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The Best Way to Find an Evacuation Route for Fire Emergency

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Abstract: Evacuation route planning for urban area is important in a natural or man-made disaster. Fires in urban area have been one of the most dangerous problems in developing countries such as Myanmar. It is needed to develop effective planning to response and rescue in time locally everywhere because damage properties of fires have increased in present day. This paper presents an offline evacuation route planning method to provide for rescue schemes as fast as possible without the internet. The proposed algorithm calculates the shortest route between the nearest fire station such as rescue place and any fire incident as accident place by adding information of parent nodes to the A* algorithm to reduce searching time. It has two parts for generating efficient evacuation route. The first is producing the shortest route for fire engines to go to emergency places. Improving the A* algorithm in this paper speeds up the computation time of the route. Comparison results show that the proposed algorithm has a faster average response time than other algorithms. The second is that handling unexpected congestion on the identified shortest route by two ways not to delay emergency response condition. The simulation experiments were executed by the proposed method. The result of this system helps to find the most likely routes to get to the emergency area quickly.

Keywords : GIS, A* algorithm, Dijkstra's algorithm, Heuristic, Open Street Map, Drone Map, shortest path

1. Introduction

Nowadays, occurring natural disasters and man-made disasters are increasing around the world. Efficient evacuation is critical for emergency situations to endanger lives and property of people, environment of disaster areas. Therefore, efficient evacuation route planning to make rescue operations in disaster areas is also more important at present.

Fire, one of the man-made disasters, is a dangerous and important problem both in urban areas and rural areas in many countries. There can be serious damage properties within a short time by fires. Moreover, the occurrence of fires has been greater than before in cities and towns of Myanmar. The ability of using immediately online applications based on geographic information system (GIS) such as Google Map is not sure in all areas where fall in disaster or emergency state although online GIS based systems have more advantages rather than offline GIS systems.

Offline GIS based systems are more effective and efficient for handling emergencies with improved workflow and easy access than web-based GIS systems. In Myanmar, it is not sure to get the internet connection whenever it is needed in some places where unexpected conditions such as bad weather conditions, technical faults in cellular services, and outbreak of electric city lines can occur.

Therefore, as our motivation, the effective offline planning method is proposed to find a shortest route by presenting fire engines to go quickly to fire accident places as case-study example in this paper. The proposed method also considers that occurring unexpected situation on the identified route so that rescue vehicles can reach emergency places in time.

Fire emergency cases of Meiktila were used as case-study data. Firstly, the nearest fire stations are calculated based on the distance between fire accident place and fire station. This distance is calculated using the Haversine distance formula. This system uses a graph to represent a map where the vertices represent the fire station and the edges represent the routes connecting to the fire stations. The nearest fire stations are calculated based on the distance between fire accident place and fire station. Then, the shortest path for vehicles to emergency place is calculate by A* algorithm which is modified by adding a new heuristic information of parent nodes, *p(n)*, for backward nodes calculations to reduce searching time. Moreover, in this paper, occurring congestion case on the identified the best road route is also considered by two ways not to be much delay time for rescue operation. Some researchers show only one path in the shortest possible time. That route may be convenient in the big cities, but it is less convenient in the smaller towns, so we have to find more possible routes. Therefore, the search algorithm has been improved to find more than one route faster. A* algorithm has been added to add a heuristic function to finds a faster route. Adding a heuristic to the routing search method increase storage space but faster routing searching. To reduce running time, the node combination is used to reduce nodes before finding a route. In the Dijkstra's algorithm, finding the shortest routes requires finding all the way out of the source, taking the least of them. In the A* algorithm, you only have to find a small path from the beginning, and then you have to find less than Dijkstra's , because A* takes into account heuristic. The roads of small towns in Myanmar are different from the big once. Our system helps rescue organizations to alleviate such incidents. Meiktila, unlike other cities, is a crossroads, making it is very expensive to travel in the event of an emergency, which can be costly. In case of emergency, it can be done online but not online there. It also compares the results with the best solution for the fire department as soon as possible. In this paper shows that the proposed algorithm is superior to other algorithms.

2. RELATED WORKS

Effective route planning is important to any emergency case and can help evacuation team and vehicles to reach emergency place in time. Many researchers proposed various methods for emergency case using many shortest route algorithms.

In 2013, Miler, Damir Medak, and Dražen Odobašić compared the performance of Dijkstra shortest path calculation with PostgreSQL (using pgRouting) and the Neo4j graph database [5] and found that the Neo4j graph database is suitable for calculating the shortest route in the transport network. However, it must be considered that the size of memory is huge when the database becomes to large transport networks.

Based on the shortcomings of Dijkstra's algorithm in large graphs, Rodríguez-Puente and Lazo-Cortés [8] proposed a modification of Dijkstra's shortest path searching algorithm in reduced graphs. The results of the proposed algorithm were compared to the results of Dijkstra's algorithm and A* algorithm. That comparison showed that, by applying the proposed algorithm, it is possible to find the best path in a comparable or even in a reduced amount of time than with heuristic algorithms.

In 2015, Dabhade, K. V. Kale, and Yogesh Gedam [2] provided the facility to find the closest hospital location based on the user's location. They used ArcGIS software and Dijkstra's algorithm to dynamically find all of the closest hospitals from the place of user to reach the right nearest hospital quickly.

In [8], the A* algorithm was applied for searching information of bus routes in downtown Yangon in order to help bus transport users. They demonstrated that A* is better for finding the best route if the starting point and destination are known and the shortest route if an acceptable heuristics function is used.

In [4], a GIS-based network analysis was implemented and applied to the Mandalay road network using a Dijkstra routing algorithm. The proposed method chose the best road route between two specific locations on the road network data by finding the nearest emergency service provider and fire department to the location of the incident depending on traffic conditions. The proposed approach revealed that it is the best one for performing network analysis in populated cities such as Mandalay.

The A* algorithm is better used to find running speeds than the Dijkstra's algorithm , and some research has shown that it can be used in a variety of experiments. Most research shows only the shortest path, only the distance. Not much is said about when it will arrive. According to the good results of the above proposed research works for road networks and A* algorithm based on heuristics function, A* algorithm is modified by adding parent node heuristics function in the proposed method to produce efficient evacuation route for offline evacuation route planning system.

3. METHODOLOGY

3.1 Graph Concept and Network Presentation

A graph, G = (V, E), consists of a set of vertices, V, and a set edges, E. To solve many problems of real life, graphs are used. Moreover, graphs are also used to represent networks such as road network, circuits, telephone network, and sale network. .

Graphs are represented on computers by two common methods: an adjacency matrix or list. The adjacency matrix

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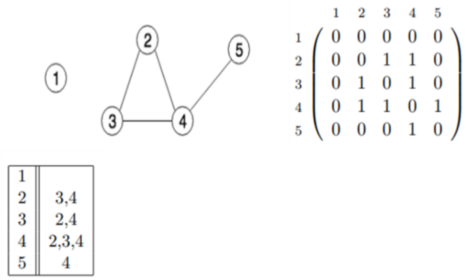

Fig. 1. Example graph with adjacency matrix and adjacency list

has size |V|×|V| with entry $A_{ij} = 1$ if edge (i, j) is in the graph, and $A_{ij} = 0$ otherwise. Example graph with adjacency matrix is presented in Fig. 1.

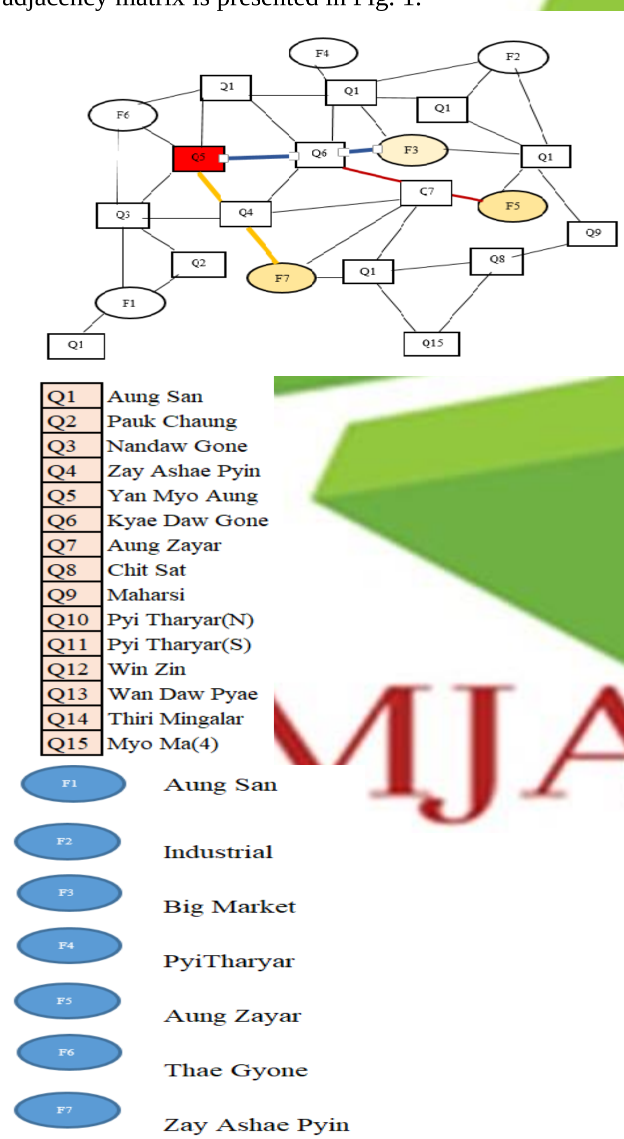

Fig.2. Graph representing of fire stations and quarters name in Meiktila city

Fig.2. shows graphical representations of fire stations and quarters in Meiktila city.

3.2 A * algorithm

For path finding, A* is the most popular choice because it's fairly flexible and can be used in a wide range of contexts. A * algorithm searches the lowest-cost shortest path between the initial and the final state. It is used in various applications, such as maps. In maps, the A* algorithm is used to calculate the shortest route between the initial source state and the final destination state. A* uses a function *f(n)* to calculate a total estimate cost of a path using that node. The pseudo code of the proposed extend A* algorithm described as follow. This algorithm is suitable for use when you want to quickly find the distance from the source to the destination. The A* algorithm calculates the shortest path by using equation (1) and (2). It also notes the time needed to find the shortest path.

$$f\ (n)\ =\ g\ (n)\ +\ h\ (n)$$

(1)

$$h(n)\ =\sqrt{(x_1-x_2)^2+\ (y_1-y_2)^2}$$

(2)

f (n) is the evaluation function of node *n* and represents the cost from the originating node to the intermediate node *n* and to the destination node. *g (n)* is the cost from the starting node to node *n* in the state space. *h (n)* is the cost estimate of the optimal path from node *n* to the target node.

3.3 Finding the Nearest Fire Station to Fire

The proposed system is tested on Meiktila regions, road network. When the information of fire has been reported to the head office of fire station, the system asks which road is on fire or the nearest thing to fire and then search the nearest fire station to burning area on the map using the distance formula as follow:

$$d\ =\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}$$

(3)

where,

d = distance

$(x2, x1)$ = coordinate of the first points

$(y2, y1)$ = coordinate of the second points

This map can show the nearest fire station where the location ignited by calculating latitude and longitude from the spatial database.

3.4 The Proposed Effective Path Finding to Fire

The shortest path between fire station and burning area is calculated by the proposed algorithm using equation (4) based on the result of the nearest station to burning area. Based on the idea of algorithm A*, the parent node of the current node is added to the improved A* algorithm, the distance rated between the node and the end point. The shortest path between fire station and burning area is calculated by the proposed algorithm using equation (4) based on the result of the nearest station to burning area. According to *f(n) of A* algorithm,* searching method goes backward to parent node to calculate the distance value of the route. It has traversal time interval for this operation. In our method, to reduce this traversal time, one parameter *p(n)*; the parent node of the current node parameter is added in equation 4. In the proposed approach, *f(n) is* calculated based on two heuristics functions as presented in equation (4). When you add another heuristic to such a fast A* , it's faster because the added heuristic lets you know the node you searched for earlier and the nodes along the search path, so it speeds up when you return to the beginning of the last route.

$$f\ (n)\ =\ g\ (n)\ +\ h\ (n)\ +\ p\ (n) \tag{4}$$

```
1.    initialize initial distance;
2.    initialize settled nodes and unsettled node lists;
3.    add the starting point to settled nodes list;
4.    while settled nodes not empty
5.    choose a node from settled nodes list;
6.    remove the chosen node from settled nodes list;
7.    if it is the emergency place then
9.    get the path and calculate distance;
10.   for each child point NEXT
11.   if NEXT is not in either list then
12.   find the value of NEXT;
13.   add NEXT into settled nodes list;
14.   else if NEXT is in settled nodes list then
15.   compare the distance value of SNEXT;
16.   update settled nodes list;
17.   else if less distance than value of unsettled node
      list then
18.   update the value of unsettled nodes list;
      remove NEXT to settled nodes list;
     end if
   end if
  end if
  end for
 19.  add FIRST to unsettled nodes list;
20.   rank the nodes in settled nodes list;
end while
```

Improved estimation function does the research more intentionally in the sense of algorithm A* approaching the end of the algorithm research can reduce the number of crossings point to the points and increase the speed. If you want, you can even introduce the parent node of the parent node of the current node the point of evaluation is to improve efficiency the algorithm is number of nodes involved algorithm reduces the number of reviews increased points, storage capacity and number of points an increase in the evaluation value means that the burden of the algorithm is enormous. The Heverisine formula is used in the proposed method to find the path between the nodes with latitude and longitude by using the equation 5.

$$haversin\left(\frac{d}{r}\right) = haversin(\emptyset 2 - \emptyset 1) + (\emptyset 1)(\emptyset 2) haversin(\varphi 1 - \varphi 2) \tag{5}$$

4. SYSTEM OVERVIEW

The overview structure of the proposed system is presented in Fig. 3. Data such as location points of fire stations and road network were collected from Drone map and Open Street Map (OSM). They were preprocessed to build the local spatial database. When the information of fire as example accident place is reported to the fire station office, the system will generate a best optimal route between fire station and fire by the proposed system. If there is congestion on the generated optimal evacuation route, the system will generates the other optimal routes by two ways which produce other three optimal routes not to be much delay time for rescue operation.

The first way of handling congestion case produces the three nearest fire stations to the burning area and the three shortest routes between these stations and fire so that fire engines from other nearest fire stations can be reached to

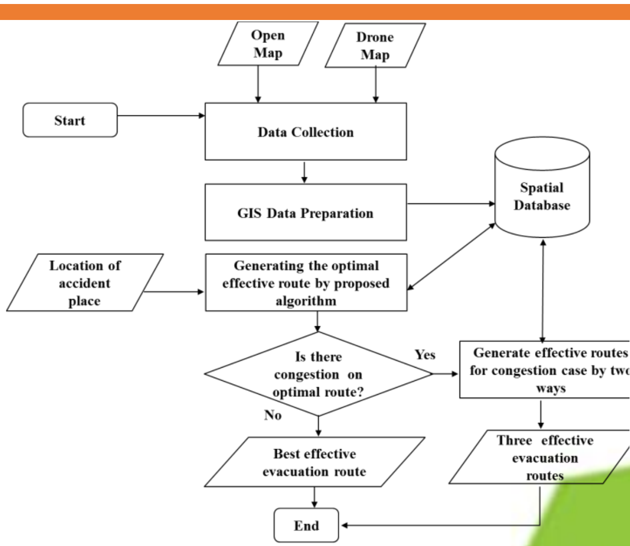

Fig. 3. Proposed System Overview

emergency place in time. The second is considering three routes from only one nearest fire station to fire.

5. EXPERIMENT

5.1 Data Preparation for GIS Data

The data of this system were collected using open street maps, drone maps, and detailed surveys of road names and road point markings by latitude, and longitude. They have been stored in a spatial database to develop the system for Meiktila which is located at 20˚ 52'09 .04 " N, 95˚ 20'52.39" E in Mandalay district of Myanmar. There are 5 main roads, 7 fire stations, 15 quarters, 410 streets, 1518 junctions and 4358 edges in Meiktila. Five main roads are Meiktila-Myingyan, Meiktila-Thazi, Meiktila-Yangon, Meiktila –Kyaukpadaung, and Meiktila-Mandalay. Most data were collected from open street map. But updated streets and junctions do not include in open street map. Therefore, 2018-2019 Drone map was used for these streets and junctions for update map information.

a) Open Street Map : In some online mapping services, users may see satellite images. When these images are captured from satellites or drones, they are just picture-like images. However, Open street map can be used offline even if they are not connected to the Internet. To display the captured images on a map, they associated the images with map coordinates called geographic references. Once the image is associated with the map coordinates, it can be overlaid on top of the street map. For geographic references, some users may use GIS "x" and "y" coordinates using the following formula:

$$x = R * cos(latitude) * cos(longitude) \quad (6)$$

$$y = R * cos(latitude) * sin(longitude) \quad (7)$$

Latitude and longitude position of main roads, streets, junctions, edges and other information are stored in the spatial database as shown in Table 1. The spherical coordinates of the system have the earth's radius (R) approximately 6371 km. Fig.4 is map data for Nan Taw Gone Qtr, Meiktila City, Meiktila. Latitude and Longitude of this point is 20.8789, 95.8608.

TABLE 1. SAMPLE SPATIAL DATABASE FOR QUARTER FROM OPEN STREET MAP

NanDawGone Quarter			
No	***Street Name***	***longitude***	***latitude***
1	Meiktila-Kyaukpadaung	95.854	20.877
2	BEHS street	95.853	20.878
3	Yone street(1)	95.853	20.876
4	Yone street(2)	95.853	20.875
5	Kanpat street	95.853	20.874
6	Yone Gyi	95.853	20.878
7	HninSi	95.851	20.878

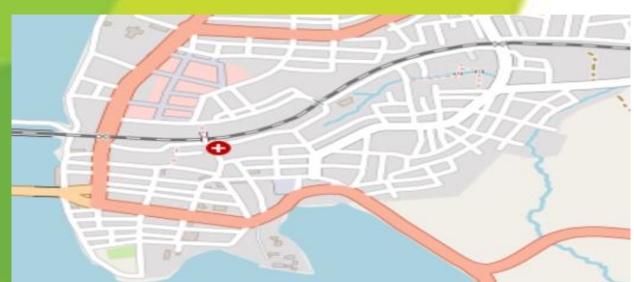

Fig. 4. Example Open Street Map for Data collection

b) Drone Map: The Meiktila Distinct topographic map has been obtained from the Department of UAV Research Myanmar Aerospace Engineering University, Meiktila as research purpose. These Drone maps have about 60 times better resolution than satellite maps and can be used offline without an internet connection. Location shots are then geo-referenced on ArcGIS and digitally mapped to capture the location point. Its precision is x, y, z. The maximum differences between open street map data and drone map data are just 5cm to 10cm. Therefore, the data of new streets and junctions from drone map are collected because these data cannot be got from open street map. The resolution and accuracy of the drone map are also good for the proposed system. Example drone map is described in Fig. 5.

TABLE 2. SAMPLE SPATIAL DATABASE FOR QUARTER FROM DRONE MAP

YanMyoAung Quarter				
No	***Street Name***	***Junction Street***	***longitude***	***latitude***
1	YanMyo Aung Street		95.867	20.877
2	Zizawar		95.867	20.877
3		Saba	95.865	20.877
4		Saba	95.866	20.866
5	Ngwe Kyal		95.946	20.888
6		Ngwe Pan	95.866	20.888
7		Swe Thaw	95.865	20.889

Fig. 5. Example Drone Map for Data collection

6. RESULTS AND DISCUSSION

6.1 Searching the Shortest Evacuation Route

In an emergency, it is important to know the correct route to get to the accident site as quickly as possible. The system generates distances based on the length of the road. Firstly, the system determines the nearest fire station for burning area. Finding the nearest fire station is mentioned in Section III. In this paper, the system compares searching time for evacuation route for fire engines to emergency fire place. In Fig. 6 showed the differences between A* and proposed A* algorithm according to cost and arrival time of nodes 20 to 60 respectively. By adding *p(n)*, arrival time of the path is reduced 2 millisecond in testing based on 20 nodes. The more travel nodes to pass, the faster the proposed method will generate.

But it reduces the shortest path searching time. This is compared to A* algorithm in Fig. 6. The shortest path searching time on nodes 60 in proposed algorithm is 0.6 millisecond and A* algorithm is 1.25 millisecond. The proposed method reduces about 0.6 millisecond. It will be less searching time than the original A* algorithm if the number of travel nodes are increased. Therefore, the proposed approach well demonstrated with the faster arrival time of the best route than arrival time of A* algorithm.

In Fig. 7 compares arrival time with another algorithm. In this comparison, the proposed algorithm is faster for each node. The more nodes in each algorithm, the faster the route searching time. Compared to A* and proposed algorithm, it is less noticeable, but compared to Dijkstra's, it is significantly faster.

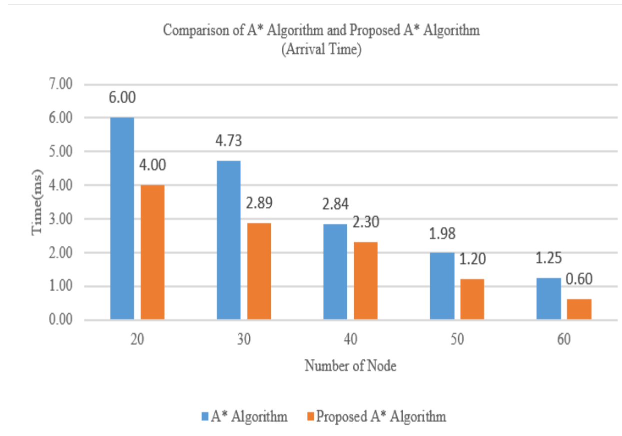

Fig. 6. Arrival Time Comparison

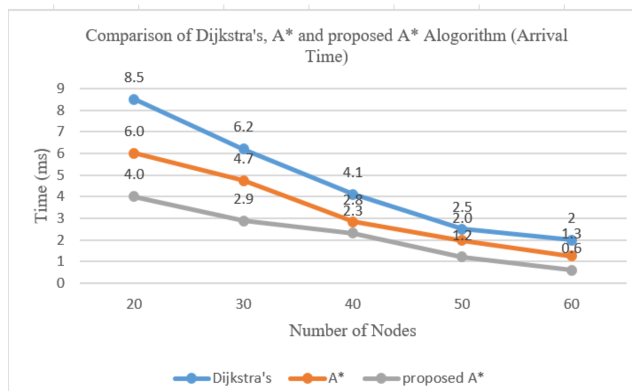

Fig. 7. Arrival Time Comparison

6.2 Considering Routes for Congestion Problems

In the absence of congestion or error conditions in the defined shortest route, estimated travel and arrival times may be possible for emergency places. If there are an error condition such as crowded in defined route while going to an emergency places, the vehicles cannot arrive the places on time. The roadblock status is taken from the speakers and phones of the motorbikes at the traffic light the city streets. In this case, the proposed system gives another ways to reach to emergency points. Congestion problem is considered by two ways in this work as described in the following two experiments. These experiments are

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based on data from the three worst-burnt quarters of Meiktila two years ago. Using this algorithm, two experiments demonstrate the appropriate route to get from the source to the destination, and which experiment is faster.

a) Experiment1: By the first method, three nearest fire stations of the fire accident places are considered to go to the fire accident quarters. Three routes for fire engines are defined and calculated average duration time for vehicles to reach to burnt quarters.

Thus, other vehicles from another fire station will reach to burnt quarters very quickly, if one vehicle from one fire station faces congestion. Table 3 shows the average time and distance that a fire engine arrives at the fire place in worst-burnt three quarters of Meiktila last two years. Number in Nearest Fire Stations indicates priority of nearest station for relative quarter.

b) Experiment2: Experiment 2 considers only nearest fire station with three routes from this station for fire engines. The average time and distance of Experiment 2 in Yan Myo Aung area are shown in Table 4 and it takes 1.201hours to reach a fire place. On the other hand, fire engines in the eastern market and the big market can take up to 1.216 hours and 1.069 hours, respectively.

As shown in Fig 8, experimental 1 takes about 0.931 hours on average, while experimental 2 takes about 1.162 hours to reach the designated fire place. Hence, it can conclude that experiment 2 takes a little longer than experiment 1 to reach to the fire place. Therefore, experimental 1 is more effective for fire engines in solving congestion problem.

According to experiment 1 results, fire engines will reach to emergency places without much delay time although they are not as fast as the fire engines driven as the best effective route. The limitation of driving the fire engine is 60 km per 1 hour. Arrival time is calculated by the following formula

$$time = \frac{distance}{limitation\ of\ driving\ the\ fire\ engine} \quad (8)$$

Table 3. Average Arrival time of congestion control Experiment 1

Quarter	***Nearest Fire Sta***	***Distan (km)***	***Time(***	***Aver Time (hr)***
Yan Myo Aun	*Pyi Thar Yar*(3)	61.2	1.019	1.015
	Aung Zayar(1)	57.8	0.963	
	East of Market (2	63.7	1.061	
Nan Daw Gon	*Aung San* (2)	52.1	0.868	0.92
	Aung Zayar(1)	48.0	0.80	
	East of Market (3	55.5	0.925	
Aung Zayar	*Pyi Thar Yar*(2)	59.9	0.916	0.92
	Aung Zayar(1)	50.8	0.847	
	East of Market (3	58.4	0.974	

Quarter	Fire Station	Shortest Distance (km)	Time(hr	Averag Time (hr)
Yan Myo Aung	Aung Zayar	77.1 (2)	1.285	1.201
		78.7 (3)	1.312	
		60.4(1)	1.007	
Yan Myo A	East of Mark	67.6 (2)	1.126	1.216
		67.5 (1)	1.126	
		83.8 (3)	1.396	
Yan Myo A	Big Market	64.2 (3)	1.069	1.069
		64.2 (1)	1.069	
		64.2(2)	1.069	

Table 4. Average Arrival time of congestion control Experiment 2

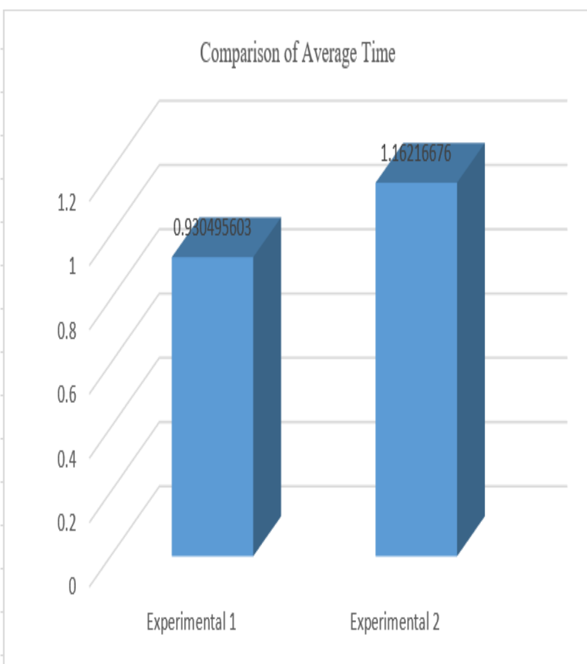

Fig. 8. Comparison of Average Time of Experiment fire engines in congestion problem

7. Conclusion and Future Work

Route planning is important for especially evacuation vehicles. The routes for fire engines to burnt quarters of Meiktila have been considered in this work. Moreover, due to congestion or some obstacle, fire engines could not reach the scene of the fire places on time and could be delayed. Two experiments have been considered to solve this problem. According to experimental results, even if a fire engine from one route encounters a roadblock, a fire engine from another route will be able to reach the scene of the fire in a short time. Tips on how to get to the scene of a fire quickly and how long it will take have a huge impact on the fire department. This paper compares the best algorithm to use when looking for more than one route from source to destination, and compares it with other algorithms and provides a quick and easy way to get there.

For future work, dynamic routing for fire engine and online data will be considered for this work.

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