

## Dereducing Fire Response Time in Medan City by Determining Hydrant Points Using ArcGis Software and Optimizing Routes Using the Djisktra Algorithm

Putri Stepvani<sup>a</sup>, Yosefin Saragi<sup>b</sup>, Irwan Budiman<sup>c</sup>

<sup>a,b,c</sup> Department of Industrial Engineering, Universitas Prima Indonesia

<sup>a</sup>Corresponding Autor : [putristevani30@gmail.com](mailto:putristevani30@gmail.com)

### Article Info

#### Article history

Received : May 27, 2021

Revised : June 06, 2021

Accepted : June 10, 2021

Published : June 30, 2021

#### Keywords:

Djisktra Algorithm;

Route;

ArcGis

Hydrant

### ABSTRACT

The development of an area will increase the risk of fire. Fire will not only cause physical, material loss, it can also cause casualties. In a span of 3 years, 46 major fire cases were recorded, not including unregistered fire cases. To be able to reduce the losses incurred, the fire fighters must be able to meet the fire response time of 15 minutes. To be able to meet this response time, a water source that can be used to douse the fire is needed as well as the fastest route to get to the destination point in the shortest possible time. The method used for laying the hydrant is the distribution method using Arc Gis software. The results obtained are that it takes 26 hydrant locations that are scattered in several central business areas and densely populated in the 3 sub-districts.



Open Access license  
CC-BY-SA

DOI: <https://doi.org/10.35891/jkie.v8i2.2534>

### 1. Introduction

The development of an urban area has brought about important problems such as the rapid flow of population mobilization from villages to cities as well as the development of various residential, industrial and commercial areas. One of the impacts of this condition is the threat of fire hazard (Lia, T., at all. 2020, Hanik, U., & Mas'ud, M. I. (2019). Recently, fire incidents have occurred frequently in the community. Rensisu, A. (2009) Fires that occur in densely populated settlements, especially in industrial areas, can cause many losses, including social, economic and psychological losses, as well as casualties (Fauzi, A., Mas'ud, M. I. 2019). Fires in industrial estates can result in cessation of business and investment losses which have an impact on termination of employment. (Marzouk, M., Othman, A. (2020).

Residential fire cases in Indonesia from 2011 to mid-2015 there were 983 cases of residential fires and 81 cases of forest and land fires. About 63 percent of fires in Indonesia are caused by short circuits in densely populated areas, 10 percent from oil lamps and candles, 5 percent from cigarettes, 1 percent from stoves, and others. Scalia, G.L., et all (2019), Shinta S. D. (2017). The trend of residential fires is increasing due to increasing population density, drier weather, poverty, land use and so on (Junaedi, D., Mas'ud, M. I. 2018, Silva, J.M., Silva, J.R. 2019), therefore the existence of the Fire Prevention and Service Agency is urgently needed. However, in the handling of fires in

Indonesia, they still face various obstacles, including a lack of number of fire stations which affects the response time and the severity of the attacks (Nourian, P., at all. 2020, Jafari, H., et all (2020).

## **2. Literature Review**

### **Mapping**

Mapping is the process of producing maps, including the stages of data acquisition with terrestrial surveys/photogrammetric surveys/remote sensing/GPS surveys, which are then processed and manipulated to produce data representations and information in the form of analog maps and digital maps (Arpanahi, S.K., et all. 2020)

### **ArcGIS**

ArcGIS is a software that allows users to create layered maps, display spatial data, and perform basic spatial analysis. ArcGis also has the ability to build new spatial data, edit, and create map designs. The main product of ArcGis is ArcGis Desktop, where ArcGis Desktop is a comprehensive professional GIS software grouped into three components, namely: Arc View, Arc Editor, and Arc Info.

### **Dijkstra's Algorithm**

Broumi, et all. (2016), Fan, D.K., Shi, P. (2010) Dijkstra's algorithm is one of the methods used to solve the problem of finding the shortest route. The terms that are often used are Shortest Path Problem (SPP) or Vehicle Routing Problem (VRP). Hadi, E.I., Iryanto. (2018), Ardyan, S., Mulyono, Suyitno, A. (2017) This algorithm is included in the conventional algorithm. Peyer, S., et all (2009) One of the uses is in an application for finding the closest route or a navigator application in an area. This algorithm was first proposed by Edger W (Nandiroh, S.A. et all 2013, Kusuma, E., Jefri, Agung, H., 2019).

### **Esponse Time**

Response Time or better known as Response time is the total time calculated from the time the fire news is received, the dispatch of troops and fire fighting facilities to the location of the fire until the condition is ready to carry out extinguishing operations (usually marked by the release of water / first water spray).

## **3. Methodology**

In this study, the case study method is used, in which case studies are extracting in-depth information through the problems that exist around us. Data or information about the problem becomes a supporting thing in finding a solution.

### **Method of collecting data**

In this study, the data used are sourced from primary and secondary data

- Primary data was obtained through field surveys to obtain information on land use conditions, building density, building materials, electricity network, road width, distance from water sources, hydrant conditions, location of fire stations, frequency of occurrence, factors causing fires, response time disaster, time of occurrence.
- Secondary data obtained from the company, namely data on fire incidents that occurred in the fire department.

### **Data Processing Methods**

Data processing in the design of laying the hydrant using the Mapping Method. At this stage, 50 samples of fire events in 2017 - 2020 were taken in several sub-districts, the data collected was processed using Arc Gis 10.3 software, to produce thematic maps, namely administrative maps, hydrant distribution maps, fire incident maps, land use maps and maps. fire hazard zone. Then the

Dijkstra algorithm is used to solve the shortest path from an origin and a destination point in a weighted graph. The shortest distance is obtained from two points if the total weight of all vertices in the graph network is the least.

#### 4. Results and Discussion

##### *Data on the number of fires in Medan City*

After sequencing 60 samples of fire data that occurred from 2017-2020, and processing the data using Pareto, we get 70% of the areas that have the highest fire hazard rates in the city of Medan. Then sort the 3 districts that have the highest frequency of incidents.

Table 1. Fire Data 2017-2020

NO	DISTRIC	FREQUENCY EVENTS
1	MEDAN MARELAN	5
2	MEDAN DENAI	4
3	MEDAN BARU	4

Based on data on the number of fires in the city of Medan, it was found that the sub-districts of Medan Marelan, Medan Denai, and Medan Baru were the districts that experienced the most fires.

##### **Medan City Fire Area Administration Map**

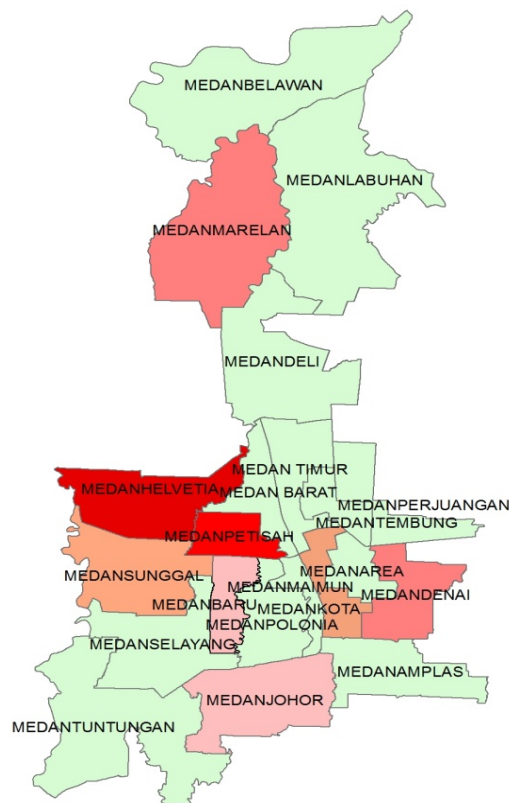


Figure 2. Administrative Map of Medan City

The city of Medan consists of 21 counties have 26.510 hectares (265.10 km<sup>2</sup>), or 3.6% of the whole territory of North Sumatra. Thus, compared with the city / county other, the Terrain has a broad area that is relatively small with a population that is relatively large. Geographically, the City of Medan is located at 3° 30' – 3° 43' North Latitude and 98° 35' - 98° 44' East Longitude. The highest

frequency of fire incidents occurred in the Medan City can be seen in Table 1. In the Medan Marelan Subdistrict, there were 5 times. The frequency of fire occurrences in an area indicates the possibility of a fire hazard being repeated in that area, the higher the frequency of fire occurrences in an area, the higher the possibility that the area will experience another fire. 2 (2012).

### Map of Protected Areas Based on the Coordinating Points of the Fire Department

Medan city has four fire brigade offices spread over four sub-districts. The fire office consists of one fire department head office located at Jl. Candi Borobudur Kec. Medan Petisah, Kota Medan, North Sumatra and three sub fire department offices in:

1. Terminal Terpadu Amplas, Timbang Deli, Medan Amplas, Medan City
2. Jl. Cimanuk Gg. 14 No.03, Belawan II, Medan Kota Belawan, Medan City
3. Jl. Pulau Natuna, MABAR, Kec. Medan Deli

Based on the position of the fire department, the fire department must handle the fire area not exceeding a radius of 7.5 km with an estimate of arriving at the fire location not more than 15 (fifteen) minutes.

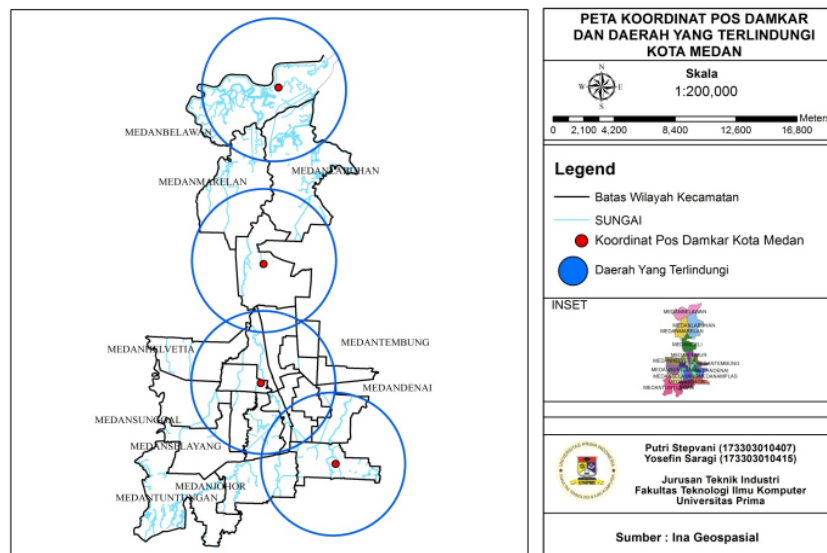


Figure 3. Map of a protected area

Nearly all fire management areas in Medan City can be reached by the fire department. However, there are also areas that are out of reach from a distance of more than 7.5 km. This area is categorized as an unprotected area. Areas that are not covered by the fire department can be seen in Figure 2.

### Hydrant

Hydrant is a fire extinguishing system that is connected to a pressurized water source and distributes water to the extinguishing site at an adequate rate. In the area of Medan Marelan District, researchers designed the coordinates of the Hydrant. The determination of the coordinate points is designed based on several stages that need to be considered, namely: the highest frequency of fire occurrences, land use conditions, building density, building materials, electricity network, road width, distance from water sources, and distance from the location of the DAMKAR post to the location of the fire. It can be seen from the map of the protected area, although some areas are within the reach of the fire department, the highest number of fires is in the Medan Marelan District. Therefore, the focus of determining the hydrant point is carried out in that area.

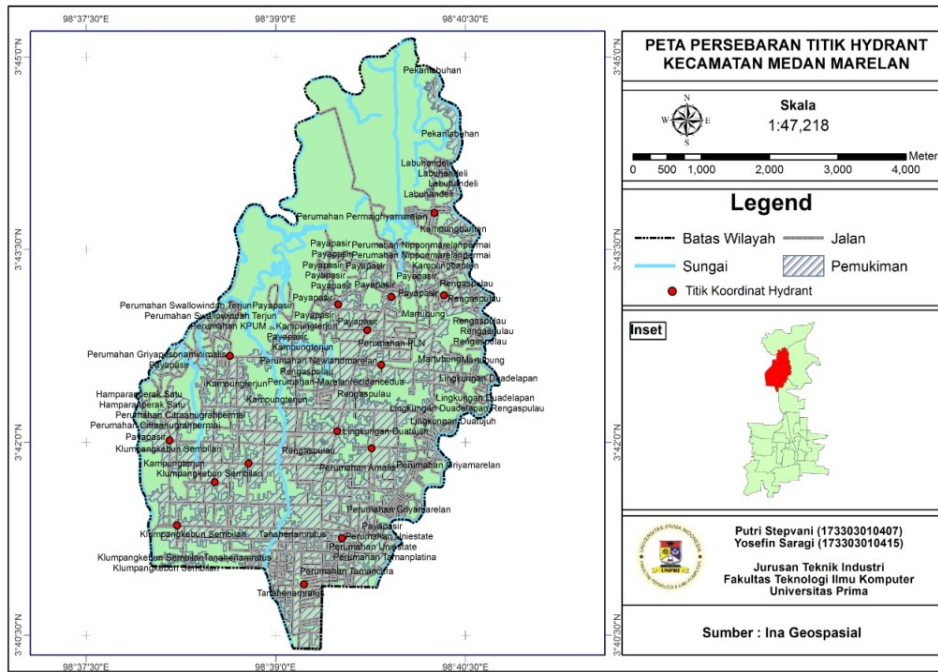


Figure 5. Map of the Distribution of Hydrant Points in Medan Marelan District

Medan Marelan sub-district which has an area of 44.47 km<sup>2</sup>, has a population of 140,414 people. To calculate the number of Hydrant Pipes placed in Medan Marelan District, it is calculated using the formula :

$$\text{number of hydrant pillar} = \frac{\text{Residential area}}{\text{wide range of hydrant}}$$

$$\frac{44.470 \text{ m}^2}{1.500 \text{ m}^2} = 29,646 \approx 30 \text{ pieces}$$

From the above calculations, we can see that the number of hydrant pipes in Medan Marelan District is 30. In this case, the problem that often occurs in the Medan Marelan District area is not recommended to put too many hydrant points, because the root of the problem here is that fire is caused by oil, we are looking for another solution, namely by :

- Have an APAR (APAR in the Car is Important to Prevent the Spread of Fires).
- Fires can also be prevented, by means that if at the location of the fire, local residents can help to extinguish the fire with water + soap with lots of foam, before the Firefighters reach the location of the fire.

Therefore, the researcher only took half the amount for the hydrant placement, which was 15 units.

Table 3 Distribution Area of Hydrant Coordinate Points

No	Area	Number of Hydrant
1	Tanah Enam Ratus	1 Pieces
2	Kelumpang Kebun Sembilan	4 Pieces
3	Perumahan Uni Estate	1 Pieces
4	Perumahan Amalia	1 Pieces
5	Lingkungan Dua Tujuh	1 Pieces
6	Perumahan Amalia	1 Pieces
7	Perumahan Griya Pesona Minimalis	1 Pieces
8	Perumahan New Land Marelan	1 Pieces
9	Paya Pasir	3 Pieces
10	Perumahan Permai Griya Marelan	1 Pieces

## Route

The shortest route problem is a classic problem in Operations Research. The shortest route in the graph is an optimization problem. The word "shortest" does not always mean the minimum physical length, in fact it has various meanings depending on the type of problem to be solved. However, in this discussion the word "shortest" means minimizing the weight of a route in the graph or determining the route with the minimum total distance.

The graph used in the search for the shortest route is a weighted or labeled graph, both directed and undirected (Munir, 2010). The weights on the sides of the graph can represent the distance between cities, travel time, shipping costs, etc.

### *The Shortest Route for Fire Locations in Medan Marelan*

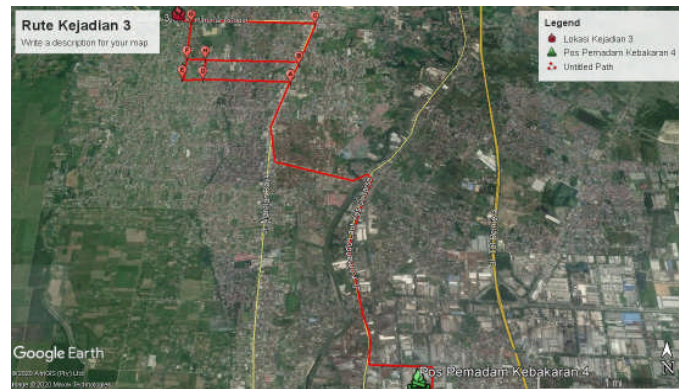


Figure 7. Aerial Photo of Postal Route 4 to the Location of the Incident

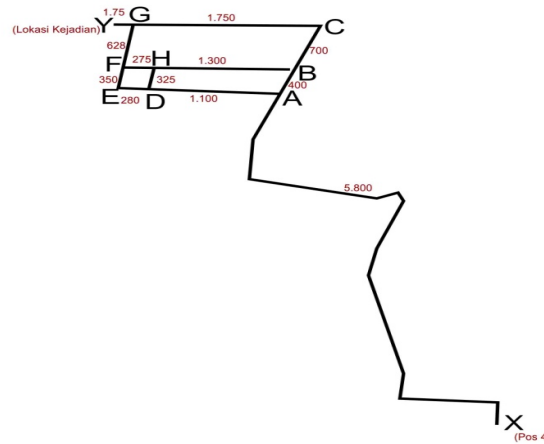


Figure 9. Weighted Graph of Heading 4 to the Event Location

V	X	A	B	C	D	E	F	G	H	Y
X	<b>0X</b>	5800X	$\infty$	$\infty$	$\infty$	$\infty$	$\infty$	$\infty$	$\infty$	$\infty$
A		<b>5800X</b>	6200A	$\infty$	6900A	$\infty$	$\infty$	$\infty$	$\infty$	$\infty$
B			<b>6200A</b>	6900B	6900A	$\infty$	$\infty$	$\infty$	7500B	$\infty$
C				<b>6900B</b>	6900A	$\infty$	$\infty$	8650C	7500B	$\infty$
D					<b>6900A</b>	7180D	$\infty$	8650C	7225D	$\infty$
E						<b>7180D</b>	7530E	8650C	7225D	$\infty$
H							7500H	8650C	<b>7225D</b>	$\infty$
F							<b>7500H</b>	8128F		$\infty$
G								<b>8128F</b>		8303G
Y										<b>8303G</b>

The results obtained for the shortest route are: Y-G-F-H-D-A-X, with a track length of 8,303 meters, where:

So the shortest route is Post 4 to the location of the fire that occurred on Jl. Capt. Rahmad Buddin, Medan Marelan, Medan City, North Sumatra are: Point X (Post 4 Fire Department) → Point A → Point D → Point H → Point F → Point G → Point Y (Occurrence Location), with a distance of 8,303 meters = 8,3 km. If the average firefighter's car is traveling at Speed 40 km/hour, then the time needed for the Firefighters to arrive at the scene is:

$$S \text{ (Distance)} = 8,3 \text{ km} \quad V \text{ (Speed)} = 40 \text{ km/hour} ; \quad t = \frac{S}{V} = \frac{8,3}{40} = 0.2075 \text{ Hour} = 12.45 \text{ minutes}$$

## 5. Conclusion

In the research conducted, the sub-district that has the highest frequency of occurrence in the city of Medan in 2017-2020 is the district of Medan Marelan. To be able to meet the response time of approximately 15 minutes, in the Medan Marelan sub-district, which should have 30 hydrant locations, it is not recommended to place too many hydrants, because in the Medan Marelan sub-district the fire is caused by oil. Where the solution in fighting fires caused by oil can be prevented by extinguishing the fire with water + soap with lots of foam before the officers arrive at the scene, therefore it is recommended to only place 15 hydrant locations, and the shortest route is needed to reach the scene. with fast time. From the results of the discussion obtained the shortest route to get to the scene of the incident, namely Post 4 Fire Department to Jl. Capt. Rahmad Buddin, Medan Marelan, Medan City, North Sumatra, with a track length of 8.3 km which can be reached in 12.45 minutes.

## References

- Ardyan, S., Mulyono, Suyitno, A. (2017). Implementasi Algoritma Dijkstra Dalam Pencarian Rute Terpendek Tempat Wisata Di Kabupaten Gunung kidul Dengan Program Visual Basic.
- Arpanahi, S.K., et all. (2020). International Journal of Electrical Power & Energy Systems (Incorporating flexibility requirements into distribution system expansion planning studies based on regulatory policies).
- Broumi, et all. (2016). Applying Dijkstra Algorithm for Solving Neutrosophic Shortest Path Problem.
- Chen, Y., Zhang, Y., Mahadevan, S. (2011). Fuzzy Dijkstra Algorithm For Shortest Path Problem Under Uncertain Environment.
- Fan, D.K., Shi, P. (2010). Improvement of Dijkstra's Algorithm and Its Application in Route Planning.
- Fauzi, A., Mas'ud, M. I. (2019). Proses Manufaktur pada Mesin Primer dan Sekunder CV. Karunia Menggunakan Metode Linier Programming. Journal Knowledge Industrial Engineering(JKIE), 6(2), 59–65.<https://doi.org/10.35891/jkie.v6i2.2055>
- Hadi, E.I., Iryanto. (2018). Penerapan Algoritma Dijkstra untuk Penentuan Jalur Terbaik EvakuasiTsunami.
- Hanik, U., & Mas'ud, M. I. (2019). Perencanaan Inovasi Pengembangan Agrowisata Bukit Flora Dengan Pendekatan Metode Bisnis Model Kanvas. JKIE (Journal Knowledge Industrial Engineering), 6(3), 91-100. <https://doi.org/10.35891/jkie.v6i3.2088>
- Jafari, H., et all (2020). Finding optimum facility's layout by developed simulated annealing algorithm.
- Junaedi, D., Mas'ud, M. I. (2018). Penerapan Metode Forecasting dalam Perencanaan Produksi Bakpia dengan Menggunakan Software POM Guna Memenuhi Permintaan Konsumen. Journal Knowledge Industrial Engineering (JKIE), 5(3), 121–128. <https://doi.org/10.35891/jkie.v5i3.2042>
- Kusuma, E., Jefri, Agung, H., (2019). Aplikasi Perhitungan Dan Visualisasi Jarak Terpendek Berdasarkan Data Coordinate Dengan Algoritma Dijkstra Dalam Kasus Pengantaran Barang Di Kawasan Jabodetabek.

- Lia, T., et al. (2020). Journal of Manufacturing Systems (Using requirement-functional-logical-physical models to support early assembly process planning for complex aircraft systems integration).
- Marzouk, M., Othman, A. (2020). Planning utility infrastructure requirements for smart cities using the integration between BIM and GIS.
- Nandiroh, S.A., et al. (2013). Implementasi Algoritma Dijkstra Sebagai Solusi Efektif Pembuatan Sistem Bantuan Bencana Real Time.
- Nourian, P., et al. (2020). A discrete event simulation procedure for validating programs of requirements: The case of hospital space planning
- Peyer, S., et al (2009). A Generalization Of Dijkstra's Shortest Path Algorithm With Applications To Vlsi Routing.
- Rensisu, A. (2009). Perancangan Ulang Instalasi Pipa Sistem Pemadam Kebakaran Pada Gedung CCV dan Perkantoran PT. SUMI INDO KABEL, Tbk Daniel Priyo Widodo, Analisis Percabangan Pipa Hydrant Dengan Menggunakan "Program Cae" (2009)
- Scalia, G.L., et al (2019). Facility layout problem: Bibliometric and benchmarking analysis.
- Shinta S. D. (2017). Analisis Optimalisasi Rute Pemadam Kebakaran Berdasarkan Area Cakupan Pipa Hidran Di Kota Semarang
- Silva, J.M., Silva, J.R. (2019). A New Hierarchical Approach To Requirement Analysis Of Problems In Automated Planning.