Managing Intellectual Capital and Innovation for Sustainable and Inclusive Society
27–29 May 2015
Bari • Italy
Management, Knowledge and Learning Joint International Conference 2015
Technology, Innovation and Industrial Management

SOLVING THE OIL DELIVERY TRUCKS ROUTING PROBLEM WITH MODIFY MULTI-TRAVELING SALESMAN PROBLEM APPROACH CASE STUDY: THE SME'S OIL LOGISTIC COMPANY IN BANGKOK THAILAND

Chatpun Khamyat
Department of Industrial Engineering, Kasetsart University, Bangkok, Thailand
ocpky@hotmail.com

Abstract:
This research work provides the approach for solving the oil delivery trucks routing problem by using multi-traveling salesman problem (MTSP) solving method with this research created algorithm. The created algorithm is used to modify the problem data format by transforming a traditional problem data form of a node-arc network routing problems to become a job sequencing and scheduling problems, which can be solved by traveling salesman problem (TSP) for a single truck logistic system or multi-traveling salesman problem (MTSP) for several trucks logistic system. This original problem data and configuration are the everyday operating procedure of one SME's oil logistic company in Bangkok. Originally, this company accomplishes customer orders of oil delivery from an oil refinery warehouse to the specific customer local gas stations in Bangkok area by using first come first serve policy with two oil delivery trucks that can not satisfy today business competitiveness because of high logistic cost. According to this problem, this research provides the heuristic approach to solve the company problem, showing by a small simulated example problem on this paper. The answer from created heuristic is a TSP tour for each truck that examines the sequencing of order for all trucks. Computation time of this heuristic model for small number of node problem is fast, but it may take a lot more time as combinatorial nature of TSP when the number of node is growing up. The solution is not guarantee optimality of shortest track traveling distance but can be a good lower bound that provides much logistic cost saving for a case study company.

Keywords: oil logistic problem, oil delivery truck, traveling salesman problem, logistic routing problem

1. INTODUCTION

Currently, Logistic business encounter with very high competitiveness and risk of business shutdown, especially the oil logistic business in Bangkok. All gas stations in Bangkok area are supplied their oils form a main oil warehouse of Petroleum Authority of Thailand (PTT) by using the oil delivery trucks of any oil logistic company. There are a lot of oil logistic companies in Thailand, which are in case of SME's business.

They try to be survival and competitiveness by doing any improvement such as cost reduction. The main cost of this business is transportation cost of oil delivery trucks that relate directly to company profitability. Normal truck delivery problems can be established by many kinds of operation research model such as transportation problem, vehicle routing problem, traveling salesman problem or etc., but this oil truck delivery problem model is not compatible with any existing. The objective is to minimize total truck traveling distance that means minimize logistic cost in this business. The job is the delivery of all gas station order of all oil type per day. There are many customer orders from many different locations and quantity demands to an oil logistic company for all working day-time from 9.00 to 17.00 o'clock that the trucks have to accomplish by night-time from 21.00 to 4.00 o'clock, which following order first come first serve' s policy. Job scheduling and sequencing is an important part of any kind of vehicle routing design problem, include this kind of oil delivery truck routing problem.

The oil delivery trucks routing problem can be analyzed and model as its structure and configulation by applyied TSP approach for single truck or MTSP approach for multiple trucks, which the most appropreat existing opration research mobel with some additonal generatd part for making the most problem accurcy and validification. Dantzig, Fulkerson and Johnson (1954) proposed that determining the optimal of TSP for large number of nodes requires too much time so that many papers propose the heuristic algorithm for finding the truck scheduling and traveling path. As NP-hard nature of original TSP, the problem may be considered as the class of NP-hard problem also when the problem structure fall into the TSP/MTSP category, Chartrand and Oellermann (1993). The original TSP/MTSP is one of the applications of network problems, it is necessary to choose a sequence of nodes to visit so as to accomplish a specified objective. TSP/MTSP is a network problem that given a network and a cost (or distance) associated with each arc, it is necessary to start from a specified originating or depot node, visit each and every other node exactly one, and return to the starting node in the least cost manner. The mathematical models of TSP/MTSP are formulated in form of integer linear programming which is 0-1 integer programming. There are so many solving approaches on existing software that can be for solving this kind of integer programming.

This paper examines the model of the oil delivery trucks routing problem and solving method base on TSP/MTSP approach. The concept of TSP/MTSP will be applied with some generated technique of assignment problem to form a specific problem data from a node-arc network routing problems to become a job sequencing and scheduling problems. The existing OR software or Excel Solver is used to solve this problem because it is already use in the case study company. Finally, the example tested problem, the result and conclusion are presented.

2. MAHEMATICAL MODEL AND SOLUTION TECHNIQUE

2.1. Traditional TSP/MTSP mathematical model

A survey of general TSP/MTSP was proposed (Lawler, Lenstra, Kan, and Shmoys, 1995) that can be formulated as integer programming. This research tries to analysis the structure of TSP mathematical model with structure of assignment sub problem. Consider the existing TSP mathematical (Miller, Tucker, Zemlin, 1960). The formulation of classical TSP was:

$$MinZ = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}x_{ij}$$

Subject to

$$\sum_{i=1}^{n} x_{ij} = 1, \qquad j = 1, 2, ..., n$$

$$\sum_{j=1}^{n} x_{ij} = 1, \qquad i = 1, 2, ..., n$$

$$y_i - y_j + nx_{ij} \le n - 1 \qquad \forall i \ne j$$

$$x_{ij} = 0 \text{ or } 1 \qquad \forall i, j$$

The number of cities is n, the distances are c_{ij} and the arcs in the tour are represented by the variable x_{ij}. The c_{ij} is the distance from city i to j (c_{ij} = α for i = j). x_{ij} is 1 if the salesman travels from city i to j and 0 otherwise. The variables y_i are arbitrary real numbers which satisfy the constrain of subtour elinimation $y_i - y_j + nx_{ij} \le n-1$ **.**

The MTSP formulation for m salesman was given (Svestka & Huckfeldt, 1973) as following:

$$MinZ = \sum_{i=1}^{r}\sum_{j=1}^{r} d_{ij}x_{ij} \qquad ; r = n + m - 1$$

Subject to

$$\sum_{i=1}^{r} x_{ij} = 1, \qquad j = 1, 2, ..., r$$

$$\sum_{j=1}^{r} x_{ij} = 1, \qquad i = 1, 2, ..., r$$

$$y_i - y_j + (n + m - 1)x_{ij} \le n + m - 2 \qquad \forall i \ne j$$

$$x_{ij} = 0 \text{ or } 1 \qquad \forall i, j$$

The new distances d_{ij} are defined from the original distance c_{ij} as an augment the matrix [c_{ij}] with new m-1 rows and columns, where each new row and column is a duplicate of the first row and column of the matrix [c_{ij}]. It is assumed that the first row and column correspond to the home city. Set all other new element of the augment matrix to infinity. All other terms have the same definition as previous model.

The approach of transformation of MTSP for m-salesman to the classical TSP (Bellmore & Hong, 1974) was proposed by adding m-1 dummy to the original network as the artificial starting node and solved MTSP from solving TSP of the modified network. According to this point, TSP/MTSP structure is not compatible to all configuration of this research problem but it is the most approach to be adapted.

2.2. The oil delivery trucks routing problem formulation

The SME's oil logistic company in Bangkok provides oil delivery service from a PTT oil warehouse to all customer gas stations. The gas station will send an order to oil logistic company during working day-time from 9.00 to 17.00 o'clock. The order is the quantity of each oil type for any gas station. The oil delivery truck with 16,000 liters'tank need to load all kind of oil at PTT warehouse and delivery to a gas stations order by order, which following first come first serve of order' s policy at night-time start from 21.00 to 4.00 o'clock. For example, if a truck got a job list of 5 orders to delivery one night as following.

Table 1: The example problem of an oil deliver job list for one oil delivery truck

Job No.	Gas Station	Oil (Liters)
1	G1	E20(14,000)
2	G3	G95(14,000)
3	G5	G91(15'000)
4	G3	Diesel(8,000)
5	G4	G95(13,000)

Given, a truck start travel from oil logistic company parking(P) to PTT warehouse(W) for oil loading of job No.1 and go to delivery at a spacific gas station(G1) for finishing job No.1. Next, a truck travel back to W again for oil loading of job No.2, go to delivery at G3 for finishing job No.2 and work continuously as order first come first serve policy until job No. 5 done at the last gas station G4. Finally, a truck travle from G4 back to company parking P. Suppose, the distance network table (matrix c_{ij}) of this example problem is given in form of a normal from/to distance table of node P, W, G1, G2, G3, G4 and G5 as following.

Table 2: The distance network matrix c_{ij} of the example problem

To / from	P	W	G1	G2	G3	G4	G5
P	-	10	12	18	7	20	25
W	10	-	7	16	15	23	27
G1	12	7	-	5	11	22	28
G2	18	16	5	-	9	3	13
G3	7	15	11	9	-	12	20
G4	20	23	22	3	12	-	7
G5	25	27	28	13	20	7	-

By using an order first come first serve policy, the job sequencing solution for one oil truck is a truck route, which is start from P to W to G1 to W to G3 to W to G5 to W to G3 to W to G4 and finally back to P. The total truck traveling distance is 10+7+7+15+15+27+27+15+15+23+20 =181 units that is not a TSP solution form.

According to this point, the original oil delivery trucks routing problem is not compatible with any existing operations research model. From the previous original TSP/MTSP mathematical model, variable x_{ij} is equal 1 if the salesman travels from node i to node j. When we do the analysis with the oil truck routing structure, the TSP/MTSP can be applied to formulate a model base on the original oil truck model as following.

$$\text{Min}Z = \sum_{i\,j} x_{i\,j} d_{i\,j} \qquad i, j = 1,2,...,n$$

Subject to

$$\sum_{i=1}^{n} x_{i\,j} = S_j, \qquad \forall j = 1, 2,...,n$$

$$\sum_{j=1}^{n} x_{i\,j} = S_i, \qquad \forall i = 1, 2,...,n$$

$$\sum_{i \in Z_L} S_i = 1 \qquad L = 1, 2,...,h$$

$$Z_i - Z_j = 0 \qquad \forall i = j$$

$$y_i - y_j + nx_{ij} \le n - 1$$

$$x_{i\,j} = 0 \text{ or } 1 \qquad \forall i, j$$

Set Z_L is a set of any gas station to delivery of all job No. i on a job list. For example, we can define set Z_L of table 1 (n = 5, h= 4) that are Z_L = {G1, G3, G4, G5}. All S_i variables are equal to 1 for each job No. i, when a specific gas station from set Z_L is delivered. Some gas stations on an example problem are delivered on many No. of job such as G3, so the formulated model of the oil delivery trucks routing problem need some more constrains than original TSP/MTSP as showing above.

The created distance matrix d_{ij} are converted from the original distance c_{ij} on table 2 as a job to job sequencing table for all No. of job = n. The conversion approach is examined firstly by converting normal distance network table to become the job to job sequencing table for lower bound solution, which compatible with TSP/MTSP problem structure without starting and ending constrain of P to W and G4 to P. From the example problem, a truck route of job No.1 is start from W go to G1 (W-G1) with distance 7 units, No.2 is W-G3 = 15, No.3 is W-G5 = 27, No.4 is W-G3 = 15 and No.5 is W-G4 = 23. When a truck starts by job No.1 and follow by job No.2, the traveling is W-G1 + G1-W + W-G3, which is 7+7+15 = 29 units. If a truck starts by job No.1 and follow by job No.3, then the traveling is W-G1 + G1-W + W-G5, which is 7+7+27 = 41 units. By doing this, the job to job sequencing table is created as following.

Table 3: The job to job sequencing table for lower bound solution

To Job / From Job	No.1	No.2	No.3	No.4	No.5
No.1	-	29	41	29	37
No.2	29	-	57	45	53
No.3	41	57	-	69	77
No.4	29	45	69	-	53
No.5	37	53	77	53	-

A truck route can be examined by solving TSP of this job to job sequencing table as a lower bound solution without starting ending constrain. The complete matrix d_{ij} still need some more rows and columns for starting and ending constrain of P to W and G4 to P and multi trucks system. An additional first row (D_r; r = 1, 2,…, m) of starting constrain is the first row of distance from P to all job No.i, which are all equal to distance from P to W = 10 units. An additional first column D_r of ending constrains is the first column of distance from all job No.i ending gas stations to P, which equal to distance from all Gi to P of each job No.i. If the problem is for m trucks (m>1), adding m-1 dummy of first starting row and column D_r to the job to job sequencing table as the artificial starting node. If the example problem is accomplished by 2 trucks, the matrix d_{ij} from distance network table is created by the previous approach is showed as following.

Table 4: The matrix d_{ij} of example problem for 2 oil delivery trucks

To Job / From Job	D_1	D_2	No.1	No.2	No.3	No.4	No.5
D_1	-	-	10	10	10	10	10
D_2	-	-	10	10	10	10	10
No.1	12	12	-	29	41	29	37
No.2	7	7	29	-	57	45	53
No.3	25	25	41	57	-	69	77
No.4	7	7	29	45	69	-	53
No.5	20	20	37	53	77	53	-

2.3. The solution of oil delivery trucks routing problem

The algorithm for crating matrix d_{ij} of m trucks from the original distance network matrix c_{ij} and problem a job list of all n jobs No. i is shown as following:

Step1: The dummy starting row D_r; r = 1, 2,…, m is all row D_r; $d_{ij} = c_{ij}$ of P to W for all job No.i. The dummy sterting column D_r; r = 1, 2,…, m is all column D_r; $d_{ij} = c_{ij}$ of all Gi to P of each job No.i.

Step2: The distance d_{ij} of sequncing any job No.i follow follow by any job No.j is all $d_{ij} = c_{ij}$ from W to Gi of any job No.i

A solution of the oil delivery trucks routing problem can be solved as MTSP from solving TSP of this created distance matrix d_{ij}. The existing OR software such as Excel Solver, which can solve TSP can be used to solve this problem. For this example problem, TSP solution of matrix d_{ij} on table 4 is a TSP tour of D_1 – job No.5 – job No.1 – job No.4 – D_2 – job No.3 – job No.2 - D_1 with total traveling distance 157 units. This solution is a MTSP solution of 2 trucks that are Truck No.1: Start from P to delivery job No.5, job No.1, job No.4, and back to P with distance 83 units and Truck No.2: Start from P to delivery job No.3, job No2 and back to P with distance 74 units.

3. CONCLUSION

In this study, the mathematical model of t the oil delivery trucks routing problem which is a modify-MTSP approach for solving a multi trucks system by using a case study example problem of the SME's oil logistic company in Bangkok, THAILAND. The algorithm for creating the distance matrix of this problem is presented. This heuristic approach for solving this specific structure of trucks routing problem can provide much shorter traveling distance, efficiency for solving large size of problem, but may take some more computation step than the original first come first serve policy. The computation time is depends on any commercial software that user use to solve TSP. By this study, the example of 20 nodes problem can be accomplished by using Excel Solver in some millisecond units' time, but the computation time will be grown up by exponential nature because of combinatorial structure of TSP. The solution from created distance matrix is a MTSP tour for m trucks, but it is not guarantee optimality of shortest track traveling distance for each truck. However, the solution can be a better answer than the previous logistic policy that provides much logistic cost saving for this oil trucks delivery routing problem.

REFERENCE LIST

1. Bellmore, M.,& Hong, S. (1974). Transformation of the multisalesman problem to the standard traveling salesman problem. *Journal of association of computing machinery, 21,* 500-504.
2. Lawler, E.L., Lenstra, J.K. , Kan, A.H.G., and Shmoys, D.B. (1995). The Traveling
3. Salesman Problem. *Wiley*. Chichester.
4. Lin, S.,& and Kernighan, B.W. (1973) An effective heuristic algorithm for the traveling salesman problems. *Operation Research*, *21*. 498-516.
5. Miller, C.E., Tucker, A.W., and Zemlin, R.A. (1960) Integer programming formulation of traveling salesman problems. *Journal of association of computing machinery*, *3*, 326-329.
6. Orman, A.J., & Williams, H.P. (2004). A survey of different integer programming formulations of the traveling salesman problem. *Working paper by London school of economics and political science,1*. No. LSEOR 04.67.