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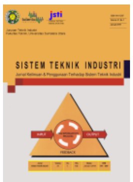

Application of Saving Matrix Approach for Minimize Distribution Cost and Route Optimization: A Literature Review

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Abstract. The objective of this research is to review the application of the savings method, to obtain optimal distribution routes. Data collection and observation of this literature review were obtained from scientific publications that were published from 2014 to 2022. The main purpose of this review study is to investigate, discuss, analyze, and the existence of various types of distribution routes problems and their solving methods. The application of the research methodology resulted in 20 articles, which aimed to identify the saving algorithms used, over the last decade. As a result, these articles were reviewed and selected using a table for further analysis This paper also presents the results of a quantitative and qualitative literature review and discusses scientific publications that have had a significant impact on logistics companies. Finally, findings show that using the savings matrix method, it is proven that this method generates a better route distribution.

Keyword: Cost, Distribution Routes, Matrix, Saving Algorithm, Transportation,

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1. Introduction

Logistics management has become the strategic element in the business world today, within it, the distribution subsystem stands out due to its impact on customers and economic importance [1]. In the context of the supply and/or distribution process, the design of routes in an optimal way has generated competitive advantages, in addition to motivating the researcher to propose routing models that improve logistics performance.

One of the biggest challenges for logistics companies is to save time and money when developing their operations. In particular, optimizing time is essential for those organizations that make last-mile shipments. The more it is possible to save time in transportation and distribution, the shorter the lead time will be from the moment the customer makes a purchase until the moment the product is delivered to his or her address [2]

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The planning of last-mile delivery routes makes it possible to identify which are the most optimal routes to carry out a shipment, considering them as "optimal" when analyzing all those variables that may affect time management and delivery speed. For example, levels of traffic on the roads, conditions for the passability of the roads, conglomerations of people in certain places, etc [3]. In this sense, by analyzing these factors and planning routes based on them, companies achieve significant savings in time and money. They save time because they can reduce delivery times, and with this they can serve more customers during the day. They save money because, by choosing the most appropriate routes, transport units cover fewer kilometers, consume less fuel, carriers are available faster, etc [4].

The transportation method is a unique application of linear programming whose objective is to determine the transportation scheme that minimizes its total cost, given the unit costs from origin i to destination j. In addition, it is known that the product is available in a certain quantity bi in each of the m origins, and it is necessary that it be taken to each of the n possible destinations in a quantity demanded dj [5]. Transportation is a key decision area in the logistics mix. Except for the cost of acquisitions, transportation absorbs, on average, a higher percentage of logistics costs than any other logistics activity. Although transportation decisions are expressed in a variety of ways, the primary ones are mode selection, route design, vehicle scheduling, and shipment consolidation [6].

Over time, different algorithms and techniques have been designed to help decision-makers determine what the appropriate route should be to make shipments since these can become quite complex when certain limitations such as capacity are added. of the vehicle, both in weight and volume, the maximum driving time, the speed limits of the roads, and driver breaks, among others [7] To try to solve these complex problems, different methods have been created and these generally represent the transport routing through a graph where there are arcs and nodes each of these must have an associated cost and it is necessary to determine the route that minimizes these costs [8]

The algorithm successively combines sub routes until the final route is obtained. The considered sub routes have a common city called the base. The procedure for joining different sub routes is based on eliminating the edges that connect two cities of different sub routes with the base city, subsequently joining the cities together[9]. Savings is known as the difference in cost between the edges removed and the one added. What it intends is to minimize the sum of the distances of the sections of the complete route that allows all the cities to be traveled starting from a city of origin [10]

The savings method makes it possible to identify the most convenient route assignment for the company [11] Savings method: The savings valuation method has stood out through the years as being flexible enough to handle a wide range of practical constraints, being relatively quick to compute on a computer for problems with a moderate number of stops, and capable of generate solutions that are close to optimum[12]. Comparisons with the optimal results of small problems, with a limited number of constraints, have shown that the "savings" method valuation yields solutions that are, on average, within 2% of the optimum.

The method can handle many practical constraints, mainly because it is capable of forming routes and ordering stops on routes simultaneously [13] The objective of the savings method is to minimize the total distance traveled by all vehicles and indirectly minimize the number of vehicles needed to service all stops [14]. This method calculates the costs of each route and simultaneously calculates the savings obtained taking into account the restrictions imposed. As the algorithm finds the greatest savings and meets the restrictions, the delivery route is created [15].

In its simplest form seeks to solve the problem of the distribution of products and/or services, designing routes that meet the demand of geographically dispersed customers from a warehouse using a homogeneous fleet of vehicles the problem of distribution from warehouses to users or consumers plays a preponderant role in the management of some transport systems and their adequate planning its objective is to minimize the cost of the routes, each vehicle serves a single route during the period of planning, having this to start and end in a central warehouse, to serve a set of customers with known demands [15].

To this end, the main objective of this paper is to review the concepts and methods of vehicle routing problems with various case studies and the methods that are applied in logistics or transportation companies. This study is structured with a theoretical basis, methodology, results and discussion, and finally the conclusions. In addition, this study constructs a comprehensive analysis of the previous study about the implementation of the savings algorithm method by collecting and critically reviewing previous research using a systematic literature review. Some case studies apply in logistics and transportation is considered.

2. Theoritical Basis

2.1. Vehicle Routing Problems

The vehicle routing problem (VRP) consists of obtaining groupings of the shortest possible routes, using a minimum number of vehicles, starting from a starting point (warehouse) and successively returning to it, supplying a number of customers that are they are geographically distributed, considering that each fleet has its maximum capacity and the amount of product demanded by customers is different [11]. In terms of graph theory, the VRP consists of determining a set “m” of routes with the minimum total cost, starting and ending at depot $V0$, such that each vertex Vij ∈ V is visited exactly once by a vehicle and the amount total product delivered on each route does not exceed the Q capacity of the vehicle serving the route[4].

2.2. Route Planning Methods

A. Saving Algorithm Method

In 1964 Clarke and Wright released their algorithm, also known as the savings method, which; Being the most significant heuristic to carry out the resolution of VRP-type problems (Vehicle Route Problems) [13]. It is a central depot and an unlimited number of vehicles to meet the known demand of a number of customers, the objective being to find the routes that these vehicles must take so that the costs are minimal and the demand is satisfied [15].

The Clarke and Wright Savings Algorithm is one of the most popular techniques to solve VRP through heuristics, it consists of the principle of combining a solution from two different routes to form a new route [16]. the Clarke & Wright VRP method to minimize total travel distances under the restriction of total customer demands, resulting in rapid savings in vehicle distances traveled, coupled with this. [10] in their research uses the VRP method to solve distribution problems, obtaining a good solution to the problem in a reasonable execution time. Figure 1 shows an example of the savings method before and after being joined:

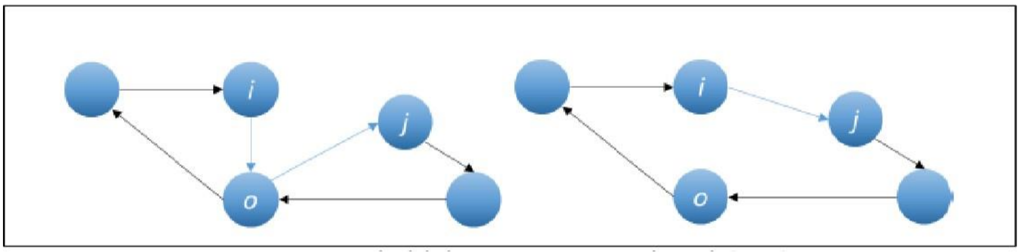

Figure 1 Saving Method Before and After

The Clark and Wright model was used because it allows establishing routes for the distribution of the products from the Logistics Operator to each of the clients, taking into account the sections that generate the greatest savings in the distances traveled which allow routes to be established with shorter distances to travel and therefore lower times and costs [17]

The Clarke and Wright model has been one of the most widely implemented algorithms to solve VRP in general [9], which consists of performing a limited exploration of the search space and giving a solution of acceptable quality in a moderate amount of time. The algorithm is developed starting from a solution with two routes (0,.., i,…,0) and (0,…, j,…,0), which can be combined thus generating a single route (0,… , i, j,…,0) as shown below [9]:

Saving algorithm is calculated using the following equation S (x,y) = J (G,x) + J (G,y) - J (x,y) where J is defined as the distance, G as the warehouse, x as the first outlet, y as the second outlet, S(a,b) as the savings distance, d(G,a) as the cost from warehouse to first outlet, d(0,b) as the cost from warehouse to second outlet and d(a,b) as the cost form first outlet to second outlet.

The algorithm starts from an initial solution and performs the connections that generate the greatest savings as long as it complies with the restrictions outlined in the problem. To use this method, it is necessary to know the costs or the distances that exist between the different nodes, that is, the cost of each path [18]. This method can be implemented in two ways, the first is parallel, that is, when all the nodes are used in the construction of all the routes, simultaneously, and the second is sequential, which refers to the construction of the routes one by one. The saving matrix helps us to find the maximum value between two nodes, and it is read from row to column Tutive. Through this matrix, we can obtain the value that is being saved in each of the different combinations of the different clients for the creation of optimal distribution routes [17]

B. The various of saving algorithm version

Savings algorithm parallel version, the steps for building the solution in the parallel version are [19]:

- Step 1 (initialization) for each client i build the route (i, 1).
- Step 2 (savings calculation) calculate Sij for each pair of customers i and j.
- Step 3 (better union). Let Si*j* = Max Sij, where the maximum is taken among the savings that have not yet been considered. Let r i* and r j* be the routes that contain clients i* and j* respectively. If i* is the last customer of r i* and i* is the first customer of r j* and the combination of r i* and r j* is feasible, combine them.
- Step 4 Eliminate Si*j* from further consideration. If there are savings to examine go to step 3, if not finish.

Savings algorithm sequential version, the steps for building the solution in the sequential version are [19]

- Step 1 (initialization) for each client i build the route (1, i, 1).
- Step 2 (savings calculation) calculate Sij for each pair of customers i and j.
- Step 3 (selection) add the arc (i, j) that has not been considered to the current path and that meets the constraints, or if clients i, j are at the end of the path.
- Step 4 (extension) let (0, i,…, j, 0) be the current path. If there are no savings in i or j go back to step 3, and repeat it until more arcs can be added, choosing the arc with the greatest savings.
- Step 5 Perform steps 3 and 4 until it is not possible to add more arcs to the path.

3. Research Methodology

The main purpose of this paper is to review the literature of saving algorithm method from various previous studies, particularly one of the most significant steps of this paper is to define the context of the review based on case study. Mostly, the factors that need to be studied are the techniques used. To record the articles, tables were used in this research This paper emphases on themes aimed at developing the theoretical concept, literature as well as case studies take into consideration.

It should be noted in this study, although the identified methods were used during the screening process, the number of publications is large enough that it was not possible to analyze all articles, and in particular, this paper analyzes several previous studies focused on distribution, routes and the method to solve the transportation and/or routing problems. Figure 2 shows the methodology of this paper, as follows:

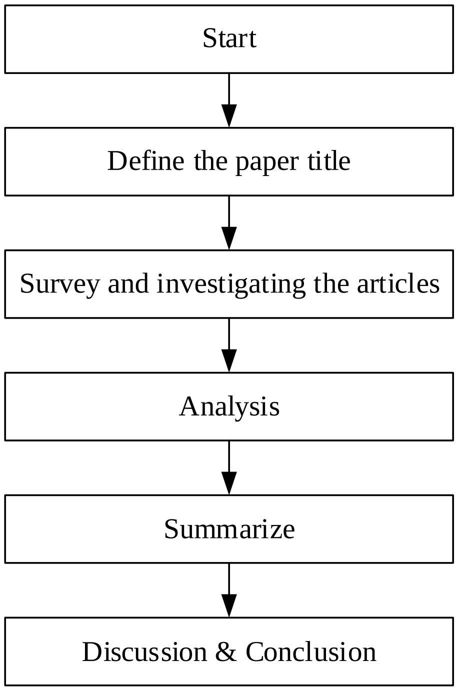

Figure 2 Methodology of Literature review

It should be noticed that while the saving algorithm method was used for the period of the selection process, the number of papers was large enough to investigate all papers, and, in noteworthy, the authors analyzed the article focused on the saving algorithm method by Clarke and Wright. We restricted the literature reviewed to only relevant articles published in Indonesian dan English language journals will be considered, i.e. conference proceedings and international journals are excluded. of the field. As a result, these articles were reviewed and selected using a table for further analysis.

4. Identified of Machine Learning Applications on Previous Literature

Seventeen case study associated to the route saving algorithm has reviewed for further analyzed and are reviewed in Table 1, and summarizes the analysis of the saving algorithm applied in various topics/fields.

Table 1 Surveys on Saving Algorithm and Its Application on Routing Problems

References	Identified method & Variables	Purposed Applied on
[20] Hu, Mo, and Ma(2018)	Method: Clarke-Wright (CW) Saving Algorithm, ParticleSwarm Optimization (PSO),Record to Record (RTR) travel algorithm. Variables: Transportation and inventory costs, cost of picking up and stocking.	This research proposed an optimization of vehicle routing involving pickup based on multibatch production.
[21]Tenahua, Olivares, Sánchez and Caballero (2018)	Method: Clarke-Wright (CW) Saving Algorithm, IteratedLocal Search (ILS). Variables: Cost of Travel, theDistances travelled, Vehiclecapacity, Transit time, and Fuel.	This study presents a methodologyfor solving the Periodic VehicleRouting Problem with an Iterated Local Search Metaheuristic. Inaddition, to know the efficiency ofthe results, Tenahua, et al benchmark Cordeau's examplewith respect to total travel distance and time.
[17] Halim and Yoanita (2015)	Method: Clarke-Wright (CW) Saving Algorithm, Capacitated Vehicle Routing Problems (CVRP). Variables: Total traveling cost, geographical area, Vehicle's capacity, Demand of customer.	This paper modeled the distribution of a single type of products, which are distributed from two depots and use N-vehicles.
[19] Pichpibul and Kawtummachai (2013)	Method: Clarke-Wright (CW) Saving Algorithm, VehicleRouting Problem (VRP), Sequential Insertion Algorithm Method. Variables: Customer Data andDrug Product Requests,	Pichpibul and Kawtummachai proposed a heuristic approach based on the Clarke-Wright (CW)algorithm to solve an open versionof the well-known capacity vehiclerouting problem where vehicles donot need to return to the depot after completing a service. The proposed CW was presented in four procedures consisting of Clarke-Wright formula modification, open route construction, two-route selection, and route post-improvement.
[8] Rohandi, Imran, and Prassetiyo (2014)	Method: Clarke-Wright (CW) Saving Algorithm, Capacitated Vehicle Routing Problems (CVRP). Variables: Pickup and Delivery time, Customer locations and Demands, Mileage, Speed and capacity of the car, Travel time, Loading time, Driver's working hours.	Rohandi et.al conducted research to solve determining the distribution route of drug productsfrom distributors to customers, andalso the delays time of product distribution and there were some customers who were not servedwithin a week of distribution.
[22] Octora, Imran, and Susanty (2014).	- Method: Clarke-Wright (CW) Saving Algorithm, VehicleRouting Problem (VRP), Sequential Insertion Algorithm Method. - Variables: Pickup and Delivery time, Customer locations and Demands, Mileage, Speed and capacity of the car, Travel time, - Loading time, Driver's working hours.	They research determined the distribution path of Mayora's product using the Clarke & WrightSavings Algorithm and theSequential Insertion Algorithm.
[23] Ramadanti, susanty and Adianto (2014)	- Method: Clarke-Wright (CW) Saving Algorithm, Vehicle Routing Problem (VRP).	The research is conducted by comparing the path of the research results and the current

	- Variables: Cost, Time, Fuel consumption, Logistics components, Distribution route data, Warehouse and Agent location data, Company policy data, Agent needs data, Transportation equipment data.	path of the company. Their research expected able to minimize mileage, optimize the use of vehicle capacity and minimize transportation costs.
[24] Liu, J., Liu, W. and Liu, Y (2014).	- Method: Clarke-Wright (CW) Saving Algorithm, Multi- dynamic Saving Algorithm. - Variables: Road distance, Transport routes, Transport costs, Distribution cost.	This study used Savings Algorithms to optimize vehicle and resource routing, on this basis, propose innovative improvements with Savings Algorithms and then use them in each SF distribution center to form "multi-dynamic" type Savings Algorithms to ensure cost savings and timeliness

5. Results and Discussions

To deepen knowledge of the works identified in Table 1, key points from the research conducted from several previous studies are described as follows:

Hu, Mo, and Ma [20] established a model for joint optimization of raw material pickup and vehicle routing problems involving a pickup. It aimed to reduce transportation and inventory costs. They built a structure for the routes in such a way that each route starts and ends at the manufacturer; meets all collection demands; a supplier is visited only by a single vehicle, and the sum of vehicle inventory and transportation costs is minimized. For the solution, the Clarke and Wright algorithm was used to generate the initial route of the vehicle for the problem of the first stage. First, it produced the shortest route between every two suppliers in the system to assign loads to vehicles in such a way that all raw materials are assigned and the total mileage covered is minimal.

Tenahua, Olivares, Sánchez and Caballero [21] presented a methodology to solve the periodic vehicle routing problem (PVRP) with an iterated local search (ILS) metaheuristic. They solved the problem in two phases: the first step is to assign visiting days to each client, and the second step is to determine the routes that each vehicle must take each day. The heuristic for this improvement was to use the Clarke and Wright heuristic.

Halim and Yoanita [17] proposed to combine the Clarke and Wright saving algorithm with the clustering algorithm. They modeled the distribution of a single type of products, which are distributed from two warehouses and use N-vehicles. They used the Clarke and Wright savings algorithm (CWSA) to solve the case. The company first receives the order from customers daily, and every evening they arrange the distribution of the order for each day for the next day. To solve the problem, they clustered the data based on latitude and longitude for each address, then adjusted the cluster based on the maximum order in each cluster that was built through the algorithms. They then routed the distribution based on CWS algorithms. Finally, they measured the distance from the center of each group to each deposit. Those groups were classified into two groups, based on the closest distance to the selected deposit. They considered that each client is visited once and the total demand cannot exceed the capacity of the vehicle.

Pichpibul and Kawtummachai [19] proposed a heuristic approach based on the Clarke- Wright (CW) algorithm to solve the trained vehicle routing problem in which vehicles are not required to return to the depot after completing service. The proposed algorithm has been presented in four procedures composed of Clarke-Wright formula modification, open path construction, two-phase selection, and post-path improvement. As a result, they indicated that their approach is competitive. In addition, it also generates the best-known solutions in 97% of all cases. They proposed a heuristic approach based on the Clarke-Wright (CW) algorithm to solve the open version of the well-known trained vehicle routing problem in which vehicles are not required to return to the depot after completing service. The proposed CW has been presented in four procedures composed of the modification of the Clarke-Wright formula, the open route construction, the two-phase selection, and the subsequent improvement of the route. As a result, they showed that the proposed CW is competitive and surpasses the classic CW in all directions. Furthermore, the best-known solution is also obtained in 97% of the tested cases (60 out of 62).

Rohandi, Imran, and Prassetiyo [8] solved the problem of vehicle routing of the distributor of pharmaceutical companies PT X in Bandung. Because you had trouble determining the optimal distribution route for medical products, from the distributor to the customer. Delays often occurred during product distribution, and some customers did not receive service within a week of distribution. The route that was used to do was based on the experience and intuition of the driver, therefore it was less effective and efficient. This problem was solved by two methods, Sequential Insertion and Clarke and Wright Savings. Both methods select the customer site based on the shortest total time and select customers based on the value of the time savings that resulted from the most effective and efficient distribution. The objective of this investigation was to obtain a route of distribution of the pharmaceutical product to minimize the total time through the sequential insertion and the saving methods of Clarke & Wright. As a result, they obtained that the route generated by the sequential insertion method resulted in a saving of 153.72 minutes compared to the route in the company's system and the route produced by the Clarke & Wright saving method resulted in a saving of 93.7 minutes. They concluded that the time utilities of both routes, both the sequential insertion and the Clarke & Wright saving methods, are good when the average vehicle utility capacity for each trip has reached 90%. Whereas for utility companies, the average time reaches 50%, but overall, it was better than the company's current system.

Octora, Imran, and Susanty [22] developed the Clarke and Wight algorithm and the sequential insertion algorithm since the company PT Panca Primamulya Lestari does not use a particular method to determine the distribution. It presented product distribution problems in which working hours are limited, a large number of consumers, as well as the distance from the warehouse. They considered that product delivery begins and ends in the same warehouse, and consumers who are visited for the first time generally depend on the driver who considers the closest distance from the warehouse. They explained the problems of the company PT. Panca Lestari Primamulya is vehicle routing with the characteristics of a Vehicle Routing Problem (VRP), ie single depot and single trip. It is said to be a single depot because the company only has 1 depot and a single trip. After all, the vehicle leaves the depot with several vehicle capacities and then returns to the depot once all the vehicle capacity is empty. The objective of this article was to determine the distribution route of Mayora's products using the Clarke & Wright saving algorithm and the sequential insertion algorithm. In conclusion, they indicated that the tour formed using the Clarke & Wright saving algorithm and the sequential insertion algorithm each produces 5 tours and each algorithm produces 2 alternatives for tour 1 formed. The total distance generated with the Clarke & Wright saving algorithm is 262.64 km with a total time of 33.638 hours, while the total distance generated with the sequential insertion algorithm is 197.88 km with a total time of 31.49 hours. The total distance and total time using the sequential insertion algorithm is better than the Clarke & Wright sparing algorithm.

Ramadanti, susanty and Adianto [23] applied the Clarke and Wright method to solve the vehicle routing problem. They stated that PT Pikiran Bandung Company has some routes for the distribution of daily newspapers, but current routes, the total distance for each route is not balanced and the vehicle capacity is uneven. The objective they set was to produce routes with a minimum distance, balance the routes, optimize the capacity of utility vehicles and minimize transportation costs. The study was conducted by comparing the routes after the study and the current routes. They concluded that using the Clarke and Wright algorithm reduced total distribution costs, total distance, and total distribution time. Total distribution costs experienced a reduction of Rp. 1,805,309, the total distance experienced a reduction of 485.90 km and the total distribution time experienced a reduction of 7 hours and 14 minutes.

Liu, J., Liu, W. and Liu, Y [24] in their article entitled "Optimization of vehicle routing in the Express company using the multiple dynamic saving algorithm" in the year 2014. They developed a model based on the Clarke and Wright algorithm to optimize the routing because there was a disorder in the circulation and problem of the SF company, which is the largest private delivery service provider in China. To apply the algorithm, they defined the distance in kilometers that exists between each point of the transport network, then estimated the saving distance, and determined the transport routes and the costs of the initial program, verifying the capacity restrictions. As a result, they were able to save around 252.2 kilometers and 527.1 yuan. With the results obtained, they concluded that the Clarke and Wright algorithm can develop a reasonable path from the scientific point of view, making the total distribution cost the lowest.

6. Conclusion

Through the savings method, it was possible to identify the appropriate routes, since this technique seeks to achieve maximum savings without neglecting the need for customers to obtain their products quickly and efficiently, and safely. This study strategy yielded the final 20 articles that, although incomplete, contains recent articles on saving algorithm and in our opinion can be considered representative. These literatures were examined, identified as relevant in the writing of this literature review article. From this research results, it is known the benefits of several saving algorithm technique used for problems solving of cost and distribution routes minimization.

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