Built environment and parking pricing: Probability on changing mode choice in Bandung urban area

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Abstract. Bandung as an urban area in the centre of Metropolitan Bandung Raya and the centre of various activities generate high movement of trips, especially the movement from commuters. The more trips use motorized vehicles, the more people need parking lots. In consequences, the massive movement using private vehicle and the use of on-street parking causes congestion in Bandung Urban Area because of the increasing of road capacity. Previous research proved that one factor to reduce private vehicle user mode choice behaviour is by having a strong strategy in parking. Hence the parking pricing is one of the most effective parking strategies in influencing driver behaviour. The binary logit regression model is used to identify the behaviours of private vehicle users and to investigate the probability of private vehicle drivers shifting to mass transportation particularly for commuter’s trip. This paper surveyed 200 commuters through revealed and stated preference in Bandung Centre Area. The best model is the model with the highest significance number shown from the Negelkerke R square number. The response keeps using private vehicle and parking in the existing area has the highest significance number which is 0.59. The model from the response is Ln P/1-P = 4.356 -1.550 (X1.1) - 1.279 (X1.2) – 0.01 (X2). The variables in this model are a medium compact area (X1.1), a compact area (X1.2) and parking pricing strategy (X.2). The result can assist decision-makers on all levels to wisely allocate resources to public transportation improvement, and optimization of parking pricing strategy, especially in Bandung Urban Area.

1. Introduction
The metropolitan growth has caused the high demand for commuting trips from surrounding areas to the city centre. The city centre is commonly well-known having clustered points of activities, which attract trips. In the centre and/or in the Central Business District Area, the level of car ownership constantly increases, and it stimulates cities to introduce the first form of parking regulation and control (Mingardo, 2013). It is shown that the area with the highest density population will need the parking strategy more effectively. Failed implementation nor the absence of parking strategy will cause problems, such as increased traffic congestion. Parking strategy has a strong relation to regulating demand to maintain car use and traffic under control (Mingardo, 2013). One of the strategies considered ineffective is dedicated or providing parking lot based on demand because it stimulates the use of private vehicles. Three factors that contribute to effective implementation of parking strategies are (Shoup, 2011): first, putting the proper charge for parking; second, using the gained money from parking for the public services; and third, changing the standard for minimum parking requirement. Then, parking pricing is one of the recommended strategies by parking experts.
In fact, some cities have implemented parking pricing such as Beijing, Los Angeles, and San Francisco. The studies on those cities show that the increase of parking pricing significantly decreases the use of private vehicles. In Beijing (Lu et al., 2011), the nested analysis result shows that pricing policies affect demand implementation. Another case of parking pricing strategy effectiveness is in Los Angeles, where the data showed that there are 20% of solo drivers to work decreased after the offering of cash out employer-paid parking subsidies. After increasing by 10% of parking pricing, the number of private vehicle users is decreasing by 0.6% (Franco, 2017). Then, the study in San Francisco also shows that a 10% increase in parking pricing indicates the decrease of driving alone to work by 0.6%. Those studies show that parking pricing strategy is effective to lower the parking demand, especially in such congested cities.

Bandung city is the second most congested city in Indonesia (Kompas, 2018). Bandung City is the core of the Metropolitan Bandung Raya area. The traffic congestion in Bandung is a serious transportation and urban management problem. It can be seen from the amount of loss caused by congestion every year which reaches 2.46 trillion (Saviena, 2007). Also, the number of vehicles in Bandung city reaches 1.738,665 consisting of public and private vehicles (BPS, 2019). The relation between the number of vehicles and traffic cost is reflected by the needs of fuel which is Rp 1.8 trillion/day (Indriyati 2018). The roads in Bandung city in 2018 are 1,172.78 km or it only increases by 0.87% each year (BPS, 2019). Bandung city has been densely developed; therefore, road expansion is not a priority option to overcome its congestion problem. Meanwhile, the on-street parking in Bandung area is increasing in number but is not well-managed by parking strategy. On-street parking problem in Bandung that worsens congestion problems is the illegal parking that has grown massively, the ineffective ERP for on-street parking in core area, on-street parking service level in some streets that exceeds the minimum significance level of service roads, and on-street parking pricing that is cheaper than off-street parking pricing (UPT Parkir, 2019).

Commuters from metropolitan area add the high demand for vehicle trips and parking in Bandung Core area. The commuters travel from the origin (mostly house) to the destination, namely travel from suburban to urban. They mostly use private vehicles because reliable public transportation is absent (Jayusman, 2011). According to Triani (2019), the movement from 2,50 million people consists of 1,111 million people working while 237,26 thousand people going to school in 2018. The data has shown that around 53.7% of Bandung citizens mobilize on weekdays both to work and school. Meanwhile, 72% of commuters mobilize by motorcycle and only 12% mobilize by public transportation. Thus, the movement of commuters is a crucial factor to consider.

The high number of private vehicles that move and park around Bandung City centre worsens the lack of effective road capacity. Since the city centre has a relatively compact built environment, it has the potential to implement specific parking policy. For example, parking prohibition in the high-density area will be more effective for sustainable transportation because the provision of excess parking will increase the level of private vehicle dependency (Yin, Chaoying et al., 2018). To illustrate this, the use of public transportation in Toronto is only 29% because of the implementation of free parking. Hence, that was the implementation of parking pricing that increase the number of public transportation user number (Toronto Community Foundation, 2015).

Those research examples show that parking pricing strategy will improve the transportation mode choice in a compact area. In other words, the relation between parking pricing strategy and built environment is quite significant. However, in the Bandung area, the research about the relation of possible result parking strategy and their implementation in a different area, such as suburban and urban area needs to be done. Consequently, the research question in this article is formulated: ‘how is the relation between parking pricing to a possible decrease of the private vehicle using in each compact area classification?’ This research aims to identify the relation between parking pricing strategy and changes of commuter’s travel behaviour in Bandung Urban Area. Meanwhile, changes in travel behaviour responses will be determined by the literature review related to parking pricing strategy.

2. Literature Review
Parking is a meeting point between the transportation system and land use. The demand for parking is generated by the movement system in the transportation system, while the land-use system provides parking supply. Each classification of land use activities generates a different number of attractions that requires the supply of parking. In parking activity, private vehicles users require two parking places which are in the beginning and at the end of the movement (Maternini and Ferrari, 2017). Parking problem issue solving can be done with two approaches which are demand and supply study. Handling the parking problem issue needs to examine the land-use and the urban planning document in the area (Alamsyah, 2005).

On-street parking has limited capacity but it has an important role in the CBD area. Some areas are built with on-street parking design. Despite the demand for on-street parking in the city centre is only 5-10% (Kuzmiyak, 2003), parking pricing strategy has a potential impact on the trip generation and mode choice within transport demand increasing problem (Å and Clinch, 2006). Parking pricing needs levying of a surcharge or tax for a private and personal vehicle that differ by location and time every day (Omari, 2018). Parking pricing in the city scale is one of Transport Demand Management’s strategy.

The previous study in the US showed that the increase of parking pricing of 10% generated the reduction of vehicular traffic volume for commuter by 10-30% (Maternini dan Ferrari, 2017). Based on www.vtpi.org, parking pricing strategy implementation should be placed in:

- Land values and parking pricing facility cost
- Parking supply is insufficient to meet demand
- Traffic congestion problem and pollution is the main problem
- Clustered and compact land-use

The study carried out in Portland (Oregon) CBD showed that free parking in that area caused 62% of users to switch to private vehicles, 16% keep using the carpool, and 22% keep using public transportation (Hess, 2001). The result supports the statements by Shoup (2005) that free parking is expensive. Another example of parking pricing in the previous study stated that parking supply and parking pricing has direct and indirect impacts to generate a compact and healthy community. The study examined that parking pricing has 10-30% of potential impact to decrease traffic congestion. (Pacific Intermountain Parking and Transportation Association, 2015). That means parking pricing has 10-30% potential impact to travel behaviour changes.

Parking pricing strategy in city centre affects commuter’s travel behaviour. For example, a study showed that parking pricing increase was able to decrease commuter’s travel movement during peak hours (Frank et al., 2011). Experiments in the US showed that an increase in parking pricing of 10% generated the reduction of private vehicle users by 1-3% and the implementation of free parking increase 35% the using of private vehicle by commuters (Maternini and Ferrari, 2017). To conclude, parking pricing strategy has a significant impact on commuter’s travel behaviour.

3. Methodology

Methodology in this article follows these sequence steps. First, the sample of areas was chosen based on their calculation of built environment variables. The built environment variables adapt to the 5D analysis introduced by Ewing and Cervero (2010). The 5Ds indicators used in this article are:

- Density: the indicator for density’s analysis is using the number of populations in each urban village in Bandung Urban Area. Then, the number of each urban village population is classified into 5 levels by the natural break tool in ArcGIS.
- Diversity: the indicator of diversity’s analysis is using the number of various land-use in each urban village in Bandung Urban Area. The more diverse the land-use, the more compact the urban village. Then, after we got the exact number of each urban village, the number is classified into 5 levels by the natural break tool in ArcGIS.
- Design: the indicator of design’s analysis is the number of street intersections in each urban village. Then, the number of each street intersection is classified into 5 levels by the natural break in ArcGIS.
Destination Accessibility: the indicator for destination accessibility’s analysis is using the classification of urban village city structure based on planning document in Bandung city. The data is classified into 3 levels by the natural break tool in ArcGIS.

Distance to Transit: the indicator for distance to transit’s analysis is using the number of public transportations serving each urban village in radius 500 m from the street. Then, the data is classified into 5 levels by using the natural break tool in ArcGIS.

Each indicator is calculated using quantitative analysis and has got the weight. After each of urban village has its total calculation, each urban village will be classified into 3 compact classifications which are compact, medium compact and not compact. The resulting map of 5D’s analysis can be seen in Figure 1.

The second step is choosing the study area based on SWK in Bandung city. SWK is parts of an urban area in one city that functions to support the core area. There are 8 SWKs in Bandung, and this study selects 2 SWKs by the most potential area for parking pricing namely Cibeunying and Tegalega which are part of Alun-alun (city centre) area. The selection of 2 SWKs is based on the following matters:

- SWK that has parking pricing plan strategy based on Bandung spatial planning document (RDTR) 2015-2035. SWK with the highest number on-street parking in Bandung city which has 96 streets in SWK Cibeunying and 17 street in SWK Tegalega.

In theory, every centre of the area will serve a circular area with a radius of 3.5 km (one hour walk). Thus, the centre of the area will be in those areas. This theory called central place theory (Kajian Penyusunan Indikator Tipologi dan Indikator Kinerja Pengembangan Kawasan Strategis Nasional Bidang Ekonomi, 2008). The radius for the study area in this study can be seen in Figure 1.

Third, determining the number of the sample using Lemeshow method. This method is used because of the unknown number of populations in this study. The formulation for Lemeshow methods is below (Lemeshow et al., 1990):

\[ n = z^2 \frac{p(1-p)}{d^2} \]  

- \( n\) = total sample
- \( z\) = Z score 5% of confidence level = 1.96
- \( p\) = maximum estimation (0.5)
- **d** = sampling error (7%) From the calculation above, it is determined that the sample for this study is 196 samples which are distributed into several classifications. The classification of the sample distribution is based on the 5D’s result and congestion classification. There will be three different built environment classifications that refer to six urban villages.

**Figure 2.** Sample Distribution for Medium Compact Classification. (Source: Analysis Result, 2020).

**Figure 3.** Sample Distribution for Medium Compact Classification. (Source: Analysis Result, 2020).
Figure 4. Sample Distribution for Compact Congested Classification. (Source: Analysis Result, 2020).

Figure 5. Sample Distribution for Not Compact. (Source: Analysis Result, 2020).
Fourth, we use binary step analysis. The questionnaires are distributed to 196 samples using stated preferences as study approach. There will be four models of this study based on the most responses
emerged from the sample. The binary logit regression model is employed to explore the relations between the willingness of the sample to change travel behaviour because of parking pricing strategy, travel behavior responses and built environment classification. Binary logit models are widely used to provide mode choices for travel behaviour Franco(2017). According to (Franco, 2017), these models used to determine LA employee’s mode choice to work. The travel behaviour of that research is the employee chooses to drive a private vehicle and parks in the nearest area or they don’t use a private vehicle at all. In this study, the explained variable is set to be one when they choose the private vehicle. Otherwise, it is set as zero.

In this study, a binary logit regression model will be employed to determine the sample’s travel behaviour choices, whether to use private vehicles or to switch mode. According to explanatory variables, binary logit models are usually used to forecast the probability of some binary explained variables. It means that the dependent variable is dichotomic (1,0) (Hensher et al., 2014). Where the binary data used is usually the opposite data. According to the study of Abdulsalam et al. (2013), binary logit models are used to identify travel behaviour of private vehicle user and public vehicle user intercity and to investigate the public transportation’s time travel subtraction response. In binary logit formulation method, interval confidence must at least be conceptually centred on 1, not 0 (Hensher et al. 2014).

4. Findings

According to the the literature review that the researcher had done, there are 9 responses classified as travel behaviour changes from the sample of the movement from the sub-urban to Bandung city centre because of parking pricing strategy. The 9 responses are tested to 196 samples. Then, four responses are selected as the most chosen by samples as travel behaviour changes because of parking pricing strategy. The following are the responses for travel behaviour changes.

- Keep Using Private Vehicle and parking in the existing area
- Switch to Public Transportation
- Switch to Online Transportation
- Change Parking Area

| Responses | N   | Binary Choice                      |
|-----------|-----|------------------------------------|
|           |     | 0                                  | 1                                  |
| Y1        | 36  | if the samples use private vehicles and parking in the existing area | If the samples don’t keep using private vehicle and parking in the existing area |
| Y2        | 54  | If the samples don’t switch to public transportation | If the samples switch to public transportation |
| Y3        | 45  | If the samples don’t switch to online vehicle | If the sample switch to online vehicle |
| Y4        | 59  | If the samples don’t change parking area | If the samples change parking area |

The binary choice model’s results are:

4.1. Keep Using Private Vehicle and Parking in the Existing Area (Y1)

This section will explain the relation between parking pricing strategy implementation, built environment classification, and commuter’s travel behaviour changes. Then, the response is interpreted to keep using the private vehicle (1) and not using the private vehicle (0). The model that will be determined is the commuter’s travel behaviour changes (y). The area classifications (X1) and parking pricing strategy (X2) are the independent variables. In this model, there will be seen whether there is a relation between the sample in different each built environment classification with parking pricing strategy and commuter’s travel behaviour changes. For this response, the Negelkerke R square score is
0.485, it means the model determined can explain 48% data in this study. The following is the significance test result from binary logit analysis:

Table 2. Significance Test Keep Using Private Vehicle Response (Source: Analysis Result, 2020).

| Variables                  | Coefficient | Sig  | Exp (B) |
|----------------------------|-------------|------|---------|
| Medium Compact Area (X1.1) | -1.550      | .000 | .212    |
| Compact Area (X1.2)        | -1.279      | .000 | .278    |
| Parking Pricing Strategy (X2) | -.001      | .000 | .999    |
| Constant                  | 4.356       | .000 | 77.969  |

The criterion for this significance test is the variable that has a significance score below 50% or below 0.05. It means the variable that qualifies in this model are X1.1 (medium compact), X1.2 (compact), X2 (parking pricing strategy) Thus, the binary logit for this response is:

\[ \ln \frac{P}{1-P} = 4.356 - 1.550 (X1.1) - 1.279 (X1.2) - 0.01 (X2) \]  
(1)

From the model above it can be interpreted that the centre area with classification medium compact congested and compact has relation to travel changes because of parking pricing strategy implementation. Every change of parking pricing strategy will affect the use of a private vehicle. A medium compact area is the most sensitive to parking pricing strategy with the highest constant value which is 1,550. The negative means the negative relation between variables. If parking pricing strategy is implemented in this area, it will increase 4,356 - 1,550 (x1.2) the using of a non-private vehicle in a medium compact at Bandung centre area. Thus, the built environment affects the parking pricing strategy implementation and commuter’s travel behaviour changes.

4.2. Switch to Public Transportation (Y2)

This section will explain the relation between parking pricing strategy implementation, built environment classification, and commuter’s travel behaviour changes. Meanwhile, the response is interpreted switch to public transportation (1) and not switch to public transportation (0). The model that will be determined is the commuter’s travel behaviour changes (y). In this model, there will be seen whether there is a relation between the sample in different each built environment classification with parking pricing strategy and commuter’s travel behaviour changes. For this response, the Negelkerke R square score is 0.18; it means the determined model can explain 18% data in this study. The following is the significance test result from binary logit analysis:

Table 3. Significance Test Switch to Public Transportation Response. (Source: Analysis Result, 2020).

| Variables                  | Coefficient | Sig  | Exp (B) |
|----------------------------|-------------|------|---------|
| Medium Compact Area (X1.2) | .816        | .000 | 2.261   |
| Compact Area (X1.2)        | -.610       | .003 | .543    |
| Parking Pricing Strategy (X2) | .000      | .000 | 1.000   |
| Constant                  | -3.691      | .000 | .025    |

The criteria for this significance test is the variable that has a significance score below 50% or below 0.05. It means the variable that qualifies in this model are X1.1 (medium compact), X1.2 (compact), and X.2 (parking pricing strategy). Thus, the binary logit for this response is

\[ \ln \frac{P}{1-P} = -3.691 + 0.816 (X1.1) - 0.610 (X1.2) + 0.00 (X2) \]  
(2)

From the model above it can be interpreted that the centre area with classification medium compact and compact has relation to travel changes because of parking pricing strategy implementation. Every
change of parking pricing strategy will affect the use of private vehicles. The medium compact congested area has the highest constant value which is 0.816. That means parking pricing strategy implementation has affected the commuter’s travel behaviour changes. Every change of parking pricing strategy implementation will increase the number of public transportations use. In a compact area, the relation between parking pricing implementation and travel behaviour has a negative relation. The fact that there are free parking regulations in a compact area affects travel behaviour changes. Hence, the parking pricing implementation will not affect the use of public transportation in a compact area positively. Thus, the built environment has affected parking pricing strategy implementation and commuter’s travel behaviour changes.

4.3. Switch to Online Transportation

This section will explain the relation between parking pricing strategy implementation, built environment classification, and commuter’s travel behaviour changes. Meanwhile, the response is interpreted to switch to online transportation (1) and not switch to online transportation (0). The model that will be determined is the commuter’s travel behaviour changes (y). In this model, there will be seen whether there is a relation between the sample in different each built environment classification with parking pricing strategy and commuter’s travel behaviour changes. For this response, the Nagelkerke R square score is 0.213, it means the model determined can explain 21% data in this study. The following is the significance test result from binary logit analysis:

Table 4. Significance Test Switch to Online Transportation Response (Source: Analysis Result, 2020).

| Variables                        | Coefficient | Sig   | Exp (B) |
|----------------------------------|-------------|-------|---------|
| Medium Compact Area (X1.2)       | 1.410       | .000  | 4.098   |
| Compact Area (X1.2)              | -.630       | .029  | .532    |
| Parking Pricing Strategy (X.2)   | .000        | .000  | 1.000   |
| Constant                         | -4.533      | .011  | .011    |

The criterion for this significance test is the variable that has a significance score below 50% or below 0.05. It means the variable that qualifies in this model are medium compact area (X1.1), compact area (X1.2) and X2 (Parking Pricing Strategy). Thus, the binary logit for this response is:

\[
\ln \frac{P}{1-P} = -4.533 + 1.410 (X1.1) -0.630 (X1.2) + 0.00 (X.2)
\]  

From the model above it can be interpreted that the centre area with classification medium compact and compact has relation to travel changes because of parking pricing strategy implementation. Every change of parking pricing strategy will affect the use of private vehicles. The medium compact congested area has the highest constant value which is 1.410. That means parking pricing strategy implementation has affected the commuter’s travel behaviour changes. Every change of parking pricing strategy implementation will increase the number of online transportations use. In the compact area, the relation between parking pricing implementation and travel behaviour has a negative relation. The fact that there are free parking regulation in a compact area affects travel behaviour changes. Hence, the parking pricing implementation will not affect the use of online transportation in a compact area positively. Thus, the built environment has affected parking pricing strategy implementation and commuter’s travel behaviour changes.

4.4. Change Parking Area

This section will explain the relation between parking pricing strategy implementation, built environment classification, and commuter’s travel behaviour changes. Then, the response is interpreted to switch to change parking area (1) and not change parking area (0). The model that will be determined is the commuter’s travel behaviour changes (y). In this model, there will be seen whether there is a relation between the sample in different each built environment classification with parking pricing
strategy and commuter’s travel behaviour changes. For this response, the Negelkerke R square score is 0.215; it means the model determined can explain 21% data in this study. The following is the significance test result from binary logit analysis:

**Table 5. Significance Test Switch to Change Parking Area (Source: Analysis Result, 2020).**

| Variables                  | Coefficient | Sig  | Exp (B) |
|----------------------------|-------------|------|---------|
| Medium Compact Area (X1.2) | -0.207      | 0.226| 0.813   |
| Compact Area (X1.2)        | 1.569       | 0.000| 4.801   |
| Parking Pricing Strategy (X.2) | 0.000     | 0.000| 1.000   |
| Constant                  | -3.267      | 0.000| 0.038   |

The criterion for this significance test is the variable that has a significance score below 50% or below 0.05. It means the variable that qualifies in this model are X1.2 (compact), X2 (parking pricing strategy). Thus, the binary logit for this response is

\[
\ln \frac{P}{1-P} = -2.3267 + 1.569 (X1.2) + 0.001 (X.2)
\]  

From the model above it can be interpreted that the centre area with classification compact has relation to travel changes because of parking pricing strategy implementation. Every change of parking pricing strategy will affect the changes in the parking area. That means parking pricing strategy implementation has affected the commuter’s travel behaviour changes. Every change in parking pricing strategy implementation increases the potency of the changes parking area. Thus, the built environment has affected parking pricing strategy implementation and commuter’s travel behaviour changes. Hence, the parking area movement regulation can be implied in a compact area to decrease parking area.

5. Conclusion

On-street parking in Bandung city has a lot of problems. They include the legality of the on-street parking area, an existing condition that doesn’t comply with existing regulations, and parking pricing. According to the related study, parking pricing for on-street parking is cheap. That condition becomes the reason for citizens to park in on-street parking rather than an off-street parking area. Other than that, parking pricing strategy has not been implemented yet because there is no study about parking pricing strategy in Bandung Centre area yet.

There are 4 models determined in this study. That 4 models are determined from 4 responses. That 4 responses are kept using private vehicle and parking in the existing area, switch to public transportation, switch to online transportation, and change parking area. The highest Neglekerke R square is the first model. The comparison between each model can be seen in the following table:
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Table 6. Binary Logit Model Comparison (Source: Analysis Result, 2020).

| Dependent Variable | Private Vehicle | Public Transportation | Online Transportation | Parking Area Changes |
|--------------------|-----------------|-----------------------|-----------------------|----------------------|
| Medium Compact Area| -1.550          | .816                  | 1.410                 | -.207                |
| Compact Area       | -1.279          | -.610                 | -.630                 | 1.569                |
| Not Compact Area   |                 |                       |                       |                      |
| Not Compact Area Parking Pricing Strategy implementation | -.001 | .000 | .000 | .000 |

The highest Neglekerke R square score is model 1 (keep using private vehicle and parking in the existing area which is 0.485 or 48%). Thus, the first model is the most significant. Based on binary logit analysis from the first response, there is the relation between parking pricing strategy implementation, built environment classification, and commuter’s travel behaviour changes. The model shows from the analysis is: \( \ln P/1-P = 4.356 -1.550 \times (X1.1) - 1.279 \times (X1.2) - 0.01 \times (X2) \). The significance dependent variable is a medium compact area, compact area and parking pricing strategy implementation. The highest coefficient is the medium compact area, it means that every change of -0.01 (X2) will affect 4.356 – 1.550 (X1.1) the use of non-private vehicles. Indeed, the increase of parking will increase the use of non-private vehicles in a medium compact area. Besides, the fact that there is free parking regulation in a compact area affects the commuter’s travel behaviour changes. Thus, parking area movement in a compact area will be more effective to decrease the use of private vehicles in a compact area.

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