Optimizing Logistics for Courier Organizations with Considerations of Congestions and Pickups: A Courier Delivery System in Amman as Case Study

Nader A. Al Theeb, Zaid Abu Manneh, Ibrahim Al-Qadi

Abstract**—**Traveling salesman problem (TSP) is a combinatorial integer optimization problem that asks "What is the optimal route for a vehicle to traverse in order to deliver requests to a given set of customers?". It is widely used by the package carrier companies' distribution centers. The main goal of applying the TSP in courier organizations is to minimize the time that it takes for the courier in each trip to deliver or pick up the shipments during a day. In this article, an optimization model is constructed to create a new TSP variant to optimize the routing in a courier organization with a consideration of congestion in Amman, the capital of Jordan. Real data were collected by different methods and analyzed. Then, concert technology - CPLEX was used to solve the proposed model for some random generated data instances and for the real collected data. At the end, results have shown a great improvement in time compared with the current trip times, and an economic study was conducted afterwards to figure out the impact of using such models.

Keywords**—**Travel salesman problem, congestions, pick-up, integer programming, package carriers, service engineering.

I. Introduction

TRANSPORTATION is a significant component of the cost for any logistics company. Hence, minimizing it is a vital issue. This study is carried out in Jordanian branch of a logistics company considered as a leading global provider of comprehensive logistics solutions. It offers a wide range of services, including international and domestic express delivery, freight forwarding, logistics and warehousing, documents managements, and consumer retail services.

The logistics company in Jordan has five main offices that are spread across Jordan with a main hub located in Amman, the capital of Jordan. There are 27 vehicles for 27 parts in Amman with 27 drivers responsible for delivering the shipment to the pre-mentioned areas.

In the current situation, no specific technologies regarding the processes of sorting, loading and delivering the shipments are currently used. In fact, the company relies on the experience of the couriers in sorting, loading and determining the routes to go on. Based on this, combinatorial optimization, which contains the TSP or the single vehicle route problem (VRP), is introduced to optimize the logistics of the above-described organization. With the aid of integer programming, a new objective function and modified constraints are suggested to create a new variant of TSP to solve the problem. Then, an optimization software is used to find the optimal solution that provides the distribution vehicle with the routes it should follow and the sequence of shipment deliveries to minimize the total distance and/or time. Determining the optimal solution for the routes can give huge savings to the company.

Nader A. Al Theeb, Zaid Abu Manneh, and Ibrahim Al-Qadi are with the Industrial Engineering Department, Jordan University of Science and Technology, Jordan (phone: +962-2-7201000, e-mail: naaltheeb@just.edu.jo, zabumanneh@gmail.com, iqibob@gmail.com).

II. Literature Review

Both VRP and TSP have been extensively studied in the literature. However, few of studies have concerned with the creation of a new variant of TSP or VRP for courier organizations. For example, authors of [1] have suggested a solution approach to optimize a special variant of TSP for couriers, which is used to optimize the transfer of commodities between pair of customers in each individual trip. Similarly, [2], [3] have suggested different solution approaches to optimize the courier dispatching system with classical objective function of minimizing the cost without any other considerations.

In addition to the previous studies, some studies suggest models and methodologies for couriers. In [4], a new model is suggested to minimize the total travel time and the unbalanced loads between couriers. Furthermore, [5] suggests a methodology to optimize the courier working systems. For more information about TSP and VRP, [6], [7] provided a full review about these problems.

Apparently, studies with consideration of congestion through the distribution in large cities, such in Amman, besides the concerning of pick-ups are not fully covered in the literature. Thus, this will be our objective in this study.

III. Methods and Techniques

A. Data Collection

In the current situation, after loading his/her work into the van, the courier revise the run-sheet (contains all the information he needs about the customers) one more time before planning which shipments he/she has to deliver or pick up first. Then, he/she plans the routes he/she has to go in unwritten way. In our large scale case of study presented in this article, there were 52 shipments loaded in the truck and needed to be delivered, with three known pick-ups daily. The most critical issues in the delivering systems are the cost of fuel and time needed to finish the intended job with no shipments to be returned.

International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:11, No:8, 2017

In order to begin analysis of the current situation, a map was printed from Google maps by a scale of 2.7 cm = 500 m of Al-Rabieh and Um-Uthaina areas; they are considered as one area in Amman out of the 27 areas, the courier is responsible for delivering the shipments for these areas. The map was then divided into 30 clusters, where each cluster has an area of 25 cm^2 on map which equals to 0.857 km^2 on ground.

The next step was recording the distance in kilometers and time in minutes needed to reach each customer by using *Nike+* application, which is connected with Google maps. The printed map was used to determine the location of each customer. Furthermore, the processing time needed to hand over or pick up the shipment and taking the signature of the customer was recorded using a stopwatch. At the end of day, an EXCEL sheet was provided by the courier containing 92 data entries, which includes name of the customer, date and time of receiving the shipment (scanning time), type of shipment (collection or pick up), reference (airway bill number), and number of shipments. Moreover, columns containing clusters, distance to reach, time to reach and processing time were added and by removing the duplicates (same customer for different shipments) out of the data, a data table was constructed. Table I shows sample from the collected data.

TABLE I
SAMPLE FROM THE COLLECTED DATA

Customer	Modified date	Distance to Reach (km)	Cluster	Time to Reach (min)	Processing time (min)
1	Jul/21/2016 at 8:37	9.7	20	19	3
2	Jul/21/2016 at 8:43	0.19	23	1.17	4.83
3	Jul/21/2016 at 8:46	0.3	19	1.21	1.79
4	Jul/21/2016 at 8:54	0.8	19	2	6
5	Jul/21/2016 at 8:57	0.56	13	1.42	1.58

The total distance that the courier travelled is 75.21 km and the total time the courier spent, from the moment he/she left the warehouse (hub) and return to it, is 463 minutes (7.72 hours), including the processing time. The summary of the case study is presented in Fig. 1.

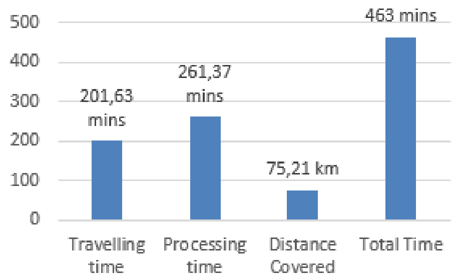

Fig. 1 Data summary of the case study

A time matrix was built using Microsoft EXCEL containing 31 rows and columns (30 cluster + 1 Hub). Rows represent the departing clusters, while the columns represent the arrival clusters so it is mainly From-To Matrix. The time that was used to fill the matrix was pulled out for google maps and manipulated to be integers, and traffic is not included, the diagonal was filled with 1 which represents the time from one customer to another within the same cluster. To incorporate the congestion, another three-dimensional matrix was built which shows a specific congestion factor. For example, if the vehicle visits customer j coming from i at morning; it takes t1, but if visits the same cluster afternoon through the same route, it takes t1 multiplied by a factor γ_ijt.

In large cities, travel time between any two locations is not constant through the day because of the congestion. For example, visiting a node (j) coming from node (i) could take long time at morning because the existence of schools in node (j) which causes traffic jams at morning, while the travel time between the same two nodes at afternoon is shorter. Thus, the congestion factor γ_ijt is higher than 1 when the time t = morning, and it is equal to 1 at other times. This provides information for the optimization model to avoid the road (i) to (j) at morning, if possible or feasible.

The same procedure is repeated for many areas and days to collect more data for the sake of validation and extermination of the proposed model.

B. Problem Description and Model Formulation

The problem will be solved here is described as follows. A vehicle leaves the depot or hub (d) at morning, holding a set of packages. It needs to deliver the packages to customers, where each customer has one or more packages. During distribution, there are sets of customers, called pick up customers, that should be visited at specific time to pick up packages from them. Vehicle should try to avoid entering some roads at times with high congestions, and should try to combine visiting customers in the same cluster as much as possible. At the end, it should return to the depot.

An integer model is constructed to optimize the above-mentioned problem, as follows. The suggested optimization model includes only one type of variable which is binary variable, as will be discussed later, and it can be considered as a new variant of TSP.

Minimize

$$Z = \left[\sum_{i=1}^{N} \sum_{\substack{j=1 \\ i\varsigma j \neq d}}^{N} \sum_{t=1}^{T} \gamma_{ijt}\, \tau_{ij}\, x_{ijt} \right] + [\zeta_1 \sum_{\substack{j=1 \\ j\neq d}}^{N} \sum_{t=0}^{T} x_{jdt(\frac{t}{T})}] - [\zeta_2 \sum_{i=1}^{N_p} \sum_{j=1}^{N} x_{ji\tau_i}]$$

Subject to:

1) $\sum_{i=1}^{N} \sum_{\substack{j=1 \\ i\in j\neq d}}^{N} x_{ijt} \leq 1 \qquad \forall\, t = 1, \dots, T$

2) $\sum_{\substack{i=1 \\ i \neq d}}^{N} \sum_{t=\tau_{id}}^{T} x_{dit} = 1$

3) $\sum_{\substack{i=1 \\ i \neq d}}^{N} \sum_{t=0}^{T} x_{idt} = 1$

4) $\sum_{t=1}^{t=\gamma_{idt}\tau_{id}} x_{dit} = 0 \qquad \forall\, i = 1, \dots, N \text{ or } i \neq d$

5) $\sum_{\substack{i=1 \\ j \in i \neq d \\ \text{or } i \neq k}}^{N} \sum_{\substack{s=0 \\ s+\gamma_{jkt}\tau_{jk}+P_j \leq t}}^{T} x_{ijs} \geq x_{jkt}$

$\forall \; k = 1, \dots, N \;\; j = 1, \dots, N \;\; t = 1, \dots T \;\; j \neq d \text{ or } j\&k \neq d$

6) $\sum_{s=1}^{t} \sum_{\substack{i=1 \\ i \in j \neq d}}^{N} x_{ijs} \geq \sum_{\substack{k=1 \\ k \in j \neq d}}^{N} \sum_{\substack{r=0 \\ t+\gamma_{jkt}\tau_{jk}+P_j \geq r}}^{T} x_{jkr}$

$\forall\, j = 1, \dots, N \;\; t = 1, \dots, T \;\; j \neq d$

7) $\sum_{\substack{j=1 \\ j \neq d}}^{N} \sum_{t=1}^{T} t * x_{jdt} \leq |T|$

8) $\sum_{\substack{i=1 \\ i \in j \neq d}}^{N} \sum_{t=0}^{N} x_{ijt} \geq c_j \qquad \forall\, j = 1, \dots, N \quad j \neq d$

9) $\sum_{i=1}^{N} \sum_{t=\tau_{j-1}}^{t=\tau_{j+1}} x_{ijt} \geq 1 \qquad \forall\, j \in N_p$

where: $\boldsymbol{Z}$**:** Objective Function, **N:** Set of Clusters & Hub, $\boldsymbol{N_p}$**:** Set of Clusters that should be visited at specific time (pick up clusters), τ_j**:** The preferable time period that the pick-up node j should be visited, $\boldsymbol{T}$: Set of time periods, |T| is the number of time periods, $\boldsymbol{t}$: Time period or slot, $\boldsymbol{\tau_{ij}}$: Time needed to travel between i & j with no congestion, $\boldsymbol{\gamma_{ijt}}$: Congestion Factor between cluster i & j at time t, $\boldsymbol{\zeta_1 \zeta_2}$: Small Numbers, $\boldsymbol{C_j}$**:** # of customers should be visited at cluster j, $\boldsymbol{P_j}$: Processing time per customer at cluster j, $\boldsymbol{d}$: Depot, $\boldsymbol{k}$: Any cluster after j, $\boldsymbol{x_{ijt}}$: A binary variable, such that $\boldsymbol{x_{ijt} = 1}$ If the vehicle reaches j from i at time t, 0 Otherwise.

The objective function consists of three terms. The first term is to minimize the total travelling time for the whole trip with consideration of congestion. The second term is to enforce the vehicle to return to hub as soon as possible, instead of performing unneeded moves. The third term is related to constraint number 9, it provides the vehicle a preference to visit the pick-up clusters at specific time, hence constraint 9 provides a relaxation time period for the pick-up visits to reduce the possibility of getting infeasible solution. In the other words, constraint 9 provides a time window, while the third term in the objective function provides a preference to visit in a specific time.

Constraints set 1 allows the vehicle to exist in only one place at a time. Constraints set 2 informs that the vehicle should leave the hub only once. Similarly, constraints set 3 informs that the vehicle should return to the hub only once. Constraints set 4 relates with the first visit as the vehicle cannot reach to any cluster when coming from the hub before it consumes all the travel time.

Constraints set 5 ensures that if the vehicle visits k coming from j, it should visit j first from another node which is i, consuming all the travel and processing time between i and j – j and k. This constraint is used to keep continuity of the route.

Constraints set 6 ensures that if the vehicle visits node j, it should leave it for another node. It is used for balancing the model and feasibility of the route. Constraints set 7 enforces the vehicle to return to the hub before time T. Constraints set 8 ensures that the number of visits to any node j comes from all other nodes at all time periods should be greater than or equal to the number of customers in node j. Finally, constraints set 9 ensures that any pick-up node should be visited at specific τ_j with a relaxation time of ±1.

The model relies in many realistic assumptions. Nodes can be revisited which allows the vehicle to deliver services and pickup packages more freely. Additionally, vehicle can return to the hub at the end of the whole trip and the hub cannot be revisited during the day. This is the company policy.

IV. Results and Discussion

In this section, for the sake of validation, results of solving the model for a small data instance, generated randomly, is presented. Then, the results of real large case study, which is discussed before, and other real small case studies are shown and discussed.

A. Random Small Data Instances

To demonstrate the benefit of using the proposed model and to validate it, a small example with six clusters is solved. Table II presents the input data for this example (congestion matrix is not presented here because it is three-dimensional).

The results obtained from solving the model for the given data are presented graphically in Fig. 2. Vehicle leaves the hub, cluster 0, and travels to cluster 3, reaches customer at time 2. It stays at the cluster and serves for six more customers at times 3, 4, 5, 6, 7, and 8. Then, it moves to cluster 5. After that, it moves to cluster 2 to serve five customers. To collect packages, it returns to cluster 5 to serve two customers and picks up a package. Then, it serves to four customers at cluster 4. Finally, it moves to cluster 1 and returns to the hub.

TABLE II
Data of Small Scale Example

Clusters: 6	**[0,1,2,3,4,5]**					
Number of visits	[1,5,6,8,5,4]					
Time Matrix	**2**	**2**	**2**	**2**	**2**	**2**
	2	**1**	**2**	**1**	**1**	**3**
	2	**2**	**2**	**2**	**1**	**1**
	2	**1**	**2**	**1**	**3**	**1**
	2	**1**	**1**	**3**	**3**	**2**
	2	**3**	**1**	**1**	**2**	**1**
Hub	**0**					
pick-up clusters	**[3,2,5]**					
pick-up times	**[9, 14, 26]**					

B. Real Data Instances

After implementing the proposed model into CPLEX, a minimization of 1 hour and 19 minutes was obtained for the collected data of the large scale set. The optimized route took 6 hours and 24 minutes with a 17.1% improvement. This improvement is calculated based on the actual case where the vehicle takes 7 hours and 43 minutes. The results of other data sets provide an average saving of 14.2%.

To figure out the impact of applying this model in the courier organization, a short economic study is carried out, as follows. The vehicle used in the company has an average fuel consumption of 52.6 MPG or 5.5 liters/100 km, using unleaded Benzene 90. Total actual trip distance is 75.26 km, saving 1 hour and 19 minutes could result in minimizing the distance to 47.86 km, saving 27.4 km.

Based on these observations, the liters saved in this model were 1.507 liters per day. As the price of fuel in Jordan is $0.81 per liter, the cost saved per day for one courier is $1.23. Cost saved for one year $320. Assuming that this cost will be the same (average) for all 27 couriers. Cost saved for 27 Couriers = $8640 per year. This saved cost could be used in maintenance, paying some salaries, insurance, property taxes, rent, and utilities and security. Fig. 3 compares between the actual distribution system and the proposed system produced by the optimization model, in terms of the distance, time, and cost.

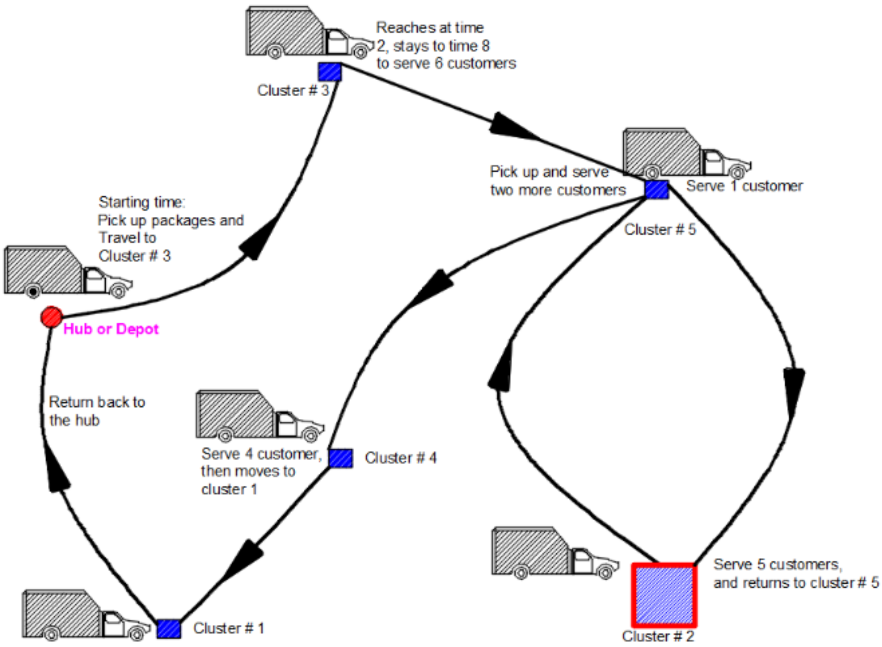

Fig. 2 Small example result

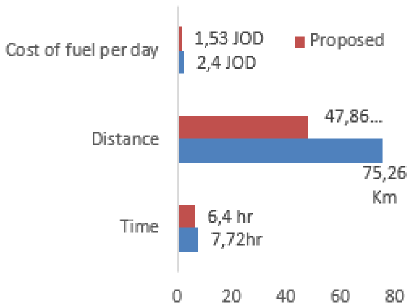

Fig. 3 Comparison between the actual situation and the results produced by the proposed model

V. Conclusions

In this research, a new variant of TSP is provided to optimize the distribution systems of courier organizations with consideration of congestions that occurred in large cities, such as in Amman, the capital of Jordan. The proposed model is tested for one area through a courier organization working in Jordan. Results provided from the model show that a minimization from 7.72 hours to 6.4 hours for a trip in one day. Cost saving of 227.24 JOD per year for this area alone can be obtained when using the proposed model.

As the use of the supposed model could save around 17% for the case study, it is highly recommended that the courier organization should utilise the model for the 27 areas in Amman to determine the route that the couriers have to follow before leaving the hub.

For future research, further integer programming equations and data analysis could be made in order to increase the accuracy of the results plus testing more than one data set. Exact solution approach was used in this model which takes long computation time to generate the solutions, while any logistics company needs to obtain the results at morning in short time. Thus, different algorithms and solution approaches can be suggested to find near optimal solutions for the model in a reasonable amount of computational efforts.

Acknowledgment

We would appreciate the Our thanks to the anonymous courier company in Amman for allowing us to collect data and carrying our project in its facility.

References

[1] Bhattacharyya, M., & Bandyopadhyay, A. K. (2008). On single courier problem. Optimization Letters, 2(4), 535-541.
[2] Singh, R., Tugave, G., & Patil, P. (2014). Cost optimization of courier dispatch system using genetic algorithm. International Journal of Management, IT and Engineering, 4(6), 91-97.
[3] Sesekin, A. N., Chentsov, A. A., & Chentsov, A. G. (2010). A

generalized courier problem with the cost function depending on the list of tasks. Journal of Computer and Systems Sciences International, 49(2), 234-243.
[4] Chang, T. S., & Yen, H. M. (2012). City-courier routing and scheduling problems. European Journal of Operational Research, 223(2), 489-498.
[5] Avila, L. L., Elezi, F., Caridi, M., & Lindemann, U. (2011, December). Improving dispatch operations in complex courier organizations. In Industrial Engineering and Engineering Management (IEEM), 2011 IEEE International Conference on (pp. 1289-1294). IEEE.
[6] Applegate, D. L., Bixby, R. E., Chvatal, V., & Cook, W. J. (2011). The traveling salesman problem: a computational study. Princeton university press.
[7] Eksioglu, B., Vural, A. V., & Reisman, A. (2009). The vehicle routing problem: A taxonomic review. Computers & Industrial Engineering, 57(4), 1472-1483.

Nader A. Al Theeb (M'2017) was born in Jordan 1982. He received his B.S. degree in Industrial Engineering from Jordan University of Science and Technology, Irbid, Jordan, in 2005 and his M.S. degree in Industrial Engineering from University of Jordan, Amman, Jordan, in 2009. He also has an M.I.S.E degree in Industrial and Systems Engineering from Auburn University, Auburn, AL, in 2012. He received a PhD degree in Industrial and Systems Engineering from Auburn University. His current research interests include operations research and its applications in the optimization of logistics and routing systems, lean systems, and quality control.