

Analysis of congestion cost at signalized intersection using Vissim 9 (Case study at Demak Ijo Intersection, Sleman)

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Abstract. Due to imbalance of road capacity and traffic volume, so traffic congestion will be occurred either along the road and intersection. Demak Ijo intersection is one of signalized junction located in the western part of Yogyakarta with high traffic volume so traffic congestion is frequently occurred. The aim of this study is to analyze the performance of existing traffic condition and then estimate the congestion cost at signalized intersection by modeling (simulation) using Vissim 9. The analysis results show that existing traffic condition is in very bad condition (level F), average delay of 80 seconds, average queue length of 48.73 meters with congestion cost is about Rp. 2,830,336 per hour.

1 Introduction

Congestion is one of significant transportation problems in many urban roads in Indonesia. Traffic congestion will be occurred either along the road and intersection due to imbalance the road capacity and traffic volume. In addition, mostly congestion will generate problems such as the reducing of vehicle speed that lead to the increasing of travel time, higher operating cost, and negative impact to the environment like air pollution produced by motorized vehicle.

The congestion will increase the transportation cost. As stated by Stubs in Sugiyanto [1], the cost of congestion is a relationship between speed and flow on the road and the relationship of speed and vehicle operating cost. It means when the existing traffic flow is increased hence the average traffic speed will decrease. Since the speed of vehicle is slower so the travel time is longer and then lead to the higher vehicle operating costs.

In general, the transportation in Yogyakarta is mixed traffic and overloaded on some road segments. It is due to the average growth of private vehicle in Yogyakarta city is 4.04% per year [2]. Demak Ijo intersection is one of the signalized junction which is located in the western part of Yogyakarta with high traffic volume where traffic congestion is frequently occurred. Therefore, this study attempts to analyze the congestion cost as a result of the low traffic performance at signalized intersection.

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2 Literature review

Congestion is defined as the impedance vehicles impose on each other, due to the speed-flow relationship, in conditions where the use of a transport system approaches its capacity [3]. Tzedakis [4] stated that the theory of congestion cost was not based on the concept of homogenous traffic and the relationship of speed and flow. The congestion cost is the quantification of delay cost and changes in vehicle operating cost caused by slow traffic. In addition, Nash in Basuki and Siswandi [5] highlighted that congestion cost is a travel expense due to traffic delay or additional vehicle volume approaching or exceeding road service capacity. Verhoef in Sugiyanto [2] defined the congestion cost as representation of the difference of marginal social cost (MSC) to marginal private cost (MPC). Some studies related to congestion cost have been conducted by Tzedakis [4], Basuki and Siswadi [5], and Sugiyanto [3, 6]. Mostly studies focused on congestion cost that were occurred in road segment.

Theory of Tzedakis [4] highlighted the congestion cost resulted by slow traffic by time period (i.e. per hour) that can be estimated by considering the followings:

- 1) Slow vehicle (traffic) due to congestion will cause the delay of fast vehicle;
- 2) As a result the queuing time will be occurred on the road segment or intersection;
- 3) The expected value of the sum queuing time of fast vehicle impeded by the slow one is then estimated;
- 4) Based on the expected value of the sum queuing time, the expected value of delay costs and the change in vehicle operating costs are then quantified;
- 5) These costs per hour are then estimated by multiplying the costs per slow vehicle journey by the hourly number of slow vehicle journeys;
- 6) The formula to calculate the congestion cost is as written on equation 1

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

where:

- C = Congestion Cost (Rupiah),
- N = Vehicle Volume (Vehicle),
- G = Vehicle Operating Cost (Rp/veh.km),
- A = Existing Speed (km/hour or kph),
- B = Ideal Speed (km/hour or kph),
- V' = Vehicle Time Value (Rp/veh.hour)
- T = Delay Time (Hour).

The Vehicle Operating Cost (VOC) in Yogyakarta can be calculated using formula proposed by Sugiyanto [6] as written in equation 2 below.

$$Voc = 0.4937v^2 - 60.218v + 29 \quad (2)$$

where

- V = vehicle speed (Km/Hour)

Vehicle Time Value is estimated by using Table provided by Indonesian Highway Capacity Manual (1995) as described on Table 1 below.

Table 1. Vehicle time value
 (Source: Indonesian Highway Capacity Manual, 1995)

Type of Vehicle	Vehicle Time Value (Rp/veh.hour)	
	Gross Domestic Product	Welfare maximation
Motor Cycle	315,00	736,00
Passenger Car	1.925,00	3.281,00
Small Bus	7.385,00	12.572,00
Big Bus	9.800,00	18.211,00
Small Truck	4.970,00	5.605,00
Medium Truck	4.970,00	5.605,00
Big Truck	4.970,00	736,00

3 Methods

The method applied in this study is as illustrated on Figure 1. Primary and secondary data collection have been conducted in order to obtain traffic data, cycle time (of traffic light), geometric data, road condition, vehicle speed, traffic volume, etc. These data are then utilized in traffic modeling/simulation by using software Vissim 9. The considerations are taken into account to the minimum congestion cost, queue length and delay, but the highest Level of Service (LOS).

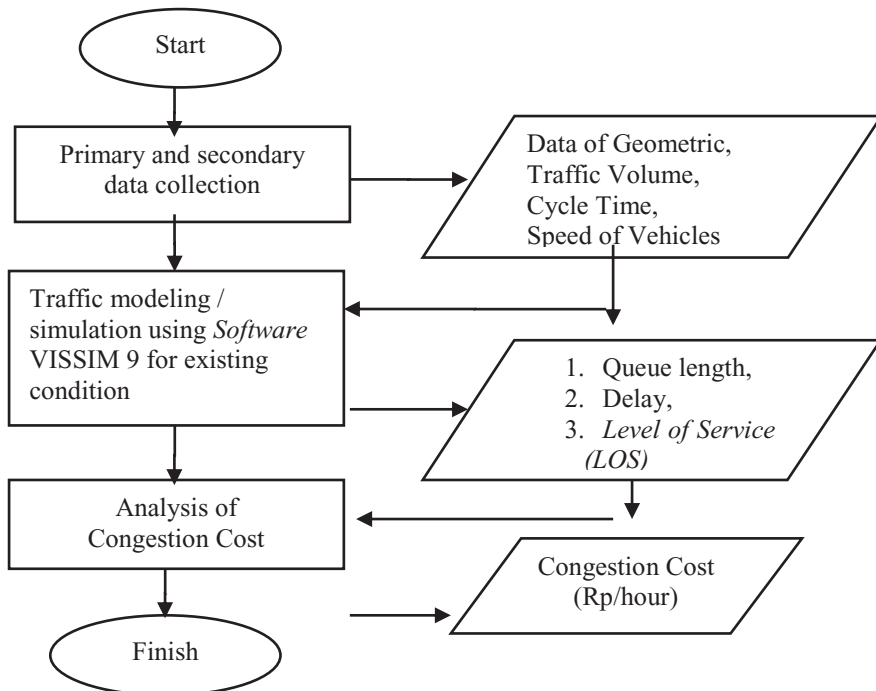


Figure 1. Research method

The study was conducted at signalized intersection of Demak Ijo, Godean Street, Sleman, Yogyakarta as shown in Figure 2 and 3. Traffic data utilizing in this study was collected by Umar [7], which was carried out for 12 hours on weekday on 06.00 up to 18.00 WIB. Moreover, in order to determine the geometric data at intersection, cycle time, road

and environmental condition, the observation survey were also carried-out. The vehicle speed (spot speed) was conducted on three time: 06.00-08.00; 12.00-14.00, and 16.00-18.00 which represents the weekday traffic condition for every type of vehicle such as HV (Heavy Vehicle), LV (Light Vehicle), and MC (Motor Cycle).



Figure 2. Demak Ijo intersection, Godean, Sleman

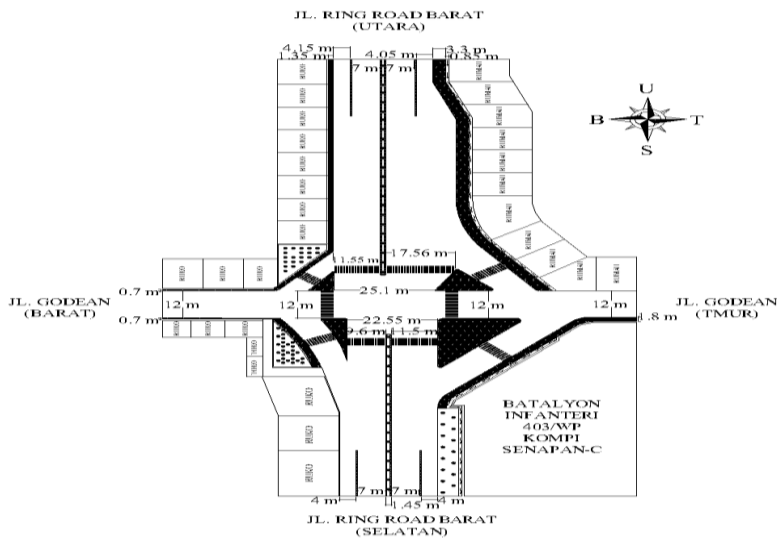


Figure 3. Geometric condition at Demak Ijo intersection, Godean, Sleman

4 Analysis result and discussion

4.1 The existing phase condition

The existing phase condition at Demak Ijo intersection can be seen in the Table 2 below. The total cycle time is 148 second for all arms.

Table 2. Existing phase condition

Signal	Arm	Type of Arm	Time (second)			
			Red	Green	Amber	All Red
Phase 1	N	Protected (P)	138	35	3	4
Phase 2	E	Protected (P)	148	25	3	4
Phase 3	S	Protected (P)	138	35	3	4
Phase 4	W	Protected (P)	148	25	3	4
Cycle Time (second)			148			

4.2 The traffic volume at peak hour

The survey of traffic counting was conducted by Umar [7] in the period of 12 hours starting from 06.00 up to 18.00. However, the data used for modelling the traffic at intersection is selected only during the peak hour (06.15.- 07.15). The traffic volume at peak hour obtained from the survey is as illustrated in Tabel 3.

Table 3 Data of traffic volume at peak hour [7]

Time	Arm Junction		HV	LV	MC	NMV	Total
6.15 s.d 7.15 WIB	North (A)	T. Left	1	68	540	16	625
		Straight	26	332	1135	2	1495
		T. Right	5	118	452	0	575
		Total	32	518	2127	18	2695
	East (B)	T. Left	1	87	268	2	358
		Straight	6	91	749	7	853
		T. Right	2	50	482	19	553
		Total	9	228	1499	28	1764
	South (C)	T. Left	5	21	87	6	119
		Straight	28	689	3118	8	3843
		T. Right	5	67	434	2	529
		Total	38	777	3639	16	4491
	West (D)	T. Left	1	210	650	9	870
		Straight	6	169	3838	34	4047
		T. Right	0	62	703	1	766
		Total	7	441	5191	44	5683

4.3 Stages of traffic modeling by using Vissim 9

In general, the stages of traffic modeling using software Vissim 9 as illustrated in Figure 4, which consist of input data, analysis, and obtain the output.

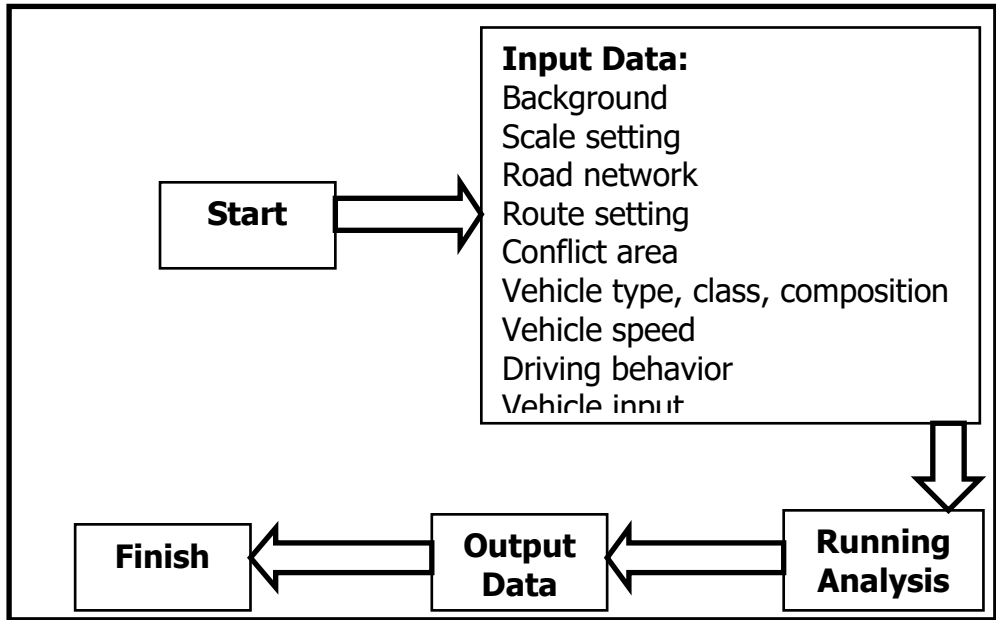


Figure 4. Stages of modeling using software Vissim 9

4.4 Output data of Vissim 9

The output resulted from simulation using software Vissim 9 is as shown in Table 4. It can be seen from the table that the maximum vehicle delay occurred is 232 second and the longest queuing is 214 meter at west arm with level of service F (very bad).

Table 4. The output data of Vissim 9 for existing condition

Time Interval	Arm	Direction	QLen (m)	QLen Max (m)	Vehs (All) (veh)	LOS (All)	LOS Val (All)	Veh Delay (All) (second)	Stop Delay (All) (second)	Stops (All) (veh.)
0-3600	North	(N) - (E)	01.24	20.51	96	LOS_A	1	08.36	0,088889	0,052083
0-3600		(N) - (S)	103.21.00	201.34.00	143	LOS_F	6	123.42.00	106.14.00	02.43
0-3600		(N) - (W)	0,884722	67.07.00	73	LOS_E	04.05	60.685	49.48.00	01.02
0-3600	East	(E) - (S)	01.12	18.24	64	LOS_A	1	3.055	2.235	00.14
0-3600		(E) - (W)	72.49.00	150.05.00	86	LOS_F	6	110.25.00	85.92	02.13
0-3600		(E) - (N)	1,014583	58.31.00	62	LOS_E	04.05	58.975	52.845	0,065278
0-3600	South	(S) - (W)	00.38	13.03	39	LOS_A	3	37.31.00	25.445	01.04
0-3600		(S) - (N)	128.18.00	186.33.00	143	LOS_F	6	135.61	104.975	04.07
0-3600		(S) - (E)	13.39	69.96	76	LOS_D	4	48.42.00	37.26.00	01.21
0-3600	West	(W) - (N)	0	12.07	145	LOS_A	1	1.195	00.52	00.18
0-3600		(W) - (E)	173.92	214.42.00	87	LOS_F	6	232.63	196.73	0,224306
0-3600		(W) - (S)	46.225	122.37.00	87	LOS_D	5	139.07.00	72.035	0,068056
0-3600	Average		48.73	214.42.00	1101	LOS_F	6	80	61.27.00	0,088889

4.5 Vehicle operating cost (VOC)

By employing equation 2 and considering the speed of vehicle, type of vehicle, and arm of intersection, so the vehicle operating cost (VOC) in existing condition at Demak Ijo

intersection as shown in Table 5. The highest VOC is at west arm which is Rp. 1594/veh.km.

Table 5. Vehicle operational cost for existing condition

No	Arm	Vehicle Type	VOC
			(Rp/Veh.km)
1	NORTH	HV	1354
		LV	1221
		MC	353
2	EAST	HV	1478
		LV	1365
		MC	351
3	SOUTH	HV	1247
		LV	1158
		MC	378
4	WEST	HV	1582
		LV	1594
		MC	351

4.6 Travel time value (V)

The time value is calculated using the study of Indonesian Highway Capacity Manual (1995) as illustrated in Table 1. Based on the vehicle type, the travel time value for Heavy Vehicle is estimated Rp. 4,970, Light Vehicle Rp. 1,925, and Motor Cycle Rp. 315.

4.7 Congestion cost analysis

The total congestion cost at Demak Ijo intersection in existing condition can be seen on Table 6 below. The total congestion cost at the junction is Rp. 2,830,336 per hour. Table 6. Total Congestion Cost for Existing Condition at Demak Ijo Intersection

5 Conclusions

By considering the analysis results of simulation using software VISSIM 9 for signalized intersection of Demak Ijo, Godean, Sleman, Yogyakarta, it can be concluded as follows.

1. The traffic performance of existing condition of signalized intersection Demak Ijo, Godean, Sleman, Yogyakarta is very bad (level F) with the highest traffic volume (peak hour) occurs in the morning at 06.15 - 07.15 WIB with traffic volume 14,633 vehicle, average delay of 80 seconds, and average queue length of 48.73 meters.
2. The congestion costs at signalized intersection of Demak Ijo, Godean, Sleman, Yogyakarta, which is occurred at peak hour, is Rp. 2,830,336 per hour.

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Referencers

1. Sugiyanto, G, *Biaya Kemacetan (Congestion Cost) Mobil Pribadi di Central Business District* (2008)
2. Sugiyanto, G, et al, Pengembangan Model Biaya Kemacetan Bagi Pengguna Mobil Pribadi di Daerah Pusat Perkantoran Yogyakarta. *Jurnal Transportasi* **11**, 2, 87-94 (2011)
3. Sugiyanto, G, et al, Modeling the Effect of Congestion Pricing on Mode Choice in Yogyakarta, Indonesia. *International Journal of Engineering & Technology IJET – IJENS* **11**, 01. 85-94 (2011)
4. Tzedakis, A, Different Vehicles Speeds and Congestion Costs. *Journal of Transport Economics and Policy* **XIV**, 1, 81-103 (1980)
5. Basuki, Siswandi, Biaya Kemacetan Ruas Jalan Kota Yogyakarta. *Jurnal Teknik Sipil* **9**, 1, 71-80 (2008)
6. Sugiyanto, G, et al, Pemodelan Biaya Kemacetan Pengguna Mobil Pribadi Dengan Variasi Nilai Aktual Kecepatan Kendaraan. *Jurnal Transportasi* **12**, 2, 123-132 (2012)
7. Umar, M.A.A, *Analisis Kinerja Simpang Bersinyal pada Persimpangan Demak Ijo*, (2016)
8. Directorate General of Highway, *Ministry of Public Works the Republic of Indonesia* (2010)
9. Khisty dan Lall, *Dasar-Dasar Rekayasa Transportasi* (2005)
10. Mahmudah. N, Bayunagoro. D.H, Pemodelan Lalu Lintas pada Simpang Bersinyal di Kota Yogyakarta (Studi Kasus Simpang Pingit). *Proceedings of SNTT IV. UMP. Purwokerto. 26 November 2016. ISSN: 2339-028X* (2016)
11. Ministry of Transportation Republic Indonesia, *Peraturan Menteri No. 96 Tahun 2015. Tentang Pedoman Pelaksanaan Kegiatan Manajemen dan Rekayasa Lalu Lintas* (2015)Munawar, A, *Dasar-dasar Rekayasa Transportasi* (2005)
12. Putranto, L.S, *Rekayasa Lalu Lintas (Edisi 3)* (2016)
13. PTV VISSION, *PTV VISSIM 9 User Manual*. PTV AG (2016)
14. The Government of Republic Indonesia, *Undang - Undang Republik Indonesia No 22 Tahun 2009 Tentang Lalu Lintas dan Angkutan Jalan* (2009)