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The Implementation of Minimum Spanning Tree in Finding Algebraically the Shortest Path of National-Exam-Sheet Distribution in All Senior High Schools over Bantul Regency

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Abstract.
Mathematics is a very important pillar in this rapidly technological developments. One application of mathematics in technological developments is determining the optimal path on a graph. The purpose of this research is to determine the optimal path for delivering national exam sheets (USBN) in SMA (public high schools) of all over Bantul regency. Kruskal's algorithm is an algorithm in graph theory that seeks a minimum spanning tree for a weighted and connected graph. Kruskal's algorithm is one of the algorithms for determining the shortest path from the location of one SMA to another SMA.

Keywords:
Kruskal, graph, tree, shortest path, USBN, algebra

INTRODUCTION

Along with today's technological developments, the application of science in the field of mathematics grows significantly, especially in determining the shortest path in a graph. Graph theory is widely used in everyday life including in determining the shortest path [3] [6].

Graph is a branch of discrete mathematics. The problem with a graph which can determine the shortest route is the Minimum Spanning Tree (MST) [4]. In MST, we have the minimum edges so that all vertices in the graph can be connected [1]. In 1956 and 1957 Joseph B. Kruskal and Robert C. Prim respectively described a much more efficient algorithm for building an MST [9]. Even for fairly large graphs, both algorithms can be implemented such that it takes relatively short computation time.

One of the problems which can be solved with MST is finding the shortest path in delivering packages. It can optimize the cost, energy, and time for the industry and its couriers. Wirabudi et. al., amplified that MST can truly increase the effectiveness in package delivery [10].

In the past, national exams (UN) and Final School Exam (US) were done to determine the graduation of students. Since the UN was demolished, then the US was

standardized to be National Level of School Exam which is known as USBN [5].

USBN exams are centralized at the capital of each province. Therefore, different province may have different questions of the exams. Since it is centered at the province, then the USBN sheets are produced at the capital of the province [7]. The sheets are then ditributed to each region (Kabupaten/Kota) and are followed by distributing them to each school.

In each region, the sheets are collected at the Dinas Pendidikan or Baldikmen. The Dinas has to send the sheets to each school. Due to the various distances and landscape of the schools, the Dinas may find it difficult to deliver the sheets effectively. In this case, MST can be a powerful tool in optimizing the deliveries [8].

Based on the background, the purpose of this study is to determine the shape of the graph of the distribution of National Exam Sheets in all senior high schools over Bantul regency and to find out the shortest distance between the schools so as to minimize costs.

RESEARCH METHODS

The steps which were conducted in this research were:

1. Retrieve map data for all SMAN in Bantul Regency.
2. Create the initial graph of the map data.
3. Search the Minimum Spanning Tree of the Graph obtained using the Kruskal's Algorithm (manually) and Python software.
4. Compare the results between the MST search using the Kruskal's Algorithm and the map graphs of SMA Negeri throughout Bantul.
5. Compare between the initial weights of the graph before and after the MST search is performed, then conclusions are drawn.

RESULT AND DISCUSSION

This study aims to determine the optimal path for the distribution of USBN sheets, where the problem in this research is to find a Minimum Spanning Tree for the distribution of USBN sheets to cover the minimum distance possible using the Kruskal's algorithm.

It is assumed that the Middle Education Center (Baldikmen) and Bantul Public High Schools (SMAN) are the points and the roads which connect them are the sides which have weight. The results of our observations from the map are shown in the following table.

Table 1. Letter Code and School-targeted for USBN-sheet delivery.

No.	Letter Code	Place
1.	A	Balai Pendidikan Menengah Kab. Bantul
2.	B	SMA N 1 Bambanglipuro
3.	C	SMA N 1 Banguntapan
4.	D	SMA N 2 Banguntapan
5.	E	SMA N 1 Bantul
6.	F	SMA N 2 Bantul
7.	G	SMA N 3 Bantul
8.	H	SMA N 1 Dlingo
9.	I	SMA N 1 Imogiri
10.	J	SMA N 1 Jetis
11.	K	SMA N 1 Kasihan
12.	L	SMA N 1 Kretek
13.	M	SMA N 1 Pajangan
14.	N	SMA N 1 Piyungan
15.	O	SMA N 1 Pleret
16.	P	SMA N 1 Pundong
17.	Q	SMA N 1 Sanden
18.	R	SMA N 1 Sedayu
19.	S	SMA N 1 Sewon
20.	T	SMA N 1 Srandakan

The picture of the schools on the real map can be explored at the following image.

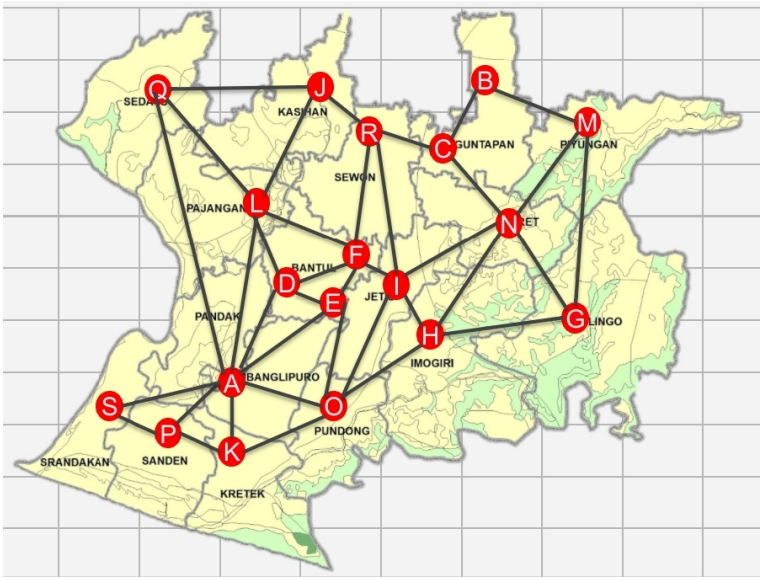

Figure 1. The Map of SMAN over Bantul Regency

The total weight in which it is the total distance of all schools is 224,5 km. In forming the shortest path, we used the Kruskal's Algorithm. The Kruskal's Algorithm as cited from Dutta in 2019 [2] can be seen as follows:

1. Arrange the edges in ascending order of weight.
2. Select the smallest one among them. If the selected edge does not form a cycle with the partial spanning tree, then insert it into the spanning tree else do not insert it.
3. Repeat step 2 to include edges one less than the total number of vertices."

After applying the Kruskal's algorithm, we get the final graph with 20 vertices, 19 edges, and 73,72 km of total weight.

CONCLUSION

Kruskal's Algorithm is one of the most effective ways in finding the shortest route in distributing USBN sheets. In the case of all Public Senior High Schools (SMAN) in Bantul Regency, before applying the Kruskal's Algorithm, the total distance which should be covered are 224,5 km. But, after applying the Kruskal's Algorithm, we get that starting from the Baldikmen, we will have all 19 SMANs covered with the total travel distance only 73,72 km. We recommend that a further research related with this USBN-sheet distribution will be conducted with various methods including the Modified Kruskal's Algorithm.

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