CAPACITATED VEHICLE ROUTING FOR THE TRANSPORTATION OF CONSTUCTION MATERIALS

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Abstract

This research presents heuristics algorithms to solve capacitated vehicle routing problem for construction material transportation with restricted capacity constraints. The objective is to minimize the total transportation distance. A case study using two types of vehicle, pickup truck and 6- wheel truck. Customers are categorized to be 2 groups according to type of goods and quantities. Four different vehicle routing algorithms are compared which are the drivers' experience, Nearest Neighborhood Algorithm, Saving Algorithm and Improved Saving Algorithm. The results of the comparison showed the shortest routes obtained from Improved Saving Algorithm. From the results, the total transportation distance is reduced by 10.91% compared with the current routes.

Keywords: Vehicle Routing Problem, Sawving Algorithm, VRP solver

Introduction

An effective transport management creates a competitive advantage in cost aspects.Fuel and time. The company sells construction materials. Located in the heart of thecity of Yala Province. Supplier of construction materials such as steel and cement pipe, the General Board, plywood, color etc customer has service and over 80, but at present, there are regular customers who want to deliver items over 35 items in Yala Province and neighboring provinces. Use the vehicle to transport goods, the customeris 2 types of vehicle and 6-wheel pickup truck. In order to reduce the distances in saving fuel costs. The route used the experience ofthe driver in the path. By using the nearest and next nearest point.

Literature review

In recently, many relevant research publications in vehicle routing problem. The vehicle routing problem is classified as an *np* – hard problem[1]. Laporte[1] developed an exact algorithm,branch and bound for solving vehicle routing problem. Some applications in real world instances were proposed. Padhipat et al. [2] develop transportation routes in Amphawa, Samut Songkram Province. To reduce transportation time, Nearest Neighbor Heuristic and Lingo are applied to generate the bus routes from the distribution center to the passengers' waiting points. Paleerat proposed the transport route from the distribution center to the customer points. The initial transportation routes are generated by the saving algorithm and revised by 2-opt operation. From the result, the shipping point can be easily located with the minimum distance.
Abichit et al. [3] applied a heuristics, Saving Algorithm with local search improvement, for concrete block distribution to determine the fleet composition. The heuristics starts by determining an initial solution through the Saving Algorithm and improves the initial solution by local search. The total transportation distance is reduced by 9.70%. In large - scale problems, metaheuristics were developed. Na LI and et al.[3] proposed a hybrid algorithm, Genetic Algorithms and Ant colony Optimization for solving the vehicle routing problem. From the results, the hybrid algorithm GA-ACO outperforms GA, ACO in transporation distance.

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Objectives

The objective of this research is to construct vehicle routing and reduce total transportation distance.

Methodology

At first, we collected related data such as customers'demand, geographic locations of customers , coordinates of 35 demand points and the distribution center. Capacities of 2 types of vehicle are 2,000 Kgs for pickup truck and 5,000 Kgs for 6- wheel truck. We catagorized customers to be 2 types. The first group of customers mostly are government organizations that own large demands of construction materials. The second group customers are local buyers who have lower deterministic demand, but on time delivery is the most important issue. In figure1, geographic locations of customers 35 nodes is shown from Google Earth.

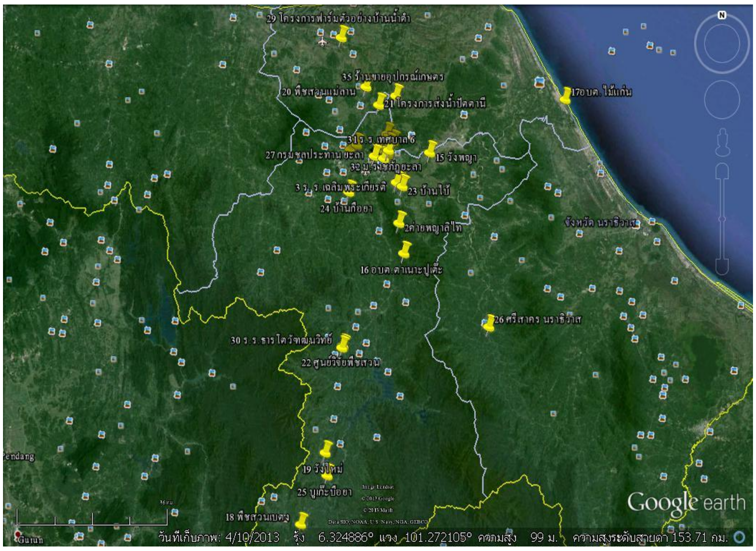

Figure 1 geographic locations of demand nodes

Capacitated Vehicle Routing problem(CVRP)

The CVRP can be defined by the mathematical model Golden et al.[5] and applied in the CVRP by Punyabha et al.[6]. Given a set of vehicle which capacity Q, delivered from a depot. Each tour starts and end at the central depot. Let graph represeting the vehicle routing network $G = (N, E)$ of n customers K vehicles with $N = \{0,1, \ldots n\}$

Let:

$Xijk$	=	1 if vehicle k travels from node i to node j
	=	0 , otherwise.
c_{ij}	=	distance from node i to node j
k	=	vehicle k^{th}
q_j	=	customers' demand at node j
Q	=	capacity of vehicle

$$\text{Minimize } Z = \sum_{i=0}^{N}\sum_{j=0}^{N}\sum_{k=1}^{K} c_{ij}x_{ijk} \qquad (1)$$

Subject to

$$\sum_{i=0}^{N}\sum_{k=1}^{K}x_{ijk} = 1 \qquad , j = 1,\dots, N \qquad (2)$$

$$\sum_{j=0}^{N}\sum_{k=1}^{K}x_{ijk} = 1 \qquad , i = 1,\dots, N \qquad (3)$$

$$\sum_{i=0}^{N}x_{ijk} - \sum_{i=0}^{N}x_{jik} = 0 \qquad , j = 0,\dots, N;\ k = 1,\dots, K \qquad (4)$$

$$\sum_{j=0}^{N}q_j\left(\sum_{i=0}^{N}x_{ijk}\right) \le Q \qquad , k = 1,\dots, K \qquad (5)$$

$$\sum_{j=1}^{N}x_{0jk} \le 1 \qquad , k = 1,\dots, K \qquad (6)$$

$$\sum_{i=1}^{N}x_{i0k} \le 1 \qquad , k = 1,\dots, K \qquad (7)$$

$$u_i - u_j + \sum_{k=1}^{K}x_{ijk} \le N - 1 \qquad , i, j = 1,\dots, N \text{ and } i \ne j \qquad (8)$$

$$x_{ijk} \in \{0,1\} \qquad , i, j = 0,\dots, N;\ k = 1,\dots, K \qquad (9)$$

$$u_i \ge 0 \qquad , i = 1,\dots, N \qquad (10)$$

The objective function is to minimize the total distance traveled in a route. Constraint (2) and (3) ensure that vehicle go to each node at once. Constraint (4) impose the number of vehicles arrives the node is equal to the number of vehicles leaves the node. Constraint (5) prevent vehicles carrying materials exceed their capacities. Constraint (6) and (7) ensure that each vehicle travel only one route. Constraint (8) avoid the subtours. Constraint (9) and (10) are sign restrictions.

Vehicle Routing for the construction materials

In this research, we compare four heuristics algorithms for vehicle routing problem which are drivers' experience, Nearest neighborhood algorithm, Saving algorithm, and Improved Saving algorithm. In VRP, each customer has a demand to be collected. Each type of vehicle has a capacity.

Nearest neighborhood algorithm

To construct a route of the nearest neighbor algorithm, the nearest neighborhood algorithm starts with a tour selecting a depot. A vehicle is assigned to serve demand of each customer. From the current demand node, go to the shortest arc to allocate the nearest node. Then, the customer is added to the vehicle route. If the capacity of the vehicle is still available, go to the next demand point. If the capacity of the vehicle is unavailable, a new route is started untill all demand nodes are visited.

Saving algorithm

Saving algorithm,the classical vehicle routing problem, developed by Clarke & Wright in 1964. Saving algorithm is the heuristics for the single depot CVRP based on the concept of saving. To determine allocation of Goods must be delivered in given quantities of customers in *n* demand points. Dispatching vehicle from depot D to each customer in *n* demand points. Saving algorithm starts from calculating the savings, $s(i, j)$, from $d(i, j)$ distance of between node *i* and node *j* as following equation .

$$s(i,j) = d(D,i) + d(D,j) - d(i,j) \qquad (11)$$

In equation (11), the savings, $s(i, j)$, is combining each pair of demand points *i* and *j*. If $s(i, j)$ is positive, a route is profitable rather than serving two separate customers. Then list the savings in decending orders, select the largest saving of all pairs and insert the selected pair with unviolated constraints in the route. The algorithm is continue processed unitill all demand nodes are completely served.

The Improved Saving algorithm is using the same rules with the Clarke-Wright savings algorithm except implemented randomly chosen the pairing of routes instead of the best pair and improved the initial solution by two – opt and swap operations. The effective saving algorithm,VRP solver, is provided by Lawrence[7].

Results

The first customer group uses the pickup truck which contains 19 demand nodes. The second customer group use the 6 – wheel truck which 16 demand nodes. We compare each solution from four heuristics algorithm. For pickup truck, the best route is obtained from the improved saving algorithm, the saving algorithm, the nearest neighbor and the current method, respectively. For the 6-wheel truck, the saving algorithm and the improved saving algorithm create the same results as shown table1.

Table 1 Comparisons of total distance from four heuristic techniques

Methods	Pickup truck	6-wheel truck
	Total distance (Km.)	Total distance (Km.)
Current method	210.85	831.9
Nearest Neighbor	204.05	821.75
Saving Algorithm	145.3	784.95
Improved Saving Algorithm	144	784.95

In comparisons of both customer groups, the total transportation distance from the improved saving algorithm requires the shortest distance as shown in Figure 2.

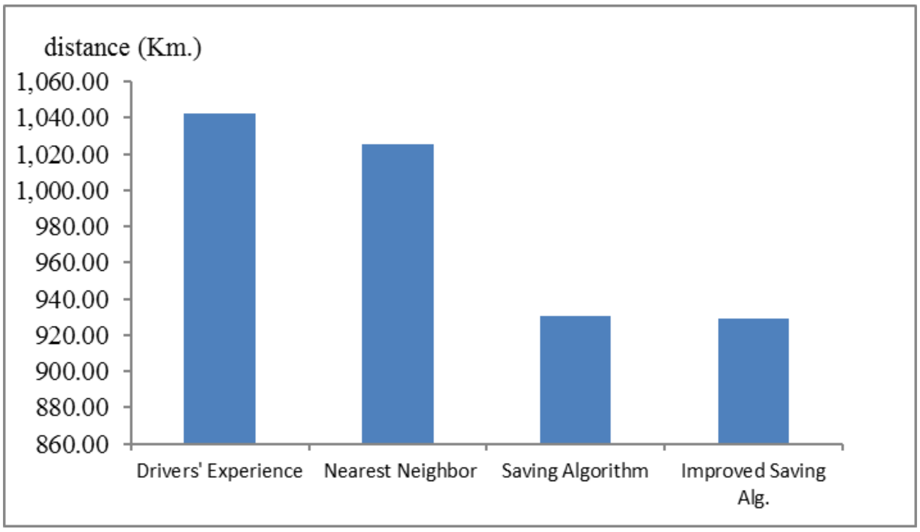

Figure 2 Comparison of transportation distance from heuristics

From the results of each type of vehicle, the generated routes from the improved saving algorithm for pickup truck is shown in table2. For the routes for the 6-wheel truck, the detailed routes are shown in table3.

Table 2 routes from the improved saving algorithm for pickup truck

Order	Routes	Weight (Kgs)	dstance (Km.)
1	0 → 1 → 2 → 14 → 5 → 0	1,941	23
2	0 → 3 → 4 → 16 → 8 → 0	1,835	8.50
3	0 → 6 → 0	1,750	0.9
4	0 → 7 → 12 → 0	1,600	12.4
5	0 → 10 → 19 → 11 → 18 → 0	1,892	90
6	0 → 13 → 9 → 17 → 0	1,980	5.4
7	0 → 15 → 0	1,120	3.8

Table 3 routes from improved saving algorithm for 6-wheel truck

Order	Routes	Weight (Kgs)	dstance (Km.)
1	0 → 8 → 3 → 1 → 7 → 0	4,306	255.85
2	0 → 14 → 2 → 0	4,736	199.9
3	0 → 4 → 0	3,969	23.8
4	0 → 5 → 6 → 16 → 0	4,962	194
5	0 → 11 → 9 → 10 → 0	4,936	74.8
6	0 → 13 → 12 → 0	3,286	10.2
7	0 → 15 → 0	2,700	26.2

Conclusion

In this research, we investigates performance of different heuristics for solving the vehicle routing problem. Initially, we categorized customers depending on their quantities of demand to be 2 groups. For the first customer group with 19 demand nodes, type of vehicle we assign is the pickup truck and the 6 – wheel truck for the second customer group with 16 demand nodes.

From the comparisons of four heuristics algorithms, the solutions from the improved saving algorithm via the VRP solver are compatible to other algorithms. The obtained trasportation distance from heuristics in ascending order are the improved saving algorithm, saving algorithm, nearest neighbor algorithm and the drivers' experience, respectively. By using the improved saving algorithm, total transportation costs are reduced by 7.79%.

References

[1] Laporte, G. (1992). The vehicle routing problem: an overview of exact and approximate algorithms. **European Journal of Operational Research** 59, 345-358.

[2] Patipat Hongsuwan, Wichai Chantaraksa and Sanwit Chuaphisutkul (2013). Study to optimize the routes of water transport of Samut Songkram Province , **National Conference on Industrial Engineering Network,** 16-18 October. (In Thai)

[3] Abhichit Maneengam, Kanokporn Sripathomsawadi and Abhinantana Udomsakdikul(2013). Solving the Vehicle Routing Problem with Traffic Time Restriction for Trucks Using Heuristics Method: A Case Study of Concrete Block Distribution in Bangkok Metropolitan Region, **Journal of Industrial Technology Ubon Ratchathani Rajabhat University** Vol. 3 No. 6 (pp. 73-85) .(In Thai)

[4] Na LI,Shoubin WANG,Yulan LI. (2011) A Hybrid Approach of GA and ACO for VRP, **Journal of Computational Information System**

[5] Golden, B.L., Magnanti, T.L., and Nguyen, H.Q. (1977). Implementing vehicle routing algorithms.**Networks**, 7(2), 113-148.

[6] Punyabha Suttijumnong and Sunarin Chanta (2013). Vehicle routing for flood evacuation. **Proceedings of Thai Value Chain Management and Logistics**, Khon Kaen, Thailand, 21-22 Nov. (In Thai)

Online

[7] Lawrence V.Snyder and Zuo-Jun Man Shen.(2011) **Fundamaentals of Supply Chain Theory: VRP Solver**, Retrieved on June 6, 2014, Available: http://coral.ie.lehigh.edu/~larry/software/vrp-solver/