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Vehicle Routing Problems for Blood Transport Delivery

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Abstract
The purpose of this study is to look into the Vehicle Routing Problem (VRP) for blood transportation delivery. The blood product delivery vehicle routes are designed with the primary target of decreasing the travel distance from the PDN to hospitals. The vehicle routingproblem (VRP) is a fleet of vehicles that design routes that start and end at a central depot after satisfying customer demands. The Clarke-Wright Saving Algorithm is used in this study as a simple and efficient methodology for research the vehicle routing problem with three types of data: cluster, random, and random cluster. The proposed algorithm for solving VRP with various types of data is coded in C++ numerical programming. According to the computational results, increasing the value of capacity constrained reduces the number of routes formed as well as the totaldistance travelled.

Keywords: Vehicle routing problem; Transportation; Clarke- Wright Saving Algorithm**;** C++ numerical programming.

1. Introduction

Blood is utilised in births, by-passes, general operations, and blood transplants, among other things. Furthermore, excessive on-site storage is not desirable because blood isa valuable item with a short shelf life. Blood cannot be produced outside of the human body. It's commonly taken in the form of whole blood. Red blood cells (RBCs), white blood cells (WBCs), platelets, and plasma are the four main blood products/components that can be separated from one unit of whole blood**.** The primary goal of a mobile blood collection systemis to increase the amount of blood collected. Blood donation logistics might be characterised as a medical supply transportation concern as a healthcare logistics issue. Even though bloodtransfusion is one of the most critical medical procedures, blood is a scarce resource.

Blood transfusion is a critical component of healthcare that can save the lives ofpeople who have been in accidents, need emergency treatment, or are undergoing trauma care. Every hospital nationwide requires approximately 2,000 units of 45o mL per unit of bloodper day, whereas hospitals in Klang Valley require 500 units per day (Shuib. and Ibrahim [4].

A blood product supply chain's general process is blood collection from volunteer donors at a blood centre or a mobile unit. Blood is then subjected to a stringent screening process to limit the danger of infectious illnesses such as HIV and viral hepatitis. Units from donors are screened and stored or extracted before being held at a blood centre after complying with all norms and regulations. According to a medical operations timetable, hospitals make an order with a blood centre. A crossmatch test is performed before a blood transfusion to ensure that the patient's blood is compatible with the donor's blood.

Bloodmobiles are motor vehicles (typically a bus or large vans) equipped with the essential equipment for blood donation. Bloodmobile blood drives are most often held to optimisation transportation of blood.

Ais unusual since blood is sensitive and should be treatedwith care. Blood quality may be maintained with knowledge of blood management and transportation.

The Vehicle Routing Problem (VRP) is one of the most commonly encountered optimisation issues in logistics. A fleet of vehicles operating out of a depot tries to reduce thecost of transportation operations. To deal with transportation for blood product distribution from the National Blood Centre (NBC) to hospitals, a Vehicle Routing Problem (VRP) was created[1].

Many studies on vehicle routing problems (VRP) have been conducted. The VRP plays a crucial role in the distribution system and logistics planning in many sectors, including blood transport delivery, garbage collection, and task sequentially; VRP can be defined as theproblem of finding the optimal routes to distribute the goods for several customers from one depot considering as vehicle capacity and distance travelled.

The Clarke-Wright algorithm is commonly implemented as a pure constructive heuristic without optimization. The Clarke-Wright (CW) savings concept is based on calculating savings for combining two customers into the same route. The CW is a well-knownheuristic for solving vehicle routing problems (VRP), and its applications have continued sinceits introduction in 1964.

2. Literature Review

2.1. Supply Chain Problems of Blood Products

According to Shuib and Ibrahim [4], the blood supply chain (BSC) problem is one of themost critical operations in the healthcare system. It may be classified as a logistical and transportation difficulty in maintaining blood supply sufficiency. Blood management is a complex system that necessitates the participation of numerous components. Mansur et al. [7] studied Blood Supply Chain Management (BSCM) is a series of interconnected blood management phases that include blood collection, production, inventory, and distribution. BSCM is an important research area due to its importance in human life. Blood management, on the other hand, has some distinct characteristics. Blood management is an issue that affects the entire human population. Despite technological advances in blood replacement, the need for donor blood and its derivative products will always exist. The blood supply chainis mainly demanded in research because it is essential in healthcare.

The blood supply chain also includes collecting, producing, and inventorying blood andits derivatives and distributing blood and its products from donors to receivers. According to Pirabán,. el. al [10], donors, mobile collection sites (CSS), blood centres (BCs), demand nodes, and patients are the five layers of the blood supply chain (BSC), which coordinates theflow of blood products from donors to patients. As a result, demand nodes include hospitals, clinics, and other transfusion facilities. Mobile CSS, BCs, and demand nodes must manage the six significant processes associated with blood donation: collection, testing, component processing, storage, distribution, and transfusion.

2.1.1. Process of Blood of Supply Chain

According to Taweeugsornpun and Raweewan [1], the beginning of the blood supply chain (BSC) starts with collecting, testing, processing, storage, distribution and transfusion. Figure 1 shows the general process of a blood product supply chain.

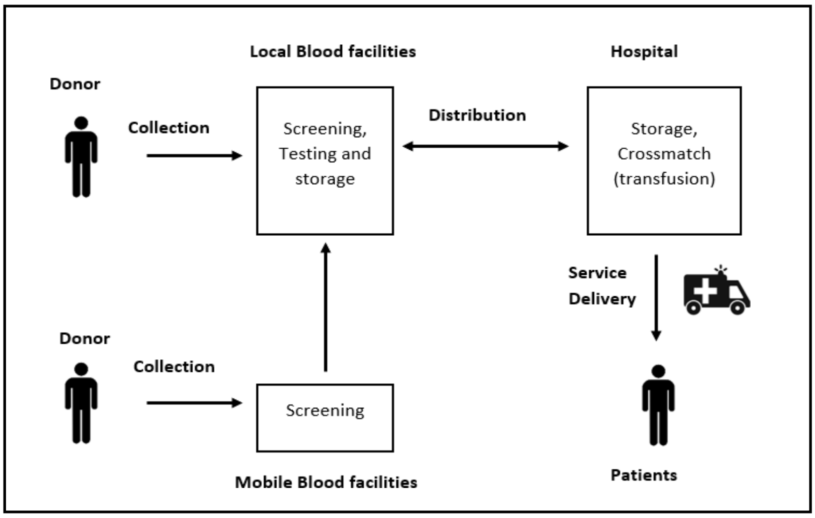

Figure 1 The general process of a blood product supply chain [1]

2.2 Transportation of Blood Products

Transportation is an integral part of logistics, with significant economic value in the production and delivery systems. Sahinyazan,et al. and Shuib, el. al. [3,4] studied that a tiny percentage improvement in fleet management could substantially save. The primary goal of amobile blood collection system is to increase the amount of blood collected. Bloodmobiles goon direct tours to various events to collect blood, but they return the collected blood to a specified depot to avoid spoilage at the end of each day. Transportation is an integral part of logistics, with significant economic value in the production and delivery systems. The NationalBlood Center (NBC) establishes blood product delivery vehicle routes to reduce travel time from the NBC to hospitals.

According to Taweeugsornpun and Raweewan [3], 3PL service providers in Thailand will replace ambulances with cars in a distribution system, allowing ambulances to be used more effectively in emergencies. An ambulance is designed to transport sick or injured peopleto and from hospitals. The third-party logistics supplier then gets the orders, organises them by pickup date, and operates a fleet of automobiles to design routes to several hospitals (patients). Shuib . and Ibrahim. [4] state that the Pusat Darah Negara Malaysia’s Pusat DarahNegara (PDN) collecting and processing. PDN's current procedure is to send staff and equipment in one vehicle. Other than that, several countries, including the United Kingdom, use motorcycles to transport blood products (see Figure 2).

Figure 2 Blood Runner or blood bike emergency vehicle in the UK

2.3 Vehicle Routing Problems

All vehicles must start and end at the exact location for a single depot vehicle route issue with a distance-dependent objective function Consequently, the Vehicle Routing Problem (VRP) is one of the most important and well-studied combinatorial optimisation problems. According to Toth and Vigo [14], the vehicle routing problem determines the optimalset of routes to be performed by a fleet of vehicles to serve a given location of customers. Morsheiov G. [16] stated that a fleet of cars from a single distribution centre that will service agroup of delivery customers with documented demands is also known as VRP. The objectiveof VRP is to minimise the total distance covered by the entire fleet.

The vehicle routing problem (VRP) determines a set of vehicle routes to perform all or some transportation requests with a given vehicle fleet at minimum cost. It is decided to handlethe vehicle which requests in which sequence so that all vehicle routes can be feasibly executed. To solve the Vehicle Routing Problem (VRP), use specialist transportation management and supply-chain coordination to identify a set of courses at the lowest possiblecost that meets all customer demand. Other than that, most real-world applications of VehicleRouting Problem (VRP), such as school bus routing, garbage truck routing and bloodtransportation routing, are solved by several mathematical models to find the optimal solution.Classical VRP aims for routes that begin and end at the depot and meet the constraint that allcustomers must be served precisely once.

2.3.1 Characteristics and Components of VRP

Toth and Vigo [22] stated that several main components need to be considered for characteristics of the routing and scheduling problems. The main features of VRP are road network, customers, depots, vehicles, drivers and operational constraints.

2.3.2 Type of Vehicle Routing Problems

Several important VRPs are Capacitated Vehicle Route Problem (CVRP), Vehicle Routing Problem with Backhauls (VRPB), Vehicle Routing Problem with Time Window (VRPTW), and Vehicle Routing Pick up and Delivery (VRPPD). Some VRPs are a combinationsuch as Vehicle Routing Problem with Backhauls and Time Window (VRPBTW) and Vehicle Routing Pick Up and Delivery and Time Window (VRPPDTW) can be made to form more.

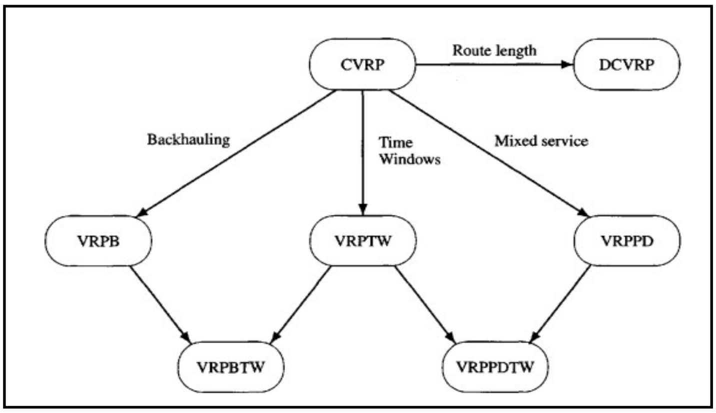

Figure 3 Important Variants of VRP and Their interconnections [22]

3. Methodology

3.1. Clarke-Wright Saving Algorithm

According to Pichpibul . and Kawtummachai[26], the Clarke-Wright (CW) concept is based on the calculation of savings for combining two customers into the same route. The Clarke Wright saving algorithm is a well-known heuristic for addressing the vehicle routing problem (VRP), and it has been used since its initial implementation in 1964 [17,18]. There are two versions of CW: sequential and parallel. Only one route is expanded in the sequentialversion until no more routes can be merged, whereas several routes can be constructed in parallel in the parallel version. Figure 4 presents the flow of the Clarke -Wright saving algorithms with sequential and parallel versions.

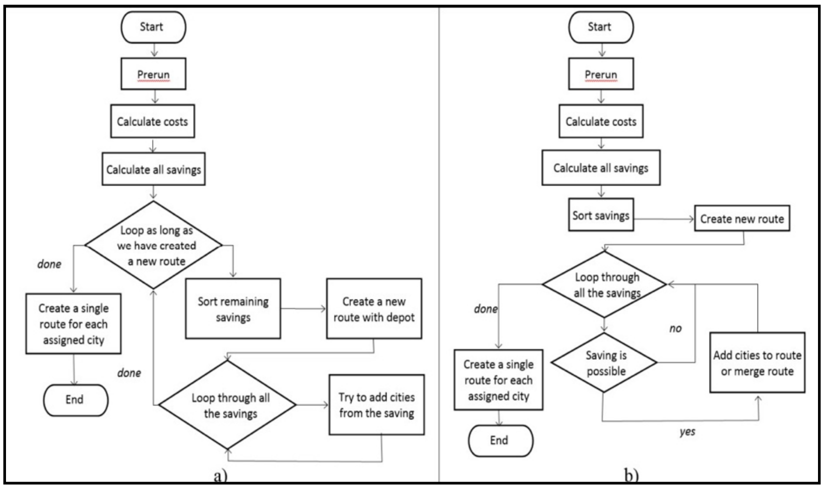

Figure 4 The flow of the Clarke -Wright saving algorithms for sequential and parallel versions.[28]

3.2. Description Clarke-Wright Saving Algorithm

According to Pamosoaji,. et al. [27], the CW saving algorithm is to find the route that maximises the accumulation of saving distance. This algorithm can be divided into the following steps. A distance matrix consisting of the distance between any nodes then is constructed, followed by a distance saving matrix. This algorithm step was published in the journal by Pichpibul., and Kawtummachai, [26]. The distance matrix (di,j) is first calculated in the general version :

$$d_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

i. xi , yi and xj, yj are the geographical locations of customer *i* and *j*

ii. The saving value between customer *i* and *j* is calculated

$$si,j = d1,i + dj,1 - di,j$$

Here, $d1,i$ is the travelling distance between depot 1 and customer *i*

iii. All savings values are sorted in decreasing order. Beginning with the topmost entry in the list which the largest si,j

iv. Starting from the top of the saving list, CW includes a link (*i,j*) in a route if no route constraints will be violated through the inclusion of customer *i* and *j* in that route

4. Results and discussion

4.1 Computational Results

Three types of data are solved in the research: clustered, random, and random clustered. The three types of data are from the Gehring and Homberger benchmarks.

4.1.1 Clustered data

The first data set chosen for analysis is the clustered data set, which includes 50 customers and a depot. Clustered refers to a group of people or things that stand or grow close together. Thus, clustered data is used to investigate VRP in congested areas so that each vehicle can meet customer demand without capacity constraints.

Table 1 Solutions of Clustered Data

Vehicle Capacity (Units)	Number of Routes	Average Number of Customers	Total Distance (Units)
100	11	5	4268.20
150	8	6	4163.11

Table 1 provides a comparison for clustered data with the capacity constraints. The average number of customers for each route increases, and fewer routes are used to meet all customer demands. However, as the value of vehicle capacity increases, the number of routes and total distance travelled are decreases. The reason for this is that a larger vehicle can transport more goods to be distributed to customers.

4.1.1 Random data

The following is random data, which includes a depot and 50 customers. Random data is appropriate for investigating the VRP in rural areas where every customer demand can be met while considering distance and capacity constraints.

Table 2 Solutions of Random Data

Vehicle Capacity (Units)	Number of Routes	Average Number of Customers	Total Distance (Units)
100	9	6	4040.09
150	6	8	3991.43

Table 2 above shows the results obtained by using vehicle capacity that are set on every vehicle in order to satisfy the customer demands. However, the increasing value of capacity constraint at the will minimize the number of vehicle routes formed by minimizing the number of customers that can be added into a route. Similar to clustered data, the increase the maximum capacity of the vehicle, the total distance travelled decreases.

4.1.1 Random Clustered data

The combination of random and clustered data is known as random-clustered data. Generally, this data type can be found in developing areas where people gather around facilities.

Table 3 Solutions of Random Clustered Data

Vehicle Capacity (Units)	Number of Routes	Average Number of Customers	Total Distance (Units)
100	9	6	3847.07
150	7	7	3779.46

Table 3 above shows the results obtained by using different vehicle capacity that are set on every vehicle in order to satisfy the customer demands. The increase of vehicle capacity will reduce the number of routes formed as well as the total distance travelled by the vehicles. The average number of customers per routes increases and fewer routes will be used to satisfy all the customer demands. While the total distance travelled has a tendency to decreased.

4.2 Result Comparison

After obtaining the solution for three different types of data with different values of capacity constraints, there some comparisons that can be made for these three data based on the vehicle capacity, number of routes, average number of customers and total distance travelled. The solutions are tabulated in

Table 4.

Table 4 Comparison of solutions between different types of data

Case	Vehicle Capacity (units)	Number of routes	Average number of customers	Total distance travelled
Clustered Data	100	11	5	4268.20
	150	8	6	4163.11
Random Data	100	9	6	4040.09
	150	6	8	3991.43
Random Clustered Data	100	9	6	3847.07
	150	7	7	3779.46

Table 4 shows that random clustered data with 150 units of vehicle capacity has the smallest total distance travelled with 3779.46 units and the number of routes is 7. Then followed by clustered data using 150 units of vehicle capacity is higher with 4268.20 units for total distance travelled than others. Therefore, it can conclude as the Clarke-Wright saving algorithm for VRP case is suitable for cluster data.

Conclusion

The value of capacity vehicle constraints influenced the total number of routes built and the total distance travelled. In general, the total distance travelled and the number of routes produced decrease as capacity constraints increase. The Clarke-Wright saving algorithm was used to generate a feasible solution for VRP with a single depot.

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References

[1] Taweeugsornpun, N., & Raweewan, M. (2017). Vehicle Routing for Blood Product Delivery Panyapiwat journal, 9, 230-243. retrieved from https://so05.tci-thaijo.org/index.php/pimjournal/article/view/107415
[2] Hardwick, J. (2008). Blood processing. ISBT Science Series, 3(2), 148–176. https://doi.org/10.1111/j.1751-2824.2008.00195.x
[3] Şahinyazan, F. G., Kara, B. Y., & Taner, M. R. (2015). Selective vehicle routing for a mobile blood donation system. European Journal of Operational Research, 245(1), 22–34. https://doi.org/10.1016/j.ejor.2015.03.007
[4] Shuib, A., & Ibrahim, P. M. (2021). a mixed integer goal programming (migp) model for donated blood transportation problem – a preliminary study. malaysian journal of computing, 6(2), 835. https://doi.org/10.24191/mjoc.v6i2.10751
[5] Yakushiji, F., Yakushiji, K., Murata, M., Hiroi, N., & Fujita, H. (2021). Blood transportation using multi-vehicle systems; optimal blood transport temperature in hemolysis. Hematology & Transfusion International Journal, 9(1). https://doi.org/10.15406/htij.2021.09.00243
[6] Gunpinar, S., & Centeno, G. (2016). An integer programming approach to the bloodmobile routing problem. Transportation Research Part E: Logistics and Transportation Review, 86, 94–115. https://doi.org/10.1016/j.tre.2015.12.005
[7] Mansur, A., Vanany, I., & Indah Arvitrida, N. (2018). Challenge and opportunity research in blood supply chain management: A literature review. MATEC Web of Conferences, 154, 01092. https://doi.org/10.1051/matecconf/201815401092
[8] Belien, J., & Forcé, H. (2011). Supply Chain Management of Blood Products: A literature review. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.1974803
[9] Ghatreh Samani, M. R., Torabi, S. A., & Hosseini-Motlagh, S.-M. (2018). Integrated Blood Supply Chain Planning for Disaster Relief. International Journal of Disaster Risk Reduction, 27, 168–188. https://doi.org/10.1016/j.ijdrr.2017.10.005
[10] Pirabán, A., Guerrero, W. J., & Labadie, N. (2019). Survey on Blood Supply Chain Management:

Models and methods. Computers & Operations Research, 112, 104756. https://doi.org/10.1016/j.cor.2019.07.014
[11] Chaiwuttisak, P., Smith, H., Wu, Y., Potts, C., Sakuldamrongpanich, T., & Pathomsiri, S. (2016). Location of low-cost blood collection and distribution centres in Thailand. Operations Research for Health Care, 9, 7–15. https://doi.org/10.1016/j.orhc.2016.02.001
[12] Rabbani, M., Aghabegloo, M., & Farrokhi-Asl, H. (2017). Solving a bi-objective mathematical programming model for Bloodmobiles location routing problem. International Journal of Industrial Engineering Computations, 19–32. https://doi.org/10.5267/j.ijiec.2016.7.005
[13] Özener, O. Ö., & Ekici, A. (2018). Managing platelet supply through improved routing of Blood Collection Vehicles. Computers & Operations Research, 98, 113–126. https://doi.org/10.1016/j.cor.2018.05.011
[14] Toth, P., & Vigo, D. (2002). The vehicle routing problem. Society for industrial and applied mathematics.
[15] Ganesh, K., & Narendran, T. T. (2007). Cloves: A cluster-and-search heuristic to solve the vehicle routing problem with delivery and pick-up. European Journal of Operational Research, 178(3), 699–717. https://doi.org/10.1016/j.ejor.2006.01.037
[16] Mosheiov, G. (1998). Vehicle routing with pick-up and delivery: Tour-partitioning heuristics. Computers & Industrial Engineering, 34(3), 669–684. https://doi.org/10.1016/s0360-8352(97)00275-1
[17] Vehicle routing problem. (n.d.). Retrieved January 25, 2022, from https://neo.lcc.uma.es/vrp/solution-methods/heuristics/savings-algorithms/
[18] Pichpibul, T., & Kawtummachai, R. (2013). A heuristic approach based on Clarke-Wright algorithm for Open Vehicle Routing Problem. The Scientific World Journal, 2013, 1– 11. https://doi.org/10.1155/2013/874349
[19] Mladenović, N., & Hansen, P. (1997). Variable neighborhood search. Computers & Operations Research, 24(11), 1097–1100. https://doi.org/10.1016/s0305-0548(97)00031-2
[20] Ai, T. J., & Kachitvichyanukul, V. (2009). Particle swarm optimization and two solution representations for solving the capacitated vehicle routing problem. Computers & Industrial Engineering, 56(1), 380–387. https://doi.org/10.1016/j.cie.2008.06.012
[21] Lin, S. W., Lee, Z. J., Ying, K. C., & Lee, C. Y. (2009). Applying hybrid meta-heuristics for capacitated vehicle routing problem. Expert Systems with Applications, 36(2), 1505– 1512. https://doi.org/10.1016/j.eswa.2007.11.060
[22] Toth, P., & Vigo, D. (2002). Models, relaxations and exact approaches for the capacitated vehicle routing problem. Discrete Applied Mathematics, 123(1–3), 487–512. https://doi.org/10.1016/s0166-218x(01)00351-1
[23] Wade, A., & Salhi, S. (2002). An investigation into a new class of vehicle routing problem with backhauls. Omega, 30(6), 479–487. https://doi.org/10.1016/s0305- 0483(02)00056-7
[24] Baldacci, R., Mingozzi, A., & Roberti, R. (2012). Recent exact algorithms for solving the vehicle routing problem under capacity and time window constraints. European Journal of Operational Research, 218(1), 1–6. https://doi.org/10.1016/j.ejor.2011.07.037
[25] Or, I., & Pierskalla, W. P. (1979). A Transportation Location-Allocation Model for Regional Blood Banking. A I I E Transactions, 11(2), 86–95. https://doi.org/10.1080/05695557908974447
[26] Pichpibul, T., & Kawtummachai, R. (2012). An improved Clarke and Wright savings algorithm for the capacitated vehicle routing problem. ScienceAsia, 38(3), 307. https://doi.org/10.2306/scienceasia1513-1874.2012.38.307