

# Geographic Information System as Tool for finding Landslide Evacuation Route using Dijkstra Algorithm in ArcView

Ryan Arya Pramudya<sup>1</sup> and Subiyanto<sup>2</sup>

<sup>1,2</sup>Jurusan Teknik Elektro, Universitas Negeri Semarang, Semarang, Indonesia  
ryanaryapramudya@gmail.com<sup>1</sup>, subiyanto@mail.unnes.ac.id<sup>2</sup>

**Abstract**—This paper present a development of Geographic information system using Dijkstra algorithm. ArcView provides component for their user to develop their own system. The user interface was made by using ArcView dialog component. For data, requirement is conducted by maps digitation. Transform printed landslide maps into digital maps. Digitation map also added route information. The system development used avenue script modification. To find the optimal route used an ArcView extension called network analyst. Dijkstra algorithm as the method for finding route was containing in network analyst. Dijkstra algorithm has similarity with network analyst, which need starting point, end point and line connection. In network analyst, definite the starting point and finish point for begin the optimal route search. A geographic information system that resulting from this research is able to give information about the distance route also the direction when use in evacuation process later.

**Keywords**—Network analyst, Dijkstra algorithm, GIS

## I. INTRODUCTION

Nowadays the utility of technology applied by using geographic information system. It can be interpreted as a system that function can be used for input, save, and call back, processing, analyze, and produce data with geographic oriented. Geographic information system ability is capture, store, manipulate, analyze, manage is able to combine multiple source as long as have same spatial reference [1].

Dijkstra algorithm use as a standard reference in short route algorithm by single source [2]. Dijkstra algorithm is an algorithm which more efficient than Warshall algorithm[3]. Adjacent node in Dijkstra algorithm is efficient for calculating a huge data and also using less space [4]. Dijkstra algorithm is faster than bellman ford algorithm. Bellman-Ford algorithm is not suggested for larger networks [9].

The reason why using network analyst in ArcView is the ability for doing route finding based on Dijkstra algorithm, that can make route finding process quicker.

## II. OVERVIEW

In order to build geographic information system evacuation route, the basic thing that should be prepared is data availability for using at route finding process. Data which was collected later would be generated by using network analyst.

### A. Data Preparation

Before building up, geographic information system should prepare data about a maps and attribute data. The requirement data is:

- a) *Road map*: is a major map for path finding process. In road map contain data attribute that used as the reference by network analyst when analyzing the path. Network analyst uses distance same real length of the road. Length of the road is the sum of the weight of the edge on the path [2].
- b) *Landslide map*: maps that contain landslide scope area in some place. Not only contain scope area but also as stop event in path finding process.
- c) *Shelter maps*: has a function as start event in path finding process. It can be start form city town hall or disaster mitigation agency.

### B. Network Analyst

Network Analyst extension aims at creating, editing and analyze network datasets [13]. A network analysis approach having a potentially powerful approach to solving transportation and routing problems [11]. Network in geographic information system software context can be described as a system which the component (geographic substance) is connected each other according to linear.

In Arcview, network depends on structure (substance) line data that created a theme network. All function or network analyze can be applied in a theme with line or polyline type, it will doing based on existed of various attribute that usually place on arc and node, directly read by ArcView that supporting its theme. Arc is representation of linear element that start and end by node [5]. The nodes represent road junctions and each edge of the graph is associated with a road segment between two junctions [9].

Almost all type of network has some similar characteristic, among of them is: [5]

1. Has a phenomenon when an exists object or resource which is moving inside relevant network.
2. Has a phenomenon when a movement from start location into end location inside network needs connected path between start location and end location.

By using network analyst, user is capable to: [6].

1. Find efficient travel route
2. Determine nearest distance based on facility or vehicle.
3. Generate travel direction.

In order to the routing problem, network analyst can be generated by two criterion [12]:

1. Distance criteria: The route is generated taking only into consideration start point until finish point. The volume of traffic in the roads is not considered in this case.
2. Time criteria: The runtime of the vehicle is calculated by considering the length of the road and the speed of the vehicle in each road.

Reference [14] used network analyst for finding urban transportation optimal route.

### C. Dijkstra Algorithm

Dijkstra Algorithms is the algorithm for finding the shortest distance from one vertex to another vertex in the weighted graph, which the distance between vertex is weight from every edge on that graph. which the distance between vertex is weight from every edge on that graph. It can solve directed graph, also true for solve undirected graph too[16].

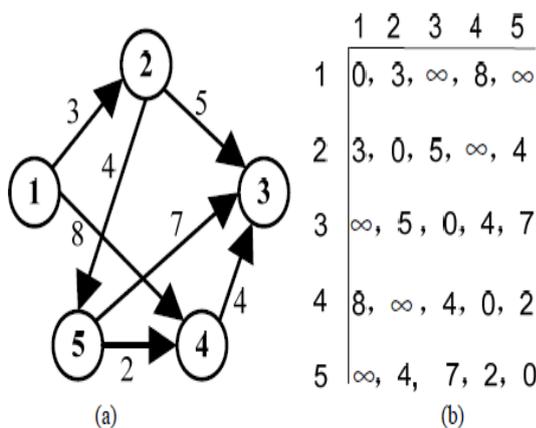


Figure 1. Example of weighted graph and adjacency matrix [8]

$G = (V, E)$  V is representing of the vertex. E is representing of edge.

Reference [15] doing the comparison about single source shortest path problem.

Some case of finding shortest line that can be solved by using Dijkstra algorithm is:

1. Do the shortest path finding between two nodes.
2. Seeking shortest path between all vertex inside the graph.
3. Solving for do find the shortest path from the certain node to all node inside the graph.

The road information that would respond about above solving problem ability are usually large and have thousands of streets, that is why one should pay more attention how the information processed [7].

Some step that can be use in Dijkstra algorithm [10].

1. Assign every tentative node distance value, set it to zero for the initial node and infinity to all other.
2. Mark all nodes as the unvisited node, set an initial node as starting. make a set unvisited nodes which contain all nodes except the initial.
3. For the starting node, calculate neighbor node tentative distance although it is unvisited. if a neighbor was examined it is not marked as "visited" at this time, and it remains in the unvisited set.
4. After finish with considering all neighbor from the starting node, mark the current node as visited and remove it from the unvisited set. A visited node will never be checked again.
5. If the destination node has been marked visited or if the smallest tentative distance among the nodes in the unvisited set is infinity then stop. The algorithm has finished.

Reference [15] doing the comparison about single source shortest route problem. Another implementation of Dijkstra algorithm is route optimization for vehicle evacuation route [13].

Suppose that is  $G = (V, E)$ . V is representing of the vertex. E is representing of edge.  $V = \{V_1, V_2, V_3, \dots, V_n\}$  is including with n nodes. For weighted direct graph adjacency matrix  $A = (a_{ij}) n \times n$  is defined by: [8]

$$a_{ij} = \begin{cases} W_{ij}, & (V_i, V_j) \in E \\ \infty, & (V_i, V_j) \notin E \end{cases}, i, j = 1, 2, \dots, n \quad (1)$$

Where  $W_{ij}$  is denoted the weight of arc  $\langle V_i, V_j \rangle$  and  $\infty$  is denoted that there is no edge between  $V_i$  and  $V_j$ .

L denotes the set of the end points that have found the shortest route from the original point[8].  $(V - L)$  denotes the set of nodes that have not yet calculated the shortest route.

Use adjacency matrix W to store network information.  $W_{ij}$  denotes the weight of arc  $\langle V_i, V_j \rangle$ . If there is no arc between  $V_i$  and  $V_j$ , then  $W_{ij}$  is set to  $\infty$ .  $d_i$  is defined as the weight from the source points to node  $V_i$ . Initialize starting point as  $d_s = 0$  and  $D_i = C_{si}$

$w(i, j)$  contain line weight from start point until end point that connected in a graph. The starting point is i and the end point is j.

$$V(G) - L = \{V_a, V_b, V_c, \dots, V_n\} - \{i\} = \{V_a, V_b, V_c, \dots, V_n\} \quad (2)$$

To noted which node that have been chosen in the calculation process use (2).

As long as  $V_n \notin L$  do:

- a. Chose point  $V_k \in V - L$  with lowest  $D(k)$
- b. For every  $V_j \in V - L$  do

$$(D(j), (D(k) + W(k, j))) \quad (3)$$

$$\text{if } (D(j) > (D(k) + W(k,j))) \quad (4)$$

at the next iteration change the weight value

$$D(j) \text{ with } (D(k) + W(k,j)) \quad (5)$$

### III. DIJKSTRA FOR SHORT PATH FINDING

#### A. Description of Dijkstra for Short Path Finding

Doing the manual calculation for proving if the distance that generated is valid by picking up another point accept disaster point and shelter point. Its taken by random. The notation of  $V_1$  in this paper changed to  $V_a$  and so with the other . The first step process to do is write the value of  $w(i,j)$ .

TABLE I. TABLE  $w(i,j)$

$W_{ij}$	$V_a$	$V_b$	$V_c$	$V_d$	$V_e$	$V_f$	$V_g$	$V_h$	$V_i$
$V_a$	0	65.13	$\infty$	45.94	$\infty$	$\infty$	$\infty$	$\infty$	$\infty$
$V_b$	65.13	0	64.54	$\infty$	44.05	$\infty$	$\infty$	$\infty$	$\infty$
$V_c$	$\infty$	64.54	0	$\infty$	$\infty$	45.90	$\infty$	$\infty$	$\infty$
$V_d$	45.94	$\infty$	$\infty$	0	77.50	$\infty$	46.34	$\infty$	$\infty$
$V_e$	$\infty$	44.05	$\infty$	77.50	0	71.95	$\infty$	44.11	$\infty$
$V_f$	$\infty$	$\infty$	45.90	$\infty$	71.95	0	$\infty$	$\infty$	43.02
$V_g$	$\infty$	$\infty$	$\infty$	46.34	$\infty$	$\infty$	0	94.44	$\infty$
$V_h$	$\infty$	$\infty$	$\infty$	$\infty$	44.11	$\infty$	94.44	0	70.83
$V_i$	$\infty$	$\infty$	$\infty$	$\infty$	$\infty$	43.02	$\infty$	70.83	0

In Table 1 which adjacent matrix, not all node have connected path between one to each other, that's why node which not connected to another node will note by sign  $\infty$  in Figure 2  $w(i,j)$  are line weight from starting point until finish point. For further information, see figure artificial node and length road.

TABLE II. TABLE  $D(k)$

$D(a) = W(c,a) = \infty$	$D(f) = W(c,f) = 45.902$
$D(b) = W(c,b) = 64.54$	$D(g) = W(c,g) = \infty$
$D(d) = W(c,d) = \infty$	$D(h) = W(c,h) = \infty$
$D(e) = W(c,e) = \infty$	$D(i) = W(c,i) = \infty$

Table 2 explain about node which adjacent with starting point, so node that didn't have line connection with starting point will be noted with  $\infty$  that mean infinity.

$$\text{In this graph, } V(G) = \{V_a, V_b, V_d, V_e, V_f, V_g, V_h, V_i\}$$

L is a union point  $\in V(G)$  that chosen in shortest path

$$\text{And then } L = \{\} \text{ and } V(G) = \{V_a, V_b, V_d, V_e, V_f, V_g, V_h, V_i\} \text{ so}$$

$$V(G) - L = \{V_a, V_b, V_d, V_e, V_f, V_g, V_h, V_i\} - \{\} = \{V_a, V_b, V_d, V_e, V_f, V_g, V_h, V_i\}$$

From Table 2 it can be find the lowest value of  $D(k)$  is  $D(f)$  which the value is 45.902 with the result that value of  $V(k) = V_f$ ,

$$L = L \cup V_k \text{ where } \{\} \cup V_f = V_f$$

$$V(G) - L = \{V_a, V_b, V_d, V_e, V_f, V_g, V_h, V_i\} - \{V_f\} = \{V_a, V_b, V_d, V_e, V_g, V_h, V_i\}$$

For the first iteration beginning by find the value of

$$(D(a), (D(f) + W(k,j)))$$

The result that obtain from manual calculation shows the distance as far as 221.918 meters.

By reading backward, so the shortest path finding by manual method is as follow:

1. Decreasing occur at index  $K = d$  in  $D(g)$ , so the chosen path is  $V_d \rightarrow V_g$ .
2. Decreasing didn't happen at index  $K = h$  in  $D(d)$ , so this not the chosen path.
3. Decreasing occur at index  $K = a$  in  $D(d)$ , so the chosen path is  $V_a \rightarrow V_d \rightarrow V_g$ .
4. Decreasing didn't happen at index  $K = e$  in  $D(a)$ , so this not the chosen path.
5. Decreasing didn't happen at index  $K = i$  in  $D(a)$ , so this not the chosen path.
6. Decreasing occur at index  $K = b$  in  $D(a)$ , so the chosen path is  $V_b \rightarrow V_a \rightarrow V_d \rightarrow V_g$ .
7. Decreasing didn't happen at index  $K = f$  in  $D(b)$ , so this not the chosen path.

So the result of the shortest path from manual calculating is  $V_c \rightarrow V_b \rightarrow V_a \rightarrow V_d \rightarrow V_g$  with total length is 221.918 meter.

#### B. Testing

Random point that was taken at manual calculation by network analyst will do path finding process.

In real map actually doesn't exist of a node, so in Figure 4 the artificial node is made in purpose to make easier when manual calculation. Finding quickest path starting from node C until node G.

Indeks D(k) minimum	L	V-L	D(a)	D(b)	D(d)	D(e)	D(f)	D(g)	D(h)	D(i)
-	0	Va.Vb. Vd.Ve. Vf.Vg. Vh.Vi	W (c,a) =∞	W(c,b) =64.54 9	W (c,d) =∞	W (c,e) =∞	W(c,f) =45.90 2	W (c,g) =∞	W (c,h) =∞	W (c,i) =∞
D(K)f	Vf	Va.Vb. Vd.Ve. Vg. Vh.Vi	∞	64.54	∞	117.85	45.90 ~	∞	∞	88.92
D(K)b	Vf.Vh	Va.Vd. Ve.Vg. Vh.Vi	129.68	64.54 ~	∞	108.60	45.90 ~	∞	∞	88.92
D(K)i	Vf.Vb.Vi	Va.Vd. Ve.Vg. Vh	129.68	64.54 ~	∞	108.60	45.90 ~	∞	159.76	88.92 ~
D(K)e	Vf.Vb.Vi. Ve	Va.Vd. Vg.Vh	129.68	64.54 ~	186.11	108.60 ~	45.90 ~	∞	152.718	88.928 ~
D(K)a	Vf.Vb.Vi. Ve.Va	Vd.Vg. Vh	129.68 ~	64.54 ~	175.57	108.60 ~	45.90 ~	∞	152.718	88.92 ~
D(K)h	Vf.Vb.Vi. Ve.Va.Vh	Vd.Vg	129.68 ~	64.54 ~	175.57	108.60 ~	45.90 ~	247.16	152.718 ~	88.92 ~
D(K)d	Vf.Vb.Vi. Ve.Va.Vh Vd	Vg	129.68 ~	64.54 ~	175.57 ~	108.60 ~	45.90 ~	221.91	152.718 ~	88.92 ~
D(K)g	Vf.Vb.Vi. Ve.Va.Vh Vd.Vg									

Figure 2. Finishing Table

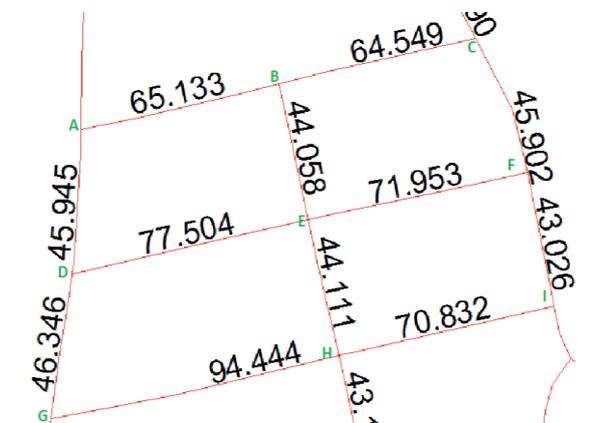


Figure 3. Artificial node and length road

TABLE III. TABLE CODE AND LENGTH

Route	Code	Length
A->B	2816	65.133 meter
B->C	1659	64.549 meter
A->D	1655	45.945 meter
D->E	1678	77.504 meter
E->F	2807	71.953 meter
B->E	1665	44.058 meter
C->F	793	45.902 meter
D->G	1656	46.346 meter
E->H	1664	44.111 meter
F->I	794	43.026 meter
G->H	1657	94.444 meter
H->I	1658	70.832 meter



Figure 4. Road code



Figure 5. Shortest path result

#### IV. RESULT AND DISCUSS

The distance that generated by network analyst as far as 220.13 meters from node C until G.

Direction that generated by network analyst are:

*Starting from Graphic pick 1 (C) Turn left onto 792. Travel on 792 for 0.56 m. Turn right onto 1659 Travel on 1659 for 64.55 m Continue straight onto 2816. Travel on 2816 for 65.13 m. Turn left onto 1655 Travel on 1655 for 45.94 m. Continue straight onto 1656. Travel on 1656 for 43.94 m. Turn left into Graphic pick 2 (G) Total distance traveled is 220.13 m*

The distance that result between manual calculation and network analyst previously be rounded become 220 meters and 222 meters.

The differences between manual calculation and network analyst adrift as long as 2 meters. It causes of the starting point and finish point not exactly in node C and node G. Its proving if the network analyst is accurate for use in finding shortest route when evacuation process happen.

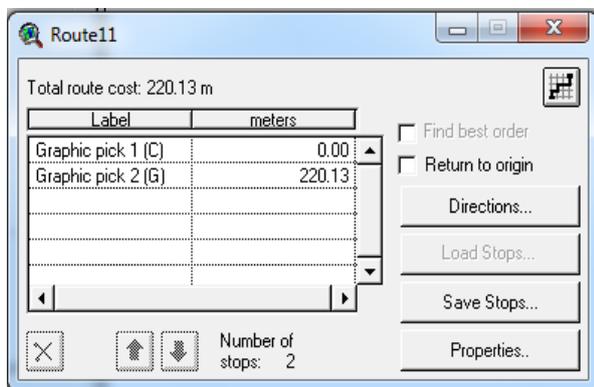


Figure 6. Distance from node C to node G

#### V. CONCLUSION

Supplying information about evacuation route by using network analyst as route finder tool. Network analyst gives detail information for supporting evacuation process. Dijkstra algorithm inside network analyst can be a solution that use for as path finding by using geographic information system. Later, this needs to combine with GPS so the direction that generated can be show by real-time.

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