

## Analysis Of Cost And Gas Emissions In The Distribution Of Gallon Packaged (Case Study At Pt. Xyz)

Muchammad Fauzi<sup>1</sup>, Ayu Swilugar<sup>2</sup>, Hikmah Goyatun Napilah<sup>3</sup>, Mimi Nur Habibah<sup>4</sup>

<sup>1</sup>Industrial Engineering Department, Engineering Faculty, Widyatama University

<sup>2</sup>Industrial Engineering Department, Engineering Faculty, Widyatama University

<sup>3</sup>Industrial Engineering Department, Engineering Faculty, Widyatama University

<sup>4</sup>Industrial Engineering Department, Engineering Faculty, Widyatama University

<sup>1</sup> muchammad.fauzi@widyatama.ac.id, <sup>2</sup>swilugar.ayu@widyatama.ac.id, <sup>3</sup>hikmah.goyatun@widyatama.ac.id

<sup>4</sup>mimi.habibah@widyatama.ac.id

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**Abstract:** Transportation is an initial presentation of a supply chain to consumers. Determination of transportation routes greatly affects the costs incurred by companies in distribution activities, an increase in transportation means an increase in the exhaust gas. Motorized vehicles are a source of air pollution in the city of Bandung. Based on these problems, the calculation of transportation costs and exhaust gas emissions is influenced by the distance of delivery on the optimal route. The optimal route is determined by the saving matrix method with asymmetric distances and branch and bound methods with symmetrical and asymmetric distances. This research is to find the most appropriate and optimal shipping route to minimize transportation costs and minimize exhaust emissions. The result of route determination shows that the branch and bound method route has the lowest delivery distance of 38.5 km, while the saving matrix route has a delivery distance of 41.5 km. The most optimal route is generated from the branch and bound method with a transportation cost of Rp. 98,359,445. Exhaust gas emissions of the branch and bound method for each composition of CO, HC, NO<sub>x</sub>, PM<sub>10</sub>, CO<sub>2</sub>, and SO<sub>2</sub> are 0.0162 tonnes/year, 0.0035 tonnes/year, 0.0341 tonnes/year, 0.0027 tons/year, 6.1061 tons/year, and 0.0016 tons/year.

### 1. Introduction

Distribution is an activity to move products from suppliers to consumers in a supply chain. transportation is an initial presentation of a supply chain to consumers. Transportation and distribution networks must be sufficient in terms of meeting needs and costs, for that estimation step is very important and vital, estimation has a role in determining the amount of demand so that a company can determine and know the role of estimation in determining demand and its effect on company revenues and costs. delivery activities (Kodrat, David Sukardi. 2009).

The use of motorized vehicles in the distribution of gallons is used to simplify and speed up delivery from distributors to consumers. The growth of motorized vehicles in the city of Bandung has increased by an average of 11% in a year. In 2018 the number of 4-wheeled vehicles in the city of Bandung reached 536,973 units. (Source from Dinas Perhubungan Kota Bandung 2018). The increase in the number of motorized vehicles resulted in an increase in the motor vehicle exhaust gas which is a source of air pollution in the city of Bandung. In a complete combustion reaction, the remainder of the combustion product is in the form of exhaust gas containing carbon dioxide (CO<sub>2</sub>), water vapor (H<sub>2</sub>O), oxygen (O<sub>2</sub>), and nitrogen (N<sub>2</sub>). The combustion that occurs in a vehicle engine does not always run perfectly, so the exhaust gas contains dangerous compounds such as Carbon Monoxide 700 Hydrocarbons (HC) Nitrogenoxide (NO<sub>x</sub>), and Particulates. (Winarno, Joko, 2014; Jabarullah, 2019).

XYZ company is a company that distributes mineral water in gallon packs in the city of Bandung. This company distributes gallons to four different locations each week using a Mitsubishi Fuso Colt Diesel FE 73 type truck. The weekly demand for mineral water is 159 gallons. This study is to find transportation costs and motor vehicle exhaust emissions during the distribution process based on optimal routes in the branch and bound method in Fauzi's research (2019), the branch and bound method with asymmetric distances, and the saving matrix method with asymmetrical distances. Based on these problems, transportation costs and gas emissions are calculated from the optimal route delivery distance. The comparison between transportation costs and gas emissions on each optimal route aims to get the most appropriate and optimal shipping route to minimize transportation costs and minimize exhaust gas emissions.

### 2. Formulating of the problem

In previous research (Fauzi, 2020) the optimal route was determined based on the saving matrix method, but it did not include transportation costs and exhaust gas emissions. This study aims to analyze transportation costs and exhaust gas emissions on the optimal route of the saving matrix method and optimal route of a branch and bound method.

### 3. Methodology

The data in this study include location maps, delivery distance, vehicle specifications, load capacity, demand data, and exhaust emission factor values. The following is the flow of this research methodology which is shown in Figure 1.

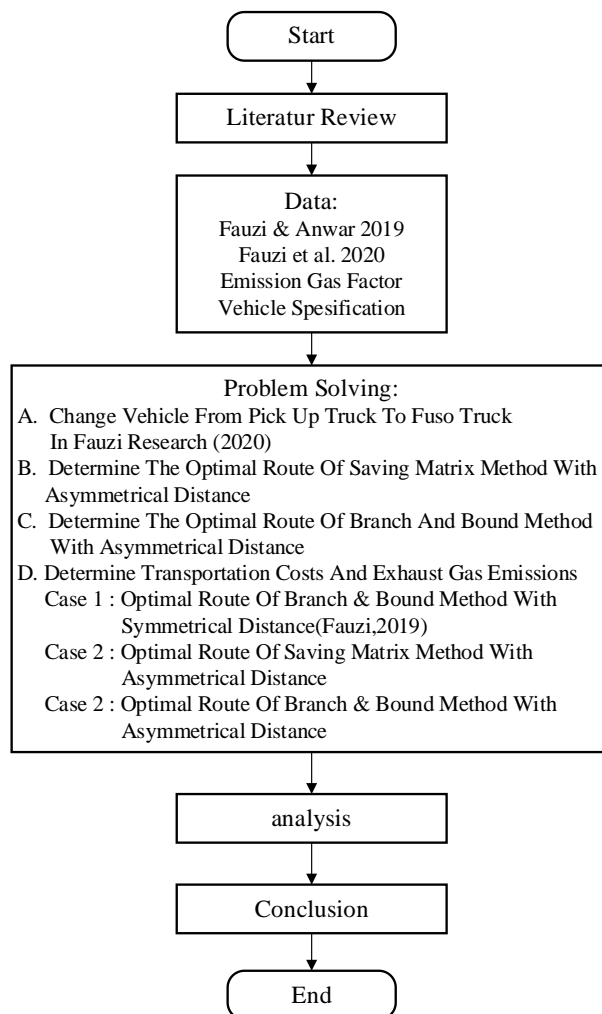


Figure 1. Flow of The Research Methodology

### 4. Result and discussion

This study examines the analysis of costs and gas emissions based on routes on gallon shipments of PT. XYZ using the saving matrix method and the branch and bound method with the asymmetric distance assumption based on the research of Fauzi (2019).

#### A. Optimal Route Determination Saving Matrix Method of Asymmetric Distance Assumption

Determination of the optimal route of the saving matrix method is based on research by Fauzi (2020) by making changes to the transportation fleet to become a Fuso Colt Diesel Double FE 73 truck. The transport capacity changes to 255 gallons/truck. The optimal route based on *saving matrix* method is  $O \rightarrow B \rightarrow C \rightarrow D \rightarrow A \rightarrow O$ . The optimal route of saving matrix method is shown in Figure 2.

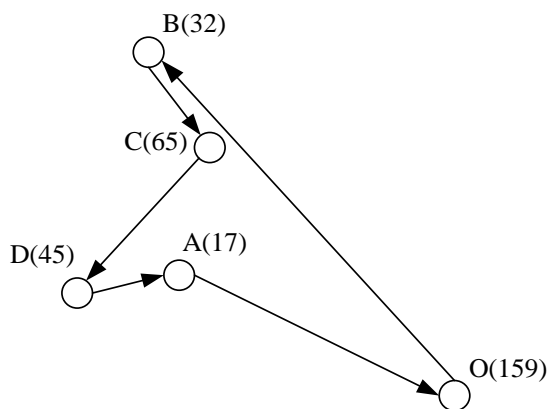


Figure 2. Asymmetric Saving matrix Method Route

$$\text{Route Distance} = OB + BC + CD + DA + AO = 15,1 + 2,5 + 9,6 + 2,5 + 11,8 = 41,5 \text{ km}$$

**B. Optimal Route Determination of Branch and Bound Methods of Asymmetric Distance Assumptions**

In contrast to research determining the optimal route for the Branch and Bound method (Fauzi, 2019). Determination of the optimal routes is based on the assumption of asymmetric distance. The optimal route resulting from the Branch and Bound method assuming the asymmetric distance is the O-D-A-B-C-O route with a total delivery distance of 38.5 km. The optimal route of the Branch and Bound method is shown in the Figure 3.

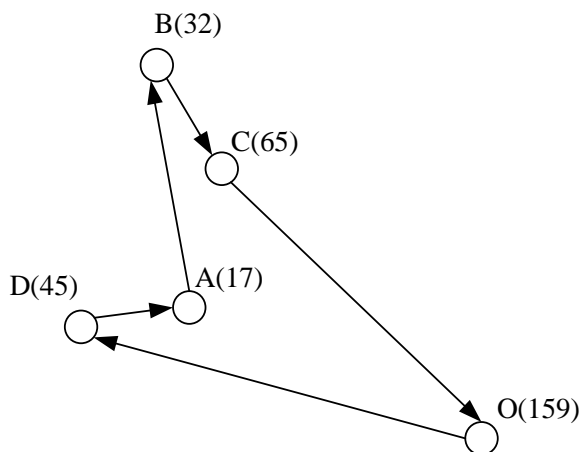


Figure 3. Asymmetrical Branch and Bound Method Routes

$$\text{Route Distance} = OD + DA + AB + BC + CO = 12,6 + 2,5 + 6,4 + 2,5 + 14,5 = 38,5 \text{ km}$$

Table 1. Optimal Route Determination Results

No	Method	Distance Assumption	Optimal Route	Total Distance (km)
1	Branch and Bound, 159 gallons (Fauzi, 2019)	Symmetrical	O-A-C-B-D-O	38,5
			O-D-B-C-A-O	
2	Saving Matrix, 255 gallons	Asymmetric	O-B-C-D-A-O	41,5
3	Branch and Bound, 255 gallons	Asymmetric	O-D-A-B-C-O	38,5

The result of the routes as in Table 1, that different between saving matrix and branch and bound methods because the saving matrix method assumes asymmetric delivery distance, while the branch and bound method in Fauzi research (2019) assumes symmetrical delivery distance. Meanwhile, the difference in the optimal route saving matrix and branch and bound assumption of the same distance is asymmetrically caused by differences in methods used. It can be concluded that the optimal route solution is influenced by the methods and distance assumptions used.

**C. Determination of Transportation Costs**

The difference in delivery distance from the optimal route in each method can be used as a parameter in calculating transportation costs. The results of calculation transportation costs for each optimal route in the saving matrix and branch and bound methods are as Table 2.

Table 2. Total Transportation Costs

Method	Distance (km)	Fixed cost/year	Variable costs/year	Transportation costs/year
Branch and Bound, 159 gallons (Fauzi, 2019)	38,5	Rp95.527.508	Rp2.831.937	Rp98.359.445
Saving Matrix, 255 gallons	41,5	Rp95.527.508	Rp2.989.870	Rp98.517.378
Branch and Bound, 255 gallons	38,5	Rp95.527.508	Rp2.831.937	Rp98.359.445

Transportation costs are influenced by the distance of delivery, the farther the distance the delivery, the greater the transportation costs. Based on Table 14, it can be seen that the optimal transportation cost is shown on the branch and bound route of Rp 98,359,445 because it has the smallest delivery distance.

**D. Exhaust Gas Emission**

The exhaust emission calculation is based on vehicle volume, delivery distance, and emission factors. The exhaust gas emission equation as follows.

$$E = f \times VKT \times Fe \times 10^{-6}$$

f = Volume of vehicle

VKT = Travel distance (km/year)

Fe = Emission factor g/km/vehicle)

Table3. Emissions Gas Factor

Gas Composition	CO (g/km)	HC (g/km)	NOx (g/km)	PM10 (g/km)	CO <sub>2</sub> (g/kg BBM)	SO <sub>2</sub> (g/km)
Emission Factor	8,4	1,8	17,7	1,4	3172	0,82

Source: (Kementerian Lingkungan Hidup dan Kehutanan RI, 2012)

The results of the calculation of exhaust gas emissions for each pollutant are as follows

Table 1. Exhaust Gas Emissions Value

Exhaust Gas Emissions	CO (ton/year)	HC (ton/year)	NOx (ton/year)	PM10 (ton/year)	CO <sub>2</sub> (ton/year)	SO <sub>2</sub> (ton/year)
Branch and Bound, 159 gallons (Fauzi, 2019)	0,0162	0,0035	0,0341	0,0027	6,1061	0,0016
Saving Matrix, 255 gallons	0,0174	0,0037	0,0367	0,0029	6,5819	0,0017
Branch and Bound, 255 gallons	0,0162	0,0035	0,0341	0,0027	6,1061	0,0016

The emission gas value of each pollutant on optimal route branch and bound method has a smaller value than optimal route of saving matrix, because branch and bound method has smallest delivery distance

**5. Conclusion**

The delivery route using the branch and bound method at asymmetric and symmetrical distances produces an optimal distance of 38.5 km, while the asymmetric saving matrix method produces a distance of 41.5 km. The optimal route chosen is the branch and bound because it has the smallest transmission distance. Transportation

costs for the branch and bound method at symmetrical and asymmetrical distances result in transportation costs of Rp. 98,359,445/ year, while the saving matrix route generates transportation costs of Rp. 98,517,378/ year. The value of exhaust gas emission produced by the branch and bound route method is symmetrical and asymmetrical, respectively 0.0162 tons/year, HC 0.0035 tons/year, NOx 0.0341 tons/year PM10 0.0027 tons/year, CO2 6,1061 tons / year and SO2 0.0016 tons / year, while the route saving matrix method produces exhaust gas emission values of 0.0174 tons / year, HC 0.0037 tons / year, NOx 0.0367 tons/year PM10 0.0029 tons/year, CO2 6.5819 tons/year and SO2 0.0017 tons/year.

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