Journal of Mathematics Technology and Education Vol. 1, No. 2, 2022 | 160 - 172

Journal of Mathematics Technology and Education

The Implementation of Dijkstra Algorithm in Searching the Shortest Path for Fire Engines in Medan City

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Abstract. Dijkstra algorithm is one of the algorithms to determine the shortest path from one vertex to another. In this study, the authors examine the shortest path that fire engines can choose from at the Regional I Fire Unit Post and Region II Fire Unit Post to the most densely populated villages that predict fires, namely Tegal Sari I Village, Sari Rejo Village and Kampung Baru Village. The results obtained are that if a fire occurs in the Tegal Sari I and Sari Rejo Villages, the Regional I Fire Unit which has the closest distance with the shortest route length is 5.16 km and 7.28 km, while if a fire occurs in Kampung Baru Village, the Regional Fire Unit is II which has the closest distance with the shortest route length of 5.32 km.

Keyword: Dijkstra Algorithm, Shortest Path

Abstrak. *Algoritma Dijkstra merupakan salah satu algoritma untuk menentukan rute terpendek dari satu simpul ke simpul lainnya. Pada penelitian ini penulis meneliti rute terpendek yang dapat dipilih mobil pemadam kebakaran di Pos UPT Kebakaran Wilayah I dan Pos UPT Kebakaran Wilayah II menuju kelurahan terpadat yang menjadi prediksi kebakaran yaitu Kelurahan Tegal Sari I, Kelurahan Sari Rejo dan Kelurahan Kampung Baru. Hasil yang diperoleh adalah jika terjadi kebakaran di Kelurahan Tegal Sari I dan Kelurahan Sari Rejo maka UPT Kebakaran Wilayah I yang memiliki jarak terdekat dengan panjang rute terpendek 5,16 km dan 7,28 km sedangkan jika terjadi kebakaran di Kelurahan Kampung Baru maka UPT Kebakaran Wilayah II yang memiliki jarak terdekat dengan panjang rute terpendek 5,32 km.*

Kata Kunci: *Algoritma Dijkstra, Rute terpendek.*

Received 25 Nov 2021 | Revised 06 Dec 2021 | Accepted 20 Dec 2021

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e-ISSN: xxxx-xxxx | DOI: 10.32734/jomte.v1i2.7659
Journal Homepage: https://talenta.usu.ac.id/jomte

1. Introduction

Fires that often occur in the city of Medan are triggered by a fairly high density of houses and a dense population that is concentrated in one location [1]. Medan City is one of the most densely populated cities in Indonesia, namely 8,600.13 people/km^2 which consists of 18 sub-districts (BPS, 2020). With the increasingly dense population, it is possible that Medan City is prone to fires. Based on data from the Medan City Fire Prevention and Fighting Service (P2K), there were 201 fire cases in 2017, 215 cases in 2018, and 257 cases in 2019. In 2019 there were 4 fatalities due to fires and material losses of 56.1 billion.

Considering the potential for fires to become more and more significant, the danger of this disaster must be immediately anticipated and faced with various comprehensive, systematic, effective, and sustainable mitigation efforts. One of the post-fire mitigation efforts is to shorten the travel time of fire engines, so that firefighters can come faster to the location of the fire. To shorten the travel time, the best route must be found [2].

The Dijkstra Algorithm to determine the shortest path for disaster evacuation for persons with disabilities [3]. The author implements the Dijkstra Algorithm in making a disaster evacuation application that produces location information and access roads/shortest routes that the evacuation team can choose so that the evacuation process for persons with disabilities can be carried out quickly.

In the research journal compared the Djikstra, Bellman-Ford, and Flyoid-Warsall Algorithms to find the shortest path from a graph. From this research, it can be concluded that the Djikstra Algorithm is the fastest algorithm in determining the shortest path of a graph compared to Bellman-Ford and Flyoid-Warsall [4]. The problem in this study is how to implement the Djikstra Algorithm in determining the shortest path for fire engines to arrive at the fire location quickly so as to minimize the occurrence of casualties and material losses during a fire.

2. Related Work

There are many structures that can be represented by graphs, and many problems can be solved with the help of graphs. The highway network in an area can be represented by a graph. The vertices are the cities contained in the area and the path between city A and city B is connected by a road called the side.

The graph G is defined as an ordered pair (V, E) and is denoted by $G = (V, E)$ with V dan E are defined as:

1. $V = \{v_1, v_2, \ldots, v_n\}$ is a finite non-empty set whose members are called vertices.
2. $E = \{e_1, e_2, \ldots, e_n\}$ is the set of edges that connects a pair of vertices [5].

Two vertices (u, v) are said to be adjacent if there is an edge connecting vertex u to vertex v. If e is the edge connecting vertex u with vertex v, then e can be written as $e = (u, v)$, then u and v are called "located" on e, and e is said incident with vertices u and v.

Suppose there is a graph of $G = (V, E)$ with $v_i, v_j \in V(G)$. If for any two vertices $v_i, v_j \in V(G)$ there is a track that connects the two vertices, then the graph G is said to be a connected graph. Connected graph with the starting vertex (v_0) is not same as the destination vertex for instance v_k is called path. The shortest path is defined as a path that has a path length minimum from vertex v_0 to v_k [6].

The association of a real number w(e) to each edge of e in graph G is called weighted. A graph G which has a value of w(e) on its edges is called weighted graph [6]. For example, in the graph below which models cities, the vertices are named cities, while the weights on the sides represent the distance between the cities.

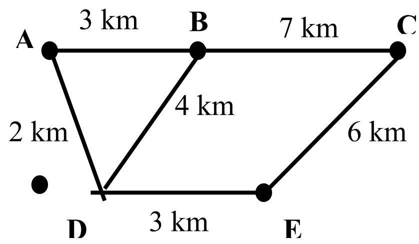

Figure 1. Weighted Graph

To representation of a weighted graph into a matrix, a_{ij}, represents the weight of each edge connecting vertex i to the vertex j. The sign "∞" represents that no side from vertex i to vertex j or from vertex i to vertex i itself, so that A_{ij} can be infinite value.

Dijkstra's algorithm uses the Greedy principle which states that at each step we choose the side with the minimum weight and include it in the solution set. The input to this algorithm is a directed graph with weight G and a source S in G and V is the set of all vertices in graph G [5].

Suppose G is a weighted directed graph with vertices $V(G) = \{v_1, v_2, v_3 \ldots, v_n\}$ and the shortest path or route to find is from v_1 to v_n. Dijkstra's algorithm starts from vertex v_1, in each iteration it will look for a vertex with the smallest number of weights from the initial vertex and these vertices are called permanent vertices and are not considered again in the next iteration.

For example,

$V(G)$: $\{v_1, v_2, v_3 \ldots, v_n\}$

L : the set of permanent vertices (the set of vertices V(G)) that have been selected in the shortest path.

$D(v_j)$: the sum of the weights of the shortest path from v_i to v_j.

$W(v_i, v_j)$: side weights from vertices v_i to v_j

$W * (1, v_j)$: sum of the weights of the shortest path from v_1 to v_j

Formally, Dijkstra's Algorithm to find the shortest path is as follows:

1. Initialization: $L = \{\}$; $V = \{v_1, v_2, v_3 \ldots, v_n\}$
2. For $i = 2, \ldots, n$; do $D\ (v_i) = W\ (v_1, v_2)$
3. During $v_n \notin L$ (v_n is not a permanent knot), either:
   a. Select a vertex $v_k \in V - L$ with the smallest $D(v_k)$, then $L = L \cup \{v_k\}$
   b. For each $v_j \in V - L$ do: if $D(j) > D(k) + W\ (k, j)$ then replace *D(j)* with $D(k) + W(k, j)$
4. For each $v_j \in V,\ W * (1, j) = D\ (j)$

According to the above algorithm, the shortest path from vertex v_1 to v_n is through the vertices in L sequentially and the weighted sum of the shortest is $D\ (v_n)$ [7].

3. Research Methodology

The data used in this study is secondary data where the data for the most populous urban village in Medan City is obtained online (BPS Medan City in Figures 2019). The author chose the 3 most populous urban villages in 3 different sub-districts, namely Tegal Sari I village in the district Medan Area with a population density of 37,158 people/km^2, Kota Matsum III village in the district Medan City with a population density of 17,245 people/km^2, and Kampung Baru village in the district of Medan Maimun with a population density of 19,694 people/km^2.

As for conducting this research, the authors obtained information on the research location with the help of Google Earth in order to make it easier to record road routes that can be passed by fire engines. According to the Minister of Public Works Regulation No.26 of 2008 the minimum road access for fire engines is 4 meters, so the researchers conducted field research on the route that was used as the research location.

The locations of this research are as follows:

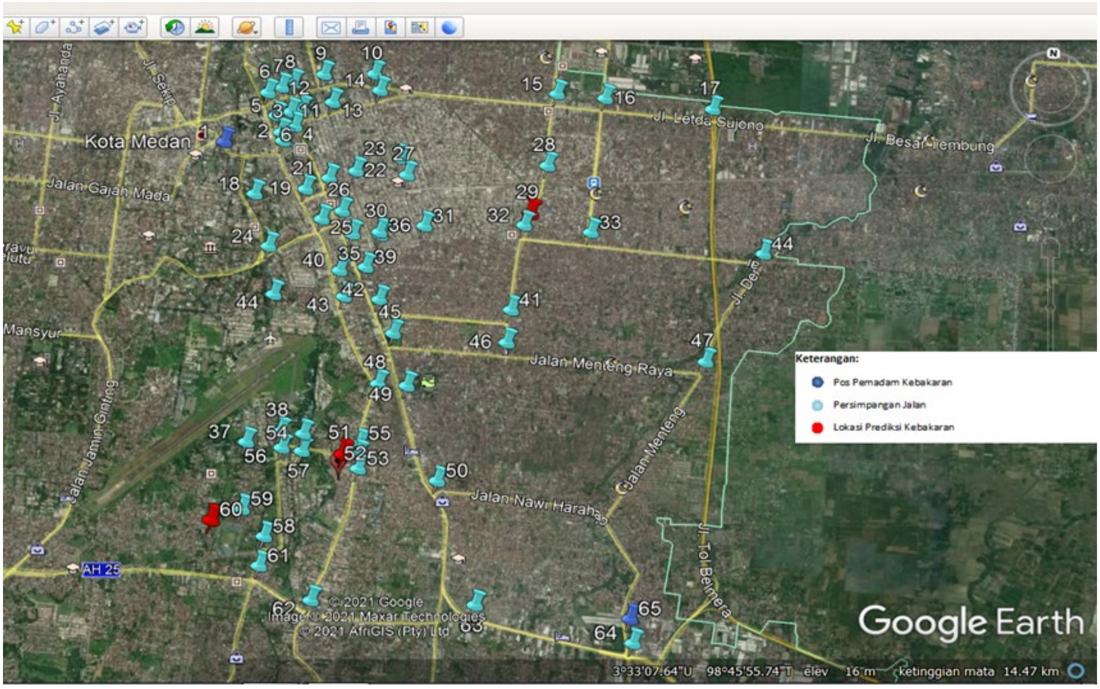

Figure 2. Vertices and Research Locations (Source: Google Earth)

Table 1. Description of Research Location in Vertices

No	Vertices	Crossroads
1	v_2	Raden Saleh Street -Balai Kota Street
2	v_3	Balai Kota Street-Bukit Barisan Street
3	v_4	Bukit Barisan Street - St.Ka Street - Kereta Api Street
4	v_5	Balai Kota Street - Prof. HM. Yamin Sh Street
5	v_6	Perintis Kemerdekaan Street - Putri Hijau Street
6	v_7	Putri Merak Jingga Street - Perintis Kemerdekaan Street
7	v_8	Gaharu Street - Perintis Kemerdekaan Street
8	v_9	Sutomo Street - Perintis Kemerdekaan Street
9	v_{10}	Perintis Kemerdekaan Street - M. H Thamrin Street
10	v_{11}	St.Ka Street - Prof. HM. Yamin Sh Street - Putri Merak Jingga Street
11	v_{12}	Prof. HM. Yamin Sh Street - Jawa Street
12	v_{13}	Prof. HM. Yamin Sh Street - Sutomo Street
13	v_{14}	M. H Thamrin Street - Prof. HM. Yamin Sh Street
14	v_{15}	Aksara Street - Letda Sujono Street - Prof. HM. Yamin Sh Street
15	v_{16}	Letda Sujono Street - Mandala By Pass Street
16	v_{17}	Tol Belmera Street - Letda Sujono Street
17	v_{18}	Palang Merah Street - Iman Bonjol Street
18	v_{19}	Palang Merah Street - Jend. Ahmad Yani Street - Pemuda Street
19	v_{20}	Kereta Api Street - Palang Merah Street - M. T. Haryono Street
20	v_{21}	M. T. Haryono Street - Irian Barat Street - Cirebon Street
21	v_{22}	M. T. Haryono Street - Sutomo Street
22	v_{23}	M. H Thamrin Street - M. T. Haryono Street
23	v_{24}	Iman Bonjol Street - Letjen Suprapto Street

24	v_{25}	Letj.Suprapto Street - Pemuda Street - Pandu Street – B. Katamso
25	v_{26}	Cirebon Street - Pandu Street - Sisingamangaraja Street
26	v_{27}	M. H Thamrin Street - Wahidin Street
27	v_{28}	Persimpangan Aksara-Jl. Wahidin
28	v_{30}	Sutomo Street - Sutrisno Street
29	v_{31}	Sutrisno Street - M. H Thamrin Street
30	v_{32}	Aksara Street - Arief Rahman Hakim Street - Denai Street - Sutrisno Street
31	v_{33}	Mandala By Pass Street - Denai Street
32	v_{34}	Panglima Denai Street - Denai Street
33	v_{35}	Sisingamangaraja Street - Rahmadsyah Street
34	v_{36}	Rahmadsyah Street - Sutomo Street
35	v_{37}	Padang Golf Street - Antariksa Street
36	v_{38}	Padang Golf Street - Adi Sucipto Street
37	v_{39}	Sisingamangaraja Street - Mesjid Raya Street
38	v_{40}	Brigjend Katamso Street - Mesjid Raya Street
39	v_{41}	Halat Street - Arief Rahman Hakim Street
40	v_{42}	Sisingamangaraja Street - Halat Street
41	v_{43}	Brigjend Katamso Street - Ir. H. Juanda Street
42	v_{44}	Iman Bonjol Street - Ir. H. Juanda Street
43	v_{45}	Sisingamangaraja Street - HM. Joni Street
44	v_{46}	Arief Rahman Hakim Street - HM. Joni Street - Menteng Raya Street
45	v_{47}	Panglima Denai Street - Menteng Raya Street
46	v_{48}	Brigjend Katamso Street - Pelangi Street
47	v_{49}	Sisingamangaraja Street - Pelangi Street
48	v_{50}	Sisingamangaraja Street - Sakti Lubis Street
49	v_{52}	Brigjend Katamso Street - Intan Street
50	v_{53}	Brigjend Katamso Street - Sakti Lubis Street
51	v_{54}	Komodor Adi Sucipto Street - Avros Street - Padang Golf Street
52	v_{55}	Brigjend Katamso Street - Avros Street
53	v_{56}	Adi Sucipto Street - DC Mahakam Street
54	v_{57}	DC Barito Street - DC Mahakam Street
55	v_{58}	Adi Sucipto Street - Karya Jaya Street
56	v_{59}	Antariksa Street - SD Inpres Street - Sejati Baru Street
57	v_{61}	Lintas Sumatera Street - Karya Jaya Street
58	v_{62}	Lintas Sumatera Street - Brigjend Katamso Street
59	v_{63}	Sisingamangaraja Street - Lintas Sumatera Street
60	v_{64}	Sisingamangaraja Street - Panglima Denai Street - Tol Street

Source: Google Maps

Methodology used by the author is with the following steps:

1. Identifying problems related to fire engine routes.
2. Collect and study various information in the form of books or journals related to Dijkstra's Algorithm.
3. Collecting data in the form of data on roads and intersections that can be passed by fire trucks obtained through direct surveys and through Google Earth.
4. Represent road and intersection data in the form of a directed graph..

5. Processing the data by implementing the Dijkstra Algorithm.

4. Result and Discussion

The Dijkstra algorithm is one of the shortest route search algorithms with approach greedy algorithm where this algorithm depends on a series of iterations, in each iteration it will look for a vertex with the smallest number of weights from the initial vertex and these vertices are called permanent vertices. The permanent vertices will be included in the solution set L and are not considered again in the next iteration.

The image representation of the research location into a weighted matrix is as follows.

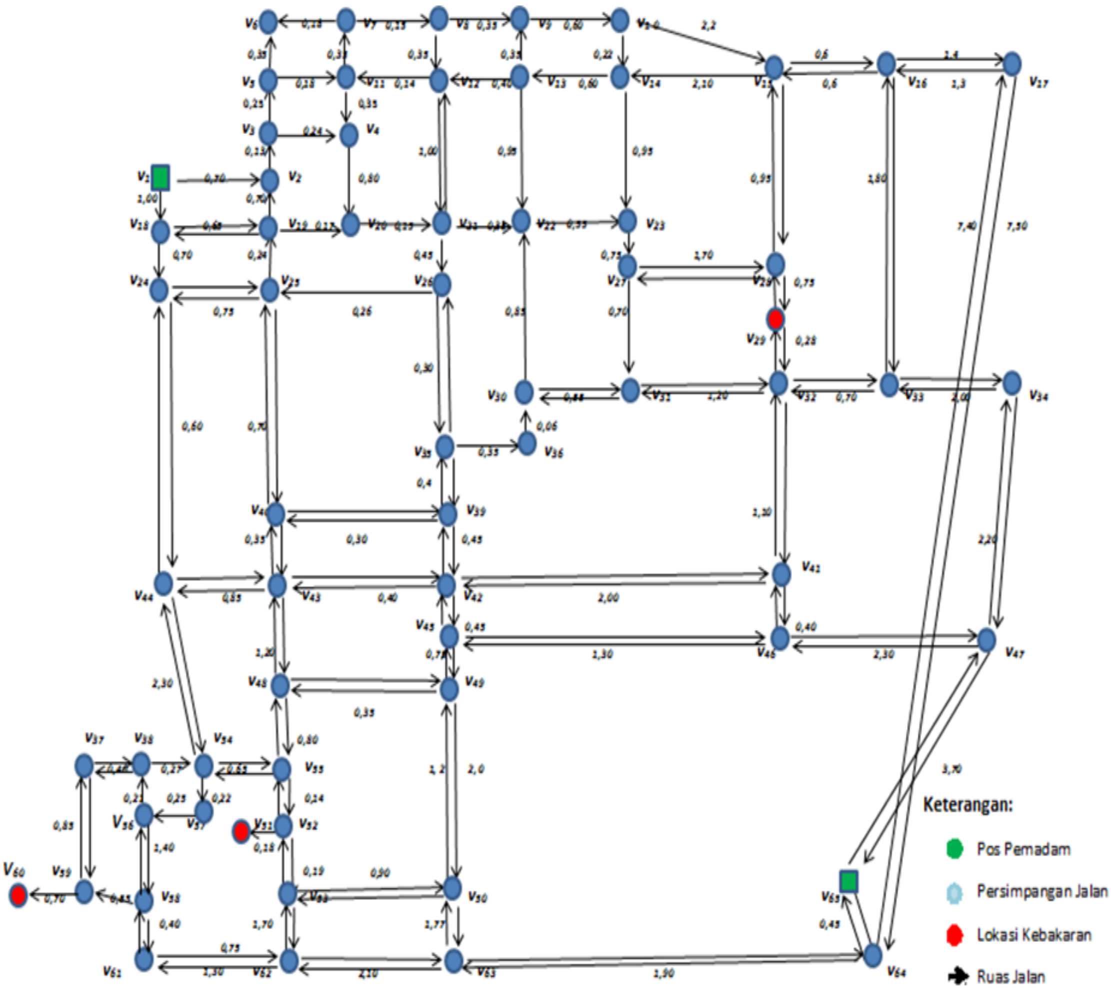

Figure 3. Weighted Graph of Research Locations

The following is the process of finding the shortest path from v_1 (UPT I) to v_{29} (Tegal Sari I Village) using the Dijkstra Algorithm manually. Resolution seeking the shortest path from v_1 to v_{29} are as follows:

Iteration 0

First $L = \{\}$ dan $V = \{v_2, v_3, v_4, v_5, \ldots, v_{65}\}$

In this iteration the initial vertex v_1 is taken as the first permanent vertex, then fill the table D(V) with D(v_1)=0 dan $D(v_2) = D(v_3) = \ldots = D(v_{65}) = \infty$.

Table 2. Iteration 0

Iteration	D(Vn)												
	1	2	3	4	5	6	7	...	20	...	21	...	65
0	0	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞

Iteration 1

$$V - L = \{v_2, v_3, v_4, v_5, \ldots, v_{65}\} - \{\} = \{v_2, v_3, v_4, v_5, \ldots, v_{65}\}$$

$D(2) = W(1,2) = 0{,}7$; $D(6) = W(1,6) = \infty$; $D(18) = W(1,18) = 1{,}0$;

$D(3) = W(1,3) = \infty$; $D(7) = W(1,7) = \infty$; $D(19) = W(1,19) = \infty$;

$D(4) = W(1,4) = \infty$; $D(8) = W(1,8) = \infty$; $\ldots$

$D(5) = W(1,5) = \infty$; $\ldots$ $D(65) = W(1,65) = \infty$

The smallest D(k) is D(2) becomes a permanent vertex and a departure vertex in the next iteration, so that $v_k = v_2$.

$$L = L \cup \{v_k\} = \{\} \cup \{v_2\} = \{v_2\}$$

Table 3. Iteration 1

Iteration	D(Vn)												
	1	2	3	4	5	6	7	...	18	...	21	...	65
1	-	0,70	∞	∞	∞	∞	∞	∞	1,00	∞	∞	∞	∞

Step 3 (a) and 3 (b) are repeated continuously until the destination vertex $v_{29} \in L$ then it will result in the 41st iteration.

Table 4. Iteration 41

Iteration	D(Vn)													
	1	...	16	...	29	...	33	35	...	41	46	...	50	52	...
41	-	-	5,51	-	5,16	-	5,58	∞	-	5,6	5,35	∞	6,75	5,7	∞

With $L = \{v_1, v_{18}, v_{19}, v_{20}, v_{21}, v_{26}, v_{35}, v_{36}, v_{30}, v_{31}, v_{32}, v_{29}\} = 5{,}16$

The process of finding the shortest path from v_1 (UPT Fire Region I) to v_{51} (Kampung Baru Village) manually by repeating steps 3(a) and 3(b) until the destination vertex $v_{51} \in L$ in order to obtain the results of iterations 51th in the following table.

Table 5. Iteration 51

Iteration	D(Vn)												
	1	...	17	34	...	47	...	50	51	...	53	...	65
51	-	-	6,91	7,58	-	7,65	-	6,75	5,88	-	7,4	∞	∞

With $L = \{v_1, v_{18}, v_{24}, v_{44}, v_{43}, v_{48}, v_{55}, v_{52}, v_{51}\} = 5{,}88$.

The process of searching for the shortest path from v_1 (UPT Fire Region I) to v_{60} (Sari Rejo Village) manually by repeating step 3 (a) and 3 (b) to the destination vertex $v_{60} \in L$ in order to obtain the results of the 58th iteration in the following table.

Table 6. Iteration 58

Iteration	D(Vn)												
	1	...	34	...	47	...	60	...	...	62	63	64	65
58	-	-	7,58	-	7,65	-	7,28	-	∞	7,59	8,45	14,41	∞

With $L = \{v_1, v_{18}, v_{24}, v_{44}, v_{54}, v_{57}, v_{56}, v_{38}, v_{37}, v_{59}, v_{60}\} = 7{,}28$.

The process of finding the shortest path from UPT Fire Region II (v_{65}) to Kampung Baru Village (v_{51}) using the Djikstra Algorithm manually.

Iteration 0

Initially $L = \{\}$ dan $V = \{v_1, v_2, v_3, v_4, v_5, \ldots, v_{64}\}$

In this iteration the initial node v_1 is taken as the first permanent vertex, then fill table D(V) dengan D(v_{65})=0 dan $D(v_2) = D(v_3) = \ldots = D(v_{64}) = \infty$

Table 7. Iteration 0

Iteration	D(Vn)												
	65	1	2	3	4	5	6	7	...	37	38	39	...	64
0	0	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞

Iteration 1

$$V - L = \{v_1, v_2, v_3, v_4, v_5, \ldots, v_{64}\} - \{\} = \{v_1, v_2, v_3, v_4, v_5, \ldots, v_{64}\}$$

$D(1) = W(65{,}1) = \infty; D(5) = W(65{,}5) = \infty;$ $D(46) = W(65{,}46) = \infty;$

$D(2) = W(65{,}2) = \infty; D(6) = W(65{,}6) = \infty;$ $D(47) = W(65{,}47) = 3{,}07;$

$D(3) = W(65{,}3) = \infty; D(7) = W(65{,}7) = \infty;$ $\ldots$;

$D(4) = W(65,4) = \infty;$ … ; $D(64) = W(65,64) = 0{,}45.$

The smallest D(k) is D(64) being a permanent vertex and a departure vertex in the next iteration, so $v_k = v_{64}$.

$$L = L \cup \{v_k\} = \{\} \cup \{v_{64}\} = \{v_{64}\}$$

Table 8. Iteration 1

Iteration	D(Vn)													
	65	1	2	3	4	5	6	7	...	37	...	47	...	64
1	-	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	3,70	∞	0,45

Iteration 2

Because the destination vertex $v_{51} \notin L$, so that step 3 (a) - 3 (b) is performed.

3(a): The smallest D(k) in first iteration is D(64) into a vertex of departure in this iteration, so that $v_k = v_{64}$..

$$L = L \cup \{v_k\} = \{\} \cup \{v_{64}\} = \{v_{64}\}$$

3(b): $V - L = \{v_1, v_2, v_3, v_4, v_5, \dots, v_{64}\} - \{v_{64}\} = \{v_1, v_2, v_3, v_4, v_5, \dots, v_{63}\}$

k = 64 (from step 3(a))

investigated every point in the V- L.

For j = 1:

$D(j) = D(1) = \infty\,; D(k) + W(k,j) = D(64) + W(64,1) = \infty + \infty = \infty$

Since $D(1) \ngtr D(64) + W(64,1)$ then D(1) fixed = ∞ .

...

For j = 17:

$D(j) = D(17) = \infty\,; D(k) + W(k,j) = D(64) + W(64,17)$

$= 0{,}45 + 7{,}40$

$= 7{,}85$

because $D(17) > D(64) + W(64,17)$ then D(17) is changed to 7,85.

For j = 55:

$D(j) = D(63) = \infty\,; D(k) + W(k,j) = D(64) + W(64,63)$

$= 0{,}45 + 1{,}90 = 2{,}35$

$= 2,35$

Since $D(63) > D(64) + W(64,63)$ then D(63) is changed to 2,35

This means that to reach the point v_{63} from v_{65}, path through v_{64}, is: $v_{65} \rightarrow v_{64} \rightarrow v_{63}$ D(64) + W(64,63) has less weight than the direct line $v_{65} \rightarrow v_{63}$ (D(63)). Then D(63) becomes a permanent vertex and a departure vertex in the next iteration, so that $v_k = v_{63}$.

$$L = L \cup \{v_k\} = \{v_{54}\} \cup \{v_{63}\} = \{v_{63}, v_{64}\}$$

Table 9. Iteration 2

Iteration	D(Vn)													
	65	**1**	**2**	**3**	**4**	**5**	**...**	**17**	**...**	**46**	**47**	**...**	**63**	**64**
2	-	∞	∞	∞	∞	∞	∞	7,85	∞	∞	3,70	∞	2,35	-

Step 3 (a) and 3 (b) are repeated continuously until the destination vertex $v_{51} \in L$ will be obtained the results in the 9th iteration are in the following table.

Table 10. Iteration 9

Iteration	D(Vn)													
	57	**1**	**...**	**17**	**...**	**34**	**...**	**45**	**46**	**48**	**...**	**51**	**...**	**64**
9	-	∞	∞	7,85	∞	5,90	∞	5,95	6,00	5,60	-	5,32	-	-

With $L = \{v_{65}, v_{64}, v_{63}, v_{50}, v_{53}, v_{52}, v_{51}\} = 5,32$

The process of finding the shortest path from v_{65} (Regional Fire Unit) II) to v_{60} (Sari Rejo Village) manually by repeating step 3 (a) and 3 (b) to the destination vertex $v_{60} \in L$ in order to obtain the results of the 29th iteration in the following table.

Table 11. Iteration 29

Iteration	D(Vn)													
	...	**17**	**25**	**26**	**...**	**32**	**33**	**36**	**...**	**44**	**...**	**60**	**...**	**65**
29	∞	7,85	7,85	7,61	∞	7,50	7,90	7,66	∞	7,65	-	7,4	-	-

With $L = \{v_{65}, v_{64}, v_{63}, v_{62}, v_{61}, v_{58}, v_{59}, v_{60}\} = 7,40$

The process of finding the shortest path from v_{65} (UPT Fire Region II) to v_{29} (Tegal Sari I Village) manually by repeating step 3 (a) and 3 (b) to the destination vertex $v_{29} \in L$ in order to obtain the results of the 35th iteration in the following table.

Table 12. Iteration 35

Iteration	**D(Vn)**													
	1	**...**	**17**	**...**	**22**	**...**	**24**	**25**	**...**	**29**	**31**	**33**	**...**	**64**
35	∞	∞	7,85	∞	8,57	∞	8,30	7,85	∞	7,78	8,21	7,90	-	-

With $L = \{v_{65}, v_{47}, v_{46}, v_{41}, v_{32}, v_{29}\} = 7{,}78$

4. Conclusions

If a fire occurs in Kampung Baru Village, the Regional II Fire UPT which has the closest distance compared to the Region I Fire UPT with the shortest path that can be traversed by fire engines, namely the Regional II UPT Fire Post → Panglima Denai Street → Sisingamangaraja Street → Sisingamangaraja Street → Sakti Lubis Street → Brigjend Katamso Street → Kampung Baru Village with the shortest route length of 5.32 km.

If a fire occurs in Kampung Baru Village, the Regional II Fire UPT which has the closest distance compared to the Region I Fire UPT with the shortest path that can be traversed by fire engines, namely the Regional II UPT Fire Post → Panglima Denai Street → Sisingamangaraja Street → Sisingamangaraja Street → Sakti Lubis Sreet → Brigjend Katamso Street → Kampung Baru Village with the shortest route length of 5.32 km.

If a fire occurs in Sari Rejo Village, the Regional I Fire Unit which has the closest distance compared to Region II Fire UPT with the shortest path that can be passed by fire engines, namely the Regional I UPT Fire Station → Imam Bonjol Street → Imam Bonjol Street → Imam Bonjol Street → Ir. H. Juanda Street → Brigjend Katamso Street → Brigjend Katamso Street → Komodor Muda Adi Sucipto Street → Dc. Barito Street → DC Mahakam Street → Adi Sucipto Street → Padang Golf Street → Street Antariksa → Sejati Baru Street → Sari Rejo Village with the shortest route length of 7.28 km.

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