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DETERMINATION OF THE FASTEST ROUTE FOR FIRE TRUCKS IN CIREBON CITY BASED ON DISTANCE, TIME, CONGESTION AND LAND USE

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ABSTRACT

Fire fighter performance can be represented by the speed of handling the fire case, where greatly influenced by the travel speed of the fire trucks to the fire location. This study aims to determine the fastest route for fire trucks in Cirebon City based on the travel distance, time, congestion and land use. The method used in this study is by applying the Geographic Information System (GIS) model in identifying several variables that affect the travel speed of fire trucks. In this study, several alternative routes were determined from the fire station (Harjamukti fire station and Bima fire station) to the location of fire (Harjamukti Market) and then calculated the travel time on each alternative route by considering travel distance, time, congestion and land use. The results showed that the fastest travel time for fire trucks in Cirebon City was largely influenced by the travel distance. However, in conditions of high traffic flow, a route with a longer distance but does not cross a congested road segment can produce a faster travel time when compared to a shorter route but crosses congested roads. The fastest route from the Bima fire station to Harjamukti market is route 1 (2,854 m) in the morning, route 3 (3,019 m) in the afternoon and evening. Meanwhile, the fastest route from the Harjamukti fire station to Harjamukti Market is Route 1 (2,069 m) in the morning, afternoon and evening because it has the shortest distance.

Keyword: *Fastest route, Fire fighter, Fire Trucks, Geographic Information System (GIS), Travel speed.*

I. INTRODUCTION

In recent times, many fire cases have occurred in Cirebon City. In 2018 there was a fire case in the shopping area on Pasuketan road which caused 1 person died, in 2019 a fire case occurred at the hotel in siliwangi road which caused 1 person injured, and there are many more cases of fires that occurred in Cirebon City. Many cases and the high rate of fatality from fire cases (causing injuries and deaths) in Cirebon City led to negative assumptions that the performance of the Cirebon City Fire Service and the Disaster Management Institution in Cirebon City was not optimal.

One of the important parameters that can represent the performance of a firefighter is the handling of fire cases, where greatly influenced by the travel speed of the fire trucks to the fire location. There are many variables that can affect the travel time of the fire trucks, there are travel distance, fire trucks speed, time of fire case, traffic conditions and type of land use on the route traversed. Therefore, it is necessary to carry out an analysis in determining the fastest route for the firefighter by considering some variables in order to get the fastest route alternatives and optimize the performance of the Cirebon City Fire Service in handling the fire case.

II. LITERATURE REVIEW

Determination of the fastest time or the best time is one form of optimization of a particular activity that involves the transportation process. For example, Mohammad Abousaedi et al (2015) conducted a GIS modeling study in determining delivery routes for fresh vegetables. The results of the study indicate that land use variables such as residential areas and population size are the most effective parameters in determining the travel time for fresh vegetables delivery. Meanwhile, Maria D.G and Sahar Babri (2020) identify variables that influence route selection based on tourist preferences in Norway. The study results suggest that tourists who chose their route based on travel time, street views, sightseeing spots among first-time visitors, and outdoor activities were among those living outside Norway. Nanang Nggufron, et al (2019) conducted a search for the best route for the Semarang city fire fighter and the study stated that based on the parameters of the level of road congestion which combines 2 parameters, there are road length and road density, it will produce 7 best routes for each fire station taken.

There are many methods or models that can be applied in conducting network analysis and route planning systems, both in regression modeling and GIS modeling. The application of regression models in several fields of study has helped identify various parameters and variables as well as different methods for problem statement regarding route determination. In connection with the application of regression models in traffic or transportation management that has been carried out by Cela, et al (2013) to find important variables related to road conditions, time of day and the main causes that affect the accident rate. Another study was conducted by Sofia, et al. (2013) who applied a regression model in determining the route which aims to determine the distance and travel time simultaneously.

In the study of determining the fastest route for firefighters in the city of Cirebon, the Geographic Information System (GIS) modeling method was used to identify several variables that affect the speed of the fire trucks, there are distance and congestion points. Route planning systems using GIS have been carried out in several studies because GIS technology provides the ability of spatial data and network systems to represent real data in the production of various types of maps. Used to determine the fastest route for delivery of fresh vegetables carried out by Mohammad Abousaeidi (2015), GIS modeling was also applied by Sayed Ahmed, et al. (2017) in conducting network analysis aimed at identifying the best route from the location of an incident/accident to a health care provider in Greater Cairo metropolitan area. Gohari (2010) developed a model to analyze the shortest path and take into account several factors, including the speed limit of cars in the highway network. Bhambulkar (2011) developed an ArcGIS Network Analyst application to model route optimization that identifies the best route and has been applied to waste-related activities. Sharifi et al (2009) conducted a technology study of selecting a hazardous waste disposal site using GIS and presented a multi-criteria decision analysis with spatial data for the best selection of a suitable location for landfills. Sadeghi-Niaraki et al (2011) applied a Geographical Information System for road network analysis where the study has a weakness that spatial model data is not included in the calculation of optimal delivery service routes.

III. METHODOLOGY

Figure 3.1 shows the methodology in determining the fastest routes of firefighter in Cirebon City based on travel distance, time , congestion and land use. Determination of the fastest route is done by applying the Geographic Information System (GIS) model to identify several variables that

influence to the speed of fire trucks. This study will determine several route options to the location of the fire (in this case the market area), then calculate the travel time for each route alternatives by considering the variable travel distance, time, congestion level and type of land use. At the end of the analysis will be discussed how the effect of each variable to the travel time. The data needed is a satellite image / raster image for the base map for determining the route, the congestion point data using the google maps application, the results of interviews and other secondary data.

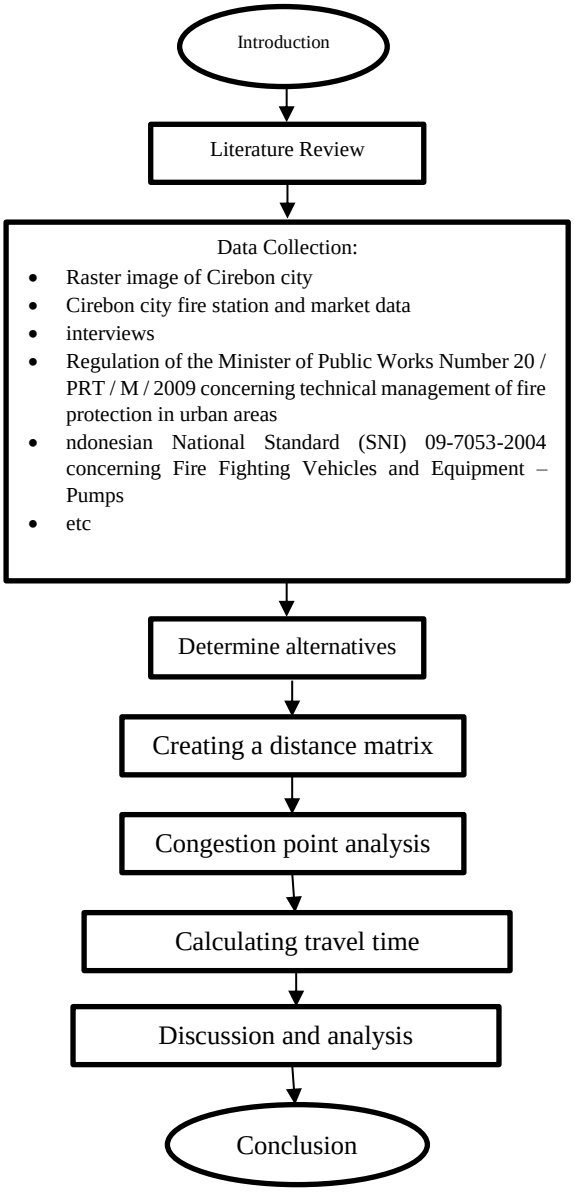

Figure 3.1 Research Methodology

Based on the results of the study, there are 2 active fire stations in Cirebon City, there are the Bima fire station located on Terusan Pemuda road (Bima) and the Harjamukti fire station located on Pramuka road, Cirebon City. There are 4 large markets in Cirebon City, are the Perumnas Market on Ciremai Raya road, Harjamukti Market on Jendral Sudirman road, Jagasatru Market on Jagasatru road and Kanoman market on Kanoman road. In its implementation, when a fire case occurs in a location in Cirebon city, so the firefighter closest to the location will move towards to the fire location. if the fire case that occurs is quite large so all firefighter units from the Bima fire station or the Harjamukti fire station will be deployed. Based on this, the alternative routes that can be made from 2 fire stations to 4 market areas in Cirebon City are very numerous and result in too broad a study to be carried out. In addition, it will make it difficult to influence distance, time, congestion level and type of land use on the speed of fire trucks. Therefore, in this study, we will develop by making the territorial boundaries of each fire station then selecting 1 (one) market area which is within the scope of 2 fire stations as the destination of the 2 fire stations.

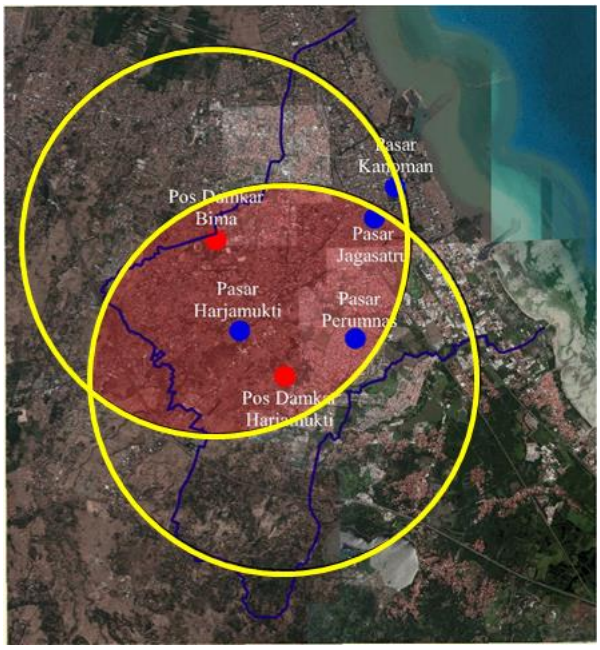

Figure 4.1 Plotting and Coverage Areas of Fire Station and Market Areas in Cirebon City

Figure 4.1 shows the plotting results of 2 fire stations and 4 market areas in Cirebon City with a boundary in the form of a circle with a diameter of 7.5 kilometers. Based on Figure 4.1, it can be ignored that there are 3 market areas that enter the area 2 fire department, namely the Perumnas market, the Harjamukti market and the Jagasatru market. Meanwhile, Kanoman Market is only included in the coverage area of the Bima fire station. To see the effect of distance, time , level of congestion and type of land use on the speed of fire trucks, this study will focus on analyzing the route from 2 fire stations to Harjamukti Market where the market position is in the middle between the Bima fire station and Harjamukti Fire Station.

The alternative route made is a route that passes through a road with a minimum width of 7 meters or 3.5 meters per lane. Determining alternative routes is also influenced by the activities and direction of fire trucks when there is a fire case at Harjamukti Market. In general, before heading to the fire location, the fire truck must first supply water from a water source or a hydrant that has been prepared by the PDAM, so that the direction of the fire engine is the Fire Station - water supply source - the fire location. Based on the results of interviews with the Cirebon City Fire departement, there are more than 100 hydrants spread across the Cirebon city, but not all hydrants function properly. Another problem is that the hydrant water channel is still attached to the PDAM channel to be distributed to residents which causes the water discharge pressure in the hydrant to not rise and cannot be used to supply water for the fire truck. Therefore, the Cirebon City Fire Departement is accustomed to not relying on PDAM hydrants to supply water and always ensures that the fire truck units are always fully filled by supplying water from toren or water storage ponds at fire stations. In addition, the Cirebon City Fire Departement has instructed all sub-districts to prepare toren/water tanks at the sub-district office to refill the water for the fire truck in the fire case in the sub-district. Therefore, in this study the starting point of the route is the fire station directly to Harjamukti Market (assuming the fire truck is fully filled with water).

Figure 4.2 and Figure 4.3 shows the alternative routes that can be made from each fire station to Harjamukti Market. From the Bima fire station to Harjamukti Market, 3 (three) routes can be made, and from the Harjamukti fire station to Harjamukti Market, 3 (three) alternative routes can also be made. Details of the roads that are passed on each alternative route can be seen in Table 4.1 and the distance matrix from 2 fire stations to Harjamukti Market can be seen in Table 4.2.

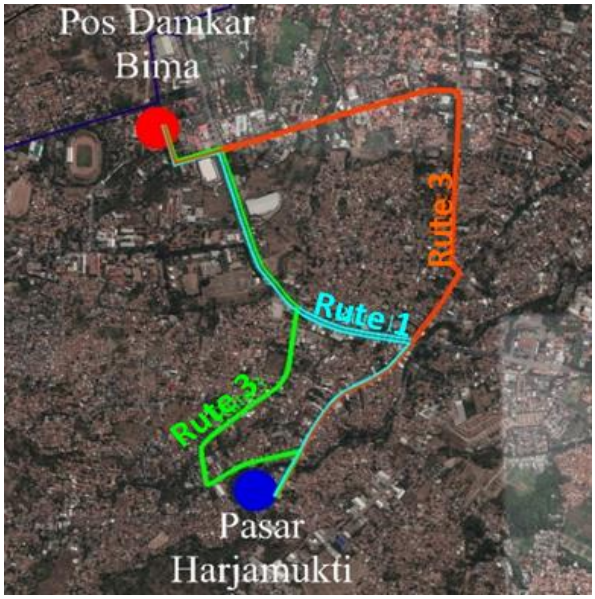

Figure 4.2 Alternative Route from the Bima Fire Station to Harjamukti Market

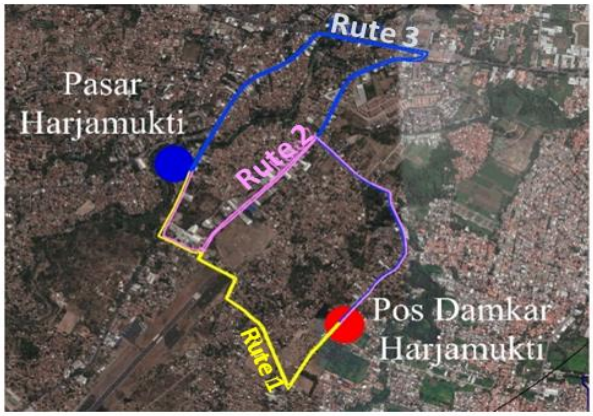

Figure 4.3 Alternative Route From Harjamukti Fire Station to Harjamukti Market

Table 4.1 Route details for each route alternative

Origin	Destination	Route	Information	Color
Bima Station	Harjamukti Market	Route 1	Bima fire station - Jl. Terusan Pemuda - Jl. Brigjen Darsono (by pass) - Jl. Kanggraksan - Jl. Jendral Sudirman – Harjamukti Market	
		Route 2	Bima fire station - Jl. Terusan Pemuda - Jl. Pemuda - Jl. Cipto MK - Jl. Kesambi Raya - Jl. Kanggraksan - Jl. Jendral Sudirman – Harjamukti market	
		Route 3	Bima fire station - Jl. Terusan Pemuda - Jl. Brigjen Darsono (by pass) - Jl. Evakuasi - Jl. Kalitanjung - Jl. Jendral Sudirman – Harjamukti market	
Harjamukti Station	Harjamukti Market	Route 1	Harjamukti fire station - Jl. Pramuka - Jl. Angkasa - Jl. Angkasa Raya - Jl. Jendral Sudirman – Harjamukti market	
		Route 2	Harjamukti fire station - Jl. Pramuka - Jl. Penggung Raya - Jl. Angkasa Raya - Jl. Jendral Sudirman – Harjamukti market	
		Route 3	Harjamukti fire station - Jl. Pramuka - Jl. Angkasa Raya - Jl. Jendral A. yani - Jl. Kanggraksan - Jl. Jendral Sudirman – Harjamukti market	

Table 4.2 Matriks Jarak Dari Pos Pemadam Kebakaran Menuju Pasar Harjamukti

Distance Matrix Data (M)			
Destination(D) \ Origin (O)		Harjamukti Fire Station	Bima Fire Station
Harjamukti Market	Route 1	2069	2854
	Route 2	2794	3847
	Route 3	3678	3019

Based on Table 4.2 it can be seen that the route from the Harjamukti fire station to Harjamukti Market has the shortest distance of 2.069 meters on route 1 and the longest distance of 2.678 meters on route 3. As for the route from the Bima fire station to Harjamukti Market has the shortest distance of 2.854 meters on route 1 and the longest distance of 3.847 meters on route 2.

4.2. Congestion Segment Analysis

After determining an alternative route from the Bima fire station and the Harjamukti fire station to Harjamukti Market, the next step is to identify the congestion point on each of the existing alternative routes. To see the congestion point on the road on each route, refer to the google maps application, then the congestion point is mapped into the respective route alternatives that have been determined. The level of congestion is divided into 3 (three) segments which are distinguished by the color where the blue color represents normal traffic, the orange color represents heavy traffic and the red color represents the traffic jam. To cover the difference in traffic flow that occurs in 1 day, in identifying the level of congestion it is differentiated based on the time of occurrence in the morning, afternoon and evening. The morning time around 08.30 - 09.00 WIB is assumed to be the peak time for Harjamukti Market services which will clearly affect traffic flow to the market, the time around 12.00 - 13.00 WIB is assumed to be the worker's rest time (lunch) so that it increases traffic flow significantly , and the time around 16.00 - 17.00 WIB is assumed as the time to return home after activities.

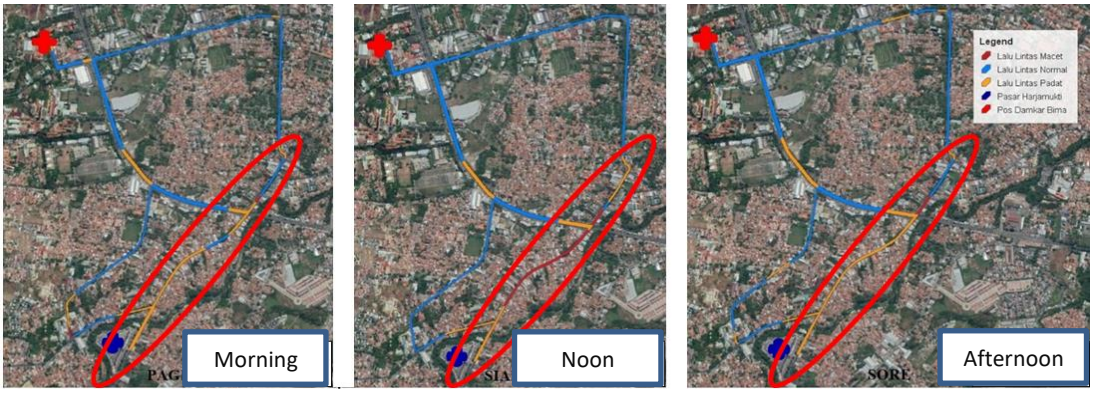

Figure 4.4 Congestion Point from Bima Fire Station to Harjamukti Market

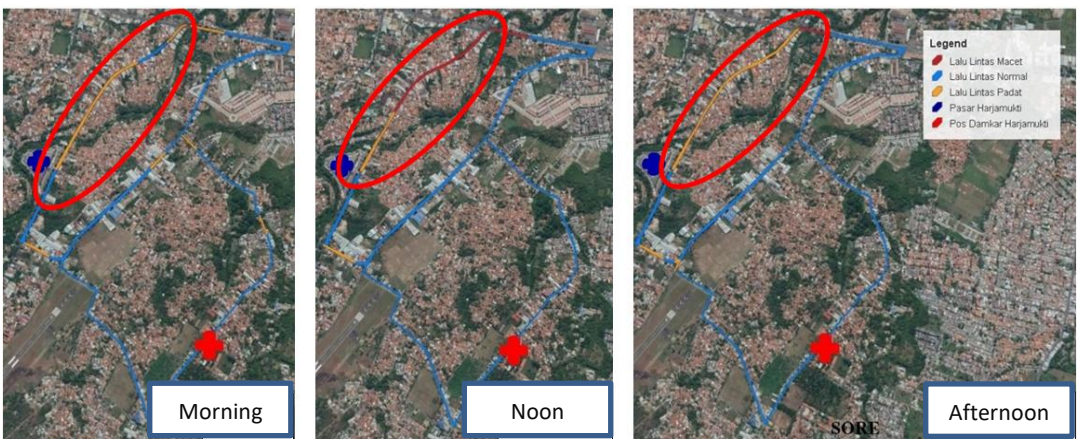

Figure 4.5 The congestion point from the Harjamukti Fire Station to the Harjamukti Market

Figure 4.4 shows the congestion point from the Bima fire station to Harjamukti Market, while Figure 4.5 shows the congestion point from the Harjamukti fire station to Harjamukti Market. Based on the results of plotting or mapping congestion points on each of the existing route alternatives in the morning, afternoon and evening, it can be seen that on the routes of Bima Fire Station to Harjamukti Market and from the Harjamukti Fire Station to Harjamukti Market has one road segment that has changed Significant traffic flow, namely on Kanggraksan road to Jendral Sudirman road (marked by a red circle). Meanwhile, other roads do not experience significant changes in traffic flow in the morning, noon or afternoon. The highest level of congestion occurs during the day, the next position is in the afternoon and the lowest level of congestion is in the morning. Details of the amount of distance based on congestion point segmentation can be seen in Table 4.3.

Table 4.3 Total Distance Based on Congestion Point Segmentation

Bima Fire Station - Harjamukti Market					harjamukti Fire Station - Harjamukti Market				
Time	Route	Congestion segment (m)			Time	Route	Congestion segment (m)		
		Blue	Orange	Red			Blue	Orange	Red
Morning	Route 1	1488	1366	0	Morning	Route 1	1827	242	0
	Route 2	2565	1238	44		Route 2	2356	438	0
	Route 3	1926	1042	51		Route 3	2420	1238	20
Noon	Route 1	1405	806	643	Noon	Route 1	1890	180	0
	Route 2	2415	687	746		Route 2	2615	180	0
	Route 3	2217	802	0		Route 3	2469	340	868
Afternoon	Route 1	1409	1445	0	Afternoon	Route 1	1856	213	0
	Route 2	2494	1227	126		Route 2	2581	213	0
	Route 3	2004	1015	0		Route 3	2588	923	167

4.3. Fastest Route Determination

In determining the fastest route, it is necessary to calculate the travel time for each alternative route and must consider the level of congestion on the roads that are passed. The calculation of travel time for fire truck is regulated in Regulation of the Minister of Public Works Number 20 / PRT / M / 2009 concerning technical guidelines for fire protection management in urban areas. The formula used in calculating travel time is as follows:

T = 0,65 + X D……..……..(1)

Where:
T = Time in minutes for a one-way trip
D = The distance traveled in one direction
X = Speed variables

Where the value of X can be found using the formula:

$$X = \frac{60\ (minutes)}{Speed\ (mph)} \text{……..(2)}$$

In this study, the travel time sought is the travel time that has been affected by the level of congestion, so the travel time calculation is divided according to the segment of the congestion point (blue, orange or red) with different speeds. In the Indonesian National Standard (SNI) 09-7053-2004 concerning Fire trucks and Equipment - Pumps confirm that at full load and complete equipment a fire truck must be able to show the following performance, when passing on dry paved roads and in good condition :

a. The fire truck must be able to reach a speed of 56 km/h (35 mph) within 25 seconds of starting moving on a level road.
b. The fire truck must be able to reach a minimum top speed of 80 km/h (50 mph) on smooth roads.
c. The fire truck must be able to maintain a minimum speed of 32 km/h (20 mph) on grade up to 6% in each direction.

Based on these standards, it is assumed that in normal traffic conditions (blue) the fire truck can use a normal speed or an average of 56 km / h (35 mph). For heavy traffic (orange) the fire engine assumes that it can maintain a minimum speed of

32 km / h (20 mph). Whereas in very heavy traffic or congested conditions (red), the fire engine speed uses half of the minimum speed of 16 km / hour (10 mph). Based on the standard and speed assumption used, the variable speed (X) can be calculated to calculate the travel time. The results of the calculation of variable speed (X) can be seen in table 4.4. After that, the travel time per congestion segment and the total travel time based on the 3 (three) types of speed used can be calculated for each alternative route, the results of which can be seen in tables 4.5 and 4.6.

Table 4.4 calculation of variable speed (X)

Speed	Km/hour	mph	X	Information	congestion point
Speed 1	56	35	1,7	Use in normal traffic flow	Blue
Speed 2	32	20	3,0	Use in high traffic flow	Orange
Speed 3	16	10	6,0	Use in very high traffic flow	Red

Table 4.5 Calculation of Travel Time for the Bima Fire Station - Harjamukti Market Route

Bima Fire Station - Harjamukti Market									
Time	Route	Distance (m)	Congestion point (m)			Travel Time (minutes)			Total Travel Time (minutes)
			Blue	Orange	Red	Blue	Orange	Red	
Morning	Route 1	2854	1488	1366	0	3,20	4,75	0,65	8,60
	Route 2	3847	2565	1238	44	5,05	4,36	0,91	10,33
	Route 3	3019	1926	1042	51	3,95	3,78	0,96	8,68
Noon	Route 1	2854	1405	806	643	3,06	3,07	4,51	10,63
	Route 2	3847	2415	687	746	4,79	2,71	5,12	12,62
	Route 3	3019	2217	802	0	4,45	3,06	0,65	8,16
Afternoon	Route 1	2854	1409	1445	0	3,07	4,99	0,65	8,70
	Route 2	3847	2494	1227	126	4,93	4,33	1,40	10,66
	Route 3	3019	2004	1015	0	4,09	3,69	0,65	8,43

Table 4.6 Calculation of Travel Time for the Harjamukti Fire Station - Harjamukti Market Route

Harjamukti Fire Station - Harjamukti Market									
Time	Route	Distance (m)	Congestion point (m)			Travel Time (minutes)			Total Travel Time (minutes)
			Blue	Orange	Red	Blue	Orange	Red	
Morning	Route 1	2069	1827	242	0	3,78	1,38	0,65	5,81
	Route 2	2794	2356	438	0	4,69	1,97	0,65	7,30
	Route 3	3678	2420	1238	20	4,80	4,36	0,77	9,93
Noon	Route 1	2069	1890	180	0	3,89	1,19	0,65	5,73
	Route 2	2794	2615	180	0	5,13	1,19	0,65	6,97
	Route 3	3678	2469	340	868	4,88	1,67	5,86	12,41
Afternoon	Route 1	2069	1856	213	0	3,83	1,29	0,65	5,77
	Route 2	2794	2581	213	0	5,07	1,29	0,65	7,01
	Route 3	3678	2588	923	167	5,09	3,42	1,65	10,16

4.4. Analysis and Discussion

4.4.1. Congestion Point Analysis Based on Time and Land Use

Based on the plotting of congestion points on each alternative route from the fire station to Harjamukti Market in the morning, noon and afternoon, it can be seen that there is 1 (one) road segment that has experienced significant changes in traffic flow, namely Kanggraksan road - Jendral Sudirman road. Meanwhile, on other roads, the level of traffic flow is influenced by the presence of signaled intersections at certain points and does not cause significant changes in flow rates. In the morning, most of the congestion spots on Kanggraksan road are orange and a small portion is blue, during the day the congestion spots on the road turn red then turn back to orange in the afternoon. This means that in the morning the traffic flow that occurs is quite dense (there are still some sections that are in normal traffic flow), at noon the road segment

experiences congestion and then the congestion gradually decreases towards the afternoon.

The congestion that occurs on Kanggraksan road is built by the use of the surrounding land and the pattern of movement/activity that occurs. In addition, congestion on Kanggraksan road can also be relied upon by the existence of a signalized intersection which is approximately 1.5 km from Harjamukti Market, resulting in high traffic flow on the road which results in very long delays at the intersection. Kanggraksan road is still included in the area around Harjamukti Market so that its land use is dominated by shops such as electrical appliance shops, building shops, printing shops, etc. This has an impact on the movement of people and vehicles on Kanggraksan road which is always active throughout the day and makes the traffic flow on the road always congested until it gets stuck.

In the morning is the operational hour of Harjamukti Market services so that activities on Kanggraksan road are dominated by vehicles heading to Harjamukti Market and returning home after shopping. In addition, in the morning there are many side obstacles caused by shopping activity beside the road and the large number of pedestrians walking beside the road, which reduces the capacity on these roads and makes traffic conditions quite heavy. Because Kanggraksan road is a connecting road to the center of Cirebon City, during the daytime which is a break time for office workers, activities on Kanggraksan road are dominated by light vehicles heading to the city center or returning from the city center. During the day there is a very significant increase in traffic flow and the length of delays that occur due to signalized intersections causing traffic jams on these roads. On the afternoon, activity on Kanggraksan road are dominated by vehicles from the city center to the residential area (activities to return to work). Illustration of congestion level on Jalan Kanggraksan can be seen in Figure 4.6.

The effect of land use and time of fire case on the travel time of the fire truck is closely related to the congestion points on the route. Because the level of congestion affects the travel time, indirectly the use of land around the congested segment also affects the travel time of the fire truck. Meanwhile, when viewed from the side of the incident, the travel time during the day (noon) produces the longest time that caused by increase in traffic flow.

Figure 4.6 Level of Congestion on Kanggraksan Road during the Day (noon)

4.4.1. Analysis Based on Distance

Based on the calculation of the travel time for each alternative route from 2 fire stations to Harjamukti Market, it can be seen that most of the alternative routes that produce the fastest travel time are those that have the shortest distance. This is common in urban areas because the mileage is not too long so that it does not pass many congestion points and several routes still cross the same road. This in turn results in the travel time of a fire truck to be greatly influenced by the travel distance.

Based on the calculation of the distance from 2 fire stations to Harjamukti Market, the fastest route that can be taken by the fire department is the route originating from the Harjamukti fire station because it has a shorter distance. This is reinforced by the calculation of the travel time which results that most of the fastest times to Harjamukti Market are the routes that originate from the Harjamukti fire station. However, this does not mean that the level of congestion has no effect on the travel time of the fire engine. In certain conditions, for example in conditions of high density or traffic jams, the results of the travel time calculation show the effect of congestion on the travel time. During the day, route 1 from the Bima fire station to Harjamukti Market with a distance of 2,854 meters produces a travel time of 10.63 minutes, while on route 3 with a distance of 3,019 meters produces a travel time of 8.16 minutes. From these results indicate that route 3 which has a longer distance can produce a shorter travel time. Looking at the traffic conditions, route 1 passes Kanggraksan road where during the day the road is in a traffic jam, while route 3 does not pass Kanggraksan road but passes Evakuasi road and Kalitanjung road where the road is in normal traffic.

IV. CONCLUSION

Based on the results of the analysis that has been carried out, it has resulted in the following conclusions:

1. The fastest travel time for fire truck in Cirebon City is mostly influenced by the travel distance. However, in conditions of high traffic flow, a route with a longer distance but does not cross a congested road segment can produce a faster travel time when compared to a shorter route but crosses congested roads.
2. Based on the calculated travel time, most of the routes with the fastest travel times are those originating from the Harjamukti fire station. Therefore, if a fire occurs in Harjamukti Market, the fire fighting unit from the Harjamukti station is recommended to handle the fire.
3. Based on the calculated travel time, the fastest route from the Bima fire station to Harjamukti Market is route 1 (2,854 m) in the morning, route 3 (3,019 m) in the noon and afternoon. Meanwhile, the fastest route from the Harjamukti fire station to Harjamukti Market is Route 1 (2,069 m) in the morning, noon and afternoon because it has the shortest distance.

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