Analysing Shortest Route Problem in Petaling Jaya: A Case Study

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***Abstract* - In graph theory, the shortest path problem is the problem of finding a path between two vertices or nodes in a graph such that the sum of the weights of its constituent edges is minimized. Shortest path is important to minimize total travelling time or cost. This paper presents a current method to construct the solution on shortest route in Petaling Jaya district area for research staff doing a survey tour. Integer linear programming (ILP), heuristic method and Google Maps were used to analyse the travelling salesman problem (TSP). Result shows that it has agreement with theoretical predictions and significant improvement over previous efforts by researchers. The work presented here has profound implications for future studies of saving time and cost behaviour and may help to solve the problem for the survey tour in the future..**

***Keywords* -** *Shortest route, travelling salesman problem, minimize time, minimum cost.* Introduction

1.1 Background of the Study

There are many ways that we can choose when we want to get to a certain location. For example, if we want to get to location A, there will be a lot of route that can be used to get the location A. The travelling distance and travelling time will be a major factor to define the fastest route to get to a certain location. Sometimes the distance can be long, but the time taken is less and sometimes the distance can be shorter, but the travelling time is longer. The travelling time depends on several factors such road congestion, traffic lights and peak hours.

1.2 Problem Statement

Travelling salesman problem (TSP) can be happened in many sectors such as logistic, transportation or even an individual that wanted to obtain the minimum total distance and travelling time. Furthermore, TSP solution also provides the best outcome for every rider that need to get to one destination faster. However, there are some constraints that need to take in calculation because it can affect the travelling time for a single journey. For example, road congestion and road construction.

This study considers a traveler that needs to go to a few petrol stations that has been assigned from the organization. He is given a week for him to finish the survey assignment. He needs to go to every station, and he can use the same route to go to a location to another. He was given a specific questionnaire and time for him to finish the survey in the station. Each time and feedback will be remarked in a report and the feedback will be analyzed and submitted to the client headquarters within a week.

The aim of this study is to help the traveler to decide the shortest path that he can use to get to every station. So, the objectives of the study are to identify the shortest path and minimum total distance to get to every station and to investigate the minimum total travelling time to every station. The proposed method will help the participants which are the research staff of a company to determine the best route to their destinations.

This paper presents a study on a real road network that connects a petrol station to another petrol station in Petaling Jaya. A total of six petrol stations involved in this study, namely Jalan Selangor (A), Petaling Utama (B), Kelana Jaya 1 (C), Damansara Jaya 1 (D), SS24/48 (E), and Kota Damansara 2 (F). Fig. 1 shows the locations of these stations obtained by searching in Google Maps.

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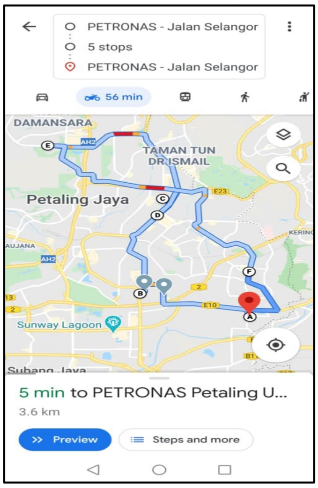

Figure 1. Locations of petrol stations in Petaling Jaya using Google Maps

2. Literature Review

This study focuses to construct a solution of shortest route for research staff to obtain the minimum total distance and travelling time and finally back to the initial station. This problem is known as TSP, one of the most prominent problems in combinatorial optimization, operations research and theoretical computer science which receives much attention because of its applications in industrial nowadays [1]. The most well-known TSP with relational optimization problem is defined as a method of solution used in genetic algorithms. TSP is a problem about finding the shortest route starting from one city and turning back to the same city while considering only one pass through each city points, nodes or components where the distances between each city are known [2].

Hashim and Ismail [3] developed a goal programming model based on TSP to connect 19 tourism destinations in Langkawi by minimizing the travel time and travel cost which are 237 minutes and Ringgit Malaysia (RM) 37 respectively. In order to maximize the profit, [3] had to find the tour with the minimal equivalent workload. This was done by solving the classic TSP by using transformed edge workloads [4]. To establish one route that begins and ends at the depot and visits a given number of cities in each family, the costs of traveling between each pair of cities and between the depot and each city are known. Hence, [3] need to determine the minimum cost route that satisfies the conditions [5]. A real-life case study for wildlife surveillance by drones can be develop and solved using the proposed algorithm. Drone service capabilities can be significantly impacted when the dynamicity of object are taken into consideration [6].

In terms of methodology and tools, there are various techniques used to solve TSP. Basically, for a small number of nodes or stations, integer linear programming (ILP) is the best to achieve the optimal solution. For larger problems, heuristics are the better solution. For example, with 10 nodes, there are $\frac{9!}{2}$ or 181440 feasible solutions. [7] evaluate the performance of heuristic methods in solving symmetric TSP and found that reactive tabu search (RTS) as the best. For a smaller problem, Excel Solver© would be one of the best tools as discussed in [8].

3. Methodology

3.1 Data Collection

For this study we used primary and secondary data to get what is needed for an optimal solution. We decided to use both data sources before we gained the solution. The map of Petaling Jaya District that is used in this study was obtained from Google Maps before the distances were calculated manually to get the most precise time and cost. Primary data will be used to measure the distance from one point to another as our reference. The data were collected manually to verify the data from the map.
The primary data sources were collected from the journey itself, recorded manually by one of the authors using motorcycle. He recorded every distance and time manually using stopwatch from one destination to another. The use of primary data is to get an accurate measurement for every distance and time to each destination. This data collection method has been done for about a week. For secondary data sources, Google Maps is used to provide an estimated distance and time for every destination. Plus, the time that has been given is included at every road congestion that occur along the way to a certain destination.

In this study, every distance is recorded in kilometre and time travelled. Next, we manage all the data that were taken in a table to calculate the result, as shown in Table 1. Then, we analysed the result that has been obtained from the calculation and finally we compare and refer to the objective of the study. The complexity of this problem could be better shown through schematic diagram as Fig. 2.

Table 1. Distance between stations

	Jalan Selangor	Petaling Utama	Kelana Jaya 1	Damansara Jaya 1	SS 22/48	Kota Damansara 2
	A	B	C	D	E	F
Jalan Selangor (A)	0	3.6	5.6	7.6	6.4	15
Petaling Utama (B)	3.6	0	6.6	13	11	15
Kelana Jaya 1 (C)	5.6	6.6	0	5.7	4.5	13
Damansara Jaya 1 (D)	7.6	13	5.7	0	2.6	7.5
SS 22/48 (E)	6.4	11	4.5	2.6	0	8.7
Kota Damansara 2 (F)	15	15	13	7.5	8.7	0

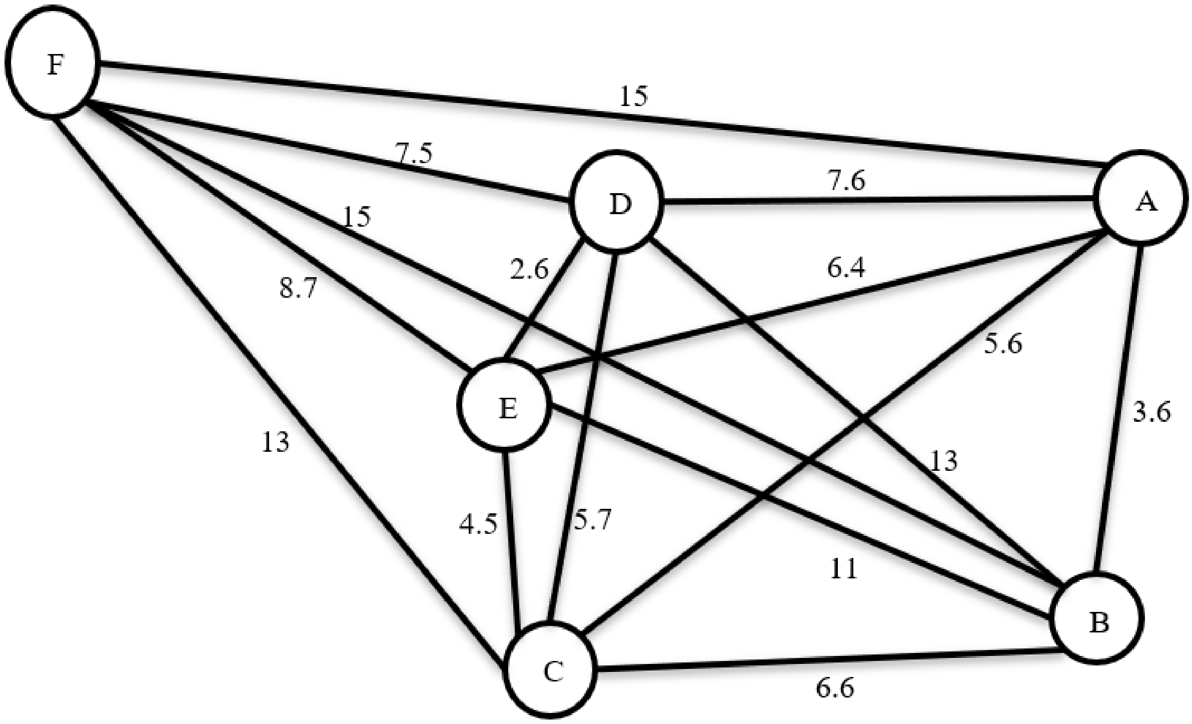

Figure 2. Schematic of travelling salesman problem (TSP)

3.2 Model Formulation

The travelling salesman problem can be modelled as an ILP with objective function:

$$\text{Minimize } Z = \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij}$$

subject to

$$\sum_{i=1}^{n} x_{ij} = 1 \qquad \forall_j \in N \qquad (1)$$

$$\sum_{j=1}^{n} x_{ij} = 1 \qquad \forall_i \in N \qquad (2)$$

$$\sum_{j=1}^{n} x_{ij} \leq |S| - 1 \qquad \forall S \subset N \qquad (3)$$

$$x_{ij} \in \{0,1\} \qquad \forall_{i,j} \in N \qquad (4)$$

For our model, the complete ILP is as follow.

The decision variables of the model are:

$$x_{ij} = \begin{cases} 1\,, if\ the\ traveling\ salesman\ goes\ directly\ from\ city\ i\ to\ city\ j, & i = A\ to\ E\ and\ j = A\ to\ E \\ 0\,, otherwise \end{cases}$$

The objective function seeks to minimize the total distance for the route:

$$\begin{aligned} \text{Minimize } Z = \quad & 3.6x_{AB} + 5.6x_{AC} + 7.6x_{AD} + 6.4x_{AE} + 15x_{AF} + \\ & 3.6x_{BA} + 6.6x_{BC} + 13x_{BD} + 11x_{AB} + 15x_{BF} + \\ & 5.6x_{CA} + 6.6x_{CB} + 5.7x_{CD} + 4.5x_{CE} + 13x_{CF} + \\ & 7.6x_{DA} + 13_{DB} + 5.7x_{DC} + 2.6x_{DE} + 7.5x_{DF} + \\ & 6.4x_{EA} + 11x_{EB} + 4.5x_{EC} + 2.6x_{ED} + 8.7x_{EF} + \\ & 15x_{FA} + 15x_{FB} + 13x_{FC} + 7.5x_{FD} + 8.7x_{FE} \end{aligned}$$

The constraints of the model are specified as follows:

1. Each node j must be visited only once:

$$x_{BA} + x_{CA} + x_{DA} + x_{EA} + x_{FA} = 1 \ (j = A)$$
$$x_{AB} + x_{CB} + x_{DB} + x_{EB} + x_{FB} = 1 \ (j = B)$$
$$x_{AC} + x_{BC} + x_{DC} + x_{EC} + x_{FC} = 1 \ (j = C)$$
$$x_{AD} + x_{BD} + x_{CD} + x_{ED} + x_{FD} = 1 \ (j = D)$$
$$x_{AE} + x_{BE} + x_{CE} + x_{DE} + x_{FE} = 1 \ (j = E)$$
$$x_{AF} + x_{BF} + x_{CF} + x_{DF} + x_{EF} = 1 \ (j = F)$$

2. Each node i must be visited only once:

$$x_{AB} + x_{AC} + x_{AD} + x_{AE} + x_{AF} = 1 \ (i = A)$$
$$x_{BA} + x_{BC} + x_{BD} + x_{BE} + x_{BF} = 1 \ (i = B)$$
$$x_{CA} + x_{CB} + x_{CD} + x_{CE} + x_{CF} = 1 \ (i = C)$$
$$x_{DA} + x_{DB} + x_{DC} + x_{DE} + x_{DF} = 1 \ (i = D)$$
$$x_{EA} + x_{EB} + x_{EC} + x_{ED} + x_{EF} = 1 \ (i = E)$$
$$x_{FA} + x_{FB} + x_{FC} + x_{FD} + x_{FE} = 1 \ (i = F)$$

3. Constraint (3) prevents formation of sub-routes with two nodes ($|S|$=2),

$$x_{AB} + x_{BA} \le 1$$
$$x_{AC} + x_{CA} \le 1$$
$$x_{AD} + x_{DA} \le 1$$
$$x_{AE} + x_{EA} \le 1$$
$$x_{AF} + x_{FA} \le 1$$
$$x_{BC} + x_{CB} \le 1$$
$$x_{BD} + x_{DB} \le 1$$
$$x_{BE} + x_{EB} \le 1$$
$$x_{BF} + x_{FB} \le 1$$
$$x_{CD} + x_{DC} \le 1$$
$$x_{CE} + x_{EC} \le 1$$
$$x_{CF} + x_{FC} \le 1$$
$$x_{DE} + x_{ED} \le 1$$
$$x_{DF} + x_{FD} \le 1$$
$$x_{EF} + x_{FE} \le 1$$

   three nodes ($|S|$=3), four nodes ($|S|$=4), and five nodes ($|S|$=5).

4. Non-negativity constraints:

$$x_{ij} \ge 0, \ i = A \ to \ E \ and \ j = A \ to \ E$$

3.3 Application of Excel Solver©

Excel Solver© is used to solve the TSP. The representation of the problem in an Excel spreadsheet is illustrated in Fig. 3. We show the complete Solver parameters in Table 2.

To	A	B	C	D	E	F
A	0	3.6	5.6	7.6	6.4	15
B	3.6	0	6.6	13	11	15
C	5.6	6.6	0	5.7	4.5	13
D	7.6	13	5.7	0	2.6	7.5
E	6.4	11	4.5	2.6	0	8.7
F	15	15	13	7.5	8.7	0

To	A	B	C	D	E	F	
A	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0
	0	0	0	0	0	0	

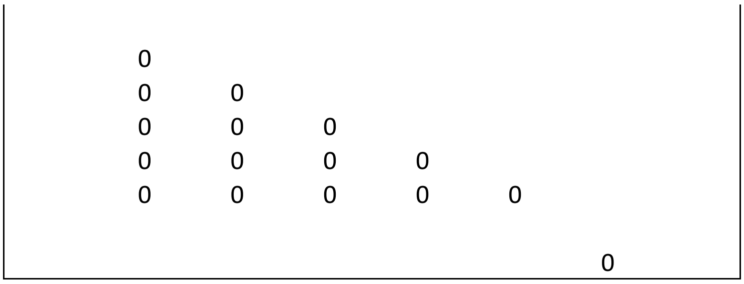

Figure 3. Representation in Excel of the traveling salesman problem

Table 2. Solver Formulation of the Problem

		Formula
Set Objective:	$J$25	SUMPRODUCT(E3:J8,E11:J16)
To:	Min	
By Changing Variable Cells:	$E$11:$J$16	
Subject to the Constraints:		Formula for constraint in defined cells
	$E$11:$J$16 = binary	
	$E$17:$J$17 = 1	
	$K$11:$K$16 = 1	
	$E$19:$E$23<=1	F11+E12; G11+E13; H11+E14; I11+E15; J11+E16
	$F$20:$F$23<=1	G12+F13; H12+F14; I12+F15; J12+F16
	$G$21:$G$23<=1	H13+G14; I13+G15; J13+G16
	$H$22:$H$23<=1	I14+H15; J14+H16
	$I$23<=1	J15+I16
	$E$11=0	
	$F$12=0	
	$G$13=0	
	$H$14=0	
	$I$15=0	
	$J$16=0	

3.4 Comparison with heuristics

Besides ILP, Excel Solver© is also capable to solve TSP using heuristic or evolutionary method, or to be specific, genetic algorithm. In Excel 2010 and above, there is a new type of integer constraint known as *AllDifferent* that form a permutation of integers, making it easy to define models with sequencing. The TSP which is hard to define using ILP, can be defined with just an objective and one *AllDifferent* constraint. The representation of the TSP in the Solver Parameters dialog box is illustrated in Fig. 3. With one constraint, solving TSP using evolutionary method would be much easier (one constraints compared to 14 constraints for ILP) and faster (optimal solution in 3.016 seconds).

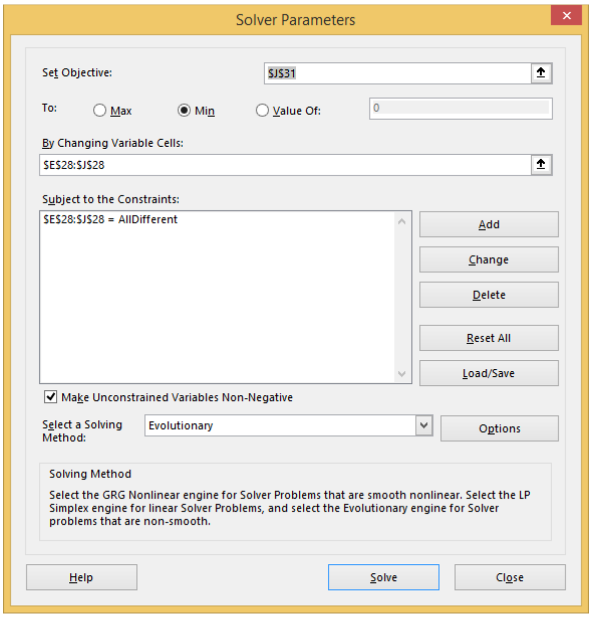

Figure 3. Solver Parameters for TSP

4. Result and Finding

Based on the results from both methods we gained the best path is from A to B, C, D, F, E, then back to A. The total travelling distance is 38.5 km. We show the suggested tour in Fig. 4. However, for evolutionary method, Excel Solver© also provides alternative solutions with the same optimal solution. The alternative solutions include E-C-B-A-D-F-E, C-E-F-D-A-B-C, C-B-A-D-F-E-C, C-B-A-F-E-D-C, B-A-E-F-D-C-B, and D-C-B-A-E-F-D.

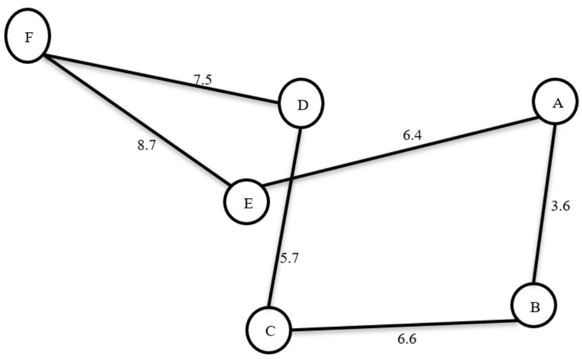

Figure 4. Optimal Solution of TSP

5. Conclusion

Our case study had achieved our objective which is to identify the shortest path and minimum total distance for the tour. From the study that has been conducted, the routes can be used for each researcher to conduct a survey. This shown that TSP can provide accurate solution that can give benefit to every researcher in terms of time and cost. The shorter the distance, the less the travelling cost. For future research, perhaps we can improve the data by expanding the number of destinations, for the whole city and get the exact time for each route for each destination and lastly we hope that we can improve our method of study.

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