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USE OF GRAPH THEORY IN THE TRANS WONOGIRI BUS TRANSPORTATION SYSTEM WONOGIRI DISTRICT TRAY

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Abstract

The development of transportation modes, both land, sea and air, encourages each region to provide adequate transportation services for its people. The land transportation system cannot be separated from daily human activities, because through transportation human mobility can become more flexible. Responding to the need to develop the trans bus project in Wonogiri District, after considering the high density of vehicles during work hours or when leaving work, it is very necessary for the government to provide solution measures. Through the application of graph theory in constructing a public transportation network model using the Dijkstra algorithm, a Trans Wonogiri Bus system will be built under the control of the Wonogiri Regency transportation service. The geographical complexity of the Wonogiri District area will be very influential in modeling the trans bus transportation mode network. Through analysis and research regarding the relevance of this graph concept, seven Trans Wonogiri Bus routes were obtained which will be an alternative solution to the inefficiency of government-managed public transportation.
Keywords: Transportation, Wonogiri District, Trans Wonogiri Bus, Graph, Dijkstra Algorithm.

1. INTRODUCTION

Wonogiri Regency is a part of Jawa Tengah Province. Wonogiri Regency has an area of 182,236.02 Ha or 5.59% of the area of Jawa Tengah Province with a coastline length of 7.6 km (Harjadi, 2017). The position of Wonogiri Regency is very strategic because it is located in the southeast of Central Java Province and is flanked by Jawa Timur Province and Daerah Istimewa Yogyakarta Province. Wonogiri Regency has 25 sub-districts, 43 sub-districts and 251 villages. The population distribution is at an interval of 602 people/km2 (Hardati and Rahayu, 2021). These sub-districts include Baturetno District, Batuwarno District, Bulukerto District, Eromoko District, Girimarto District, Giritontro District, Giriwoyo District, Jatipurno District, Jatiroto District, Jatisrono District, Karang Tengah District, Kismantoro District, Manyaran District, Ngadirojo District, Nguntoronadi, Paranggupito District, Pracimantoro District, Puhpelem District, Purwantoro District, Selogiri District, Sidoharjo District, Slogohimo District, Tirtomoyo District, Wonogiri District, and Wuryantoro District.

Geographical conditions between Wonogiri sub-districts are separated by quite a distance from the city center and separated by mountains. The location of the sub-districts which are separated by natural landscape means that the connecting media between sub-districts is limited, namely only one main road and no other alternative roads. These limited transportation routes have a cutting point in the city center which brings together sub-districts at the east, south and west ends. So far, the transportation medium that has been the intermediary for balance is privately owned public transportation, the existence of which has not been optimal in meeting the needs of the community, therefore adequate transportation is needed and is able to answer the needs of the community to speed up mobilization from one place to another in an effective time.

The unequal geographic range between sub-district areas in Wonogiri causes an accumulation of vehicle volumes during working hours in the Wonogiri Sub-district area. The buildup in vehicle volume is caused by the large number of elementary, middle, high school, vocational school students, as well as workers in the eastern and southern sub-districts using public transportation to get to the city center. Apart from only one road lane, the inaccuracy of vehicle arrival hours has resulted in the need to create a special transportation route in the Wonogiri District area and provide transportation managed by the regional government, in order to reduce vehicle density during working hours and after work hours.

2. METHODS

The availability of transportation in Wonogiri District has not responded to the needs of the community, resulting in less interest in using public transportation. The development and increasingly advanced public service facilities, both in the industrial and other sectors, provide an idea for applying the concept of graph theory to the development of the transportation sector in Wonogiri District.

Graph theory is very relevant to be applied in the transportation sector because it is able to model an effective transportation system that makes it easier for people to use it. Graph theory makes it easy to construct transportation systems by determining points at a certain distance and connecting them with lines that connect one point to another. The Trans Wonogiri Bus transportation system will be developed using a directed graph network model. Using the concept of a rooted tree graph, where there is a bus stop root that has many roots spreading out, so it is very relevant to be applied in the idea of the Trans Wonogiri Bus route system.

Wonogiri District is the center of government in Wonogiri Regency. Has an area of 8,292.36 ha. The administrative area consists of six sub-districts, namely Giriwono Village, Giritirto Village, Wonoboyo Village, Wonokarto Village, Wuryorejo Village, and Giriwono Village, and consists of 9 villages, namely Sendang Village, Pokoh Kidul Village, Purworejo Village, Bulusulur Village, Purwosari Village, Manjung Village , Sonoharjo Village, Wonoharjo Village, and Wonokerto Village.

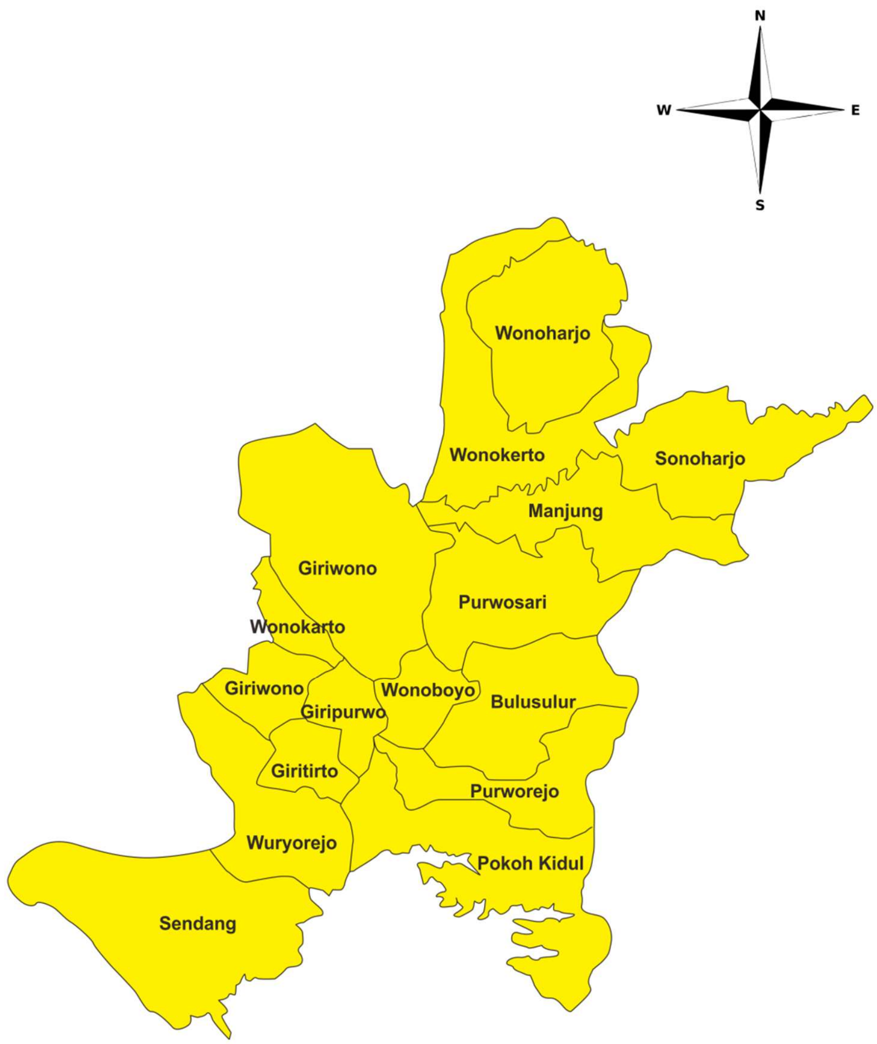

Figure 1. Map of Wonogiri District

3. RESULTS AND DISCUSSION

The Trans Wonogiri City Bus System is an example of transportation modeling using graph theory concepts to solve transportation problems in Wonogiri District. Through graph modeling, the trans Wonogiri City bus travel route will be determined from a main stop, namely at the Wonogiri Shelter, to the bus stops where the routes have been determined, after leaving the initial stop, only passing once through the bus stops and the road section that connects between the stops and back. Returning to the initial stop the bus exits.

The transportation routes in Wonogiri District are not like routes in cities such as Solo City which already has the Trans Solo Batik Route. The application of the graph concept in the initiation of the creation of the Trans Wonogiri Bus route system still uses a very simple concept, which is limited to making appropriate stops that can function optimally. Therefore, this research still focuses on determining the graph node points for the transportation system that serves the needs of the community, students and workers in mobility between sub-districts/villages.

Gambar 2. Wilayah Strategis di Kecamatan Wonogiri

Dijkstra's algorithm is a method for finding the shortest path based on the lowest weight. The weights in graph G are values on the path, namely the distance between vertices. The unit of distance between nodes is kilometers (km). Let's say the initial node to find the shortest path is v_1, then look for the path of other nodes with the smallest weight. Weight calculations always start from the starting node.

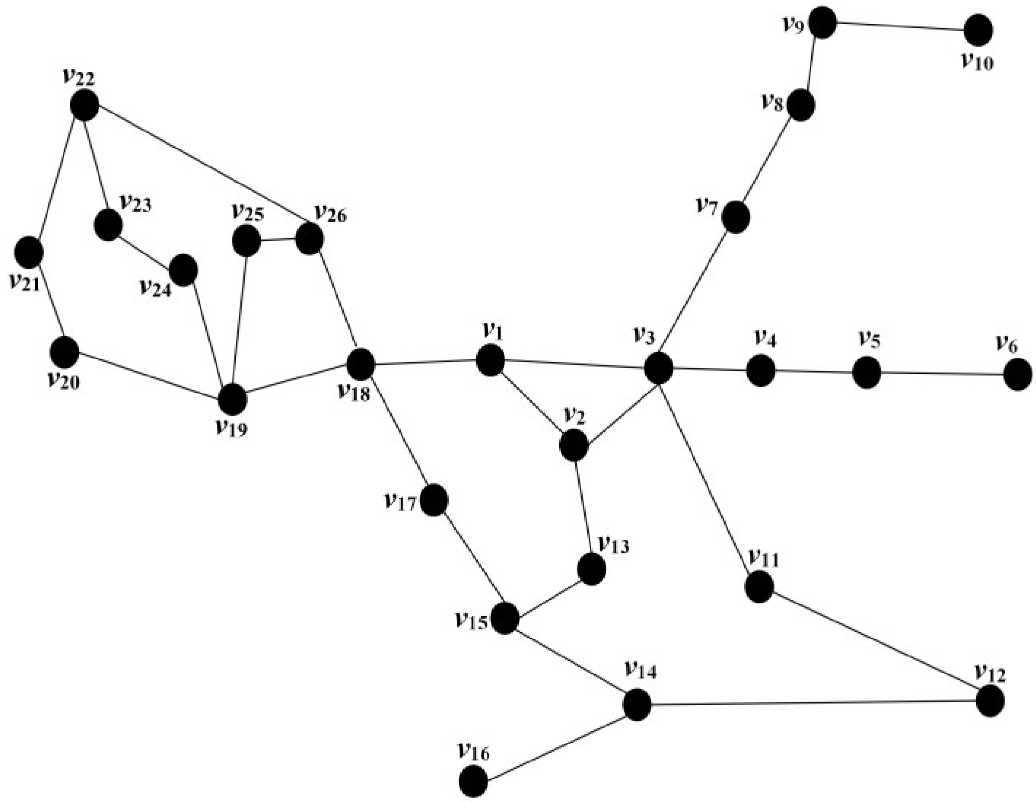

Figure 3. Strategic Area Nodes in Wonogiri District

Table 1. Description of Figure 3

Code	Location
v_1	Shelter Wonogiri
v_2	SMAN 1 Wonogiri
v_3	Pasar Pokoh
v_4	SMPN 2 Wonogiri
v_5	SMKN 2 Wonogiri
v_6	RS Medika Mulya
v_7	PLN Kedungsono
v_8	Balai Desa Purwosari
v_9	Balai Desa Manjung
v_{10}	Balai Desa Sonoharjo
v_{11}	Balai Desa Purworejo
v_{12}	Bendungan Plaza Pokoh Kidul
v_{13}	SMPN 6 Wonogiri
v_{14}	Tugu Kalpataru Wuryorejo
v_{15}	SMPN 1 Wonogiri
v_{16}	Kelurahan Sendang
v_{17}	Pasar Kota Wonogiri
v_{18}	Hutan Kaki Gandul Alas Kethu
v_{19}	RSUD Kabupaten Wonogiri
v_{20}	RSU Mulia Hati
v_{21}	RSU Astrini
v_{22}	Indomaret Wonokarto

Code	Location
v_{23}	Dinas Perindustrian dan Perdagangan Wonogiri
v_{24}	Lapangan Pringgondhani
v_{25}	SMKN 1 Wonogiri
v_{26}	SMAN 2 Wonogiri

Searching for the shortest path with Dijkstra's Algorithm starts at node v_1. Dijkstra's algorithm iteration is used to find a node with the smallest weight from node v_1. The selected nodes are separated and these nodes are not considered in the iteration of Figure 4.

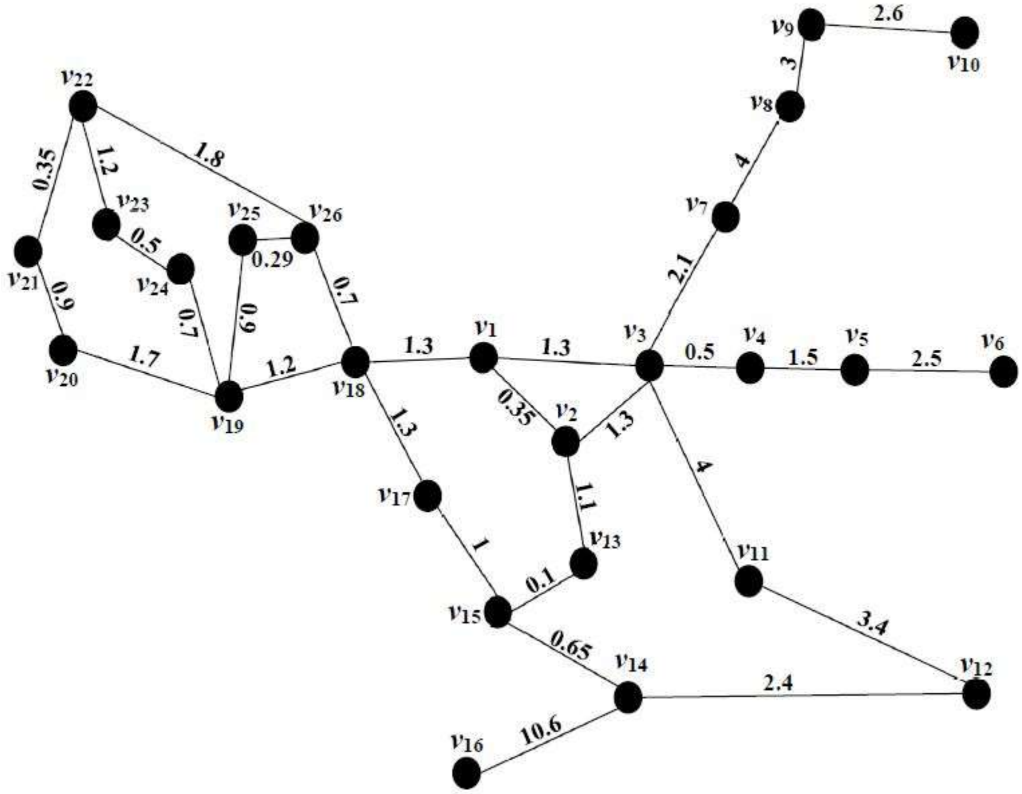

Figure 4. Trans Bus Route Graph

Each node in the graph represents a bus stop and each line represents a road segment that is used to connect one bus stop to another. The distance between nodes will be described as the shortest distance to the related nodes. Table 2 is the distance between nodes.

Table 2. Distance Between Vertices

No.	Vertices	Distance (km)
1.	$v_1 - v_2$	0.35
2.	$v_1 - v_3$	1.3
3.	$v_1 - v_{18}$	1.3
4.	$v_2 - v_3$	1.3
5.	$v_2 - v_{13}$	1.1
6.	$v_3 - v_4$	0.5
7.	$v_3 - v_7$	2.1
8.	$v_3 - v_{11}$	4
9.	$v_4 - v_5$	1.5

No.	Vertices	Distance (km)
10.	$v_5 - v_6$	2.5
11.	$v_7 - v_8$	4
12.	$v_8 - v_9$	3
13.	$v_9 - v_{10}$	2.6
14.	$v_{11} - v_{12}$	3.4
15.	$v_{12} - v_{14}$	2.4
16.	$v_{13} - v_{15}$	0.1
17.	$v_{14} - v_{15}$	0.65
18.	$v_{14} - v_{16}$	10.6
19.	$v_{15} - v_{17}$	1
20.	$v_{17} - v_{18}$	1.3
21.	$v_{18} - v_{19}$	1.2
22.	$v_{18} - v_{26}$	0.7
23.	$v_{19} - v_{20}$	1.7
24.	$v_{19} - v_{24}$	0.7
25.	$v_{19} - v_{25}$	0.9
26.	$v_{20} - v_{21}$	0.9
27.	$v_{21} - v_{24}$	0.5
28.	$v_{22} - v_{23}$	1.2
29.	$v_{22} - v_{26}$	1.8
30.	$v_{23} - v_{24}$	0.5
31.	$v_{25} - v_{26}$	0.29

We let $V(G) = \{v_1, v_2, \dots, v_{26}\}$ be the set of vertices in graph *G*. The set V' is the set of vertices that have not been selected in the shortest path. The set L is the set of vertices in the shortest path that has been selected in graph *G*. The weight of the shortest path from to is symbolized by $D(i)$. The matrix entry from row 1 to column is symbolized by $A(1, i)$. The first step is to determine the value of v_1 based on the weight of the nodes which can be seen in Table 3.

Table 3. $D(i)$ Value

$D(2) = A(1,2) = 0.35$	$D(11) = A(1,11) = \infty$	$D(20) = A(1,20) = \infty$
$D(3) = A(1,3) = 1.3$	$D(12) = A(1,12) = \infty$	$D(21) = A(1,21) = \infty$
$D(4) = A(1,4) = \infty$	$D(13) = A(1,13) = \infty$	$D(22) = A(1,22) = \infty$
$D(5) = A(1,5) = \infty$	$D(14) = A(1,14) = \infty$	$D(23) = A(1,23) = \infty$
$D(6) = A(1,6) = \infty$	$D(15) = A(1,15) = \infty$	$D(24) = A(1,24) = \infty$
$D(7) = A(1,7) = \infty$	$D(16) = A(1,16) = \infty$	$D(25) = A(1,25) = \infty$
$D(8) = A(1,8) = \infty$	$D(17) = A(1,17) = \infty$	$D(26) = A(1,26) = \infty$
$D(9) = A(1,9) = \infty$	$D(18) = A(1,18) = 1.3$	
$D(10) = A(1,10) = \infty$	$D(19) = A(1,19) = \infty$	

The ∞ sign indicates there are no connected edges between vertices. The first step, we determine the initial node, namely: v_1; $L = \{\square\}$, and $V' = \{v_2, v_3, \dots, v_{26}\}$. We obtain $V' - L = \{v_2, \dots, v_{26}\} - \{\square\} = \{v_2, v_3, \dots, v_{26}\}$. The second step, from Table 3, $D(k)$ the smallest is $D(2)$, so $v_k = v_2$. Therefore, $L = L \cup \{v_k\} = \{\square\} \cup \{v_2\} = \{v_2\}$ We obtain $V' - L = \{v_2, \dots, v_{26}\} - \{v_2\} = \{v_3, \dots, v_{26}\}$.

For $i = 3$ or $v_i = v_3$, so $D(i) = D(3) = 1.3$; $D(k) + A(k, i) = D(2) + A(2,3) = 0.35 + 1.3 = 1.65$. Because $D(3) < D(2) + A(2,3)$, then $D(3)$ still has a value of 1.65.

For $i = 4$ or $v_i = v_4$, so $(i) = D(4) = \infty$; $D(k) + A(k,i) = D(2) + A(2,4) = 0.35 + \infty = \infty$. Because $D(4) < D(2) + A(2,4)$, then $D(4)$ still has the value ∞.

For $= 5, i = 6, \dots, i = 12, \dots, i = 14, i = 15, \dots, i = 26$ is the same as $i = 4$. For $i = 13$ or $v_i = v_{13}$, so $D(i) = D(13) = 1.1$; $D(k) + A(k,i) = D(2) + A(2,13) = 0.35 + 1.1 = 1.45$. Because $D(13) < D(2) + A(2,13)$, then $D(13)$ still has a value of 1.45. This step is repeated until $L = \{v_2, v_3, \dots, v_{26}\}$

The research results from the graph method, obtained several routes in the Trans Wonogiri Bus system using the Dijkstra Algorithm. This algorithm starts from a completely empty graph. Each point on the graph represents a bus stop and each line represents the road segment that is used to connect one bus stop to another.

The line distances connecting each point are determined by the most efficient routes to be implemented in the Trans Wonogiri bus system. Seeing the geographical conditions of the regional distribution in Wonogiri sub-district, seven Trans Wonogiri bus routes were created. Route 1 connects point $v_1 - v_2 - v_{13} - v_{15} - v_{17} - v_{18} - v_1$ with a route length of 5.8 km. Route 2 connects point $v_{18} - v_{19} - v_{20} - v_{21} - v_{22} - v_{23} - v_{24} - v_{18}$ with a route length of 6,850 km. Route 3 connects point $v_{22} - v_{26} - v_{25} - v_{19} - v_{18} - v_1$ with a route length of 5,490 km. Route 4 connects points $v_{15} - v_{14} - v_{16}$ with a route length of 11,250 km. Route 5 connects point $v_{10} - v_9 - v_8 - v_7 - v_3 - v_2 - v_1$ with a route length of 11.7 km. Route 6 connects point $v_3 - v_{11} - v_{12} - v_{14} - v_{15} - v_{17} - v_{18} - v_1$ with a route length of 14,050 km. The last route, Route 7 connects point $v_1 - v_3 - v_4 - v_5 - v_6 - v_5 - v_4 - v_3 - v_1$ with a route length of 5.8 km but back and forth so the total route length is 11.6 km.

4. CONCLUSION

Through this paper, we propose an algorithm for planning the creation of a Trans Wonogiri bus transportation system based on the Dijkstra Algorithm. We have maximized the use of the graph concept in the Trans Wonogiri bus project, considering the geographical conditions of Wonogiri District as stated above. The results of the research and analysis produced seven Trans Wonogiri bus routes which were created based on the shortest route according to conditions between sub-districts and villages in Wonogiri District. The longest route is Route 6 with an arrival route from the Pasar Pokoh bus stop to the Wonogiri Shelter in a southerly direction of 14,050 km and the shortest route is Route 3 with an initial arrival from Astrini Hospital to the Wonogiri Shelter with a route length of 5,490 km. The route designed in this research can be used as a tool for planning the procurement of the Trans Wonogiri Bus transportation system under the Wonogiri Transportation Service to provide comfortable and cheap facilities for the people of Wonogiri District. In future research we will deepen the study of graph theory so that in implementing this project it can be evaluated periodically towards a system that minimizes route inefficiencies and so on.

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