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OPTIMIZATION OF VEHICLE ROUTES FOR INTER-WAREHOUSE OPERATIONS USING THE CLARK AND WRIGHT'S SAVING ALGORITHM

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ABSTRACT: In today's increasingly competitive conditions, the importance of transportation and distribution has increased. With the rapid progress of technology, companies are making efforts to reduce their costs to stay on the market, protect and develop existing customer potential. Finding the best route (optimum) for a vehicle to follow in the network, which will give the shortest time or distance to reduce delivery costs and increase the quality of service offered to customers, has become the most controversial topic today. As a result, the importance of transportation and distribution has increased in increasingly competitive conditions. The vehicle routing problem aims to meet customer demands by determining appropriate value rods from the shortest route. For this purpose, a sample of the VRP (vehicle routing problem) was made. High discount (hard discount) the company providing services in the retail sector in Poland, vehicle routing modelling is done via the central warehouse of the company.

KEYWORDS: *Transport, Clark and Wright's saving algorithm, vehicle routes plan*
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1. INTRODUCTION

Transportation is one of the most significant sectors of the economy through the provision of transport services and support to other branches of the economy. It enables the exchange of goods and services; it is a condition and a factor determining economic growth. Development can be defined as improving the welfare of a society through appropriate social, political, and economic conditions (Meyer & Meyer, 2016). The expected outcomes are quantitative and qualitative improvements in human capital (e.g. income and education levels) as well as physical capital such as infrastructures (utilities, transport, and telecommunications) (Saleh et al., 2020). Road transport means transportation of goods and personnel from one place to the other on roads. There are many advantages of road transport in comparison to other means of transport. The investment required in

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road transport is less compared to other modes of transport such as railway and air transport. The cost of constructing, operating, and maintaining roads is cheaper compared to the railway transportation system (Burkard et al., 1994).

The efficient flow of goods is the main requirement in modern times and is based on the delivery of products at the right time and place as required by the supplier or recipient. Transport performs a service function towards participants in the logistics process (Xiang, 2014; Mulcahy, 1994). Transport also plays an important role in the distribution and supply process, which is one of the logistics subsystems of the organization responsible for the flow of goods and information from the producer to the final recipient, which may be the final customer. Optimization of delivery routes to warehouses is one of the key factors of economic efficiency and ensuring the appropriate level of customer (Shetty et al., 2020). Anily and Federgruen (1990) outline distribution procedures where one warehouse (depot) can be harnessed and optimized to handle multiple retailer systems with the aim being to lower cost and increase profitability for the logistics company (Lawrence et al., 2005; Thompkins & Smith, 1998; Vega, 2004). The selection and application of a selected tool of such optimization is the subject of the study in this article

2. LITERATURE REVIEW

Integration of supply chain management involves the seamless exchange of information and communication between the stakeholders throughout the supply chain processes in the product's lifetime. The green supply chain integration (GSCI) thus involves the strategic and integrative approaches used in the attainment of green supply chain performance (Govindan et al., 2014; Suryanto et al., 2018; Scur & Barbosa, 2017). The green supply chain integration takes various forms to achieve efficiency in organizational performance, including customer integration, internal operations integration, and supplier integration.

The optimization process in both external and internal transport is a necessary solution often used in the warehouse management of large concerns and enterprises (Wehner, 2018; Laporte, 1992). Thanks to the optimization of transport, you can use all available means of transport to a large extent, to better organize the working time of operators or enhance the work process in the entire warehouse. Optimization is also associated with the reduction of transport costs and the simplification of its organization, among others in the area of supply. Procurement is a process that aims to source all kinds of goods and services to complete an enterprise (Vivaldini et al., 2012).

In trying to optimize warehouse operations to enhance service delivery, De Koster et al. (2007) informed that order picking is a warehousing operation which entails selecting products from storage depot locations with the intention to fulfil orders from customer. Frazelle (2001) maintains that order picking is one of the most complex and costly processes encountered by warehouse managers in the smooth running of warehouse operations. Order picking has been projected to account approximately 50% of all operating costs documented in warehouse operations (Fu et al., 2011; De Koster et al., 2007, 1999; Goetschalckx & Ratliff, 1988). This has been mostly been blamed on the fact that order picking involves the use of human order pickers because automating the process will be even more costly and an inefficient method of allocating expenditure (De Koster et al., 2007). Hence, order picking has in recent years become an area of increased interest among warehouse professionals for improving productivity in warehouses (Dondo & Cerda, 2007; Frazelle, 2001).

Sicilia et al. (2016) proposed an innovative optimization algorithm made up of experimental heuristic procedures to resolve issues associated with the capillary delivery of products in foremost metropolitan regions with the everyday vagaries taking into account: time windows, capacity limitations, the congruence between vehicles and orders, maximum capacity allocated to each vehicle, orders that depend on the delivery and pickup without returning back to the depot, with the purpose being to reduce the various types of restrictions and complexities (Ji & Chen, 2007; Lahyani et al., 2015; Crainic et al., 2015; Oturakçı & Uyan, 2014). This type of complexity is referred to as the Rich Vehicle Routing Problem. The algorithm presupposes that viable alternatives are needed to reduce the costs by minimizing distances and cutting down on the number of vehicles deployed so long as the service quality to potential customers is at an optimum level and ensuring that a load balance among vehicles is strictly maintained.

An overview of quasi experimental heuristic processes developed in prior studies are provided by Vidal et al. (2013), they provide a comparison of their performances for different types of Vehicle Routing Problem (Mohr, 2014). The experimental heuristics (meta-heuristics) were ranked based on population-based methods, neighborhood searches, hybrid and cooperative or parallel. Simulated Annealing and Tabu Search are categorized in the neighborhood category (Mohr, 2014). Brandao and Mercer (1997) utilized a tabu search heuristic for a multi-trip VRP with time windows and a vehicle fleet that is heterogeneous when measured in terms of capacity (Mohr, 2014). Chabot et al. (2018) in their analysis developed an Adaptive Large Neighborhood Search heuristic to evaluate the solution to their CVRP model of the 3D narrow aisle warehouse. Similarly, Jin et al. (2012) uses a tabu search algorithm for a conventional CVRP that is based on the application of various neighborhood structures and performs parallel search (Mohr, 2014). Nguyen et al. (2013) utilized tabu search to solve a VRP with time windows in a storage warehouse facility enclosing one depot and numerous zones.

In the consideration of these models, purchase of goods should be carried out under all the requirements set by the company and the client, and above all, avoiding downtime and empty runs. Procurement is considered in three dimensions according to Babalska (2013), they include;

- Strategic - consisting in searching for new suppliers, purchasing materials, semi-finished products, and products to monitor their quality later. In this dimension, relations between all participants of the supply chain are shaped.
- Qualitative - meeting the quality standards of materials and services is a key element of the execution of the order at a high level, which in turn generates very high profits for the company.
- Cost-effective - the cost of the material is a key factor in the overall cost of the project. It largely determines the price of the order.

Supply logistics is mainly responsible for connecting all participants of the supply chain so that the material or service is of high quality. The materials that are the basis to produce high-quality finished products directly affect the level of satisfaction of recipients, i.e., customers, and, consequently, the reputation and profit of the company. The number of warehouse halls used depends on the specificity of the business and the technological process implemented in production companies used to produce products (Coyle & Bardi, 2010).

3. METHODOLOGY

The topic under consideration is particularly important in the case of shortening the distance and reducing transport costs on a national and international scale. For this purpose, the model was analyzed Vehicle Routing Problem in the optimization of transport between warehouses such as those of the Polish company TEXTROZ S.A. The vehicle routing problem (VRP) is an integer programming problem seeking to service several customers with a fleet of vehicles. Proposed by

Dantzig and Ramser in 1959, VRP is an important problem/study in the fields of transportation, distribution, and logistic (VRP: Vehicle Routing Problem). The basic components of the Vehicle Routing Problem are demand, material type, distribution/collection points, and vehicle fleet (Cao, 2012; Pichpibul & Kawtummachai, 2012; Jeřábek et al., 2016; He et al., 2009; Toth & Vigo,(2002). The company TEXTROZ S.A. was established in 1998. There are 513 stores and 5 main distribution depots (warehouse). The company's goal is to present products at a low price and high quality to customers at every level of income.

In the existing system, the routes are determined manually. Routing is determined by the delivery Chief. This study is done for only 1-week routing. This is made manually in Excel and it took a long time. There are dozens of routes in one day in reality. if something like computer programming happens, they can use it. Matters to attention in vehicle routing problem in the existing system of the company:

- Customer needs should be met as soon as possible;
- One vehicle should operate on a route, and preferably once a week on the network;
- The route must start and stop at the depot.(for example:0-x-y-0);
- The total capacity of the routes the vehicle travels must not exceed the vehicle ;capacity;
- Every vehicle should follow certain routes;
- Products are delivered to customers.

The company has 513 stores and 5 main distribution depots (warehouses). The company's goal is to present products at a low price and high quality to customers at every level of income. There is one main distribution depot (warehouse) and 15 demand points in the study (store). The demands of the store are standard; eight vehicles are attached to service every depot. Routes start and end at the depot.

$$\text{Store demands} \leftarrow \text{total capacity of vehicles}$$

3.1 Solution of Research Problem by VRP Method – Clark Wright Algorithm

3.1.1. Examination of Existing Distribution System

In this section, vehicle locational problems with different size points from 24 stores are solved by Clarke & Wright's heuristic algorithm. As a result of this solution, routes will be created and the total route will be calculated. Constraints of solution:

- Demand is received 3 times a week from stores;
- Claiming takes place one or two days before distribution days;
- Distribution is made 3 days a week (Tuesday, Thursday, Saturday);
- Sunday is the holiday day of the depot;
- Store demands are not variable. It is usually the same.

Table 1. Store Demand Quantities (palette)

Store Name	S. Code	Tuesday	Thursday	Saturday
DEPO	0	*	*	*
FENERBAHCE	1	6	5	5
ORTADAG	2	18	15	13
EBUBEKIR	3	3	5	4
SAMANDIRA	4	5	3	5
TOPRAK	5	5	9	10
GENÇOSMAN	6	10	6	6
YENİ ÇİFTLİKYOLU	7	5	11	6
KIZILAY	8	6	5	5
FEYZA	9	4	4	3
YALÇINKAYA	10	5	8	2
SEFA	11	4	2	3
ŞEMS	12	5	16	7
DENİZ	13	6	0	8
YUNUS EMRE	14	5	4	6
AŞIK VEYSEL	15	6	6	5
YENİDOĞAN	16	3	4	0
BULVAR	17	5	5	5
SELİMİYE	18	5	14	10
KÖSE	19	4	5	5
AKYILDIZ	20	5	6	7
BURCU	21	3	6	5
FSM	22	5	9	6
SULTANGAZİ	23	3	6	6
BAHÇELIEVLER	24	5	0	0

Source: Company's data

In the surveyed company, 8 vehicles were identified that support transport between warehouses and have the following transport capacity as shown: two vehicles can transport 25 pallets, the remaining six 16 pallets.

3.1.2. Solution with Clarke & Wright Saving Algorithm

The solution is to use the sequential version of the Clarke & Wright Savings Algorithm. First, the saving matrix is formed by sorting the savings values from large to small. Taking into account the demands received on Tuesday, the largest savings are started to be calculated from the values of 10 and 1-2. As the capacity is completed, the 0-1-2-0 route is created. Then the 8, which has the greatest value in the savings matrix, is looked at. 12-13-13 When the routes are merged, the vehicle capacities will be completed. Considering all saving orders, the remaining customer pairs are checked, and alternative routes are created as 0-x-y-z-0. The vehicles are routed to the appropriate capacities. Moving from the savings values, the routes, the total routes are taken and the vehicles that are created considering the capacity and demand amounts are determined. These operations are repeated for the other distribution days of the week (Thursday, Saturday) and the total path taken for the Clarke & Wright algorithm is calculated. The solutions for the distribution days are given in Table 2-4.

Table 2. Results for Tuesday

Savings value	Route for code store	Clarke & Wright Saving Algt. Total Road	Demand	Assigned Vehicle
10	0-1-2-0	12	24	Vehicle 1
8	0-12-13-14-0	11	16	Vehicle 2
8	0-7-18-20-0	12	15	Vehicle 3
6.5	0-22-23-24-3-0	16.5	16	Vehicle 4
6	0-15-19-4-0	15.5	15	Vehicle 5
5.5	0-6-10-0	7.5	15	Vehicle 6
4.5	0-5-9-11-16-0	14	16	Vehicle 7
3.5	0-17-21-8-0	10.5	14	Vehicle 8
Total Road(km):		**99**		

Table 3. Results for Thursday

Savings value	Route for code store	Clarke & Wright Saving Algt. Total Road	Demand	Assigned Vehicle
10	0-1-2-8-0	11	25	Vehicle 1
6.5	0-7-9-0	8.5	15	Vehicle 2
7	0-10-20-0	9	14	Vehicle 3
6.5	0-14-15-19-0	9.5	15	Vehicle 4
6.5	0-22-23-0	8.5	15	Vehicle 5
6	0-11-18-0	12	16	Vehicle 6
4.5	0-5-6-0	6.5	15	Vehicle 7
4.5	0-16-21-3-0	10	15	Vehicle 8
Total Road(km):		**75**		

Table 4. Results for Saturday

Savings value	Route for code store	Clarke & Wright Saving Algt. Total Road	Demand	Assigned Vehicle
10	0-1-2-8-0	11	23	Vehicle 1
8	0-12-13-0	10	15	Vehicle 2
8	0-7-18-0	12	16	Vehicle 3
7	0-10-20-22-0	11.5	15	Vehicle 4
6.5	0-14-15-19-0	9.5	16	Vehicle 5
6	0-4-23-21-0	20.5	16	Vehicle 6
5.5	0-6-11-17-0	9.5	14	Vehicle 7
4.5	0-9-5-0	8.5	13	Vehicle 8
Total Road(km):		**92.5**		

When the problem is solved with the Clarke Wright algorithm, a total of 266.5 km of roads are taken during the weekly distribution process.

3.1.2. The capacity analysis for days

The solution is to use the sequential version of the Clarke & Wright Savings Algorithm. First, the saving matrix is formed by sorting the savings values from large to small. Taking into account the demands received on Tuesday, the largest savings are started to be calculated from the values of 10 and 1-2. As the capacity is completed, the 0-1-2-0 route is created. Then the 8, which has the capacity utilization rates of the vehicles used are determined and compared with the Pearson Correlation Coefficient method was applied with SPSS. On Tuesday, Thursday, and Saturday, rotalara vehicles were created by requesting departures. The occupancy rates of the vehicles resolved are shown in Table 5.

Table 5. Vehicle occupancy rates for Clarke Wright Algorithm

Vehicle	Capacity	Tuesday	Thursday	Saturday
Vehicle 1	25	24	25	23
Vehicle 2	16	16	15	15
Vehicle 3	16	15	14	16
Vehicle 4	16	16	15	15
Vehicle 5	16	15	15	16
Vehicle 6	16	15	16	16
Vehicle 7	16	16	15	14

Vehicle 8	16	14	15	13

The total capacity of 8 vehicles is 137 pallets. Total requests for 3 days are as follows: 131 for Tuesday, 134 for Thursday, 132 for Saturday. Total vehicle capacity, total capacity utilization ratios from the pallet loads of the vehicles used are obtained and are shown in Table 6-7.

Table 6. Vehicle Capacity Utilization Rates

Distribution Days	Total Vehicle Capacity	Demand Quantities	Process steps	Capacity utilization rate	Ranking
Tuesday	137	131	100*131/ 137	95,62%	3
Thursday	137	134	100*134/ 137	98%	1
Saturday	137	132	100*132/ 137	96,35%	2

Table 7. Vehicle Capacity Utilization Rates for Clarke Wright Algorithm

Clarke & Wright	Tuesday	Thursday	Saturday	Total Capacity for Three Distribution Days	Capacity Used	Process steps	The capacity utilization rate	Ranking
Vehicle 1	24	25	23	75	72	(72/75)* 100	%96,00	1
Vehicle 2	16	15	15	48	46	(46/48)* 100	%95,83	3
Vehicle 3	15	14	16	48	45	(45/48)* 100	%93,75	4
Vehicle 4	16	15	15	48	46	(46/48)* 100	%95,83	3
Vehicle 5	15	15	16	48	46	(46/48)* 100	%95,83	3
Vehicle 6	15	16	16	48	47	(47/48)* 100	%97,92	2
Vehicle 7	16	15	14	48	45	(45/48)* 100	%93,75	4
Vehicle 8	14	15	13	48	42	(42/48)* 100	%87,50	5

4. RESULTS

The major objective of this section was to test the study hypotheses, which were geared towards answering the study problem. The hypotheses of the study were evaluated using the Structural Equation Model (SEM). However, before running the model, the proposed model was evaluated for its suitability and fitness. Since the study was carried for three countries, the evaluation of the model and test of hypotheses was carried out independently for each county. The results are discussed in the following section:

The introduced method of optimizing transport between warehouses will also lead to the reduction of overhead costs in this transport model which is presented in Tables 8-9.

Table 8. Total Cost for Existing System

Existing System	Total Road(km)	Fuel Burn at 1 km	Price of diesel / liter	Cost (euro)
Tuesday	115	0,22	5,6	26,23
Thursday	90	0,22	5,6	20,53
Saturday	110	0,22	5,6	25,096
Total	315	-	-	80,98

Table 9. Total Cost for Clarke &Wright

Existing System	Total Road	Fuel Burn at 1 km	Price of diesel / liter	Cost
Tuesday	99	0,22	5,6	22,58
Thursday	75	0,22	5,6	17,11
Saturday	92,5	0,22	5,6	25,1
Total	266,5	-	-	65,79

When compared with the current system, total cost result from the proposed Clarke & Wright Algorithm would lead to a decrease of (80, 98-65, 79) Euro per week. According to the current system, 18 (75) % reduction in total cost was achieved during the one-week study period. As a result, the problem with Clarke & Wright being used has been improved.

5. CONCLUSION

For logistics activities to be carried out in a planned and systematic way, the enterprises need to use the scientific methods or software developed for these activities. These methods and software increase the efficiency and performance of logistics activities and provide great advantages to managers. Increasing logistics costs and customer expectations are leading companies to think in this direction. Logistics and distribution managers are required to apply these methods and software to reduce costs, improve the quality of distribution, and meet customer expectations in a short time while performing distribution activities.

The companies should reduce the logistics and distribution costs, which have a significant share in the total cost of the operator, to the minimum level to survive in a rapidly developing and changing competitive environment, compete with competitors and expand the market share. This is done by establishing a suitable distribution plan. A key point to note in the realization of distribution activities is the creation of an optimal distribution plan that will fully meet customer needs. Optimal vehicle loading and punctuation is one of the most important issues in the creation of this plan.

Having the vehicles loaded with the appropriate capacity to reach the customer points in the shortest time and at the shortest time will enable both to decrease the total distribution costs (table 9) and to increase the service quality and to be more advantageous position in competition conditions of the company.

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