REDUCTION OF URBAN ROAD PERFORMANCE IN CONSEQUENCE OF CURB PARKING

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Abstract

Traffic congestion usually occurs on urban roads in large cities in developing countries. A number existing conditions worsen traffic congestion including unbalance rapid increase of vehicle number towards low increase of road density per year, poor land use planning, poor adherence to traffic regulation, and curb parking. The aim of this study is to evaluate the reduction of urban road performance in consequence of curb parking. Case study is carried out on Abdul Rahman Saleh Street (4/2UD) in large city Bandung, Indonesia. Indonesian Highway Capacity Manual 1997 is used to evaluate the urban road performance. Results indicated that traffic performance indicator i.e capacity (pcu/h) increase 25%, degree of saturation (v/c) reduce 25%, and speed (km/h) increase 33%, if there is no curb-parking on the observeb street. The most important thing is, using the results to provide recommendations and implement it consistenly to decrease traffic congestion based on existing conditions.

Keywords: urban road, developing countries, traffic congestion, curb parking, urban road performance

Abstrak

Kemacetan lalulintas biasa terjadi di jalan perkotaan di kota besar di negara-negara berkembang. Kondisi-kondisi yang ada memperburuk kemacetan yang terjadi, termasuk pertumbuhan jumlah kendaraan yang tidak seimbang dengan pertumbuhan densiti jalan per tahun, perencanaan *land use* yang tidak baik, ketidakpatuhan terhadap peraturan lalulintas, dan parkir di atas badan jalan. Tujuan dari studi ini adalah mengevaluasi penurunan kinerja jalan perkotaan sebagai akibat adanya parkir di atas badan jalan. Studi kasus dilaksanakan di jalan Abdul Rahman Saleh (4/2UD) di kota besar Bandung, Indonesia. Manual Kapasitas Jalan Indonesia 1997 digunakan untuk mengevaluasi kinerja jalan perkotaan. Hasil evaluasi menunjukkan bahwa indikator kinerja, yaitu kapasitas meningkat 25%, derajat kejenuhan (v/c) menurun 25%, dan kecepatan (km/h) meningkat 33%, dalam kondisi tidak ada parkir di atas badan jalan. Tetapi hal yang terpenting adalah menggunakan hasil evaluasi ini untuk memberikan dan kemudian menjalankannya secara konsisten sehingga kemacetan lalulintas dapat berkurang dengan kondisi-kondisi yang ada.

Kata-kata kunci: jalan perkotaan, negara berkembang, kemacetan lalulintas, parkir di atas badan jalan, kinerja jalan perkotaan

INTRODUCTION

The transportation system exists to meet perceived social and economic needs. The challenges are managing congestion, improve safety, providing equal access, protecting the environment, incorporating new technology, securing financial resources, and developing adequate institutional arrangement. The first four of these challenges are primarily related to the performance of the transportation itself (Kutz, M., 2004; Fricker, J.D., Whitford, R.K., 2004: Banks, J.H., 2002; Khisty, G.J. and Lall, B.K., 1998).

Traffic congestion exists whenever demand exceeds the capacity of transportation systems. Congestion is most often thought as a problem of urban roads and has long been recognized as a challenge (Kutz, M., 2004; Fricker, J.D., Whitford, R.K., 2004: Banks, J.H., 2002; Khisty, G.J. and Lall, B.K., 1998). It worsen by a number of existing conditions including unbalance rapid increase of vehicle number towards low increase of road density per year, poor land use planning, poor adherence to traffic regulation, and curb parking. The aim of this study is to evaluate the reduction of urban road performance in consequence of curb parking. The most important thing is, using the results to provide recommendations and implement it consistenly to decrease traffic congestion based on existing conditions.

PARKING OPERATION AND FACILITY TYPE

There are two general types of facilities for parking i.e. at the curb and in off street parking. The total number of vehicle in most cities could not possibly be parked at the curb. Even if such space were available, the cost of congestion and accidents would be unacceptable. Therefore, off street parking at public and private places is needed (Fricker, J.D., Whitford, R.K., 2004; Pline, J.L., 1999).

There is a consequence of curb parking to the urban road performance. Urban road performance can be described by traffic volume, capacity, degree of saturation, and speed. In more detail, the explanation regarding vehicle is as follow (Kutz, M., 2004; Roess, R., Mc Shane, W.R., and Prassas, E. 2004; Khisty, G.J. and Lall, B.K., 1998; Directorate General of Highway, Directorate of Urban Road Development, 1997): traffic volume is the number of vehicle passing a point during a specified time period, which is usually one hour. Capacity is the maximum houly rate at which vehicle can be reasonably expected to traverse a pont or uniform segent of a lane or roadway during a given time period under prevailing roadway, traffic, and roadway conditions. Capacity analysis estimates the maximum number of vehicle that can be accommodated by a given facility in reasonable safety within a specified time period. Furthermore, capacity depends on physical and environmental conditions. Degree of saturation or volume to capacity ratio (v/c) is ratio between actual incoming flow and capacity at a given geometry, traffic flow pattern and composition, and environmental factors.Two different ways of calculating the average speed of a set of vehicles are Space Mean Speed (SMS) and Time Mean Speed (TMS). The difference in computing the average speed leads to two different values with different physical significance. SMS is defined as the average speed of all vehicles occupying a given section of road over a specified time period. TMS is define as the average speed of all vehicles passing a point on a road over a specifiv time period. Moreover, TMS is a point measure and SMS is a measure relating to a length og road or lane. TMS and SMS may be computed from a series of measured travel time over a measured distance. TMS

takes the aritmetic mean of the observation and SMS could be calculated by taking the harmonic mean of speeds measured at a point over time. The formulas are as follow:

$$TMS = \frac{\sum \frac{d}{t_i}}{n} \quad (1)$$

$$SMS = \frac{d}{\sum \frac{t_i}{n}} = \frac{nd}{\sum t_i} \quad (2)$$

with:
TMS = time mean speed (mph or km/h)
SMS = space mean speed (mph or km/h)
d = distance traversed (mi or km)
n = number of travel time observed
t_i = travel time for *i*th vehicles (sec or hr)

DATA AND ANALYSIS

Field data is primary data that carried out on Abdul Rahman Saleh Street as one of congested urban roads in large city Bandung, Indonesia (Oktavianto, P., 2015). Type of observed road is 4/2UD with 14m travelled way, 3.5 m lane width, and 2.3 m parking lane. Location of the observed road is presented in Figure 1, while traffic volume, travel time, and space mean speed (SMS) data during weekend and weekday are presented in Table 1 and Table 2.

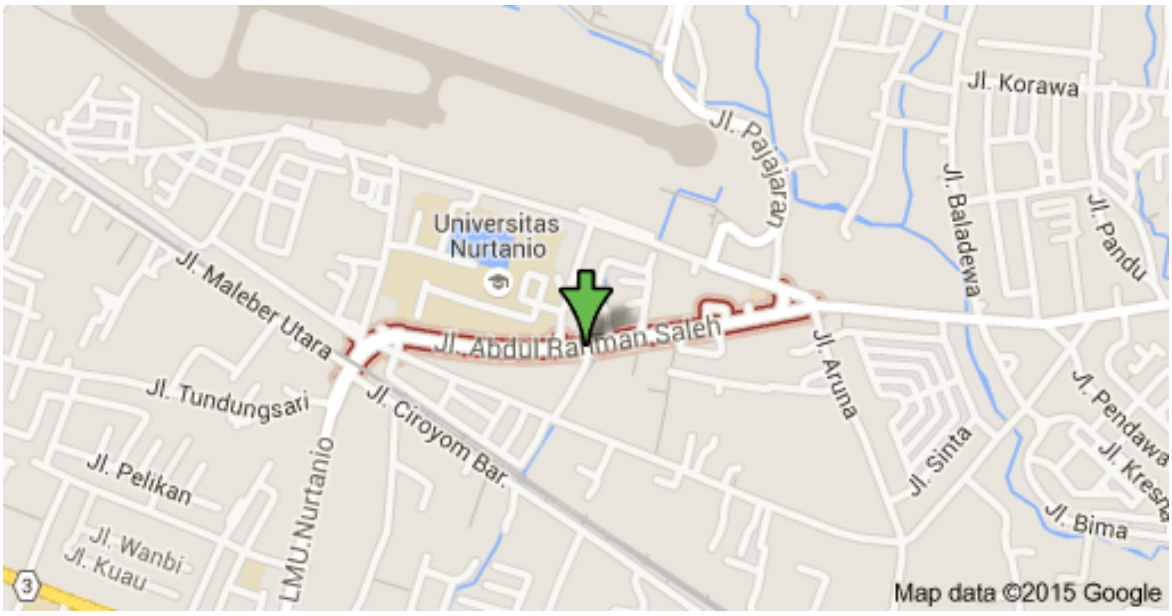

Figure 1 Location of Observed Road (Google maps, 2015)

Table 1 Traffic Volume Data of Observed Road During Weekend and Weekday

Day/ Direction	Time	Traffic Volume (Q, veh/h)			Total Q (pcu/h) 0.25MC+1LV+1.2HV
		MC	LV	HV	
Weekend west to east	07.00 am-08.00 am	2,502	658	10	1,296
	08.00 am-09.00 am	2,083	656	9	1,188
	12.00 am-01.00 pm	1,772	724	13	1,183
	01.00 pm-02.00 pm	1,791	766	10	1,226
	04.00 pm-05.00 pm	1,563	807	9	1,209
	05.00 pm-06.00 pm	1,648	727	8	1,149
Weekend east to west	07.00 am-08.00 am	2,386	560	9	1,167
	08.00 am-09.00 am	1,917	647	5	1,132
	12.00 am-01.00 pm	2,187	652	7	1,207
	01.00 pm-02.00 pm	1,995	768	8	1,276
	04.00 pm-05.00 pm	2,334	681	5	1,271
	05.00 pm-06.00 pm	1,937	709	8	1,203
Weekday west to east	07.00 am-08.00 am	2,882	724	12	1,459
	08.00 am-09.00 am	2,335	733	9	1,328
	12.00 am-01.00 pm	2,015	748	8	1,261
	01.00 pm-02.00 pm	2,384	749	9	1,356
	04.00 pm-05.00 pm	1,995	595	10	1,106
	05.00 pm-06.00 pm	1,968	680	6	1,179
Weekday east to west	07.00 am-08.00 am	2,544	677	13	1,329
	08.00 am-09.00 am	2,042	645	9	1,166
	12.00 am-01.00 pm	1,887	811	13	1,298
	01.00 pm-02.00 pm	2,214	819	5	1,379
	04.00 pm-05.00 pm	1,782	786	10	1,244
	05.00 pm-06.00 pm	1,666	853	11	1,283

Average space mean speed (SMS) in Table 2 is obtained using equation 2, from all average SMS of light vehicle, heavy vehicle, and motor cycle. An example of counting steps of average SMS during weekend (west to east) at 7:00 am to 8:00 am, with distance traversed, d = 100 m = 0.1 km and number of travel time observed, n = 10, is as follow:

$$SMS_{MC} = \frac{d}{\sum \frac{t_i}{n}} = \frac{nd}{\sum t_i} = \frac{10x0.1}{120/3{,}600} = 30.00\ km/h$$

$$SMS_{LV} = \frac{d}{\sum \frac{t_i}{n}} = \frac{nd}{\sum t_i} = \frac{10x0.1}{121/3{,}600} = 29.75\ km/h$$

$$SMS_{HV} = \frac{d}{\sum \frac{t_i}{n}} = \frac{nd}{\sum t_i} = \frac{10x0.1}{122/3{,}600} = 29.50\ km/h$$

$$SMS_{AVG} = \frac{SMS_{MC}xQ_{MC} + SMS_{LV}xQ_{LV} + SMS_{HV}xQ_{HV}}{Q_{MC} + Q_{LV} + Q_{HV}}$$

$$SMS_{AVG} = \frac{30x2{,}502 + 29.75x658 + 29.5x10}{2{,}502 + 658 + 10} = 29.94km/h$$

Table 2 Travel Time and Space Mean Speed (SMS) Data During Weekend and Weekday

Day/ Direction	Time	Travel Time (t_i, second)			Average SMS (km/h)
		MC	LV	HV	
Weekend west to east	07.00 am-08.00 am	120	121	122	29.94
	08.00 am-09.00 am	107	126	118	32.40
	12.00 am-01.00 pm	122	135	117	28.68
	01.00 pm-02.00 pm	112	130	126	30.79
	04.00 pm-05.00 pm	111	135	113	30.46
	05.00 pm-06.00 pm	108	123	99	32.07
Weekend east to west	07.00 am-08.00 am	118	123	111	30.25
	08.00 am-09.00 am	111	121	61	31.72
	12.00 am-01.00 pm	129	135	86	27.60
	01.00 pm-02.00 pm	105	123	97	32.87
	04.00 pm-05.00 pm	110	128	57	31.69
	05.00 pm-06.00 pm	118	121	99	30.29
Weekday west to east	07.00 am-08.00 am	119	125	126	29.95
	08.00 am-09.00 am	116	120	106	30.92
	12.00 am-01.00 pm	124	134	98	28.85
	01.00 pm-02.00 pm	109	127	110	31.89
	04.00 pm-05.00 pm	113	122	120	31.30
	05.00 pm-06.00 pm	112	128	72	31.10
Weekday east to west	07.00 am-08.00 am	114	118	128	31.33
	08.00 am-09.00 am	124	122	112	29.14
	12.00 am-01.00 pm	112	120	121	31.48
	01.00 pm-02.00 pm	122	119	60	29.70
	04.00 pm-05.00 pm	120	116	123	30.52
	05.00 pm-06.00 pm	123	123	116	29.26

Based on primary data regarding road geometric and primary data presented in Table 1 and Table 2, then Indonesian Highway Capacity Manualis used to evaluate the urban road performance. The following equation is used to determined capacity of observed urban road (Directorate General of Highway, Directorate of Urban Road Development, 1997).

$$C = C_0 \times FC_W \times FC_{SP} \times FC_{SF} \times FC_{CS} \text{ (pcu/h)} \quad (3)$$

with:

C = capacity (pcu/h)

C_0 = base capacity (pcu/h)

FC_W = carriageway width adjustment factor

FC_{SP} = directional split adjustment factor

FC_{SF} = side friction adjustment factor

FC_{CS} = city size adjustment factor

Steps of capacity analysis are as follow:

1) Base capacity, C_0 = 1,500 pcu/h/lane for 4/2UD road type;
2) Carriageway width adjustment factor, FC_W = 1 (lane width = 3.5 m) for without curb parking condition andFC_W = 0.746 (lane width = 1.2 m) for with curb parking condition;
3) Directional split adjustment factor, FC_{SP} = 1 for 4/2UD road type and directional traffic split of 50-50;
4) City size adjustment factor, FC_{CS} = 1 for 2,470,802 million people in the large city Bandung (BPS, 2014);
5) Side friction adjustment factor, FC_{SF} is presented in Table 3. Frequency of events including pedestrian, parking, stopping vehicle, enter/exit vehicle, and slow moving vehicle are observed per hour on 200 m length of road segment on both road sides;
6) Capacity of observed urban road is presented in Table 4.
7) Furthermore, degree of saturation describe volume to capacity ratio (v/c) is presented in Table 5. Moreover, The following equation (Directorate General of Highway, Directorate of Urban Road Development,1997) is used to determined travel speed of light vehicle on observed urban road and the result is presented in Table 6.

$$FV = (FV_0 + FV_W) \times FFV_{SF} \times FFV_{CS} \text{ (km/h)} \quad (4)$$

with:

FV = free flow speed (km/h)
FV_0 = base flow speed (km/h)
FV_W = carriageway width adjustment factor for velocity
FFV_{SF} = side friction adjustment factor for velocity
FFV_{CS} = city size adjustment factor for velocity

Table 3 Side Friction Analysis of Observed Urban Road

Side Friction	Symbol	Weight Factor	Frequency of Event	Weight Frequency	Effective Shoulder Width (WS)	Side Friction Class/ FC_{SF}
Weekend						
Pedestrian	PED	0.5	144	72	1m 4/2UD	Low FC_{SF} = 0.97
Parking/ Stopping vehicle	PSV	1	24	24		
Enter/exit vehicle	EEV	0.7	124	86.8		
Slowing moving vehicle	SMV	0.4	42	16.8		
Total				199.6		
Weekday						
Pedestrian	PED	0.5	231	115.5	1m 4/2UD	Medium FC_{SF} = 0.95
Parking/ Stopping vehicle	PSV	1	70	70		
Enter/exit vehicle	EEV	0.7	281	196.7		
Slowing moving vehicle	SMV	0.4	60	24		
Total				406.2		

Table 4 Capacity Analysis of Observed Urban Road

Day	Direction	C_0	FC_W	FC_{SP}	FC_{SF}	FC_{CS}	C
Weekend							
Without Curb Parking	west to east	1,500	1	1	0.97	1	1,455
	east to west	1,500	1	1	0.97	1	1,455
With Curb Parking	west to east	1,500	0.746	1	0.97	1	1,085
	east to west	1,500	0.746	1	0.97	1	1,085
Weekday							
Without Curb Parking	west to east	1,500	1	1	0.95	1	1,425
	east to west	1,500	1	1	0.95	1	1,425
With Curb Parking	west to east	1,500	0.746	1	0.95	1	1,063
	east to west	1,500	0.746	1	0.95	1	1,063

Table 5 Degree of Saturation of Observed Urban Road

Day/ Direction	Time	Total Q (pcu/h)	Capacity C (pcu/h)		DS = Q/C	
			without parking	with parking	without parking	with parking
Weekend west to east	07.00 am-08.00 am	1,296	1,455	1,085	0.89	1.19
	08.00 am-09.00 am	1,188	1,455	1,085	0.82	1.09
	12.00 am-01.00 pm	1,183	1,455	1,085	0.81	1.09
	01.00 pm-02.00 pm	1,226	1,455	1,085	0.84	1.13
	04.00 pm-05.00 pm	1,209	1,455	1,085	0.83	1.11
	05.00 pm-06.00 pm	1,149	1,455	1,085	0.79	1.06
Weekend east to west	07.00 am-08.00 am	1,167	1,455	1,085	0.80	1.08
	08.00 am-09.00 am	1,132	1,455	1,085	0.78	1.04
	12.00 am-01.00 pm	1,207	1,455	1,085	0.83	1.11
	01.00 pm-02.00 pm	1,276	1,455	1,085	0.88	1.18
	04.00 pm-05.00 pm	1,271	1,455	1,085	0.87	1.17
	05.00 pm-06.00 pm	1,203	1,455	1,085	0.83	1.11
Weekday west to east	07.00 am-08.00 am	1,459	1,425	1,063	1.02	1.37
	08.00 am-09.00 am	1,328	1,425	1,063	0.93	1.25
	12.00 am-01.00 pm	1,261	1,425	1,063	0.88	1.19
	01.00 pm-02.00 pm	1,356	1,425	1,063	0.95	1.28
	04.00 pm-05.00 pm	1,106	1,425	1,063	0.78	1.04
	05.00 pm-06.00 pm	1,179	1,425	1,063	0.83	1.11
Weekday east to west	07.00 am-08.00 am	1,329	1,425	1,063	0.93	1.25
	08.00 am-09.00 am	1,166	1,425	1,063	0.82	1.10
	12.00 am-01.00 pm	1,298	1,425	1,063	0.91	1.22
	01.00 pm-02.00 pm	1,379	1,425	1,063	0.97	1.30
	04.00 pm-05.00 pm	1,244	1,425	1,063	0.87	1.17
	05.00 pm-06.00 pm	1,283	1,425	1,063	0.90	1.21

DISCUSSION AND RECOMMENDATION

Based on field data and analysis presented in Table 1 up to Table 6, results of analysis explaining difference between traffic parameters with and without curb parking on

the observed urban road is presented in Table 7. It can be seen in Table 7 that there is reduction of traffic performance. Afterwards, the important thing is to use the results of urban road performance to reduce traffic congestion based on existing conditions, as soon as possible consistently. Integrated action steps towards better urban road performance are as follow:

1) Usual existing traffic congestion on urban road and poor urban road performance lead to the need of routine inspection;
2) Indonesian Highway Capacity Manual (IHCM) 1997 or later revised IHCM is used to evaluate urban roads performance;
3) Primary data identification regarding road geometric, traffic, and environmental conditions is needed in routine inspection;
4) Results of analysis of free flow speed, capacity, and traffic behaviour is obtained using IHCM 1997. Inspection team to implement, report and provide results of routine inspection has to be available;
5) If urban road performance is good, then routine inspection has to be done consistently and continuously;
6) If urban road performance is not good, then integrated action program including restricted curb parking and other action programs has to be done in order to reduce traffic congestion;
7) After implementation of integrated action program, the urban road performance should be evaluated again;
8) Consistent and sustainable routine program have to be done regularly to obtain better urban road performance.

Table 6 Travel Speed of Light Vehicle on Observed Urban Road

Day/ Direction	Time	Total Q (pcu/h)	DS = Q/C		Travel speed V_{LV} (km/h)		Travel time,sec length=0.1km	
			without parking	with parking	without parking	with parking	without parking	with parking
FV (without parking) = $(FV_0 + FV_W) \times FFV_{SF} \times FFV_{CS}$ (km/h) = (53+0) x1 x 1 = 53								
FV (with parking) = $(FV_0 + FV_W) \times FFV_{SF} \times FFV_{CS}$ (km/h) = (53-12.8) x1 x 1 = 40.2								
Weekend west to East	07.00 am-08.00 am	658	0.45	0.61	49	36	7	10
	08.00 am-09.00 am	656	0.45	0.60	49	36	7	10
	12.00 am-01.00 pm	724	0.50	0.67	48	33	8	11
	01.00 pm-02.00 pm	766	0.53	0.71	47	32	8	11
	04.00 pm-05.00 pm	807	0.55	0.74	47	32	8	11
	05.00 pm-06.00 pm	727	0.50	0.67	48	33	8	11
Weekend east to West	07.00 am-08.00 am	560	0.38	0.52	52	36	7	10
	08.00 am-09.00 am	647	0.44	0.60	49	36	7	10
	12.00 am-01.00 pm	652	0.45	0.60	49	36	7	10
	01.00 pm-02.00 pm	768	0.53	0.71	47	32	8	11
	04.00 pm-05.00 pm	681	0.47	0.63	49	34	7	11
	05.00 pm-06.00 pm	709	0.49	0.65	48	34	8	11

Table 6 Travel Speed of Light Vehicle on Observed Urban Road (Continue)

Day/ Direction	Time	Total Q (pcu/h)	DS = Q/C		Travel speed V_{LV} (km/h)		Travel time,sec length=0.1km	
			without parking	with parking	without parking	with parking	without parking	with parking
FV (without parking) = $(FV_0 + FV_W) \times FFV_{SF} \times FFV_{CS}$ (km/h) = (53+0) x1 x 1 = 53 FV (with parking) = $(FV_0 + FV_W) \times FFV_{SF} \times FFV_{CS}$ (km/h) = (53-12.8) x1 x 1 = 40.2								
Weekday west to East	07.00 am-08.00 am	724	0.51	0.68	48	33	8	11
	08.00 am-09.00 am	733	0.51	0.69	48	32	8	11
	12.00 am-01.00 pm	748	0.52	0.70	47	32	8	11
	01.00 pm-02.00 pm	749	0.53	0.70	47	32	8	11
	04.00 pm-05.00 pm	595	0.42	0.56	50	35	7	10
	05.00 pm-06.00 pm	680	0.48	0.64	48	34	8	11
Weekday east to West	07.00 am-08.00 am	677	0.48	0.64	48	34	8	11
	08.00 am-09.00 am	645	0.45	0.61	49	36	7	10
	12.00 am-01.00 pm	811	0.57	0.76	46	31	8	12
	01.00 pm-02.00 pm	819	0.57	0.77	46	31	8	12
	04.00 pm-05.00 pm	786	0.55	0.74	47	32	8	11
	05.00 pm-06.00 pm	853	0.60	0.80	45	32	8	11

Table 7 Reduction of Urban Road Performance in Consequence of Curb Parking

Urban road performance indicator	Weekend	Weekday	Explanation
Total traffic volume, Q (pcu/h)	1,209	1,283	$Q_{weekday} > 5.7\% Q_{weekend}$ $SMS_{weekday} = SMS_{weekend}$ $SF_{weekday} > SF_{weekend.}$ It means that the observed urban road is busy during weekday and weekend
SMS (km/h)	30.73	30.45	
Side friction, SF	Low	Medium	
Capacity, C (pcu/h) without / with curb parking	1,455 / 1,085	1,425 / 1,063	Capacity during weekday and during weekend seems similar but $C_{without\ curb\ parking} > 25\% C_{without\ curb\ parking}$
DS (v/c) without / with curb parking	0.83 / 1.11	0.90 / 1.21	DS during weekday and during weekend seems similar but $DS_{without\ curb\ parking} < 25\% DS_{without\ curb\ parking.}$ It means that although a part of left lane is used by parking, vehicle still travel in two lanes.
Travel speed of light vehicle, V_{LV} (km/h), without / with curb parking	48.50 / 31.17	47.42 / 32.83	$V_{LV\ without\ curb\ parking} > 33\% V_{LV\ without\ curb\ parking}$

CONCLUSIONS

This study evaluates the reduction of urban road performance in consequence of curb parking, in large city in developing country. Indonesian Highway Capacity Manual

(IHCM) 1997 or then revised IHCM is used to evaluate the performance. Inspection team to implement, report and provide results of routine inspection is needed. If urban road performance is good, then routine inspection has to be done consistently and continuously. But, if urban road performance is not good, then integrated action program including restricted curb parking and other action programs has to be done in order to reduce traffic congestion. The most important thing is, using the evaluation results throughintegrated action steps consistenly and sustainably to decrease traffic congestion based on existing conditions.

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