve two or more objectives simultaneously in designing a network model with two or more objectives, for example minimizing costs and minimizing distances (Faisal, 2015). The multi-objective optimization model is a complex form of MILP that can optimize network flow with multiple objectives, such as minimizing costs and reducing the resulting CO2 emissions (Kazancoglu et al, 2021). In short, multi-objective optimization aims to minimize Objective Function 1 and Objective Function 2.

3. Mathematical Model

3.1. Describe the Problems

The model is made as a simple form of real conditions to represent decision making in a distribution process by considering the environmental aspects. Objective 1 of this study is to minimize emissions during shipping. Objective 1 can be obtained by finding the minimum value of the emission parameter relationship to the quantity of rice shipped on a route (decision variable).

In shipping operations, every market player would prefer cheaper shipping rates. Thus, the author tries to design a network model whose approach can be applied to actual conditions by including objective 2, namely minimizing shipping costs. The parameter used to achieve objective 2 is the cost of shipping from the origin node to the destination node per unit mass (kg) of rice sent. Objective 2 can be obtained by finding the minimum value of the cost parameter relationship to the quantity of rice shipped on a route (decision variable).

The designed will not involve transhipment. The following are some of the assumptions used:

1. Vehicles are homogeneous (only transporting rice commodities)
2. Shipments are consolidated shipments, both direct delivery (1:1) and one-to-many (1: ∞)
3. Supply and demand are deterministic as constraints in this network model
4. Without involving facility location

In a distribution flow, it is necessary to determine how many quantities are distributed. If there is a quantity of rice distributed from one area (node i) to another (node j), it shows an active route which in network terminology is represented by an arc. This selected route also determines the carbon footprint generated, so that optimization of route selection is needed for the decarbonization process as the goal of green logistics. The quantity of rice (kg) sent from the origin node to the destination node becomes the decision variable.

3.2. Model Formulation

In this model, the distributed rice is directly flowed from the production area to the destination with assumptions mentioned in point 3.1 are applied.

Table 1: Decision Variable.

x_{ij}	The quantity of rice (kg) sent from the origin node to the destination node

Table 2: Parameter.

c_{ij}	Delivery cost from node i to node j per unit mass of rice
D_j	Demand of node j
e_{ij}	The level of carbon footprint on the shipping route from node i to node j per unit mass of rice
S_i	Supply from node i

Objective Function

Objective-1: Min Z_1 = $\sum_i \sum_j e_{ij}x_{ij}$

Objective-2: Min Z_2 = $\sum_i \sum_j c_{ij}x_{ij}$

Equation 3 -- Objective Function of The Model

The solution of this objective function uses a single approach by considering the objective function 1 (f1(x), optimization of the carbon footprint during delivery) as the main objective. Furthermore, the achievement of objective 1 will be constraint for objective 2 (f2(x), optimization of shipping costs).

Constraints of Objective-1

The following are constraints of objective-1 in decision making of this modelling:

$$\sum_j x_{ji} \leq S_i \forall\, i \in S$$

$$\sum_i x_{ij} \geq D_j \forall\, j \in D$$

$$x_{ij} \geq 0 \forall\, ij$$

Equation 4 -- Constraints of Objective-1 of The Model

Constraints of Objective-2

The following are constraints of objective-2 in decision making of this modelling:

$$\sum_j x_{ji} \leq S_i \forall\, i \in S$$

$$\sum_i x_{ij} \geq D_j \forall\, j \in D$$

$$x_{ij} \geq 0 \forall\, ij$$

$$f_2(x) \leq Z_2^*$$

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Equation 5 -- Constraints of Objective-2 of The Model

Value of decision variable of the objective function 2 (f2(x)) must not exceed the value of decision variable of the objective function 1.

4. Case Study

The model formulation will be implemented on representative data: rice production and consumption among districts in DI Yogyakarta Province (data for year 2020), then we will see the recommended flow of rice distribution among districts in this province. The difference between production and consumption in each district is shown in the following table.

TABLE 3: Surplus District in DIY.

District	*S_i (Ton of Rice)*
Kulon Progo (KP)	11294
Gunung Kidul (GK)	54767

S_i show the number of over rice production in the district that will delivered to deficit districts.

TABLE 4: Deficit District in DIY.

District	*D_j (Ton of Rice)*
Bantul (B)	15409
Sleman (S)	38210
Yogyakarta (Y)	35795

D_j show the number of shortage rice production in the district.

Matrix distance of among districts in kilometers are show as follows:

TABLE 5: Distances Among District in km.

District	*Kulon Progo*	*Bantul*	*Gunung Kidul*	*Sleman*	*Yogyakarta*
Kulon Progo (KP)		72,01	51,37	102,79	138,87
Bantul (B)	72,01		41,04	75,76	97,01
Gunung Kidul (GK)	51,37	41,04		54,17	88,10
Sleman (S)	102,79	75,76	54,17		38,37
Yogyakarta (Y)	138,87	97,01	88,10	38,37	

5. Result

5.1. Estimation of Emission Parameters

Reduction of carbon footprint is a set of objectives in this study. The carbon footprint will refer to the amount of fuel used. The amount of fuel used is estimate of the amount of work of the vehicle. It can be approximated by calculating the aerodynamic or force drag and friction force experienced by the vehicle with consider the combustion efficiency as far as distance reached. The released emission is the energy consumed multiplied by the fuel emission factor.

Referring to allowed load capacity of various sizes of freight trucks as per Indonesian government regulation and using average physical parameters of vehicle activity on the road, the authors get an estimated lower limit of 1.98 x 10^{-6} and an estimated upper limit of 2.63 x 10^{-6} kg CO_2 per meter travelled per kg of rice. By performing a random simulation using 2000 rows on Microsoft Excel, the average results of U[1.98 x 10^{-6}; 2.63 x 10^{-6}] is 2.29 x 10^{-6}. Thus, this value is used to obtain the e_{ij} parameter by multiplying it with the distance travelled from node i to node j.

5.2. Estimation of Delivery Cost Parameters

The estimated delivery or shipping cost parameter per unit mass of rice is calculated using secondary data: cargo rates of some freight forwarding trucks in Indonesia per unit mass (kg). The author uses the shipping rate of 32 expeditions, both cargo rates and truck rental rates. The average cost rate obtained is around Rp. 14/kg per kilometer traveled. The c_{ij} value will be estimated from that value multiplied by the distance between node i to node j.

5.3. Best Route for the Optimization

As shown by table 1 and table 2, the total rice production in DI Yogyakarta province would not fulfil the consumption needs of the people in this province thus it is needed supplied by others province. By implemented the data in the point 4 to formulation in the point 3, here is below the advised route of the rice distribution of this case study:

Delivery of rice that only between districts in this province generate carbon emissions (objective 1) more than 10 ton CO_2 per year and spend (objective 2) more than Rp 61 billion a year.

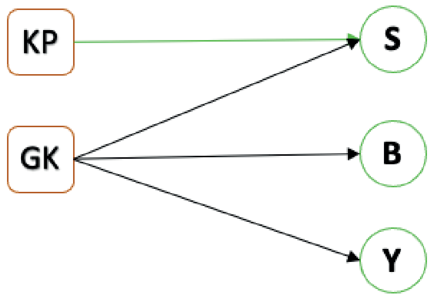

Figure 2: Distribution Route Among District in DIY.

6. Conclusions

The mathematical model in this paper addresses the green logistic that begun by estimated the emission parameters of each arc. The proposed model is a mixed integer linear programming model considering total cost minimization and environment impact maximization by providing the minimum emission generated. From this model seen that the best route or the minimize distance set in a network will release the minimal emission.

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