Optimization of Multi-Products Distribution by Tabu Search Algorithm (Case Study: Fuel Distribution)

Sri Wulandari and Norma Puspitasari

Indonusa Polytechnic Surakarta, JL. KH. Samanhudi No, 31, Mangkuyudan, Central Java, Indonesia.

Authors' contributions

This work was carried out in collaboration between both authors. Author SW designed the research, designed the programs, analyzed the data, wrote the protocol and wrote the first draft of the manuscript. Author NP managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

ABSTRACT

Aims: Determine the vehicle’s fuel distribution as distributing case of multi-product based on the number of routes and the total mileage optimal manner using a split delivery tabu search algorithm.

Study Design: Trial percentage loading capacity of the three types of fuel to determine the percentage which gives optimum results.

Place and Duration of Study: Indonusa Surakarta Polytechnic to make the application of a tabu search algorithm to determine the route and calculate the total mileage of the vehicle. The time required 1 month.

Methodology: In this study as a central depot supplier number one, the number of consumers who have served are 19, types of products to be distributed is 3, and the type of transport vehicle used is one where vehicles are not restricted. There are 37 scenarios percentage payload capacity tested in this study to find the percentage of transport capacity which gives optimum results.

Results: The results showed that for three types of fuel distribution to 19 customers, scenarios percentage of premium transport capacity of 25%, 18% kerosene, diesel fuel 57% provide optimal
results. Optimal results based on the number of routes of distribution and total mileage. The amount of the distribution as much as 5 routes with a total distance is 9.727 nautical miles.

**Conclusion:** Tabu search algorithm can be used to complete the Split Delivery Vehicle Routing Problem in the case of multi-product distribution by creating a scenario type of fuel carrying capacity of each product.

**Keywords:** Vehicle routing problem; split delivery; multi-products; tabu search.

1. **INTRODUCTION**

To support its operations in marketing their products, companies need a distribution system. The distribution system is a system for the distribution of goods/services from producers to consumers by the number of goods and certain delivery time. The problem of the distribution of goods/services cannot be separated from the problem of transportation. Transport is one area in supply chain management that determine how and when to send the goods to the consumer. Transportation also plays an important role in the logistics activities [1]. Determination of the distribution effect on transport costs [2]. Transportation costs can contribute up to 40% of total logistics costs [3].

In shipping goods, companies must be able to determine the exact configuration of the distribution channels so that delivery is quick and it does not cost that much. The problem distribution system is an important factor that involves a few key considerations. Some of the major considerations include the route selection of vehicles, fleet vehicles, and vehicle scheduling [4].

**Routing Vehicle The Problems (VRP)** is a model of the distribution of goods/services from a / some depot (warehouse) to several agents (consumers) using a number of vehicles, which was to determine the optimal distribution of vehicles. VRP problem was first modeled by a homogeneous fleet of trucks serving demand for oil to a couple of gas stations by considering the minimum mileage [5]. The problem then developed into an optimization problem in logistics and transportation [6]. In umumVRP defined as the problem of determining a route for a vehicle which aims to minimize the total cost of transportation to meet a number of constraints that reflect the characteristics of the real situation [7]. VRP can also be defined as a problem of distribution route search with a minimum fare from one depot to customers who are dispersed by the number of requests (demand) different [8].

VRP with split deliveries (SDVRP) is a distribution model where consumers can visit more than one service vehicle [9,10]. In contrast to the VRP, where each consumer can only be visited by 1 service vehicle. This is caused by exceeding consumer demand than the capacity of the vehicle [11,12]. SDVRP typically used to reduce the number of routes and a total distance [13]. Interest SDVRP approach is to produce an efficient service [14]. SDVRP also tasked to find a number of these vehicles which begins and ends at the depot to meet customer demand at the lowest possible shipping costs [15].

SDVRP first introduced by [16] then [17]. SDVRP problem is said to be NP-hard, because it is not easy to handle [17]. Several approaches are used to solve the problem of SDVRP. Methodological search [16], branch and bound method [18], dynamic programming and shortest path [19], local search with the grouping procedure [20], picking algorithm [21], dynamic program [22], tabu search algorithm [23-28], a heuristic approach [29], and scatter search algorithm [30,31].

The type of goods carried by a vehicle distribution may consist of one type of goods/products or can be more than one type of goods/products. The type of goods/products of more than one type is called a lot of stuff or multi goods/products. Zhang and Chen [32] and Kabcome & Mouktonglang [33] have made a multi-product distribution model with two types of products.

Some distribution of goods/products is sometimes carried out in accordance with the will of the vehicle driver regardless of distance traveled. This can cause the vehicle mileage can be longer and result in cost he costs of traveling vehicles were also great. Based on these issues, this research will provide solutions on set route vehicles that carrying three types of fuel (premium gasoline, kerosene, diesel fuel) by way of a split delivery using a Tabu search algorithm so as to obtain the vehicle slightly and total mileage minimal.
2. MATERIALS AND METHODS

The problem in this research is a multi-product distributor by way of a split delivery. The data used are secondary data from Paillin and Wattimena (2015) about the distribution of fuel in eastern Indonesia. Data-related data in this study consisted of:

1. Depot: Depot used only one. This study, which is regarded as the fuel depot is the Transit Terminal in Wayame-Ambon.
2. Vehicle: Vehicles used for fuel distribution is a tanker. The tanker that is assumed to only one type, the type of medium fuel range with a payload capacity of 1,000 KL. Where the tanker has several

![Flowchart](image)

**Fig. 1. Flow troubleshooting multi-product distribution**
compartments. The compartment used is a dedicated compartment (compartment that has been devoted to loading one type of product and cannot be used to load a different type of product). Each vehicle can do more than one route.

3. Products are distributed. Products are distributed is the fuel that consists of three types, namely premium, kerosene, and diesel.

4. Agent: In this study is the agent depot which is the goal of fuel distribution from the Transit Terminal. There are 19 depots purpose, namely Biak, Bula, Dobu, the consortium, Jayapura, Kaimana Labuha, Manokwari, Masohi, Merauke, Nabire, Namelea, Sanan, Saumlaki, Serui, Sorong, Ternate, Tobelo, and Tual.

5. Distance: Comprising distance data from the distance between the depot with each agent and spacing agent. The distance is known and assumed to be symmetric.

Multi-product distribution problem with this delivery split respect to the total mileage of at least meet the criteria in accordance with VRP models with split delivery as follows:

The objective function:

\[ \text{Min} \sum_{i=0}^{n} \sum_{j=0}^{n} \sum_{k=1}^{m} x_{ijk} c_{ij} \]  

(1)

With restrictions:

1. Each customer can be served more than 1 time by another vehicle

\[ \sum_{k=0}^{N_1} \sum_{j=1}^{N_2} x_{ijk} \geq 1, \forall j = 1, ..., N \]  

(2)

2. Every vehicle leaving the depot, after arriving in the consumer vehicle took off again and finally back to the depot

\[ \sum_{j=0}^{N_1} x_{0jk} = 1, \quad \forall k = 1, ..., K \]  

(3)

\[ \sum_{j=0}^{N_1} x_{ijk} = 1, \quad \forall k = 1, ..., K \]  

(4)

\[ \sum_{j=0}^{N_1} x_{ihk} - \sum_{j=0}^{N_1} x_{hjk} = 0, \quad \forall h = 0, ..., N \forall k = 1, ..., K \]  

(5)

3. The charge for each product must be less than or equal to the capacity of the vehicle

\[ \sum_{p=1}^{p} B_{pk} \leq Q_k, \quad \forall k = 1, ..., K \]  

(6)

4. The amount of each product load carried by the vehicle must be less than or equal to the number of consumer demand

\[ \sum_{p=1}^{p} f_{ikp} \cdot d_{ip}, \forall k = 1, ..., K \]  

(7)

5. Each customer will receive a shipment demand in full

\[ \sum_{k=1}^{K} f_{ikp} = 1, \forall i = 1, ..., N, \forall p = 1, ..., P \]  

(8)

6. Consumers can only be served by visiting the consumer vehicle

\[ \sum_{j=1}^{N} x_{ijk} \geq f_{ikp}, \forall i = 1, ..., N \]  

(9)

Problem-solving multi-product distribution with a split delivery using a tabu search algorithm. Step completion is described in Fig. 1.

3. RESULTS AND DISCUSSION

The settlement of the case of multi-product distribution with a split delivery using a tabu search algorithm is the case of the distribution of the three types of fuel are transported by one vehicle type. The first step is to create multiple scenarios the percentage of the capacity of each product to be loaded by a vehicle. Then perform these calculations and the calculation of total mileage. The calculation of the number of routes and the total mileage of the vehicle using a software application programming language PHP with MySQL database and web server XAMPP. Demand each agent (consumers) are presented in Table 1, whereas the distance between agents (consumers) are presented in Table 2.

Based-on-demand data in Table 1 descriptively known that depot (consumers) the greatest use premium gasoline is Jayapura 2,749.5 usage amount; or approximately 27.495%. Depot greatest use kerosene fuel is Ternate 1,411.5 usage amount; or approximately 14.111%. And the biggest depot using Solar Fuel is Sorong with a total of 6978 or around 68.78%.. While the average use of BBM for premium is 6.06%, the average Kerosin fuel is 4.29% and the average diesel is 13.99%. So the biggest demand is diesel fuel when compared to kerosene and premium.

The optimized capacity of each product to be loaded by a vehicle impact also on mileage so that the distribution of each product through multiple routes will affect the total mileage. Several scenarios load the capacity of each products to be carried out are created by making combinations of 3 types of products. The results are presented in Table 3.
From several scenarios percentage of each product by vehicle transport, optimum results indicated by the scenario transports 20% premium cotton, 20% kerosene, 60% diesel and 20% premium, 40% kerosene, 40% diesel. Both scenarios produce a number of distribution routes 6 vehicles with a total mileage of 13,179 nautical miles. A new scenario on the percentage of each product transportation by vehicles made based on the calculation of the total demand for each product using the following formula:

\[
\text{Percentage of the capacity of each product in the vehicle} = \frac{\text{number of requests for each type of product}}{\text{the total number of requests}} \times 100\%.
\]

Then it would earn a percentage of each product being transported by vehicle is a 25% premium, 18% kerosene, and 57% diesel. By using the percentage of freight vehicles for each of the products tested to calculate many routes and total mileage. The result was 5 routes with a total distance of 9727 nautical miles. Comparison of results from several scenarios percentage payload capacity can be seen in Fig. 2.

### Table 1. Consumer demand data

| No | Depot (Consumer) | Premium | Kerosene | Solar |
|----|------------------|---------|----------|-------|
| 1  | Masohi           | 343.5   | 525.0    | 397.5 |
| 2  | Tual             | 291.0   | 363.0    | 1426.5|
| 3  | Dobob            | 118.5   | 250.5    | 513.0 |
| 4  | Kaimana          | 190.5   | 82.5     | 589.5 |
| 5  | Bula             | 120.0   | 187.5    | 153.0 |
| 6  | Saumlaki         | 154.5   | 285.0    | 946.5 |
| 7  | Merauke          | 949.5   | 513.0    | 2467.5|
| 8  | Namlea           | 249.0   | 195.0    | 241.5 |
| 9  | Sanana           | 151.5   | 220.5    | 214.5 |
| 10 | Labuha           | 231.5   | 23.5     | 307.5 |
| 11 | Ternate          | 1245.0  | 1411.5   | 3723.0|
| 12 | Tobelo           | 665.5   | 337.5    | 976.5 |
| 13 | Sorong           | 1414.5  | 975.0    | 6978.0|
| 14 | Manokwari        | 808.5   | 333.0    | 951.0 |
| 15 | Serui            | 370.5   | 217.5    | 292.5 |
| 16 | Nabire           | 711.0   | 327.0    | 715.5 |
| 17 | FakFak           | 246.0   | 234.0    | 265.5 |
| 18 | Biak             | 514.5   | 301.5    | 1063.5|
| 19 | Jayapura         | 2749.5  | 1377.0   | 4365.0|

![Fig. 2. Results distribution with multiple scenarios](image-url)
Table 2. Mileage

|       | Ambon | Masohi | Tual | Dobo | Kaimana | Bula | Saumlaki | Merauke | Namlea | Sanana | Labuha | Ternate | Tobelo | Sorong | Manokwari | Serui | Nabire | FakFak | Biak |
|-------|-------|--------|------|------|---------|------|----------|---------|--------|--------|--------|---------|--------|--------|------------|-------|--------|--------|------|
| Masohi| 78    |        |      |      |         |      |          |         |        |        |        |         |        |        |            |      |        |        |      |
| Tual  | 325   | 285    |      |      |         |      |          |         |        |        |        |         |        |        | C1         | 115  |        |        |      |
| Dobo  | 410   | 365    | 115  |      |         |      |          |         |        |        |        |         |        |        |            |      |        |        |      |
| Kaimana| 400  | 347    | 130  | 135  |         |      |          |         |        |        |        |         |        |        |            |      |        |        |      |
| Bula  | 285   | 230    | 202  | 280  | 255     |      |          |         |        |        |        |         |        |        |            |      |        |        |      |
| Saumlaki| 380 | 384    | 215  | 250  | 326     | 360  |          |         |        |        |        |         |        |        |            |      |        |        |      |
| Merauke| 860  | 803    | 532  | 490  | 560     | 710  | 547      |         |        |        |        |         |        |        |            |      |        |        |      |
| Namlea| 80    | 122    | 417  | 465  | 460     | 225  | 428      | 900     |        |        |        |         |        |        |            |      |        |        |      |
| Sanana| 180   | 230    | 483  | 542  | 563     | 300  | 547      | 984     | 115    |        |        |         |        |        |            |      |        |        |      |
| Labuha| 230   | 300    | 458  | 518  | 478     | 238  | 561      | 1017    | 203    | 180    |        |         |        |        |            |      |        |        |      |
| Ternate| 320  | 335    | 582  | 677  | 625     | 370  | 688      | 1098    | 265    | 210    | 90     |        |        |        |            |      |        |        |      |
| Tobelo| 445   | 480    | 598  | 659  | 618     | 383  | 824      | 1247    | 385    | 360    | 245    | 150    |        |        |            |      |        |        |      |
| Sorong| 332   | 390    | 379  | 470  | 445     | 216  | 521      | 833     | 274    | 357    | 223    | 303    | 308    |        |            |      |        |        |      |
| Manokwari| 545 | 570    | 575  | 620  | 585     | 340  | 807      | 1067    | 465    | 541    | 399    | 489    | 420    | 185    |            |      |        |        |      |
| Serui | 660   | 690    | 710  | 722  | 700     | 490  | 812      | 1112    | 625    | 618    | 540    | 619    | 570    | 330    | 150      |      |        |        |      |
| Nabire| 700   | 720    | 690  | 725  | 724     | 554  | 82       | 1107    | 652    | 621    | 497    | 686    | 600    | 375    | 170      | 103  |        |        |      |
| FakFak| 282   | 245    | 160  | 212  | 180     | 106  | 403      | 678     | 329    | 400    | 330    | 420    | 450    | 218    | 501      | 553  | 503    |        |      |
| Biak  | 631   | 660    | 695  | 680  | 665     | 454  | 780      | 1132    | 594    | 667    | 533    | 692    | 530    | 310    | 116      | 110  | 148    | 626    |      |
| Jayapura| 940 | 996    | 992  | 1060 | 1020    | 770  | 1193     | 1440    | 890    | 1017   | 883    | 1015   | 828    | 660    | 425      | 320  | 391    | 858    | 291  |
Table 3. Distribution with multiple scenarios

| Scenario | Premium (%) | Kerosene (%) | Solar (%) | Number of routes | Total mileage (Nautical miles) |
|----------|-------------|--------------|-----------|------------------|-------------------------------|
| 1        | 10          | 10           | 80        | 12               | 24,459                        |
| 2        | 10          | 20           | 70        | 12               | 24,355                        |
| 3        | 10          | 30           | 60        | 12               | 25,622                        |
| 4        | 10          | 40           | 50        | 12               | 28,358                        |
| 5        | 10          | 50           | 40        | 12               | 25,695                        |
| 6        | 10          | 60           | 30        | 12               | 23,427                        |
| 7        | 10          | 70           | 20        | 14               | 29,876                        |
| 8        | 10          | 80           | 10        | 27               | 50,404                        |
| 9        | 20          | 10           | 70        | 9                | 21,561                        |
| 10       | 20          | 20           | 60        | 6                | 13,179                        |
| 11       | 20          | 30           | 50        | 6                | 14,083                        |
| 12       | 20          | 40           | 40        | 6                | 13,179                        |
| 13       | 20          | 50           | 30        | 9                | 21,036                        |
| 14       | 20          | 60           | 20        | 14               | 29,044                        |
| 15       | 20          | 70           | 10        | 27               | 47,060                        |
| 16       | 30          | 10           | 60        | 9                | 20,909                        |
| 17       | 30          | 20           | 50        | 6                | 14,020                        |
| 18       | 30          | 30           | 40        | 7                | 17,453                        |
| 19       | 30          | 40           | 30        | 9                | 21,818                        |
| 20       | 30          | 50           | 20        | 14               | 27,368                        |
| 21       | 30          | 60           | 10        | 27               | 43,454                        |
| 22       | 40          | 10           | 50        | 9                | 23,275                        |
| 23       | 40          | 20           | 40        | 7                | 19,935                        |
| 24       | 40          | 30           | 30        | 9                | 18,003                        |
| 25       | 40          | 40           | 20        | 14               | 26,362                        |
| 26       | 40          | 50           | 10        | 27               | 41,909                        |
| 27       | 50          | 10           | 40        | 9                | 20,304                        |
| 28       | 50          | 20           | 30        | 9                | 21,751                        |
| 29       | 50          | 30           | 20        | 14               | 24,950                        |
| 30       | 50          | 40           | 10        | 27               | 41,079                        |
| 31       | 60          | 10           | 30        | 9                | 17,835                        |
| 32       | 60          | 20           | 20        | 14               | 27,883                        |
| 33       | 60          | 30           | 10        | 27               | 42,147                        |
| 34       | 70          | 10           | 20        | 14               | 27,963                        |
| 35       | 70          | 20           | 10        | 27               | 44,950                        |
| 36       | 80          | 10           | 10        | 27               | 47,355                        |

Table 4. This based distribution by percentage transports calculation of total demand

| Route       | Trip                                                                 | Distance (nautical miles) |
|-------------|----------------------------------------------------------------------|----------------------------|
| 1           | Ambon - Masohi - Namlela - Sanana - Tobelo - Ternate - Labuha -      | 1,145                      |
|             | Ambon                                                                |                             |
| 2           | Ambon - the consortium - Bula - Tual - Kimana - Dobo - Saumlaki -    | 2,031                      |
|             | Nabire - Serui - Biak - Ambon                                         |                             |
| 3           | Ambon - Ternate - Tobelo - Manokwarri - Sorong - Ambon                | 1,407                      |
| 4           | Ambon - Sorong - Manokwarri - Biak - Jayapura - Serui - Ambon         | 1,904                      |
| 5           | Ambon - Merauke - Jayapura - Ambon                                    | 3,240                      |
| Total       | Distance                                                             | 9,727                      |

Based on the results of multiple scenarios the percentage of freight vehicles based on a combination of three types of products and the results of calculation of the percentage of conveyance total demand of each product, optimum results shown by calculating the
percentage of freight based on the total demand of each product that is 25% premium, 18% kerosene, and 57% diesel. These routes distributions resulting from the optimal percentage of freight vehicles are presented in Table 4.

Based on the results in Table 4 it appears there are some consumers who are served by more than one service vehicle distribution. Tobelo and Ternate are served by two routes of the vehicle, Route 1 and Route 3, Manokwari and Sorong served by these vehicles 3 and 4, Jayapura served by Route 4 and 5. So the optimization of distribution carried out by vehicles with multi-product loading can be done by dividing consumer demand for vehicles serviced by a different route. The optimization can also be done by making the percentage of each product transport capacity.

4. CONCLUSION

Tabu search algorithm can be implemented in the case of determining the multi-product distribution vehicles in order to obtain optimal results. Optimization of the results is done by dividing the number of requests (depot) so that consumers can be served by multiple vehicles. Optimal results are seen by the number of vehicles and the total mileage of the vehicle. The percentage of freight each product by each vehicle also has an effect on the outcome. The percentage of transports any product that can meet the optimal results calculated based on the ratio between the number of requests for each product of all consumers by the number of overall demand for all products.

This research can be developed by using another method as a comparison of the results of the tabu search algorithm. This type of vehicle also affects the distribution of product distribution optimization. For further research can make a combination of several different types of distribution vehicles.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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