

Bike-sharing Stations Planning using a GIS Suitability Model on Optimal Locations and Demand Analysis: A Case Study in the City of Bandung

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Abstract: Non-motorized transport such as bike sharing has become a popular phenomenon across the globe; it is also the case around South East Asia. The implementation of Bike Sharing in one of the city in Indonesia emerges since 2012. The objective of this paper was to investigate potential location of bike sharing stations in Bandung City. GIS analysis was used to best determine the most suitable locations to place bike-sharing stations in regards to connectivity to public transport and transportation network, as well as convenient accessibility to the city's land use and regional activity. A demand analysis using stated preference survey was carried out to capture demographic profile of potential user and location preference for bike shelter. The study results showed that there are 105 potential locations of bike sharing stations in Bandung City which are centralized in primary area of Bandung City: Cibeunying and North Karees.

Keywords: Bike sharing, Bike Station, Bandung City, GIS analysis, Stated Preference

1. INTRODUCTION

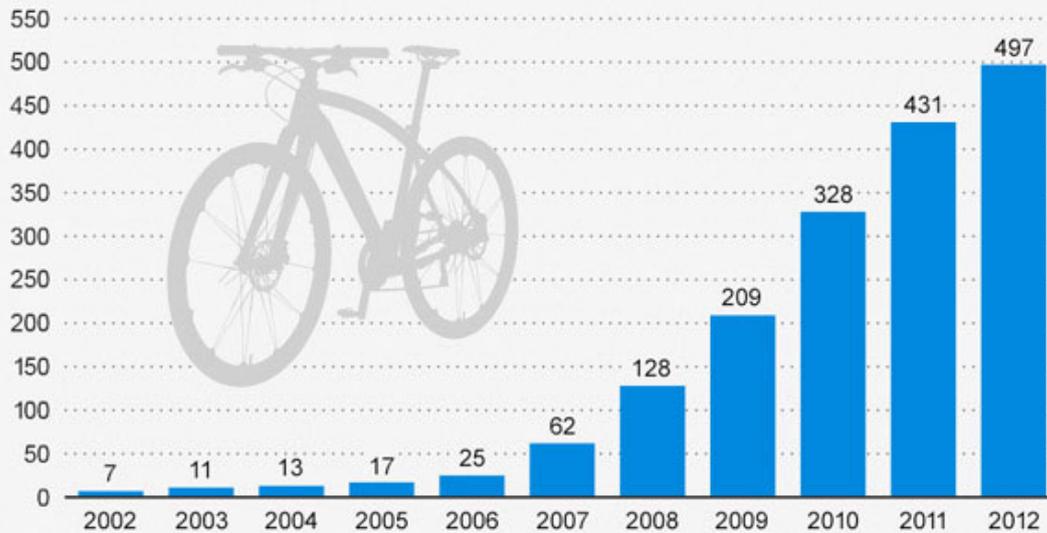
Bike sharing is one of innovative transportation ideas that offers the community additional option of eco-friendly public transportation. Implementation of bike sharing program is expected to improve air quality, reduce congestion, increase cycling activities, and offer healthy mobility.

Bike-sharing has become a popular phenomenon across the globe (Figure 1), starting in cities such as Paris, London, and Copenhagen; more recently, many North American cities such as Washington DC, Philadelphia, Montreal, Denver, San Francisco, and Portland, and Asian cities such as Guangzhou, Hangzhou, and Seoul, are either developing plans for a bike-sharing program or have already initiated one (Chen, 2011). By August 2014, more than 600 cities worldwide had bike-sharing programs (Walker, 2014).

Bike Sharing Takes Off

Yearly growth of bike sharing services worldwide

Number of bike sharing services worldwide



Development of bike sharing services per continent

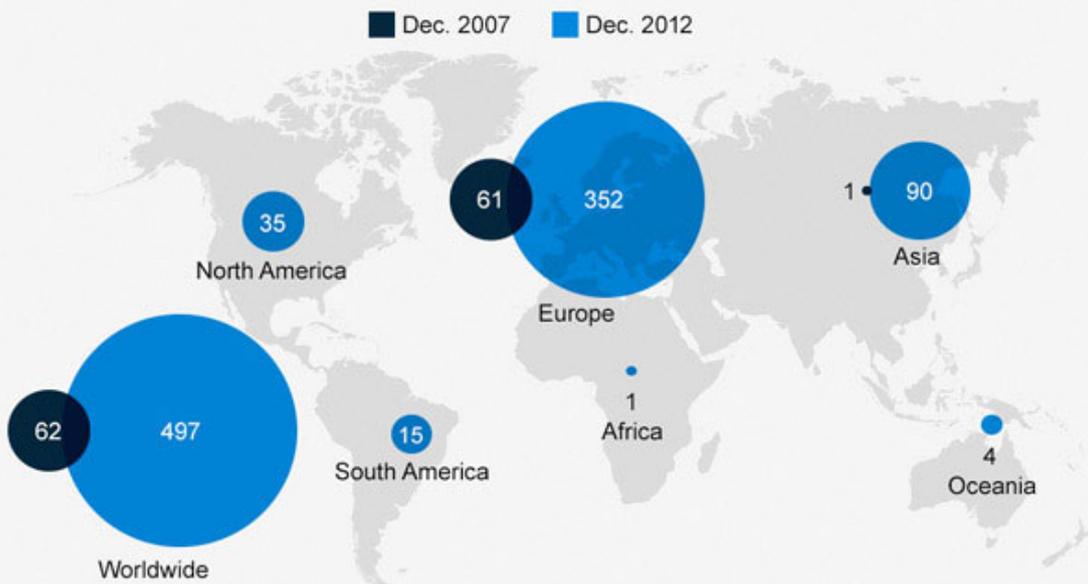


Figure 1. Development of Bike Sharing Program Worldwide

Bike sharing has become a popular method to fill in gaps in urban transportation networks. It has the potential to supplement existing public transportation networks. Short distance trips, representing either standalone or final connection trips that would otherwise be

taken on transit, can be shifted to bike share. The result is a relatively low cost, quickly implemented alternative transportation system that promotes active lifestyles and environmental stewardship.

Table 1. Trip Type Replaced by Bike Share in Barcelona, Montreal, Paris, and Lyon

Type of Trip Replaced	Bicing Barcelona	BIXI Montreal	Vélib' Paris	Vélo'v Lyon
Bus or Metro	51%	33%	65%	50%
Car or motorcycle	10%	2%	8%	7%
Taxi		8%	5%	
Walk	26%	25%	20%	37%
Bicycle	6%	28%		4%
New Trip		4%		2%

Sources: Buis, J. , 2008; Curran, A, 2008; Bachand-Marleau, J. , 2010.

Bike sharing is ideal for short distance trips, allowing users to pick up a bicycle at the nearest bike-station and return it to any station within the system area. Bike sharing users benefit from the freedom of not having the responsibilities and costs of owning the bike. Claimed to be the first city bike share system in Indonesia, bike sharing system in Bandung City plays an important role as a feeder for other transportation modes and is promoted as sustainable public transportation. The program started in June 2012 with very simple system and is funded by local residents. Based on bike rent user survey in the same year, about 47.42% of bike users are aged between 17 to 25 years old.

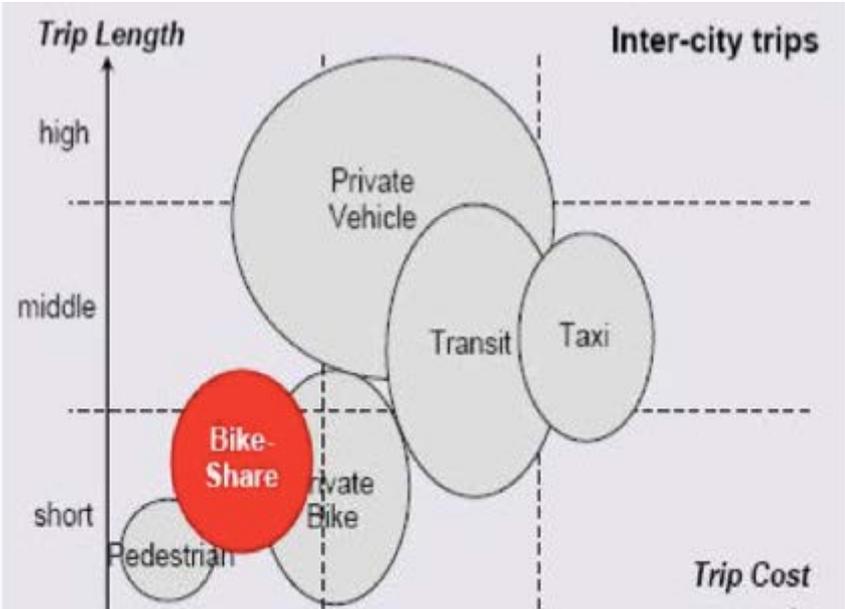


Figure 2. Trip Cost vs Trip Length

Source: Quay Communications Inc. 2008. Trans Link Public Bike System Feasibility Study. Vancouver.

Development of bike-share system should consider local available resources and must adapt to the city's topography, density, weather and culture. Research on bike share system in Bandung is being conducted. The study includes the formulation of mechanical and electrical system, the design of the bikes and the determination of the station location along with the formulation of the wayfinding and signage.

This paper specifically assessed the location of bike-share stations within the area of Bandung City. This paper explores a GIS model which best determines the optimal locations to place bike-sharing stations, as well as stated-preference analysis in order to provide more comprehensive chosen location from the perspective users.

2. METHODOLOGY

2.1 GIS-Based Analysis

The GIS analysis geospatially enabled decision making of bike-share stations. This analysis was not only used to synthesize geospatial data input but also to manage and conduct geospatial analysis (e.g., connectivity, containment, and contiguity) that results in map visualization. Suitability analysis is a GIS-based tool used to rank potential sites and determine the best place according to suitability for a proposed type of activity, in this case: bike-share stations. This analysis is based on a tool devised by renowned landscape architecture and urban planning professor of University of Pennsylvania Ian McHarg.

When performing suitability analysis, a set of criteria are selected and organized to rate sites relative to one or more characteristics. All data must be in vector or raster data. GIS shape files including city land use, public transportation network lines, traffic volume data, transport infrastructures (e.g. street, bike line, etc), attraction data (residential area, offices, and universities), population density, and public park area are prepared. All these data are combined and overlaid on one another (in form of GIS layer) to help visualizing the analysis. Overlay map of different GIS layers are called opportunities which then are weighted properly. The constraints in placement of bike-share stations are such as traffic collision data, road speed limit, accessibility to public transport, and topography elevation.

In this study, we used several GIS data such as public transport connectivity, transportation network nodes, land use, and regional activity (city center, sub city center, e. All data also store attribute information that complemented the analysis. GIS buffers were drawn around each potential location to determine accessibility and connectivity between the stations, using the assumption of average walking distance of people in Bandung city is between 300 – 500 meters. Then, we combined all these GIS shape files of these spatial attributes and overlay them to create a suitability map identifying the best places to place bike-sharing stations.

2.2 Stated-Preference Analysis

Stated-preference analysis accounts for Bike sharing demand analysis. It is a social experimentation which can be used in analyzing quantitative impacts of “hypothetical” policy measures. This study employed a stated preference survey to investigate demographic profile of potential users (such as age, gender, home town, how many years that respondent has lived

in there, respondent' income, respondent' travel expenses, respondent' transport, and how many vehicle do respondent has), and then we analyzed respondent' travel behavior based on the usage frequency of private vehicle and public transportation.

Currently, bike sharing system in Bandung has existed, but it is very limited in term of location and bike availability. Thus, further demand analysis was carried out to investigate poor performance of the current program. In addition, all respondents were informed about new system and asked whether they want to use it or not. The survey also explored the range of optimal price that respondent will be willingly to pay if they use the new bike sharing system. The last part of the survey was about potential location of bike sharing stations. Participants were presented a list of potential locations of bike sharing stations and were asked which potential locations that would be a good location for housing a bike sharing station.

A primary target of this survey is citizen of Bandung City. To complement demand analysis, tourists also participated in the survey as potential users for leisurely rides around the city using bike sharing system. Notice that this system is planned to connect places within 30 minutes distance.

The survey will be held both offline and online. Offline survey will take place on planned station's location. These methods are used in order to spread the information of new bike-sharing system faster and to get quick result. The survey is expected to provide a big picture on how the system should be built based on evaluation of the current system and people' interest to the new system. The optimum price and good location of the stations can also be determined.

3. RESULTS

Bike sharing program was officially launched in June 2012 with support from Bandung municipality, Bandung Transport Agency, local communities such as bike.bdg and BCCF, Bandung Park and Cemeteries Division, as well as private sectors. The idea to develop bike-sharing program is supported by the Government rule (Peraturan Daerah) No. 16 Year 2012 about transportation and retribution. Under that rule, it says that the government of Bandung City is able to build bicycle facilities such as bike's shelter.

Development of bike sharing program was started with 5 initiatives: (i) bike2work, (ii) bike2school, (iii) bike2lunch, (iv) bikesharing, (v) biking day. Through bike2work program, the city government commanded all of their staff to use a bike for work. As a result, bike sharing program becomes more popular and is well accepted by the citizen of Bandung City. They started establishing local bike communities in Bandung, such as bike2work, bike2campus, cyclechic, bike2school, and also Bandung Bikeshare which is an original idea of the current bike-rent facility in Bandung.

Supporting development of the idea, there is main element that should be determined, the location of bike stations. The location will determine whether the program works or not because of its direct relation to bike user demands. Every region/city has its own physical, structural, social, economic, and cultural characteristics. The placement of the stations must adapt to the city's characteristics. Therefore, there will be different empirical approach to determine the location of the stations, with no particular standard that can be applied to choose the location of the stations.

Still, there are some criteria that should be considered to determine the location of bike sharing stations in Bandung. These criteria (see Table 2) refer to ITDP – Institute for

Transportation and Development Policy.

Table 2. Criteria of Location Areas For Bandung Bike-sharing

LOCATION CRITERIA	DESCRIPTION
Distance (Radius)	400 – 500 meter (adapted from average walking distance in Bandung)
Integrated mode	Trans Metro Bandung, public transportation's shelter, terminal dan stations
Location	<ul style="list-style-type: none"> - On-street parking - The area inside a city park or near public area - Dead space, such as under bridge area - Commercial area such as shopping centre, minimarket area, and hotel area - Private property or residential area
Land use	Residential area, school, office, commercial Effecting by land's function and land use that are written on RTRW Kota Bandung

Based on criteria mentioned in Table 2, desk study analysis should be conducted. This particular study used literature reference and field observation to determine potential locations of bike sharing stations. In general, there are four areas that will cover development of Bandung Bike-sharing (shown in Figure 3): Cibeunying-Bojonegara, Tegalega, Karees, and Gedebage-Ujungberung.

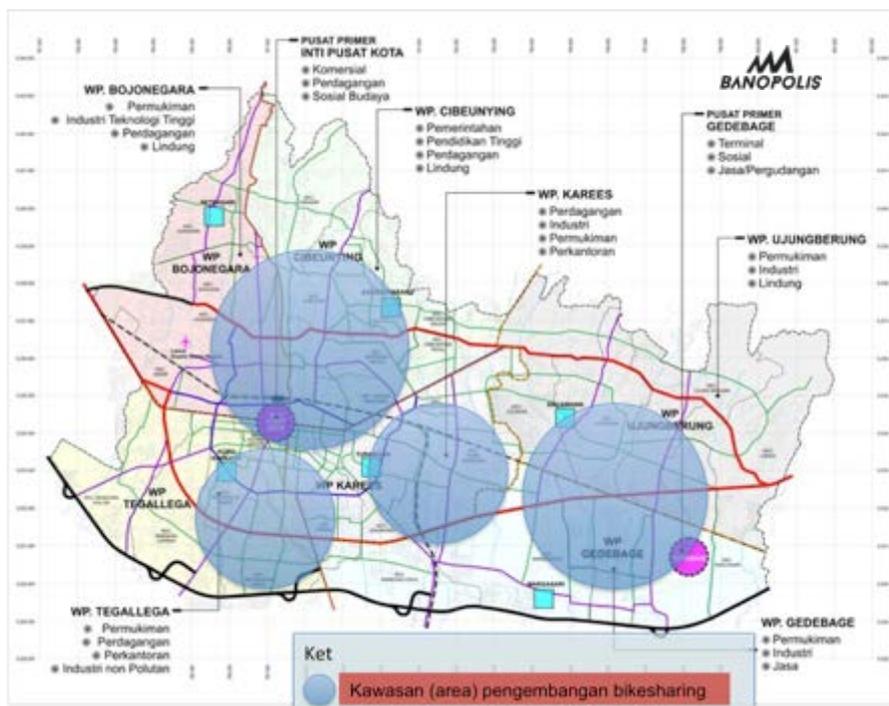


Figure 3. Potential Area for Developing Bandung Bike-sharing (colored and circled in blue)

3.1 Development Phase of Bandung Bike-sharing

Development of Bandung Bike-sharing cannot be done simultaneously in all potential areas. The development should also consider availability of local resources. Thus, development of this program was divided into three (3) development phases in 15 years of development period.

3.1.1 Phase 1 of Bandung Bike-sharing

Focus area of Phase 1 is primary area in Bandung, such as Alun-alun Kota Bandung, Bojonegara, and Cibeunying. These 3 areas were selected because of their land uses for governmental area, office area, school/education, commercial area, trading area, socio-cultural area, university area, and residential area. Phase 1 is planned to be completed in 2 years, in which during that period it is expected to build 100 bike stations with gap distance of 500 meter to 1 kilometer between each station. Sixty (60) stations are scheduled to be completed in the first year and the remaining 40 stations will be finished in the following year. Figure 4 showed 100 locations of Bandung bike sharing stations, which will be completed in phase 1.

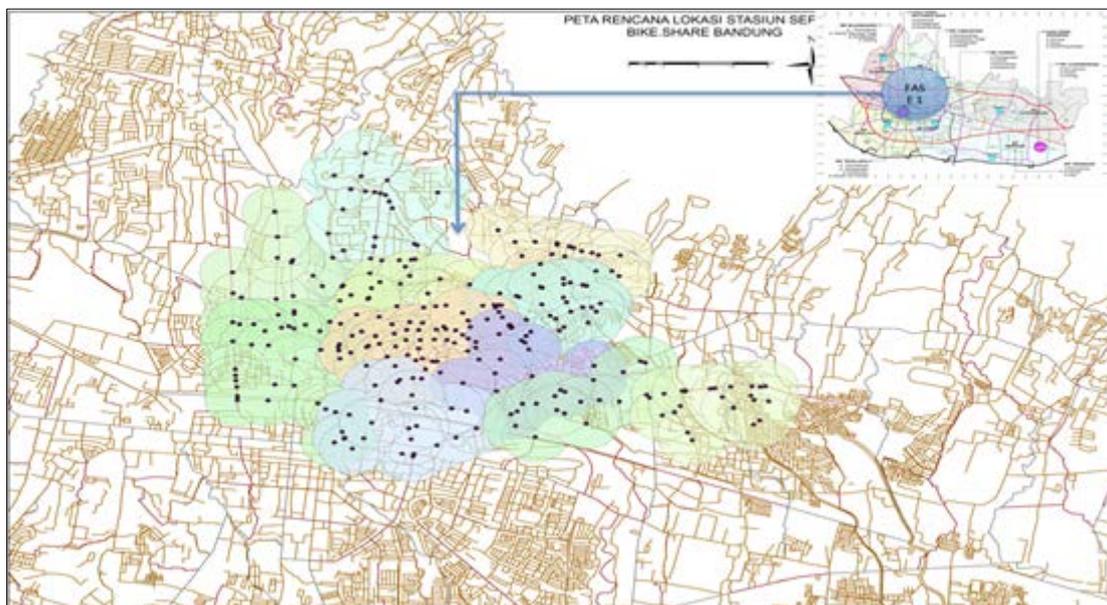


Figure 4. The 1st Phase of Bandung Bike-Share Development
Source: Researched by Banopolis

3.1.2 Phase 2 of Bandung Bike-sharing

Phase 2 is extending development of Bike-sharing stations in Phase 1 to the other area: Tegalega and Karees (showed in Figure 5). These two areas covered residential area, trading area, office area, and industrial area. Phase 2 will start once Phase 1 is completed, or it can also start at certain time as agreed. In this phase, about 30 – 40 bike stations will be built.

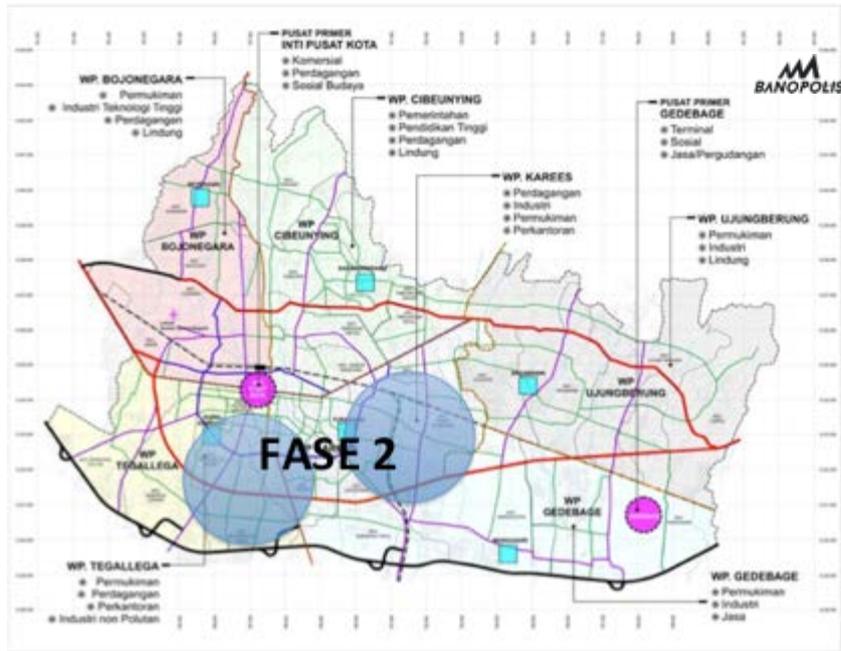


Figure 5. Phase 2 of Bandung Bike-sharing Development

3.1.3 Phase 3 of Bandung Bike-sharing

Phase 3 is the final phase of Bandung Bike-sharing development. Phase 3 will focus on second primary area in Bandung, Gede Bage and Ujung Berung (showed in Figure 6). In these areas, there are terminal, trade center, industry, service center, residential area, commercial area, and Bandung's sport center (planned). This phase will follow the development of second primary area in Bandung, Gede Bage, by the government of Bandung City. Number of stations that will be built in this phase is 50 stations.

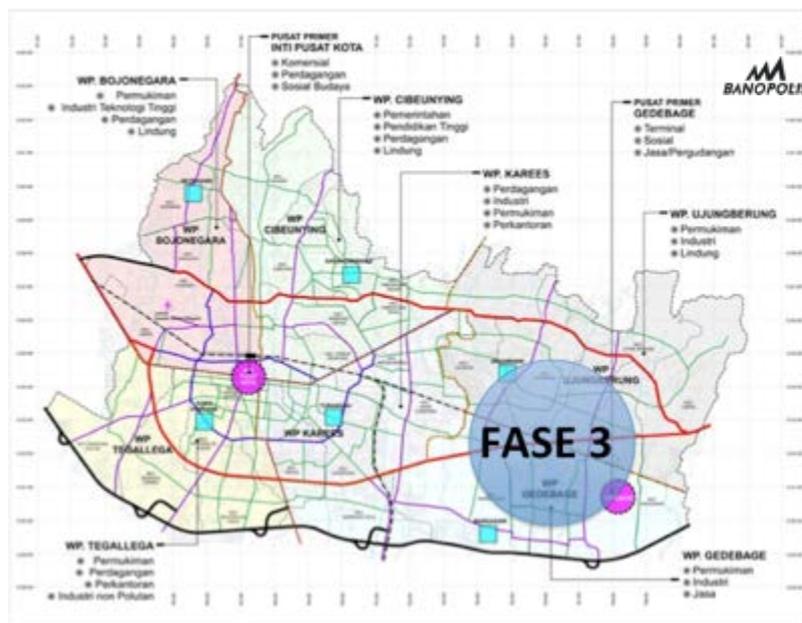


Figure 6. Phase 3 of Bandung Bike-sharing Development

3.2 Role of Bandung City's Land Use

Characteristics of city's land use and facilities surrounding the bike sharing stations play an important role in determining the required capacity as well affecting the flows of bike sharing usage. Designed for point-to-point local trips, bike sharing becomes a convenient way to transport in office area and educational area. As shown in Figure 7, most offices in Bandung City (colored in green) are centralized in Cibeuuying and North Karees. Thus, it makes sense to introduce bike sharing stations in this area to support bike2work program. Potential locations of bike sharing stations in this area are colored in blue. In addition, placement of bike sharing stations surrounding educational centers in Bandung is expected to enhance the government program of bike2school. Location map of educational centers in the city is showed in Figure 8 and colored in green.

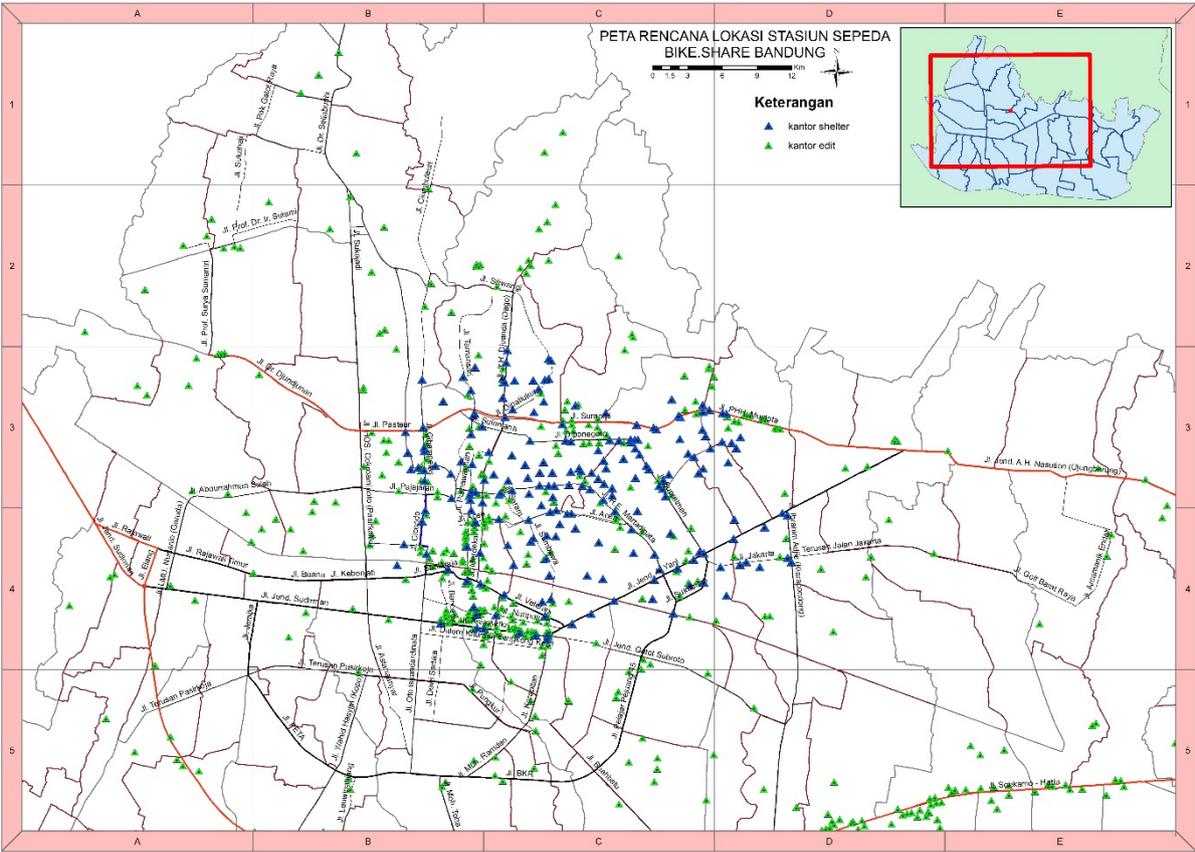


Figure 7. Office Location Map in Bandung City

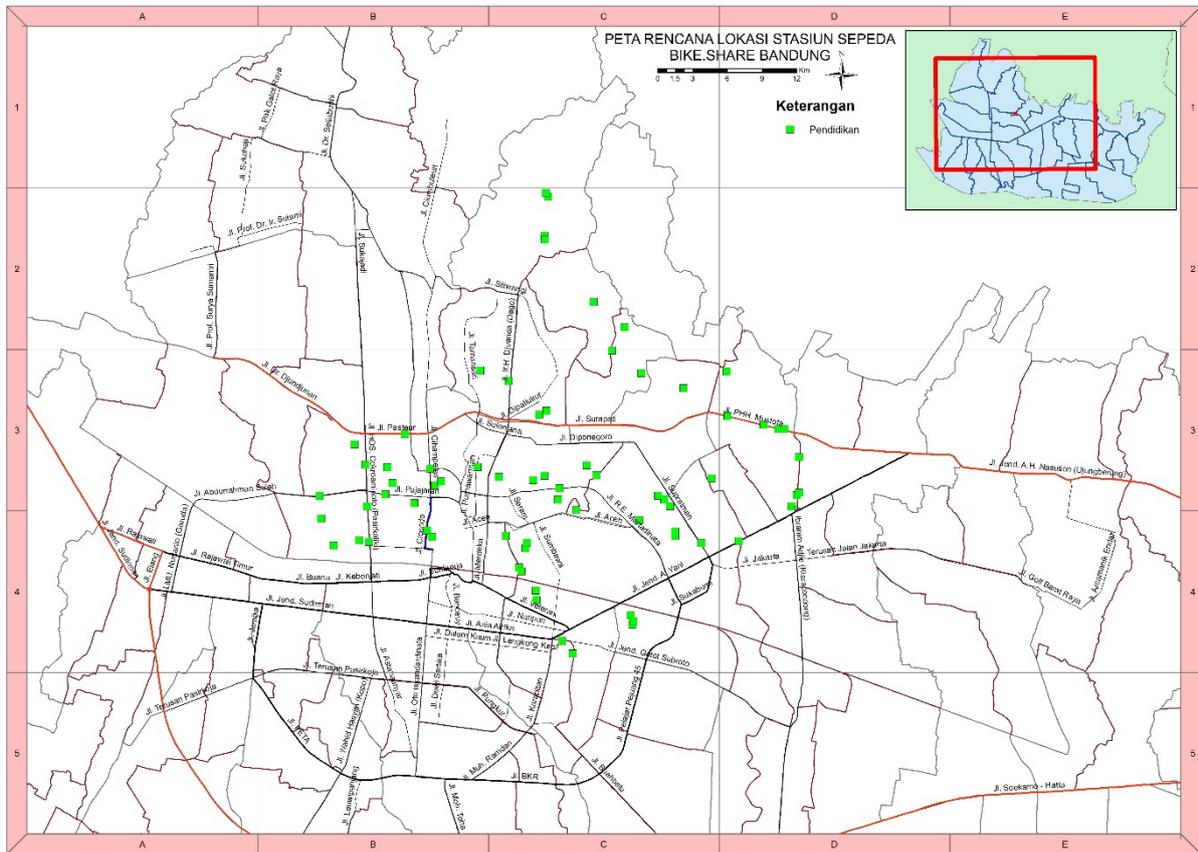


Figure 8. Educational Center Location Map in Bandung City

Bandung has the advantages of friendly weather for bicycling and relatively flat terrain. Thus, bike sharing program will also be made available for leisurely rides. There are 2 routes that will be geared for leisurely rides from North to South of Bandung City, spreading throughout Cibeuuying and North Karees (see Figure 9). The first route (colored in blue) covers Dago area and Jl. Diponegoro in Cibeuuying. The second route (colored in red) covers both area of Cibeuuying and Karees, starting from Jl. Diponegoro in Cibeuuying and ends in Jl. Dalem Kaum in Karees. Both routes intersect in Jl. Diponegoro, where Gedung Sate is located. Gedung Sate is a symbol of Bandung City and currently serves as the Governor's office of the West Java Province.

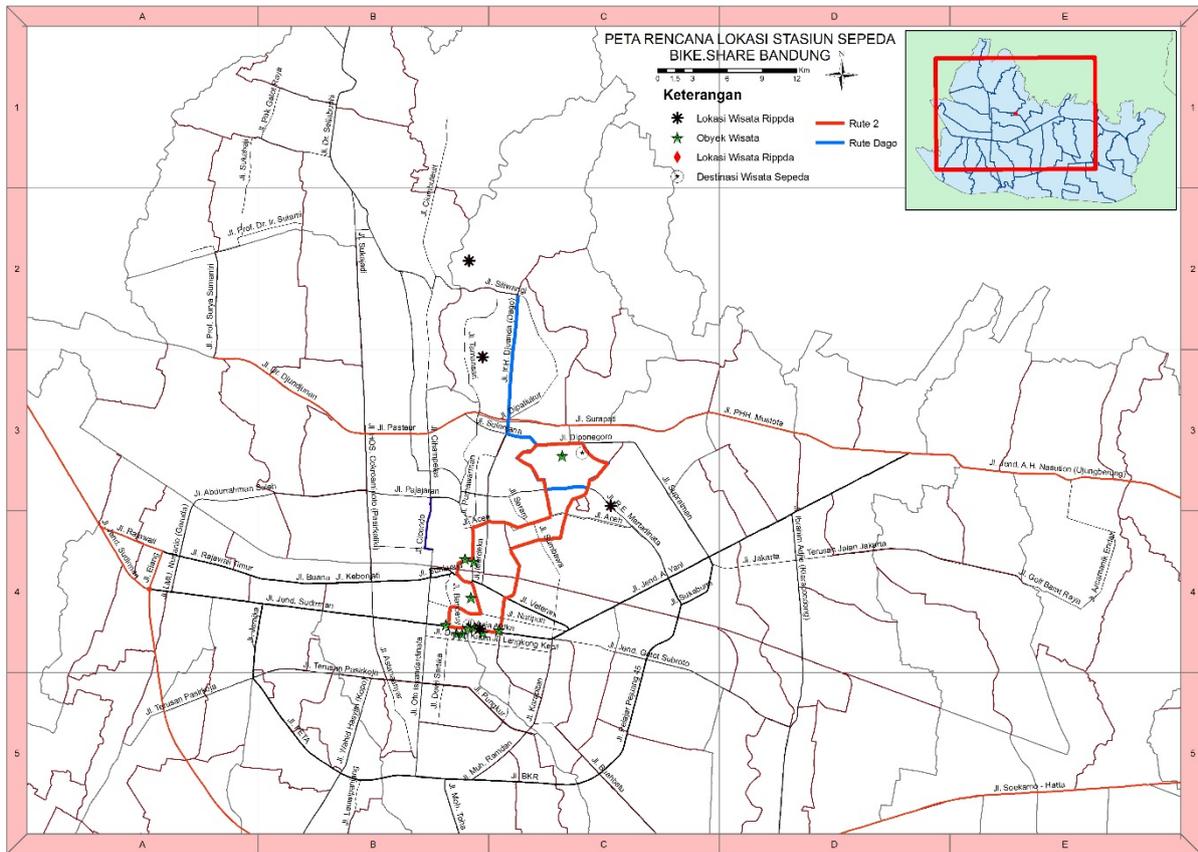


Figure 9. Bike Sharing Lines for Leisurely Rides in Bandung City

Since 2013, the current mayor of Bandung City – Mr. Ridwan Kamil, has initiated the development of cable car to solve congestion problem in the City. As of today, the location of 11 cable car stations has been determined. Placement and provision of bike sharing stations should take the idea of bike-mass transit integration into its development plan, which bike sharing will act as feeder for mass transportation. Integration of bike sharing with mass transit such as cable car will enhance the benefits of both modes to the public. It also will encourage people to bike more and use public transport. Since only 11 cable car stations are planned to be built and are centralized in primary area of Bandung City, bike sharing is expected to support the function of mass transit feeder, which will satisfy user demands of cable car that are far beyond walking distance to cable car stations. It is also expected that bike sharing is able to be an alternative of mini-buses (read: angkot) in the city at much lower cost. The locations of cable car stations are showed in Figure 10.

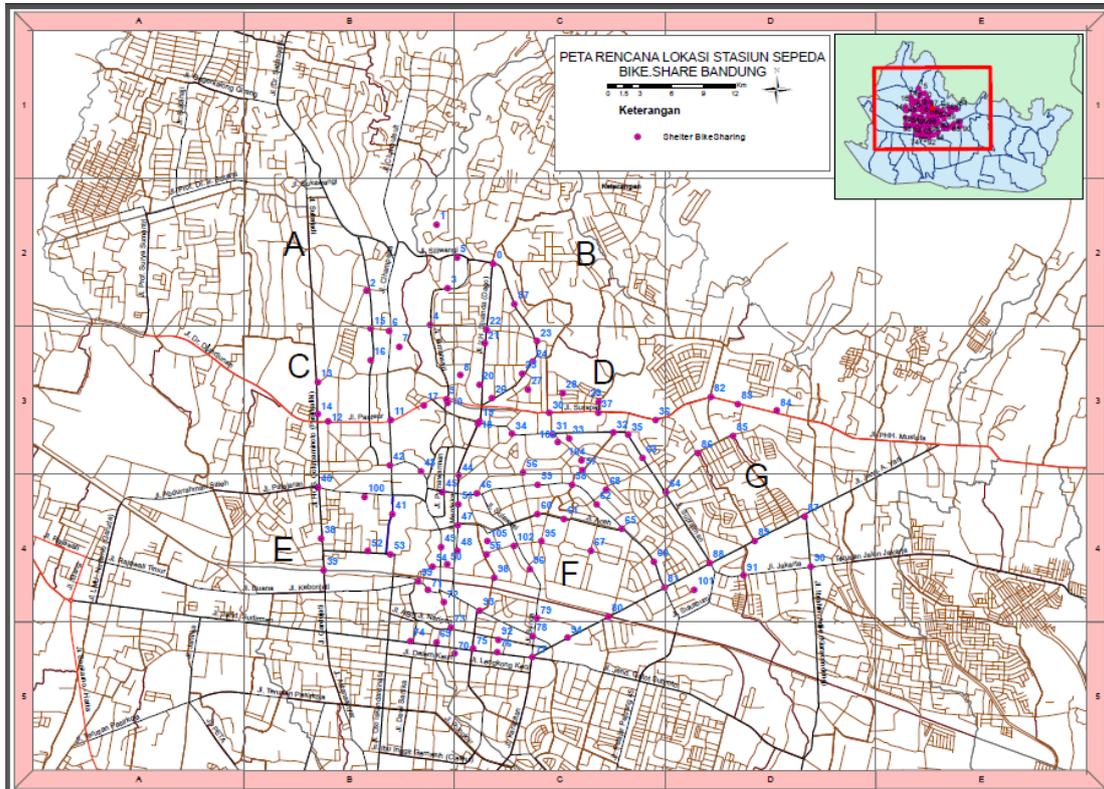


Figure 11. Bikelane and Bike Station Site Plan

A detailed list of potential locations of bike sharing stations is listed in Table 3. There are 106 locations of bike sharing stations which are centralized in primary area of Bandung City, Cibeuving and North Karees.

Table 3. List of Potential Locations of Bike Sharing Stations

NO	LOCATION	NO	LOCATION
0	Simpang Dago	53	kebun kawung
1	Ekowisata Dago Utara	54	perempatan bi - balaikota - ke braga
2	dekat samudra hotel	55	jalan sumatera
3	gerbang belakang itb	56	progo - jonas
4	taman sari, ITB samping	57	smu 20 / mesjid
5	Siliwangi	58	perempatan kfc riau
6	RS ADvent (cable car)	59	riau / gothe / tarbak
7	ciwalk (Cable car)	60	gor saparua
8	badak singa (stasiun cable car)	61	jln aceh
9	cikapayang (Stasiun Cable Car)	62	cihapit
10	Scikapayang (tasiun Cable Car)	63	supratman
11	cihampelas bawah (Stasiun Cable Car)	64	supratman
12	deket lampu merah paskal - sukajadi	65	taman pramuka dsktr
13	RS Hasan sadikin	66	riau
14	lampu merah paskal - sukajadi	67	perempatan jl tongkeng dan patrakomala
15	lampu merah cipaganti - deket advent	68	taman cibeuving

NO	LOCATION	NO	LOCATION
16	deket lampu merah cipaganti	69	alun-alun
17	taman jomblo / taman film	70	pendopo / alun alun
18	sekitar lampu merah dago deket dukomsel	71	ujung stasiun timur
19	sekitar lampu merah dago deket dukomsel	72	jembatan deket stasiun timur
20	lampu merah dago - bawah jembatan cikapayang	73	pertigaan braga pasar baru
21	deretan FO di Dago/boromeus	74	alun-alun deket dalem kaum
22	pertigaan mau ke DU	75	asia afrika (deket bank btn)
23	DU - unpad - ujung teuku umar/teuku umar dskt	76	asia afrika
24	DU - unpad	77	simpang lima
25	DU - unpad	78	jalan sunda
26	hasanudin - deket rs boromeus	79	jalan sunda
27	monumen	80	gudang selatan
28	telkom	81	perempatan ujung riau - laswi /taman
29	jalan tikukur dsk (jln burung2an)	82	pahlawan
30	telkom / gasibu	83	itenas
31	gedung sate	84	pln / sma pribadi / ypkp
32	diponegoro	85	katamso
33	cisangkuy	86	katamso
34	diponegoro	87	pertigaan kircon dsktr
35	dekat mesjid pusdai	88	supratman ujung / disbudpar
36	surapti	89	ahmad yani / awi bitung
37	jalan burng2an - c59	90	perempatan jalan jakarta - terusan jakarta
38	paskal hypersquare dskt	91	ujung jalan jakarta
39	perempatan stasiun kereta api	92	naripan
40	istana plaza	93	sumatera - veteran - lengkong
41	cicendo - rs	94	kosambi
42	cihampelas - novotel	95	graha manggala siliwangi
43	wastu	96	graha manggala siliwangi dsktr
44	dago - taman flexi	97	DU
45	xl	98	Jln jawa
46	riau junction	99	abc
47	perempatan aceh	100	gor padjadjaran
48	balai kota samping / sd	101	pemkot bandung
49	balai kota / mesjid	102	taman sentrum / smu 3 dan 5
50	balai kkota / BI	103	taman lansia
51	BIP	104	taman
52	kebun kawung	105	taman lalu lintas

Unfortunately, due to the time constraint, the stated preference survey was only conducted as a pilot survey to finalize the questionnaire form. The stated-preference survey is described on pictures below and the online form can be accessed in <https://docs.google.com/forms/d/1tT7KsNkohW2A7WBVBfqc5UNpj31DHb6KKCK6E69gq2Q/viewform>.



Figure 12. Stated Preference Survey

4. CONCLUSION

The study results showed that there are 105 potential locations of bike sharing stations in Bandung City. Most potential locations of the stations are centralized in primary area of Bandung City: Cibeunying and North Karees. In addition, we expected that the results from stated preference survey are able to provide a big picture on how the bike sharing system in Bandung City should be built based on performance evaluation of the current bike sharing system and people' interest to the new system.

It is time to consider bike sharing system as a long-term investment for urban transportation, not only as an alternative cheaper transportation mode. Thus, it is very important to strategically assess the locations of bike sharing stations to ensure that the program remains viable for the long term. To successfully capture bike sharing demands and expand the service area, future study should look into potential number of users that will choose to switch modes to use bike sharing for their short distance trips, reflecting the attractiveness of the shared modes in the city.

5. ACKNOWLEDGEMENTS

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