CHAPTER 1

MINIMIZING TRAVEL DISTANCE ACROSS SELANGOR

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1.0 INTRODUCTION

The Malaysian Department of Surveying and Mapping (JUPEM) is undertaking a project to determine the most efficient route to visit every region in Selangor exactly once, aiming to gather accurate distance data between all pairs of regions [1]. This task involves minimizing the total travel distance while ensuring complete coverage. In graph theory, such problems can be modelled using a spanning tree, which connects all vertices (regions) with the minimum number of edges [2].

A Minimum Spanning Tree (MST) is a spanning tree with the least possible total edge weight, representing the minimal travel distance required to connect all [3]. Two primary algorithms to find an MST are Prim's and Kruskal's algorithms. Prim's algorithm starts with a single vertex and expands the MST by adding the smallest edge connecting a vertex inside the tree to a vertex outside it, making it suitable for dense graphs [4]. In contrast, Kruskal's algorithm begins by sorting all edges and adds them one by one to the MST, ensuring no cycles are formed, which is effective for sparse graphs [5]. By applying these algorithms, JUPEM can efficiently plan routes that minimize travel distances. In this study, minimum spanning trees will be constructed using both Prim's and Kruskal's algorithms.

1.1 METHODOLOGY

In this study, Graph Online [6] was utilized to construct an undirected, weighted graph, as depicted in Figure 1.1. This graph visually represents all regions within Selangor. The nine nodes correspond to the nine regions, while the edges represent the paths connecting these regions. The weights associated with the edges signify the traveling distances in kilometre (km) between the respective regions.

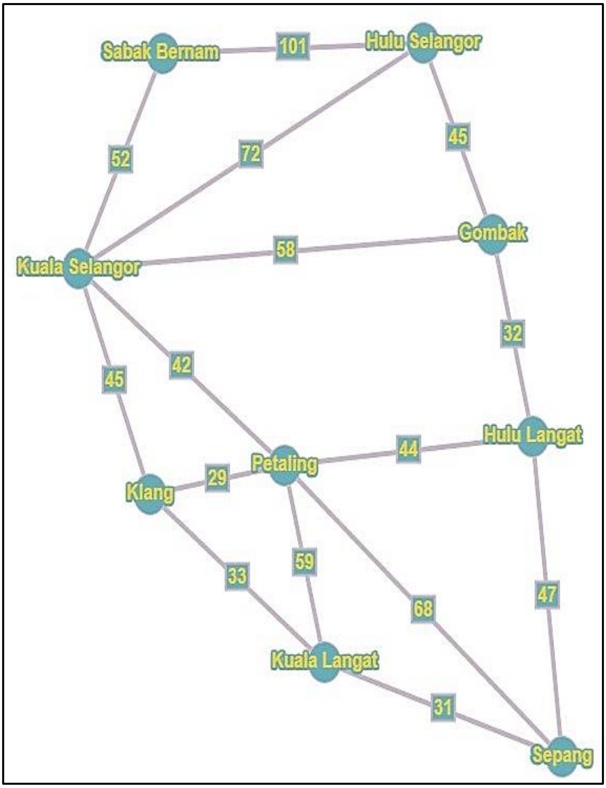

Figure 1.1: An undirected weighted graph representing the regions in Selangor

The following are the abbreviations to represent each region.
SB- Sabak Bernam
KS- Kuala Selangor
P- Petaling
K- Klang
KL- Kuala Langat
S- Sepang
HL- Hulu Langat
G- Gombak

HS- Hulu Selangor

Figure 1.1 displays a graph with nine vertices and fifteen edges. Table 1.1 lists these edges and their corresponding weights.

Table 1.1: All edges and weight

No.	Edges	Weight (km)
1	SB,HS	101
2	SB,KS	52
3	KS,HS	72
4	KS,G	58
5	HS,G	45
6	KS,K	45
7	KS,P	42
8	K,P	29
9	K,KL	33
10	KL,P	59
11	KL,S	31
12	P,S	68
13	HL,P	44
14	HL,S	47
15	HL,G	32
Total weight of all edges		726

Figure 1.1, with details in Table 1.1, illustrates a graph with 15 edges totalling 726 km. This study seeks to minimize travel distance between the nine locations in Selangor by finding a minimum spanning tree, a task that will be carried out using both Prim's and Kruskal's algorithms.

1.1.1 PRIM'S ALGORITHM

One of the two algorithms employed to determine the minimum weight of all edges is Prim's Algorithm. Prim's

Algorithm operates by selecting an arbitrary starting vertex (e.g., Sabak Bernam). Subsequently, the edge with the smallest weight connected to Sabak Bernam is identified. This process continues by selecting the edge with the smallest weight incident to either Sabak Bernam or the previously included vertex (in this case, Kuala Selangor). These iterations are repeated iteratively until all vertices are incorporated into the tree, ensuring no cycles are formed.

Table 1.2: Calculation by using Prim's algorithm

Iteration	Edges	Visited vertices	Unvisited vertices	Weight (km)
1	SB, KS	SB, KS	P, K, KL, S, HL, G, HS	52
2	KS, P	SB, KS, P	K, KL, S, HL, G, HS	42
3	P, K	SB, KS, P, K	KL, S, HL, G, HS	29
4	K, KL	SB, KS, P, K, KL	S, HL, G, HS	33
5	KL, S	SB, KS, P, K, KL, S	HL, G, HS	31
6	P, HL	SB, KS, P, K, KL, S, HL	G, HS	44
7	HL, G	SB, KS, P, K, KL, S, HL, G	HS	32
8	G, H	SB, KS, P, K, KL, S, HL, G, HS	-	45
Total weight				308

Based on Table 1.2, the minimum spanning tree constructed using Prim's algorithm connects all nine regions in Selangor with eight edges and a total weight of 308 km.

1.1.2 KRUSKAL ALGORITHM

The second algorithm utilized was Kruskal's algorithm. This approach involves iteratively selecting the edges with the lowest weights, ensuring that each selected edge does not create a cycle within the growing tree, until all vertices are connected. In this problem, the edge with the smallest is K,P with a weight of 29 km. The second smallest edge is KL, S with weight, 31 km. The process continues until all regions are connected.

Table 1.3: Calculation by using Kruskal algorithm

Iteration	Edges	Visited vertices	Unvisited vertices	Weight (km)
1	K, P	K, P	HS, S, SB, KS, KL, G, HL	29
2	KL, S	K, P, S, KL	HS, SB, KS, G, HL	31
3	G, HL	K, P, S, KL, G, HL	HS, SB, KS	32
4	K, KL	K, P, S, KL, G, HL	HS, SB, KS	33
5	KS, P	K, P, S, KL, G, HL, KS	HS, SB	42

6	P, HL	K, P, S, KL, G, HL, KS	HS, SB	44
7	HL, G	K, P, S, KL, G, HL, KS, HS	SB	45
8	SB, KS	K, P, S, KL, G, HL, KS, HS, SB	-	52
Total weight				308

Based on Table 1.3, the minimum spanning tree connecting all nine regions in Selangor comprises eight edges with a total weight of 308 km.

1.2 MINIMUM SPANNING TREE

Following the application of Prim's and Kruskal's Algorithms, a Minimum Spanning Tree (MST) with a total weight of 308 km was constructed, as illustrated in Figure 1.2. This solution satisfies the defining characteristics of an MST. Firstly, it adheres to the property of having (n-1) edges, where 'n' represents the number of vertices. Secondly, it exhibits the minimum sum of weights among all possible spanning trees.

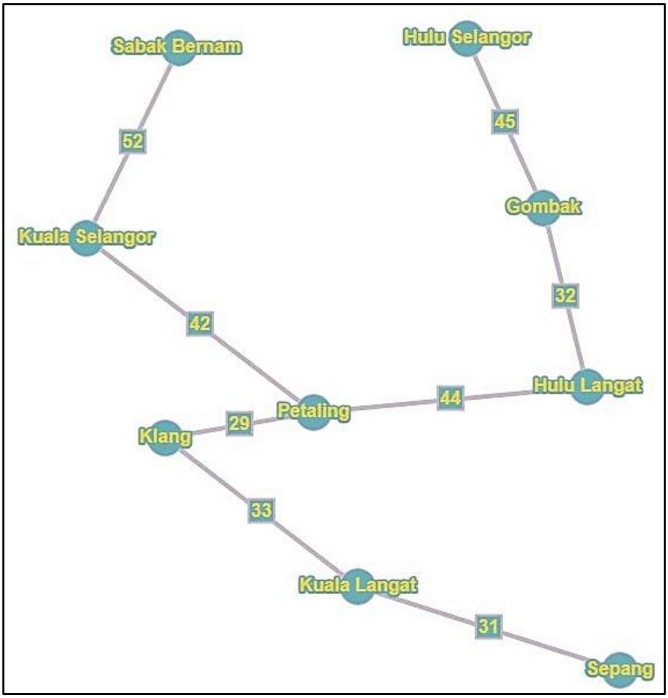

Figure 1.2: Minimum spanning tree for JUPEM's problem

1.3 CONCLUSION

The minimum total distance required to cover all regions in Selangor, visualized as a minimum spanning tree, was determined using two distinct algorithms: Prim's and Kruskal's algorithms. By solving this problem, JUPEM can now identify the shortest total distance connecting all regions within Selangor.

1.4 REFERENCES

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