Mapping of Congesting Cost for Road Network Performance in Urban Area (Case Study of Urban Intersection on Yogyakarta)

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***Abstract*— As an urban area, Yogyakarta is one of the cities in Indonesia that has an agglomeration area by connecting 3 districts (Yogyakarta city, Bantul and Sleman district) in the one ring-road. One of the biggest problems in urban area is about traffic congestion and more specific occurred in the signalized intersection. The purpose of this study tries to approach the cost congestion based on the database, identification and creating map the road network at each intersection that can be used as a transport policy for the government. The research method is using ArcGis program by collecting various data on the Yogyakarta urban intersections that have been studied using the 1997 Indonesian Highway Capacity Manual and some theories about cost congestion and the regulations as well. To produce a GIS map, map of Yogyakarta Administration and Google Earth Image maps are used as the main source. From the 20 intersections studied, the results showed that urban intersections, the road network tended to experience a poor level of service intersection (LOS F) with the percentage in 97%. The percentage of queue lengths tends to be as high as 62%, and percentage degree of saturation with a scope limit (LOS F) of 57% and the most expensive intersection costs congestion is the Gejayan intersection.**

Keywords*— *ArcGis; intersection; mapping; road network; level of service

I. BACKGROUND

As one of the tourist destination cities in Indonesia, Yogyakarta has experienced an increase in traffic congestion from year to year. A lot of problems in agglomeration area, one of the important problems is about traffic or congestion. One of the biggest traffic problems in that agglomeration is located in the intersection, particularly signalized intersections.

One of the factors the highest congestion in urban area is depending on the number population. According to (BPS, 2016) in 2015 the population of Yogyakarta reached 3,679,176 people with a population density of 1,555 people per km. The impact that occurs with the population density in the city of Yogyakarta is the potential for increased congestion that occurs in the urban road network of Yogyakarta. The arrangement of the transportation system on the Yogyakarta road network should be well organized such as creating the road network performance database. Jihan and Widyastuti (2016) stated that mapping the road network is very influential to increase economic activity and services, accurate information in mapping road networks can help structuring a good transportation system. Congestion that occurs on the Yogyakarta urban road network is a serious problem that must be overcome. Disturbances that cause congestion often occur due to increased traffic demands such as long queues, large delay times, and traffic violations and so on.

One of the effects of congestion is the addition of costs. This additional cost is influenced by the addition of delay time, queue length, vehicle operating costs, speed and traffic volume. This study will estimate how much the cost in signalized intersection based on the database, particularly in study area. The numbers of the intersection will be deployed in this study is 20 intersection locations.

This research is intended to produce a road network map of Yogyakarta as a reference in knowing several congestion points in the study area. The studies conducted are expected to provide accurate information to road users in driving to avoid the intersections identified as having congestion.

II. CONGESTION COST IN URBAN AREA

A. Congestion Cost Approach

Urban transportation has a variety of very complex problems, namely the problem of traffic congestion, parking, public transportation problems, and pollution. Traffic congestion is one of the most serious problems affecting urban transportation. Identifying the location of traffic jams and patterns that occur is a requirement for urban transport managers to take appropriate precautions to reduce traffic congestion. Congestion that occurs on the road is also a serious problem besides having an impact on discomfort as well as congestion at the intersection (Wibisana and Utomo 2016). Traffic congestion will be detrimental to the driver itself and in terms of economy and environment. For drivers of vehicles, traffic congestion will cause stress problems, in terms of economy, in the form of increasing long waiting times due to long congestion, in addition to increasing vehicle operating costs such as (gasoline, engine maintenance) due to vehicles that stop frequently.

Congestion is the condition of the traffic flow on the road being reviewed exceeding the capacity of the road plan and causing the free speed of the road to be 0 km / hour which then causes a long queue. When congestion occurs, the degree of

saturation in the road section is reviewed where congestion will occur if the value of degree of saturation has reached more than 0.5 (Bina Marga, 1997). According to Small & Verhoef (in Dillon, 2015) transportation congestion can be measured by the importance of service quality and travel time expected by road users, so traffic congestion occurs when the quality of transportation services decreases in intensity of use.

The high level of congestion, causing the addition of time or called the time delay. This can affect the high cost of congestion. Based on to Stubs (1980, in Sugiyanto, 2008), he mentions that the cost of congestion is a relation between speed and flow also the relation between speed and vehicle cost. In urban areas, traffic costs are felt to be quite high when compared to rural areas. The high number of vehicle volumes and the number of travel generating areas causes a large number of trips that can burden the road network.

B. *Level of Service*

It's important to measure the parameters of level of service on the road which needs to be done to prevent congestion at various intersections (Putro, 2009). The level of service at the intersection according to Ministerial Regulation No. 96 of 2015 is explained in Table 1 which regulates the level of service at the intersection according to the delay parameters.

TABLE I. LEVEL OF SERVICE IN INTERSECTION BASED ON DELAY

Level of Service	Delay (Second)	Notes
A	< 5	Excellent
B	> 5 - 15	Good
C	> 15 - 25	Average
D	> 25 - 40	Less Average
E	> 40 - 60	Poor
F	> 60	Very Poor

Source: Ministry Regulation Number 96 in 2015 about The guidelines for Implementing Traffic Management and Engineering Activities

C. *Mapping in Transport and Geography Studies*

According to Ball and Petsimeris (2010) maps are objects that are familiar to everyone, as a form of getting information, maps are needed, the quality of maps must be assessed primarily in terms of geometric accuracy. Maps are useful in everything, especially in geography and transportation, which are often used to provide accurate information about the mapping that is done. In the field of transportation, maps are used to find the shortest route in the application by utilizing the Geographic Information System (GIS) (Buana, 2010). Maps are also used in the delivery of specific cities through ArcGis Online utilizing information that is on the system (Hamdani and Jamil 2017). The benefit of maps in geography is as a digital map location marker application. Digital maps are images of the earth's surface that are digitally collected and scaled down to a certain scale through a projection system (Hati et al, 2013).

III. RESEARCH METHODOLOGY

A. *Location of Study*

Research on road network mapping is carried out at intersections with Ring-road boundaries as the research area. The map used is Google Earth imagery, 2018. The location of this study is at 20 intersection where the study area in the agglomeration of Yogyakarta.

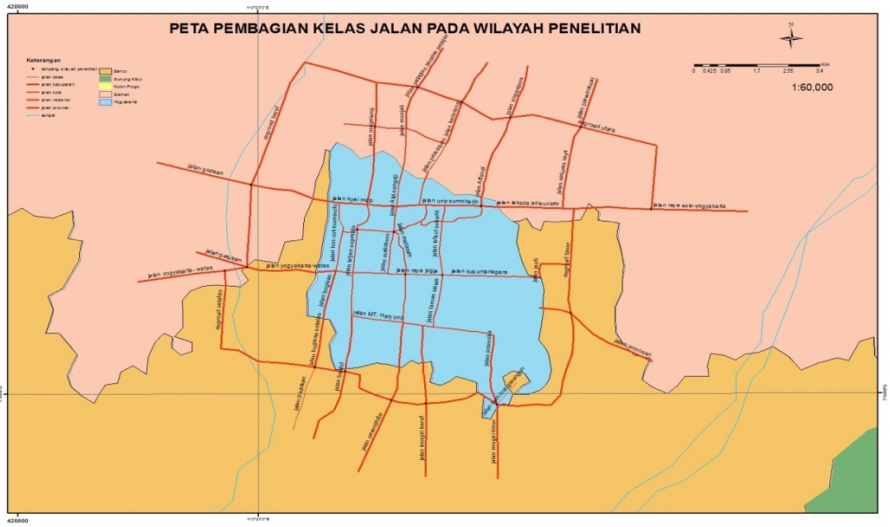

Fig 1. THE ROAD NETWORK OF STUDY OCATION

TABLE II. LIST OF THE INTERSECTION LOCATION

NO.	LOCATION
1	Intersection of Imogiri Barat, South Ringroad, Bantul Regency
2	Intersection of Parangtritis, Bantul Regency
3	Intersection of Giwangan, South Ringroad, Yogyakarta City
4	Intersection of Bantul Street, South Ringroad, Bantul Regency
5	Intersection of East Ringroad and Laksda Adi Sucipto, Sleman Regency
6	Intersection of Ketandan, East Ringroad, Bantul Regency
7	Intersection of Monjali, Yogyakarta City
8	Intersection of Tamansiswa, Yogyakarta City
9	Intersection of Demangan, Yogyakarta City
10	Intersection of Abu Bakar Ali, Yogyakarta City
11	Intersection of Pelemgurih, Yogyakarta City
12	Intersection of Panembahan Senopati, Yogyakarta City
13	Intersection of Selokan Mataram-Magelang Street, Sleman Regency
14	Intersection of Jlagran, Sleman Regency
15	Intersection of Demak Ijo, West Ringroad, Sleman Regency
16	Intersection of Madukismo, South Ringroad, Bantul Regency
17	Intersection of Gamping Market, West Ringroad, Sleman Regency
18	Intersection of Gejayan, North Ringroad, Sleman Regency
19	Intersection of UPN, North Ringroad, Sleman Regency
20	Intersection of Kentungan, North Ringroad, Sleman Regency

B. Analysis Method

In this study, a method is used to determine the level of intersection service by conducting scoring and classification methods. The parameters used refer to regulations but there are modifications to the ArcGis program. The parameters at the intersection carried out are as follows:

a. Delay
To identify and score on the parameters of intersection delays is to refer to Ministerial Regulation No. 96 of 2015 in Table I.

b. Queue Length
To identify the queue length that occurs at the intersection, a division of 3 classes is done in ArcGis, namely low, medium, and high.

c. Degree of Saturation
To identify intersections with degree of saturation (Volume (V) / Capacity (C)) parameters based on those listed in Table III.

TABLE III. LEVEL OF SERVICE IN INTERSECTION BASED ON V/C RATIO

Level of Service	The Range of V/C	Notes
A	0.00-0.19	Excellent
B	0.20-0.44	Good
C	0.45-0.74	Average
D	0.75-0.85	Less Average
E	0.85-1.00	Poor
F	>1.00	Very Poor

Source: Abubakar (1996)

d. Capacity
Specific capacity parameters at the intersection are not carried out, but only the input capacity of the intersection data in the ArcGis program.

e. Traffic flow
Specific traffic flow parameters at the intersection were also not identified but only input data in the ArcGis program and mapping traffic flows. Map results can be seen in the next discussion to display a map of traffic flow.

f. Congestion Cost Analysis
Based on (Nash, 1997, in Basuki and Siswandi, 2008), Congestion cost is a travel expense due to traffic delay or additional vehicle volume approaching or exceeding road service capacity. This following equation describes the variables that affected congestion cost.

$$C = N * \left[G\ A + \left(1 - \frac{A}{B}\right) V' \right] T$$

where:
C = Congestion Cost (Rupiah),
N = Vehicle Volume (Vehicle),
G = Vehicle Operating Cost (Rp/Veh.Km),
A = Existing Speed (Km/Hour),
B = Ideal Speed (Km/Hour),
V' = Vehicle Time Value Fast (Rp/Veh.Hour),
T = Delay Time (Hour).

IV. RESULT AND DISCUSSION

A. Geometric Correction

In this study the map used as a reference in the mapping is a Google Earth Image map, 2018 scale 1: 55,000. following Table IV Calculation of linear shift according to ArcGis 2018 analysis.

TABLE IV. CALCULATION OF LINEAR SHIFT

No	X	Y	X *Google Earth*	Y *Google Earth*	RMS
1	502.9	-450.3	425.5	913.7	8.4
2	1188.4	-333.1	437.1	913.9	6.3
3	632.4	-75.7	427.7	914.3	6.9
4	939.5	-686.3	432.9	913.3	7.8
Total RMS Error = 7.4					

According to Nicholas and Chrisman (in Jihan and Widyastuti 2016), for tolerance of linear shift errors is equal to 0.5 mm then multiplied by the scale number on the reference map. Tolerance in linear shift is 0.5 mm x 55 mm number on the reference map scale (55,000) the result is 27.5 m. The results obtained show that the average linear shift on Google Earth maps is 7.4 m, so that value is still in tolerance.

B. Intersection Database

The intersection database is data that has been collected and arranged based on the parameters needed and makes it easy for users to obtain information. The database that has been created will be displayed in spatial form in the form of the results of identification of intersections. The database that has been dispensed makes it easier to identify and analyze secondary data that has been obtained.

C. Identifying Service Levels in Yogyakarta Agglomeration Area

Analysis of service levels on the parameters contained in the intersection is based on the scoring method.

- Delay
  Based on the results of the intersection service level classification, it shows that many levels of service with F score mean bad. Thus, from that various intersections, Yogyakarta has a lot of congestion due to delays in various intersections.
- Queue Length
  Based on the results of the queue length classification of various intersections, welding tends to be medium and high at each intersection, only a few have very high queue lengths.
- Degree of Saturation
  Scoring is done on the value of degree of saturation, each intersection tends to be at the boundary of C, D, E and F. For scoring B at the Giwangan intersection to the northeast, namely the Giwangan terminal road, and at the Abu Bakar Ali intersection in Mataram.

  Scoring on intersection capacity and traffic flow is not done because only the input data of the value of the capacity and traffic flow are then displayed in the mapping results.

D. Percentage and Results of Service Level Map at Intersections of Various Parameters

- Percentage and map results based on delay parameters

  Percentage results obtained from maps based on scoring results, the level of intersection is marked in blue with service level F, the level of service with E score is marked in red and the level of service at intersections with scores C and D tends to be low. The service level F is more dominant, the percentage reaches 97% of the scoring result of the intersection service level of the delay parameter. The following are the results of the percentage delay at the intersection described in Fig 2.

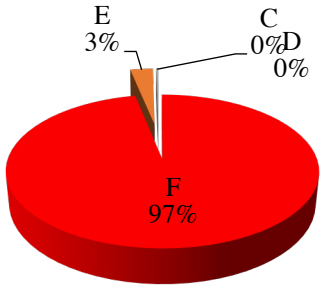

Fig 2. Percentage Diagram of Intersection Delay

And this is the map of performance level based on delay.

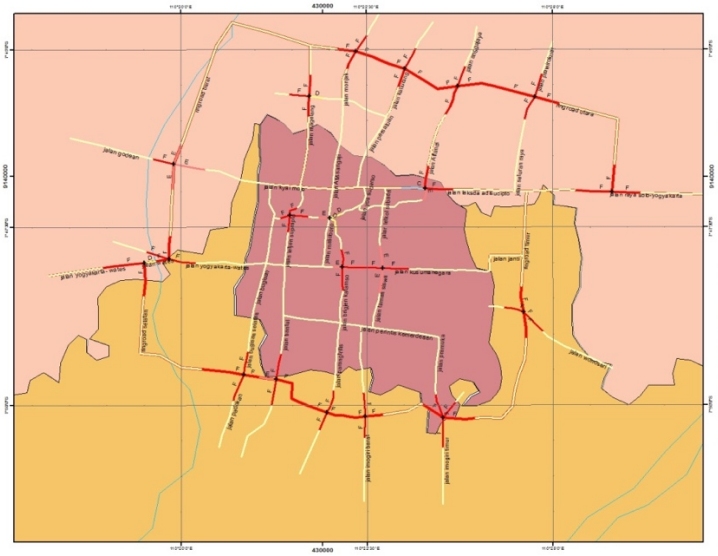

Fig 3. The Map of Road Network Performance Based on Delay Parameter

- Percentage and map results based on queue length parameters

  The percentage results that obtained from the scoring in ArcGis and range classification can be seen in this following description.

TABLE V. CLASSIFICATION BASED ON QUEUE LENGTH

No	Range	Class
1	0 – 100	Low
2	101 – 200	Medium
3	>200	High

Based on the results of class classification in the ArcGis program, the results tend to be in the high class with a percentage of 62% and are marked in red on the diagram. Thus, the results of the queue length with the medium class are marked in yellow. For the queue length with high class occurs at the North Ring-road intersection, Kaliurang Street from west direction 648 meters, Laksda Adisucipto Street, East Ring-road with a queue length of 700 meters to the east, and the intersection of Parangtritis, South Ring-road with a queue length of 974 meters to the west.

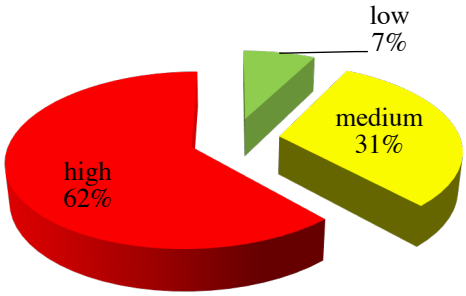

Fig 4. The Percentage of Queue Length Classification

And this is the map of performance level based on queue length.

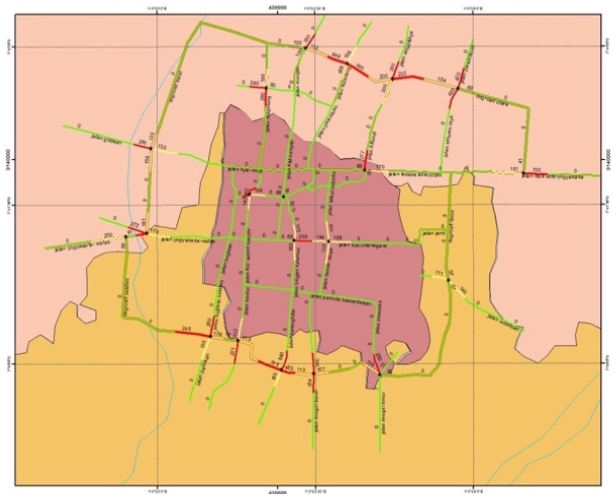

Fig 5. The Map of Road Network Performance Based on Queue Length Parameter

- Percentage and map results based on degree of saturation parameters

  Percentage results obtained from analysis and levelling for Degree of Saturation (DS) values. Based on the high DS value that with F level (very poor) is marked in blue with percentage 57%. The degree of saturation E is indicated by the red color of 20%. Almost every intersection tends to be at the level of C, D, E and F. For DS values with level B occur at the Giwangan intersection to the northeast, that is the Giwangan terminal road, and at the Abu Bakar Ali intersection in Mataram road. The following explanation in the form of a diagram can be seen in Fig 6.

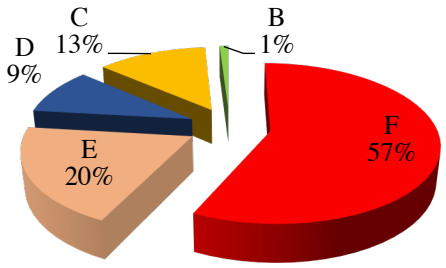

Fig 6. The Percentage of Degree of Saturation Level

And this is the map of performance level based on degree of saturation.

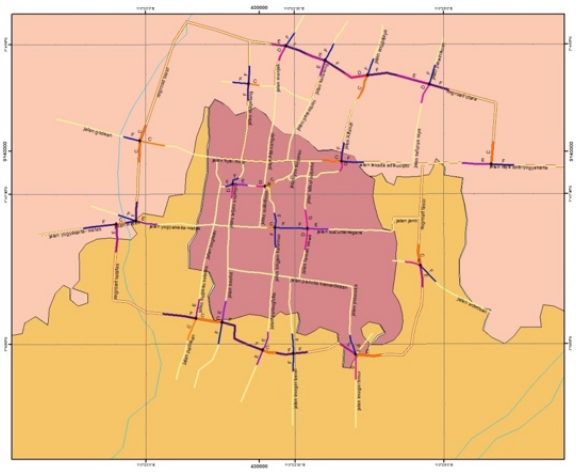

Fig 7. The Map of Road Network Performance Based on Degree of Saturation Parameter

E. Estimating Congestion Cost in the Intersections

Regarding to Muchlisin et al (2017) who tried to make approach of estimating congestion cost in the intersection, these are the result of the cost based on Nash, (1997), in Basuki and Siswandi, (2008). For the calculating BOK (Vehicle Operation Cost) is taken from Sugiyanto (2012) who did research about the correlation operational cost from vehicle and speed. And in this is the result.

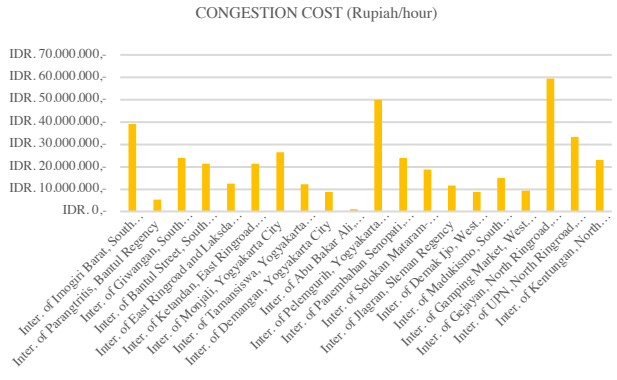

Fig 8. The Result of Cos Congestion Estimation in the Intersections

Based on the result, the most expensive intersection is in the Gejayan intersection with the cost is IDR. 59.252.053,-. Therefore, this intersection should be evaluated to elevated intersection due to the highest delay time.

V. SUMMARY

Based on the results of data processing analysis that has been done with ArcGis software, it can be concluded that:

1. The scope of study location, 20 intersections, a lot of intersections is in the poor and very poor level (E and F) of services based on delay which is increasing more than 60 seconds.
2. Class level according to queue length on the road at each intersection, namely:
   a. Low class range 0 - 100 meters as much as 7%.
   b. Medium class with a range of 101¬ 200 meters which is as much as 31%.
   c. High class range> 200 meters 62%.
3. Degree of Saturation

   At the intersection point which is the research area for the boundary scope in the degree of saturation tends to be at the service level C, D, E and F at each intersection. For score B, it occurs at the Giwangan intersection, precisely in the northeast direction, namely the Giwangan terminal road, and at the intersection of Abu Bakar Ali Mataram Street. Percentage for degree of saturation with score F is as much as 57%, and E as much as 20%.
4. Cost Congestion

   Due to the analysis result, the most expensive cost for the congestion is in the Gejayan Intersection. Therefore, the evaluation should be done to optimize the intersection's performance.

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