Car Free Day as An Effort of Sustainable Transportation Systems Towards Smart City in Developing Countries

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Abstract: Sustainable transportation system is a large part of developing smart cities. In developing countries, the large challenges are specific conditions of traffic, geometric, and road users' behavior. Car free day is one of efforts of sustainable transportation system towards smart city. The aim of this study is to evaluate car free day policy as an effort of sustainable transportation system towards smart city to traffic performance of alternative roads around the location. Case study is carried out in large city Bandung, Indonesia. Indonesian Highway Capacity Manual 1997 is used in analysis as a national guideline. Results of analysis show that traffic volume (pcu/h) increases 29.5%, traffic speed (km/h) decreases 38%, and degree of saturation increase 30.9% on alternative road around the location, during car free day operation. The results indicated that the policy is good but the impact to alternative roads should also be taken into account.

Keywords: Car Free Day, Sustainable Transportation Systems, Smart City, Developing Countries

1. INTRODUCTION

There are many challenges for large cities in developing countries towards smart cities. Specific traffic conditions, geometric conditions, and road users' behavior are the reasons, for examples limited road network density compare to city area, rapid increase in number of vehicles but low increase of road network physically, various type, capacity, and level of service of existing public transportation, and poor lane discipline (Sutandi, A. Caroline, 2015a, 2015b, 2016).

Sustainable transportation system represents transport and mobility with non-declining capital that would include human capital, monetary capital, and natural capital, for future generations (World Bank, 2015; Black, William R., 2010; European Union Council of Ministers of Transport, 2001). Sustainable transportation system is a part of smart city. Furthermore, car free day is one effort of sustainable transportation system towards smart cities. The aim of this study is to evaluate car free day policy, as an effort of sustainable transportation system towards smart city, to traffic performance of alternative roads around the location. Case study is carried out in large city Bandung, Indonesia.

2. SMART CITY, SUSTAINABLE TRANSPORTATION SYSTEM, CAR FREE DAY

2.1 Smart City

Smart city is a global sustainable development agenda (World Bank, 2015). Smart city is a

term of a city that fulfills many aspects regarding many components to be fulfilled, for example innovation and green city, green and sustainable transportation with low level of travel time and pollution emission, efficient in the use of resources, resulting in cost and energy savings, and quality of life, using advanced technology including information and communication technology (ICT), and also the very important role of the mayor of the city (Rama, Martin, 2015). It can be seen that a large part of aspects are regarding sustainable transportation. The top 10 smart cities in the world are Vienna, Toronto, Paris, New York, London, Tokyo**,** Berlin, Copenhagen, Hong Kong, and Barcelona (Cohen, Boyed, 2012; Sutandi, A. Caroline, 2015b, 2016).

2.2 Sustainable Transportation System

Rapid increase of automobile number cause increases of fuel consumption and pollution emission. Another impact is increase in number and fatality of casualties. Furthermore, increase of traffic congestion especially in large cities and urban area because of many reasons including limited road density available compare to city and urban area. Moreover, increase of road development is not as fast as increase of number of vehicle.

There are many definitions of sustainable transportation systems. Sustainable transportation including to improve fuel efficiency, less emission and pollution to the environment, renewable energy, and lower cost towards green transport that will then improve quality of community life. Considering existing specific conditions of traffic, geometric, and road users' behavior, efforts to be sustainable transportation as a part of developing smart city, are in the range of possible solutions among planning, policy, education, and technology. Moreover, the decisions varies from one country to another depend on location, traffic condition, and priority (Black, William R., 2010; Sutandi, A. Caroline, 2015b, 2016).

2.3 Car Free Day

Car free day has been implemented in many large cities around the world, especially in large cities in developing countries that experience traffic congestion, almost everyday. Car free day is an effort of sustainable transportation system in developing smart city with the purpose to reduce number of vehicles on the road. Therefore, less traffic congestion, reduce fuel consumption, reduce pollution emission, and greener environment of the day will occur. During car free day, many people of society in the city can do many activities, for example, exercising, cycling, jogging, walking, roller skating, skateboarding, gathering, and socializing. These activities can improve the quality of life of society in the city.

Although car free day on specific roads is a good policy in order to improve quality of life of society, in developing smart city, the impact to traffic performance of alternative roads around the car free day location have to be evaluated. If there is a decrease of traffic performance on the roads around, solutions have to be implemented in order to reduce the problem.

3. METHODOLOGY

3.1 Traffic Parameters Used to Measure Traffic Performance of Alternative Roads, Around Car Free Day Location

The impact of car free day policy to the traffic performance of alternative roads around the location has to be evaluated. Traffic parameters used to measure traffic performance of roads are traffic volume (pcu/h), traffic speed (km/h), and degree of saturation (traffic flow per road

capacity) (Roess, Roger, et.al., 2004; Ogden, K.W. and Taylor S.Y., 1999; Khisty, G. John and Lall, B. Kent., 1998; Robertson, HD, Hummer, JE & Nelson, DG., 1994). Indonesian Highway Capacity Manual 1997 is used as a national guideline to measure traffic parameters (Government of Republic of Indonesia, 1997).

3.2 Research Framework

Steps of research framework are presented in Figure 1. Road location of car free day and alternative road around the location, in large city Bandung, Indonesia are presented in Figure 2.

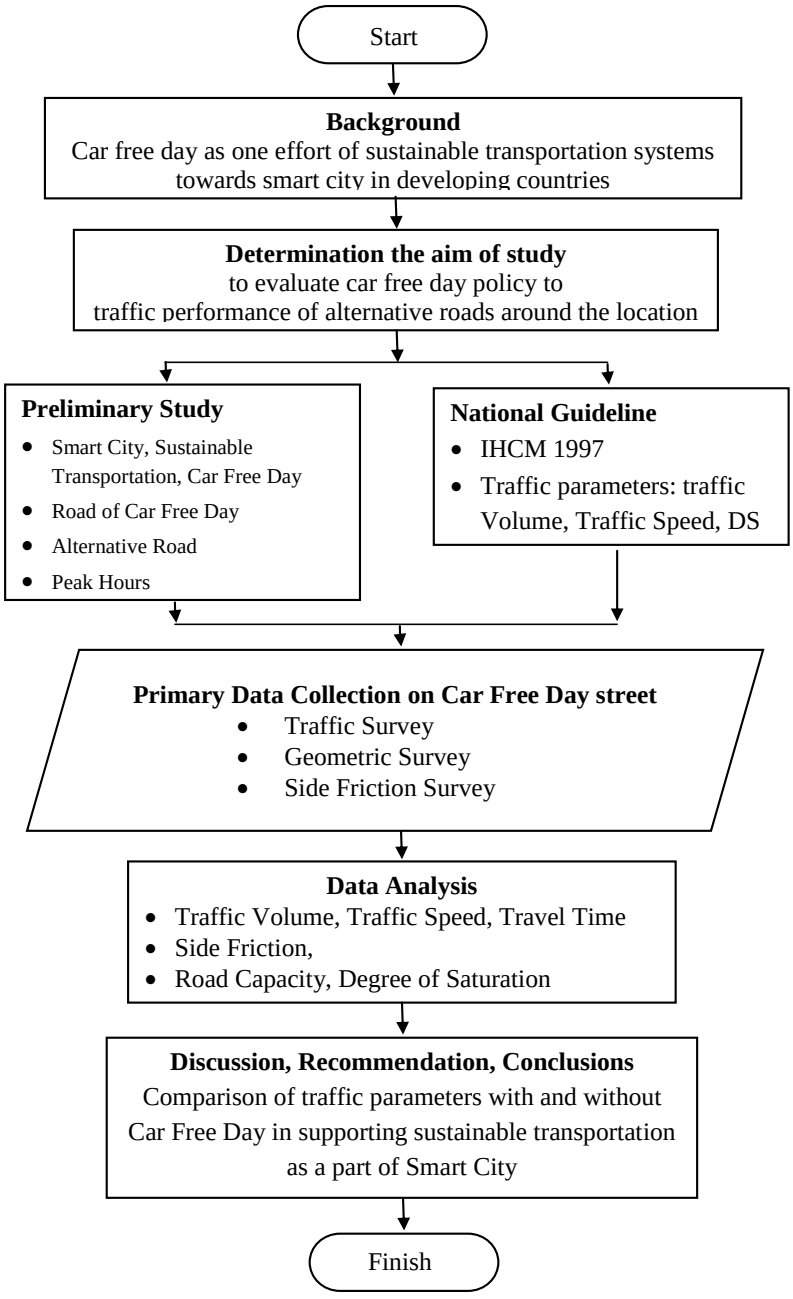

Figure 1. Steps of research framework

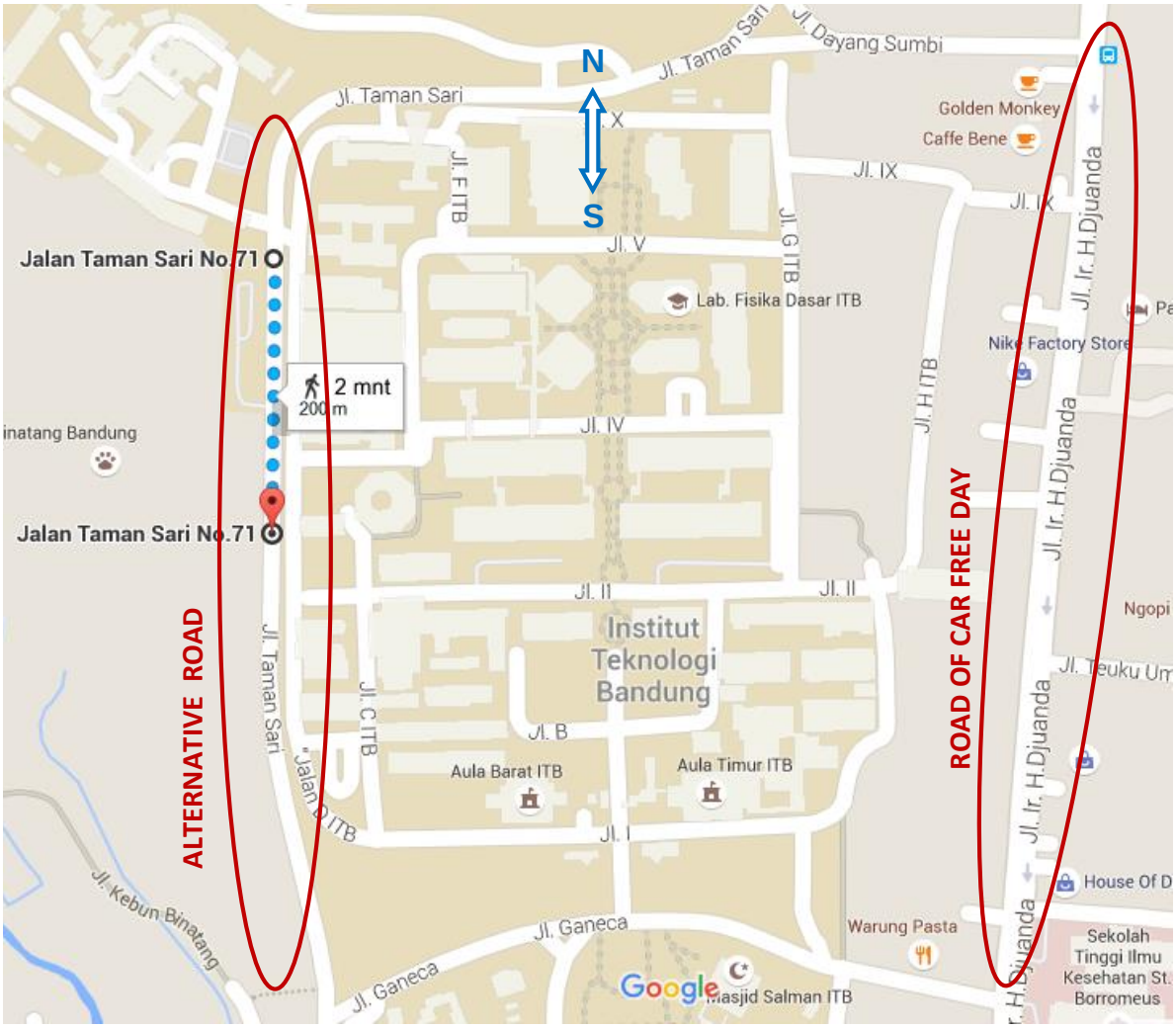

Figure 2. Road location of car free day and alternative road around the location, in large city Bandung, Indonesia

4. DATA AND ANALYSIS

Primary data is carried out in large city Bandung, Indonesia. Car free day located on Ir. H. Juanda street and operated between 06.00am to 10.00am, in Bandung. And alternative road in order to accommodate traffic flow because of car free day policy is the parallel street, Taman Sari street, in Bandung, Indonesia.

Preliminary traffic data obtained from preliminary study are presented in Table 1. Preliminary traffic data that collected in 2016 with and without car free day operation is traffic volume (veh/h). From the preliminary data, peak hour period with and without car free day operation can be determined.

This data is used as a guideline to collect research data for study. The research data for study with and without car free day operation, i.e. traffic volume (veh/h), traffic speed (km/h), and side friction (events per 200m per hour). Furthermore, road capacity (pcu/h) and degree of saturation are counted. Indonesian Highway Capacity Manual 1997 (IHCM 1997), as national guideline, is used to collect the data and analyses the data. The research data is presented in Table 2, Table 3, and Table 4. Moreover, the counted data i.e. road capacity (pcu/h) and degree of saturation are presented in Table 5 and Table 6.

Table 1. Traffic volume (veh/h) of preliminary study with and without car free day

North - South Direction								
TIME	Without Car Free Day				With Car Free Day			
	MC	LV	HV	TOTAL	MC	LV	HV	TOTAL
06.00-07.00	1,029	704	246	1,979	951	774	354	2,079
07.00-08.00	**1,201**	**877**	**373**	**2,451**	1,250	1,148	508	2,909
08.00-09.00	989	817	377	2,183	**1,196**	**1,347**	**546**	**3,089**
09.00-10.00	1,018	654	431	2,103	1,089	1,301	519	2,909
South - North Direction								
TIME	Without Car Free Day				With Car Free Day			
	MC	LV	HV	TOTAL	MC	LV	HV	TOTAL
06.00-07.00	1,029	559	9	1,597	982	394	8	1,384
07.00-08.00	**1,201**	**589**	**7**	**1,797**	1,414	604	4	2,022
08.00-09.00	989	525	12	1,526	**1,520**	**649**	**6**	**2,175**
09.00-10.00	1,018	555	17	1,590	1,485	614	4	2,103

Table 2. Traffic volume (pcu/h) as research data with and without car free day

North - South Direction						
	Without Car Free Day			With Car Free Day		
VEHICLE	LV	MC	HV	LV	MC	HV
Number (veh/h)	356	819	0	560	1,235	3
pcu coefficient	1	0.4	1.3	1	0.4	1.3
Number (pcu/h)	356	328	0	560	495	4
Total (pcu/h)		684			1,059	
South - North Direction						
	Without Car Free Day			With Car Free Day		
VEHICLE	LV	MC	HV	LV	MC	HV
Number (veh/h)	579	1,196	12	668	1,372	0
pcu coefficient	1	0.4	1.3	1	0.4	1.3
Number (pcu/h)	579	478	16	668	549	0
Total (pcu/h)		1,073			1,217	

Table 3. Traffic speed (km/h) as research data with and without car free day

North - South Direction						
	Without Car Free Day			With Car Free Day		
VEHICLE	LV	MC	HV	LV	MC	HV
Number (veh/h)	819	351	0	1,234	560	3
Vehicle Speed (km/h)	51.9	46	0	34.95	24.6	16.6
Traffic Speed (km/h)		50			30.8	
South - North Direction						
	Without Car Free Day			With Car Free Day		
VEHICLE	LV	MC	HV	LV	MC	HV
Number (veh/h)	1,126	520	12	1,302	663	0
Vehicle Speed (km/h)	44.2	38.1	30.2	35	33.2	0
Traffic Speed (km/h)		42			34.4	

Table 4. Side friction as research data - analyzed based on IHCM 1997 with and without car free day

North - South Direction								
	Without Car Free Day				With Car Free Day			
SIDE FRICTION (event per 200m per hour)	Pedes -trian	Veh In/Out	Slow Veh	Parking Veh	Pedes -trian	Veh In/Out	Slow Veh	Parking Veh
Frequency	4	0	12	3	17	0	179	7
Weight (IHCM 1997)	0.5	0.7	0.4	1	0.5	0.7	0.4	1
Weight Frequency	2	0	5	3	9	0	72	7
Total Weight Frequency	**10** (<100 Very Low, IHCM 1997)				**88** (<100 Very Low, IHCM 1997)			
South - North Direction								
	Without Car Free Day				With Car Free Day			
SIDE FRICTION (event per 200m per hour)	Pedes -trian	Veh In/Out	Slow Veh	Parking Veh	Pedes -trian	Veh In/Out	Slow Veh	Parking Veh
Frequency	5	18	36	10	15	122	144	10
Weight (IHCM 1997)	0.5	0.7	0.4	1	0.5	0.7	0.4	1
Weight Frequency	3	13	14	10	8	85	58	10
Total Weight Frequency	**40** (<100 Very Low, IHCM 1997)				**161** (100-299 Low, IHCM 1997)			

Table 5. Road capacity (pcu/h) analyzed based on IHCM 1997 with and without car free day

No	Factors for Analysis	Without Car Free Day	With Car Free Day
1	Base Capacity (Co) pcu/h	2,900	2,900
2	Lane Width Adjusted Factor (FCw)	0.87	0.87
3	Separated Direction Adjusted Factor (FC_{SP})	0.97	0.97
4	Side Friction Adjusted Factor (FC_{SF})	0.94	0.92
5	City Size Adjusted Factor (FCcs)	1	1
Capacity of 2 Lanes (pcu/h) = Co x FCw x FC_{SP} x C_{SF} x FCcs		2,300.5	2,251.5

Table 6. Degree of saturation (DS) analyzed based on IHCM 1997 with and without car free day

Factors for Analysis		Without Car Free Day	With Car Free Day
Total Traffic Volume (pcu/h), IHCM 1997		684+1,073 = **1,757**	1,059+1,217 = **2,276**
Road Capacity (pcu/h)		2,300.5	2,251.5
Degree of Saturation (DS) = Q/C		0.764	1
Traffic Speed (km/h)	North-South Direction	50	30.8
	South-North Direction	42	34.4

5. DISCUSSION AND RECOMMENDATION

It can be seen in Table 1 that preliminary study on alternative road indicated the peak hour as the time period with highest number of traffic volume (veh/h). The peak hour is between 07.00am to 08.00am during no car free day operation and 08.00 to 09.00, during car free day operation. The peak hour is used as time period to collect research data for study, i.e. traffic volume (pcu/h), traffic speed (km/h), and side friction (events per 200m per hour).

Based on traffic volume data (pcu/h) in Table 2, traffic speed data (km/h) in Table 3, and side friction data (events per 200m per hour) in Table 4, then road capacity (pcu/h) of alternative road can be determined and presented in Table 5. Furthermore, degree of saturation (DS) can also be determined and presented in Table 6. Traffic parameters in Table 6 regarding traffic performance of alternative road during car free day operation are as follow:

1) Traffic volume (pcu/h), based on IHCM 1997 for 2 lanes two directions undivided road (2/2UD), is increase from 1,757 pcu/h to 2,276 pcu/h (29.5%).
2) Alternative road is measured by number of events on the roadside including pedestrian activity, vehicle in and out from land use, vehicle that cruise with low speed, and parking vehicle activity. Side friction of Side friction of North to South direction is increase from 10 events to 88 events, but still at Very Low (VL) level based on IHCM 1997. IHCM 1997 said that side friction event per 200m per hour that less than 100 events is at Very Low (VL) level. While side friction of South to North direction is increase from 40 events to 161 events. This condition change from Very Low (VL) level of side friction to Low (L) level of side friction based on IHCM 1997. IHCM 1997 said that side friction event per 200m per hour between 100 events to 299 events is at Low (L) level.

3) Traffic speed of North to South direction decreases from 50 km/h to 30.8 km/h (38%) and those of South to North direction decreases from 42 km/h to 34.4 km/h (18%).
4) Degree of saturation (DS) increase from 0.764 to 1 (at capacity) or increase 30.9%.

Although car free day operation has some positive advantages, for example less traffic congestion, reduce fuel consumption, reduce pollution emission, greener environment of the day, and improve the quality of life of society in the city, but the impact to traffic performance of alternative road is not good. Alternative road experiences more traffic congestion than usual. Based on data and analyses mentioned earlier and also existing conditions of the road network, recommended solution in order to reduce the impact of car free day operation on the alternative road that can be provided are as follow:

1. Car free day operation is better implemented on road with alternative road more than one, so that the increase of traffic congestion of alternative roads can be reduced.
2. Dissemination of information of alternative roads during car free day operation has to be more active, so that not only citizen of the city know about the alternative roads, but also domestic and international visitors or tourists as well.
3. Availability of parking areas around car free day location is needed to accommodate passenger cars of society that join the car free day activity.
4. Public transportation towards car free day location has to still operate or operate with purpose to the location of car free day.
5. Asking the society to come to the car free day location by public transportation, bicycle, or walking.
6. Availability of bicycle lanes on alternative roads around the car free day location to accommodate the society who come to the location by bicycle.

6. CONCLUSIONS

Car free day has been implemented in large cities around the world including in developing countries with specific conditions. Many good impacts of car free day operation in order to increase the quality of life of city society as one of efforts of sustainable transportation systems towards smart city, has to be balanced and accompanied by effort to increase traffic performance of alternative roads around car free day location, seriously and consistently. Further study that can be done is to identify car free day locations in the cities with more than one alternative road and implement other important recommendations as the results of this study, as well.

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