**Saving Matrix Application to Minimize Fuel Distribution Route Allocation**

**E. W. Yunitasari1, E. Nurhayati2, K. Sriyanto3, and F. S. Wijaya4**

1, 2, 3, 4Industrial Engineering Study Program, Universitas Sarjanawiyata Tamansiswa, Yogyakarta

E-mail: ellywy@ustjogja.ac.id

**Abstract.** This High demand for fuel that is not offset by a more efficient refuelling system so that at certain times there is a buildup and vacancy, as well as a lack of standard distribution services that are some of the problems that exist in PT. XYZ. This research allocates routes and distribution schedules and determines the capacity and number of effective and efficient tank trucks to provide profit to the company. This research uses the savings matrix method, which is essentially a method to minimize distance or time or cost by taking into account existing constraints. The result of the calculation of the savings matrix method obtained fuel distribution in shift 1 has 30 routes, 2 has 28, and 3 is 25. Route 1 shift 1 includes refreshment stand, gas station 44,562.10 (A62), gas station 44,562.01 (A64), gas station 44,562.09 (A66), and return to refreshment stand with a total travel distance of 192 km with a required time of 6.4 hours with 64 litres of fuel, with a fuel cost of Rp 329,600.00. The result of the calculation of the savings matrix method obtained fuel distribution in shift 1 has 30 routes, 2 has 28, and 3 is 25. Route 1 shift 1 includes refreshment stand, gas station 44,562.10 (A62), gas station 44,562.01 (A64), gas station 44,562.09 (A66), and return to refreshment stand with a total travel distance of 192 km with a required time of 6.4 hours with 64 litres of fuel, with a fuel cost of Rp 329,600.00.

1. **Introduction**

When Increasingly sophisticated technology certainly has an impact on the development of a company, so each company is required to improve all aspects so that the company's profits also increase. Routes are said to be optimal if all channels can be consistent in different sales times and are not independent of profit allocation [1]. The parameters discussed are mileage, number of routes, and travel time [2]. One aspect that we should consider in achieving these goals is the distribution aspect. The proposed distribution determination can determine the route of the distribution channel achieved, the efficiency of time and distance, taking into account capacity and route [3]. Companies are required to determine specific routes that will serve specific customers, as well as the order in which they will visit to minimize the total distance travelled [4]. Some companies do not currently have a fixed or standard distribution line, the distribution channels obtained only based on interviews, or daily distribution are based solely on the order of the address list intended by the driver [3]. Errors in determining distribution channels and delays in product delivery may hinder the distribution of products from manufacturers to consumers, which can result in reduced or declining corporate profits and may also potentially cause harm to the company. Excellence in omnichannel distribution can achieve by expanding delivery mode, improving delivery speed, and service level [5]. One way to lower transportation costs is to streamline the distribution and use of existing modes of transportation. The growth of online purchasing services with direct delivery to customers makes distribution and transportation activities increasingly important, and the cost component of this activity is increasing in the supply chain. Supply Chain Management (SCM) handles the management of all activities from upstream to downstream to provide goods or services to end customers [1], [4]–[9]. Routes decided by suppliers affect the profits of all members of the supply chain [1], [4], [6]–[11]. Vehicle route problems generally aim to design routes that minimise transport costs [1], [2], [12]–[16], [17]–[26], [3], [27], [28], [4], [5]. The efficiency of the distribution system can do by determining the distribution route to minimize the total mileage, and the length of travel to optimize the use of capacity as well as the number of vehicles. This representation determines the batch and route of each vehicle in the distribution system and has three advantages.

First, each vector represents an actual delivery order, and this structure facilitates design for a simple and efficient environment. Second, given that decision-making about time exclude, this representation minimizes the relationship between production and distribution. Third, through the delivery time of each product, the start time (latest) to ship each work can be easily obtained [29]—some of the problems that exist in PT. XYZ, among others, the high amount of fuel demand is not offset by optimal fueling system so that at certain times it experiences buildup and emptiness. The study allocated routes and distribution schedules and determined the capacity and number of tank truck vehicles capable of minimizing mileage, length of travel, and transportation costs. Reducing the number of routes will reduce vehicle allocation costs and distribution transport costs [2]. With limited distance, efficiency will achieve at all costs [30]. Earliness on-demand delivery for a variety of reasons such as storage costs or human resource allocation can lead to customer dissatisfaction so that it can consider for orders delivered before maturity time [17]. Produce optimal departure routes so that they are more than useful, a new approach is developed for optimal design and allocation of departure routes [31]. Because different stakeholders may have other interests, so the allocation methods applied should be closely scrutinized [26]. Scheduling algorithms can be incorporated into the framework to resolve issues facing vehicles and crew as well as to optimize resource allocation within a certain period [28].

1. **Method**

Data processing begins by calculating the number of vehicles, cost, and distance for the initial condition of distribution of products which will be used as a comparison, after which the next calculation is done with the saving matrix method to get the results according to the pre-defined objectives. It can also be by calculating the proportional cost allocation used, which is based on each customer's distance to the depot or based on the product of each customer's request (load) and its reach to the depot [32]. The steps of data processing using the saving matrix method are as follows:

1. Identify the distance matrix from the refreshment stand to each gas station.
2. Calculate savings matrix by using formulas: Si,j = do,i + do,j – di,j.
3. Combine the two gas stations that produce the largest savings and check if the two gas stations can be serviced by the same vehicle or not.
4. Update the cells that have the largest saving value and calculate the total delivery volume.
5. Sort consumers in routes formed with the nearest insert and nearest neighbour.
6. **Results**

PT. XYZ has a distribution area of 178 gas stations. Table 1 is a list of gas stations supplied from XYZ fuel terminals as well as daily average fuel demand data for gas stations and distance data from refreshment stand to each gas station. The required data is as follows:

a. Data were filling sheed NGS.

b. Fueling time to tank car.

c. Some fleets are used.

d. Data Round Trip Hours (RTH)

e. Fuel Delivery Shift Data

**Table 1.** List of gas stations along with request data and distance from the refreshment stand.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| The Gas Station | Order | Distance |  | The Gas Station | Order | Distance |  | The Gas Station | Order | Distance |
| 4455516 | 8 | 2 |  | 4455609 | 24 | 23 |  | 4456121 | 24 | 48 |
| 4455714 | 8 | 5 |  | 4455709 | 8 | 24 |  | 4456105 | 8 | 50 |
| 4455207 | 40 | 5 |  | 4455204 | 24 | 25 |  | 4457425 | 8 | 51 |
| 4455506 | 8 | 11 |  | 4455517 | 8 | 26 |  | 4456118 | 8 | 58 |
| 4355218 | 16 | 15 |  | 4455713 | 24 | 27 |  | 4456103 | 8 | 55 |
| 4455711 | 16 | 15 |  | 4455708 | 8 | 27 |  | 4456206 | 8 | 63 |
| 4455528 | 8 | 16 |  | 4355715 | 8 | 25 |  | 4456504 | 8 | 61 |
| 4455103 | 8 | 16 |  | 4455534 | 8 | 25 |  | 4456216 | 16 | 68 |
| 4455530 | 8 | 17 |  | 4455507 | 16 | 28 |  | 4456202 | 16 | 69 |
| 4455111 | 8 | 17 |  | 4455702 | 8 | 29 |  | 4456212 | 8 | 59 |
| 4455118 | 8 | 18 |  | 4455512 | 8 | 25 |  | 4456204 | 16 | 68 |
| 4455523 | 8 | 18 |  | 4455525 | 40 | 31 |  | 4456213 | 16 | 73 |
| 4455209 | 8 | 18 |  | 4455501 | 16 | 31 |  | 4456203 | 8 | 74 |
| 4455707 | 8 | 18 |  | 4455521 | 8 | 32 |  | 4456208 | 8 | 75 |
| 4455509 | 8 | 19 |  | 4455533 | 8 | 26 |  | 4456205 | 8 | 80 |
| 4455502 | 8 | 20 |  | 4457416 | 8 | 37 |  | 4456207 | 8 | 83 |
| 4455505 | 16 | 20 |  | 4457401 | 8 | 37 |  | 4456210 | 8 | 81 |
| 4455803 | 16 | 20 |  | 4457411 | 8 | 43 |  | 4456214 | 24 | 86 |
| 4455602 | 16 | 21 |  | 4457419 | 8 | 35 |  | 4456201 | 16 | 83 |
| 4455508 | 8 | 21 |  | 4456104 | 40 | 48 |  | 4456211 | 16 | 91 |
| 4455217 | 16 | 22 |  | 4457404 | 8 | 46 |  | 4456209 | 8 | 96 |
| 4455110 | 8 | 22 |  | 4156101 | 16 | 52 |  | 4456215 | 8 | 77 |
| 4455518 | 16 | 23 |  |

From the determination of the order of the visit is obtained the schedule and delivery route as follows:

**Table 2.** Results of the Nearest Insert Shift Method.

| **Route With Nearest Insert Method** | | | | | | | **Order** | **Round Trip Distance** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|
| Route 1 | Refreshment stand | 4456210 | 4456201 | | 4456209 | Refreshment stand | 32 KL | 192 |
| Route 2 | Refreshment stand | 4456214 | | | | Refreshment stand | 24KL | 172 |
| Route 3 | Refreshment stand | 4456205 | 4456207 | | 4456211 | Refreshment stand | 32 KL | 184 |
| Route 4 | Refreshment stand | 4456204 | | 4456215 | | Refreshment stand | 24 KL | 154 |
| Route 5 | Refreshment stand | 4456213 | 4456208 | | 4456203 | Refreshment stand | 32 KL | 156,5 |
| Route 6 | Refreshment stand | 4456216 | | | | Refreshment stand | 16 KL | 136 |
| Route 7 | Refreshment stand | 4456212 | 4456206 | | 4456202 | Refreshment stand | 32 KL | 148,2 |
| Route 8 | Refreshment stand | 4156101 | | 4456103 | | Refreshment stand | 24 KL | 110,7 |
| Route 9 | Refreshment stand | 4456121 | | | | Refreshment stand | 24 KL | 96 |
| Route 10 | Refreshment stand | 4456104 | | | | Refreshment stand | 32 KL | 96 |
| Route 11 | Refreshment stand | 4456104 | 4456105 | 4456118 | 4456504 | Refreshment stand | 32 KL | 130 |
| Route 12 | Refreshment stand | 4457419 | | 4457425 | | Refreshment stand | 16 KL | 94,2 |
| Route 13 | Refreshment stand | 4457416 | 4457401 | 4457404 | 4457411 | Refreshment stand | 32 KL | 90,1 |
| Route 14 | Refreshment stand | 4455525 | | | | Refreshment stand | 32 KL | 62 |
| Route 15 | Refreshment stand | 4455533 | 4455501 | | 4455525 | Refreshment stand | 32 KL | 69,4 |
| Route 16 | Refreshment stand | 4455713 | | | | Refreshment stand | 24 KL | 54 |
| Route 17 | Refreshment stand | 4455609 | | | | Refreshment stand | 24 KL | 46 |
| Route 18 | Refreshment stand | 4455534 | 4455708 | 4455702 | 4455521 | Refreshment stand | 32 KL | 69,5 |
| Route 19 | Refreshment stand | 4455512 | | 4455507 | | Refreshment stand | 24 KL | 57,1 |
| Route 20 | Refreshment stand | 4455508 | 4455518 | | 4455517 | Refreshment stand | 32 KL | 52 |
| Route 21 | Refreshment stand | 4455803 | 4455709 | | 4355715 | Refreshment stand | 32 KL | 58,4 |
| Route 22 | Refreshment stand | 4455204 | | | | Refreshment stand | 24 KL | 50 |
| Route 23 | Refreshment stand | 4455209 | 4455505 | | 4455509 | Refreshment stand | 32 KL | 42 |
| Route 24 | Refreshment stand | 4455217 | | 4455110 | | Refreshment stand | 24 KL | 53 |
| Route 25 | Refreshment stand | 4455714 | | 4455602 | | Refreshment stand | 24 KL | 42 |
| Route 26 | Refreshment stand | 4355218 | 4455502 | | 4455523 | Refreshment stand | 32 KL | 47 |
| Route 27 | Refreshment stand | 4455711 | 4455103 | | 4455118 | Refreshment stand | 32 KL | 37,1 |
| Route 28 | Refreshment stand | 4455516 | 4455207 | 4455111 | 4455707 | Refreshment stand | 32 KL | 53,4 |
| Route 29 | Refreshment stand | 4455207 | | | | Refreshment stand | 32 KL | 10 |
| Route 30 | Refreshment stand | 4455506 | 4455528 | | 4455530 | Refreshment stand | 24 KL | 43,6 |

The next step is to calculate the travel time required in 1 fuel delivery route, to calculate the travel time then use the formula as follows :

w=j/k+wb+wt+wp (3)

w : time wb : unloading time

j : distance wt : waiting time

k : speed wp : charging time

Then the example of the calculation is as follows :

w=192/50+0,75+1.5+0.3 =6.39 jam

Furthermore, calculate the cost of fuel used in distributing fuel in one trip route. The fuel used by hauliers in distributing fuel is bio solar/B30 type which is a mixture of pure diesel 70% and Fame 30%, with the price per litre is Rp 5.150. In calculating the cost of such fuel by using the following formula:

Cost=L x Rp 5.150 (4)

L: Number of Liters used in distributing one travel route.

Then the example of the calculation is as follows :

Cost=64 x Rp 5.150 = Rp 329.600

1. **Conclusion**

Shift 1 has 30 routes, shift two as many as 28 ways, and shift three as many as 25 routes. With this, it can conclude that there has been a decrease in travel routes than before. The allocation of travel routes on route one shift 1 includes refreshment stand, gas station 44.562.10 (A62), gas station 44.562.01 (A64), gas station 44.562.09 (A6 6), and return to refreshment stand with a total return distance of 192 Km with a travel time of 6.4 hours with fuel spend of 64 Liters with a fuel cost of Rp 329.600.00.

1. **References**

[1] I. Moon and X. Feng, “Supply chain coordination with a single supplier and multiple retailers considering customer arrival times and route selection,” *Transp. Res. Part E Logist. Transp. Rev.*, vol. 106, pp. 78–97, 2017, doi: 10.1016/j.tre.2017.08.004.

[2] V. Sydneyta and Komarudin, “Optimization of distribution route and schedule with vehicle routing problem with time windows (VRPTW),” *ACM Int. Conf. Proceeding Ser.*, pp. 127–132, 2017, doi: 10.1145/3178264.3178287.

[3] H. Adianto, A. I. Riawan, and E. Susanto, “Determination of liquid product distribution route using clark and wright saving and tabu seacrh algorithm for a milk industry in indonesia,” *Int. J. Eng. Technol.*, vol. 7, no. 2, pp. 102–105, 2018, doi: 10.14419/ijet.v7i2.29.13138.

[4] M. F. Saeed Osman, “Capacitated transport vehicle routing for joint distribution in supply chain networks,” *Int. J. Supply Chain Manag.*, vol. 5, no. 1, pp. 25–32, 2016.

[5] C. Bayliss, L. do C. Martins, and A. A. Juan, “A two-phase local search with a discrete-event heuristic for the omnichannel vehicle routing problem,” *Comput. Ind. Eng.*, vol. 148, no. July, p. 106695, 2020, doi: 10.1016/j.cie.2020.106695.

[6] S. B. Ebrahimi, “A stochastic multi-objective location-allocation-routing problem for tire supply chain considering sustainability aspects and quantity discounts,” *J. Clean. Prod.*, vol. 198, pp. 704–720, 2018, doi: 10.1016/j.jclepro.2018.07.059.

[7] M. Ganji, H. Kazemipoor, S. M. Hadji Molana, and S. M. Sajadi, “A green multi-objective integrated scheduling of production and distribution with heterogeneous fleet vehicle routing and time windows,” *J. Clean. Prod.*, vol. 259, p. 120824, 2020, doi: 10.1016/j.jclepro.2020.120824.

[8] Sumadi, Jumintono, and F. Ardiani, “Supply chain brown sugar agroindustry in Banyuwangi district: Analysis study with a dynamic system approach,” *Int. J. Supply Chain Manag.*, vol. 9, no. 1, pp. 626–632, 2020.

[9] W. Zhang, Z. Chen, S. Zhang, W. Wang, S. Yang, and Y. Cai, “Composite multi-objective optimization on a new collaborative vehicle routing problem with shared carriers and depots,” *J. Clean. Prod.*, vol. 274, p. 122593, 2020, doi: 10.1016/j.jclepro.2020.122593.

[10] F. Hein and C. Almeder, “Quantitative insights into the integrated supply vehicle routing and production planning problem,” *Int. J. Prod. Econ.*, vol. 177, pp. 66–76, 2016, doi: 10.1016/j.ijpe.2016.04.014.

[11] L. Huang and J. Yang, “Location-distribution of cruise ship supply logistics distribution centre considering time window,” *Syst. Sci. Control Eng.*, vol. 7, no. 1, pp. 338–345, 2019, doi: 10.1080/21642583.2019.1674221.

[12] U. Tarigan, R. F. Sidabutar, U. P. P. Tarigan, and A. Chen, “Analysis of Optimal Transport Route Determination of Oil Palm Fresh Fruit Bunches from Plantation to Processing Factory,” *J. Phys. Conf. Ser.*, vol. 1007, no. 1, 2018, doi: 10.1088/1742-6596/1007/1/012028.

[13] I. Rizkya, N. Matondang, M. D. Yahya, and M. S. Ningsih, “Design of Distribution Routes Using Saving Matrix Method to Minimize Transportation Cost,” *ICSECC 2019 - Int. Conf. Sustain. Eng. Creat. Comput. New Idea, New Innov. Proc.*, pp. 48–51, 2019, doi: 10.1109/ICSECC.2019.8907004.

[14] J. Los, F. Schulte, M. T. J. Spaan, and R. R. Negenborn, “The value of information sharing for platform-based collaborative vehicle routing,” *Transp. Res. Part E Logist. Transp. Rev.*, vol. 141, no. April, p. 102011, 2020, doi: 10.1016/j.tre.2020.102011.

[15] D. Chen, Y. Ba, H. Qiu, J. Zhu, and Q. Wang, “ISRchain: Achieving efficient interdomain secure routing with blockchain,” *Comput. Electr. Eng.*, vol. 83, p. 106584, 2020, doi: 10.1016/j.compeleceng.2020.106584.

[16] J. Brandão, “A memory-based iterated local search algorithm for the multi-depot open vehicle routing problem,” *Eur. J. Oper. Res.*, vol. 284, pp. 559–571, 2020, doi: 10.1016/j.ejor.2020.01.008.

[17] R. Alizadeh Foroutan, J. Rezaeian, and I. Mahdavi, “Green vehicle routing and scheduling problem with heterogeneous fleet including reverse logistics in the form of collecting returned goods,” *Appl. Soft Comput. J.*, vol. 94, p. 106462, 2020, doi: 10.1016/j.asoc.2020.106462.

[18] S. P. Parvasi, M. Mahmoodjanloo, and M. Setak, “A bi-level school bus routing problem with bus stops selection and possibility of demand outsourcing,” *Appl. Soft Comput. J.*, vol. 61, pp. 222–238, 2017, doi: 10.1016/j.asoc.2017.08.018.

[19] F. M. Puspita, A. Meitrilova, and S. Yahdin, “Mathematical modelling of traveling salesman problem (TSP) by implementing simulated annealing and genetic algorithms,” *J. Phys. Conf. Ser.*, vol. 1480, no. 1, 2020, doi: 10.1088/1742-6596/1480/1/012029.

[20] X. Wei, H. Qiu, D. Wang, J. Duan, Y. Wang, and T. C. E. Cheng, “An integrated location-routing problem with post-disaster relief distribution,” *Comput. Ind. Eng.*, vol. 147, p. 106632, 2020, doi: 10.1016/j.cie.2020.106632.

[21] A. Soriano, T. Vidal, M. Gansterer, and K. Doerner, “The vehicle routing problem with arrival time diversification on a multigraph,” *Eur. J. Oper. Res.*, vol. 286, no. 2, pp. 564–575, 2020, doi: 10.1016/j.ejor.2020.03.061.

[22] H. Seyyedhasani, J. S. Dvorak, and E. Roemmele, “Routing algorithm selection for field coverage planning based on field shape and fleet size,” *Comput. Electron. Agric.*, vol. 156, no. December 2018, pp. 523–529, 2019, doi: 10.1016/j.compag.2018.12.002.

[23] F. Lehuédé, O. Péton, and F. Tricoire, “A lexicographic minimax approach to the vehicle routing problem with route balancing,” *Eur. J. Oper. Res.*, vol. 282, no. 1, pp. 129–147, 2020, doi: 10.1016/j.ejor.2019.09.010.

[24] V. C. G. Karels, L. P. Veelenturf, and T. Van Woensel, “An auction for collaborative vehicle routing: Models and algorithms,” *EURO J. Transp. Logist.*, vol. 9, no. 2, p. 100009, 2020, doi: 10.1016/j.ejtl.2020.100009.

[25] V. Ho-Huu, S. Hartjes, H. G. Visser, and R. Curran, “An optimization framework for route design and allocation of aircraft to multiple departure routes,” *Transp. Res. Part D Transp. Environ.*, vol. 76, no. October, pp. 273–288, 2019, doi: 10.1016/j.trd.2019.10.003.

[26] B. P. J. Leenders, J. C. Velázquez-Martínez, and J. C. Fransoo, “Emissions allocation in transportation routes,” *Transp. Res. Part D Transp. Environ.*, vol. 57, pp. 39–51, 2017, doi: 10.1016/j.trd.2017.08.016.

[27] S. Yoon and J. Kim, “Efficient multi-agent task allocation for collaborative route planning with multiple unmanned vehicles,” *IFAC-PapersOnLine*, vol. 50, no. 1, pp. 3580–3585, 2017, doi: 10.1016/j.ifacol.2017.08.686.

[28] G. E. Sánchez-Martínez, H. N. Koutsopoulos, and N. H. M. Wilson, “Optimal allocation of vehicles to bus routes using automatically collected data and simulation modelling,” *Res. Transp. Econ.*, vol. 59, pp. 268–276, 2016, doi: 10.1016/j.retrec.2016.06.003.

[29] J. Wang, S. Yao, J. Sheng, and H. Yang, “Minimizing total carbon emissions in an integrated machine scheduling and vehicle routing problem,” *J. Clean. Prod.*, vol. 229, pp. 1004–1017, 2019, doi: 10.1016/j.jclepro.2019.04.344.

[30] A. Almouhanna, C. L. Quintero-Araujo, J. Panadero, A. A. Juan, B. Khosravi, and D. Ouelhadj, “The location routing problem using electric vehicles with constrained distance,” *Comput. Oper. Res.*, vol. 115, p. 104864, 2020, doi: 10.1016/j.cor.2019.104864.

[31] V. Ho-Huu, S. Hartjes, H. G. Visser, and R. Curran, “Integrated design and allocation of optimal aircraft departure routes,” *Transp. Res. Part D Transp. Environ.*, vol. 63, no. October 2017, pp. 689–705, 2018, doi: 10.1016/j.trd.2018.07.006.

[32] H. Chen, “Cross-Evaluation Cost Allocation for Vehicle Routing Games,” *IFAC-PapersOnLine*, vol. 49, no. 12, pp. 1856–1861, 2016, doi: 10.1016/j.ifacol.2016.07.853.