Regional Conference in Civil Engineering (RCCE)
The Third International Conference on Civil Engineering Research (ICCER)
August 1ˢᵗ-2ⁿᵈ 2017, Surabaya – Indonesia

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The Modelling Concept of Volume and Duration of Parking for Various Types of Landuse in Surabaya

Anak Agung Gde Kartika[1], Indrasurya B. Mochtar[2], Hera Widyastuti[2]

[a]*Ph.D.Student of ITS, Jurusan T Sipil ITS, Surabaya 60111, Indonesia*
[b]*Lecturer of ITS, T Sipil ITS, Surabaya 60111, Indonesia*

[*]*Corresponding author: a.agung.kartika@gmail.com*

Abstract— **Both parking fee and parking tax are the potential income for most local authorities in Indonesia since they are considered as the parts of of local authority's revenue (Pendapatan Asli Daerah, PAD). However, currently many local authorities including that in Surabaya has a problem in determining target as well as the achievement of annual parking revenue. This situation takes place due to the lack of reliable method to estimate the parking revenue including both parking fee and parking tax either on-street parking nor off-street parking. Meanwhile, there are growing investments of public and private facilities in many capital cities of both regency and provincy including apartments, hotels, malls, campus, hospitals, convention buildings, terminals, offices, restaurants and mixed uses in which many parking spaces will be provided to support their activities later on. The providing of new parking spaces will therefore potentially contribute to the local authorities's revenue as the consequences. Main variable to contribute the parking revenue are the number of parked vehicle as well as the parking duration (when progressive tariff is applied). The concept of both number of parked vehicle and parking durations for several landuses will be introduced in this paper so that they can be elaborated more in depth as a mathematical model. Furthermore they can be used as references for estimating the anual parking revenue of local authotities as the part of local authorities revenue (PAD). Moreover, these models will be useful for parking facilities investors to analyse the their financial investment.**

Keywords— *Parking, Off-street, Landuses, Local Government's Revenue (PAD), Surabaya.*

I. INTRODUCTION

Currently, parking supply and parking restriction are commonly used as the vehicle movement restriction (Darmaningtyas, 2011 and Aucland Transport, 2016). On the other hand, parking activity is one of the potential local government's revenue especially for those having high car ownership as well as high economy activity. Eventhough, compared to other local tax components, parking revenue is not the biggest share (Arditia and Nuswantara, 2013).

However, it is publicly known that in most of local governments in Indonesia, including Jakarta and Surabaya, the parking management of both on-street and off-street, in terms of revenue collected, is indicated as less than supposed to be obtained due to the absence of collecting system method especially parking revenue prediction tools. In example, in Surabaya, the target for annual parking revenue in 2014 is IDR 80 billion while the real income is only IDR 48 billions which is only 60% of the targeted revenue (Suarasurabaya.net, 2016). This low realisation parking revenue has lasted for long time period, it is can be proved by following records; according to Beritasurya (2012), the realisation percentage of on-street parking revenue in 2009 and 2010 are 65.5% and 51.73% respectively. Meanwhile, Hakim (2014) mentioned that the lost of parking revenue is 40%. Moreover, Arditia and Nuswantara mentioned that within the period of 2008-2011 the realisation of total parking tax is always below the target.

The absence of system to predict the potential parking revenue due to this following reasons; first, the real number of parked vehicle is not yet recorded totally, second, in the real situation, the parking tariff per vehicle is not applied uniformly (higher parking fee is found), third, progressive tariff is applied in some facilities which make parking duration is important, fourth, there is no guidance regarding the collecting parking tax for both on-street and off-street parking, fifth, the variation of landuse influencing parking characteristic, sixth, the numerous non-registered parking facilities are identified due to the development of the city, seventh, many free-parking facilities in both goverment office and private facility still charge parking fee to users. Therefore, this paper will suggest the modelling concept of measuring the parking volume and parking duration for several landuses within the city so that they can be used as the input to predict the parking revenue of local authority. This parking model is expected to support the parking system revenue collecting of local authorities.

Additionally, by the existence of parking system collecting method, the parking operator and investor can make their financial planning accurately, while the local authority can easily predict their future income base on the existing and future parking facilities. Moreover, local authorities can eliminate or at least minimize the parking lost revenue (parking fee and parking tax) so that more fund for local income (bahasa: Pendapatan Asli Daerah, PAD) will be achieved. The flowchart of the conceptual idea is shown in Figure 1.

The goal of this paper is to suggest the concept of modelling parking volume as well as parkir duration of vehicles within various landuses (Hotel, Apartment,

Mall, Campus, Hospital, Train Station, Restaurant, Convention building, Office, Mixed used) related to the parking performances including turnover, accumulation, index, dynamic capacity and operational characteristic (operational duration) as well as physical variables including number of parking space and parking area.

II. LITERATURE REVIEW

Currently, parking research is mainly discussing about the need of future parking space as well as the performance of such existing parking space. Sutapa, Suthanaya and Suweda (2008) create model of the need of parking space of mall in Denpasar Bali, while Widhiastuti et.al (2013) analyse the need of parking space of campus in Kalimantan. Moreover, Khalid and Hamsa (2013) discussed about the performance of park and ride at LRT Putra Jaya terminal and Kelana Jaya Station in Malaysia.

However, there are already some researchs discuss a little bit about the potential parking revenue as conducted by Kartika and Himawan (2013) in which the potential revenue of on-street parking in Surabaya is analysed eventhough in that research the discussion about the progressive parking tariff is neglected. Hidayah and Widyastuti (2014) discussed about the potential parking revenue of Kabupaten Hulu Sungai Tengah for both on-street and off-street parking. But this paper only discuss about one landuse only (market) with no discussion about the modelling and progressive tariff. While the revenue will depend on number of vehicle (volume) parked and parking duration if the progressive tariff applied. Therefore, it is important to have these two variables modelled. Here are summary of some research regarding parking facillities.

The Local authorities (AT, Auckland Transport) apply a policy focusing on how to reduce the duration as well as distribute thae peak hour more evenly in a day. The principles is applied in restriction process are as follow:

1. Consistent Pricing policy to limit visitation into CBD area, promoting public transport utilisation, restricting the peak hour trip and reducing traffic congestion.
2. Priority to short time parking duration.
3. When deciding the parking tariff, the approach will be consistent, simple, law-based, transparant and data-based.
4. Using demand-responsive pricing and apply as low as possible tariff to achieve targeted occupancy.
5. Guarantee the availability of short duration parking space need.
6. Price-cut on off-peak parking tariff to reduce trips during peak hour so that the congestion can be reduced.
7. Conducting Parking Special management to meet special event i.e. school holidays.

2.2 The Behaviour of Parking User

One of the research relating the parking behaviour in Surabaya is the research regarding the probability of choosing parking location for motorcyclist in Surabaya. In that reasearch, three options including on-street parking, garage parking, and lot parking are set. This reasearch use multinomial regression model as the tool to analyse. The result of the model are as follows: (Mudjanarko et. al.. 2013)

$$P_{(lot\ parking)} = \frac{1}{1+e^{-1.082x1-2.185x2+1.393x3+0.449x4}+e^{-0.228x1-1.215x2+1.160x3+0.002x4}} \quad \cdots\cdots(1)$$

$$P_{(garage\ parking)} = \frac{e^{-1.082-1.154x1-2.185x2+1.393x3+0.449x4}}{1+e^{-1.082-1.154x1-2.185x2+1.393x3+0.449x4}+e^{-0.228x1-1.215x2+1.160x3+0.002x4}} \quad \cdots\cdots(2)$$

$$P_{(onstreet)} = \frac{e^{-0.228x1-1.215x2+1.160x3+0.002x4}}{1+e^{-1.082-1.154x1-2.185x2+1.393x3+0.449x4}+e^{-0.228x1-1.215x2+1.160x3+0.002x4}} \quad \cdots\cdots(3)$$

where :
X1 = availability on street parking,
X2 = availability lot parking,
X3 = parking time in afternoon, and
X4 = income

2.1. Parking as the Demand Restriction Instrument
The need of parking space is ussually design to meet the demand occured, while the demnd itself is calculated based on several variables depending on the type of landuses served. The new paradigm of parking space supply is as the instrument to limit the uses of vehicle itself as found in many developed country. However the restriction programme can not be a stand alone programme but it need to be supported with other mandatory programme i.e. the reliable alternative mode of transportation, in this case good public transport facilities (AT, 2016). In most developed countries, this paradigm, can cause the reduction of utilization of private vehicle in significant number (Darmaningtyas, 2011).

2.3 Analysis of Parking Performance and the Need of Parking Space

Many reasearchs on the need of parking space as well as their technical performances (duration, volume, dynamic capacity, index, turnover and capacity) are found, those involve different locations. Those are including Machsus and Mukafi (2011) with malls in Surabaya as the location, Sutapa, Suthanaya, and Suweda (2008) with malls in Denpasar as the location, Khalid and Hamsa (2013) with LRT station in Malaysia as the location, Widhiastuti, Priyadi and Akhmadi (2013) with the polytechnic campus in Pontianak as the location,

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Dirganakbari, Hayati and Suyoso (2015) with malls in Jember as the location.

2.4 Economic and Financial aspect of Parking Facility

The research regarding the financial aspect of parking facility is relating to the potential on-street parking revenue in Surabaya is conducted by Kartika A.A.G and A. Himawan (2013) in which the model of potential parking revenue are shown below.

Y=1746232x (if the parking tariff based on Local Law (*bahasa: Perda*) no. 1/2009)   (4)

=2608238x (if the parking tariff based on the real charged which higher than stated in local law)   (5)

Y=2807819x (if the progressive parking tariff is applied)   (6)

where:
Y   : potential annual revenue (IDR/yr)
x   : the length of on-street parking available

Additionally, Hidayah and Widyastuti (2014) analyse the difference parking revenue between the target and realisation of market building in Kabupaten Hulu Sungai Tengah Kalimantan Selatan. While Rizki, Kosakoy and Joewono (2014) the willingness of students to pay parking fee in their campus. Samples are taken from both car user and motorcycle user at Parahyangan Chatolic and the attribute considered in the analysis are including parking duration and the availability of parking equipments.

Meanwhile, Mantecchini (2015) discuss about the decision making of the location future parking facility development of airport in Italia. The alternative locations is separated from the existed airport. The issues discussed here is that farther parking location will make the less passenger to use that parking facility. On the other hand farther location has some advantages including lower land price and less congested eventhough shuttle service must be provided as the consequences. The proving of shuttle service, in this case by using bus will be calculated as the additional cost and the shuttle service tariff will be calculated as the restriction.

The decision of best parking location based on the trade off between demand and operational cost of parking facility including shuttle bus. The method of
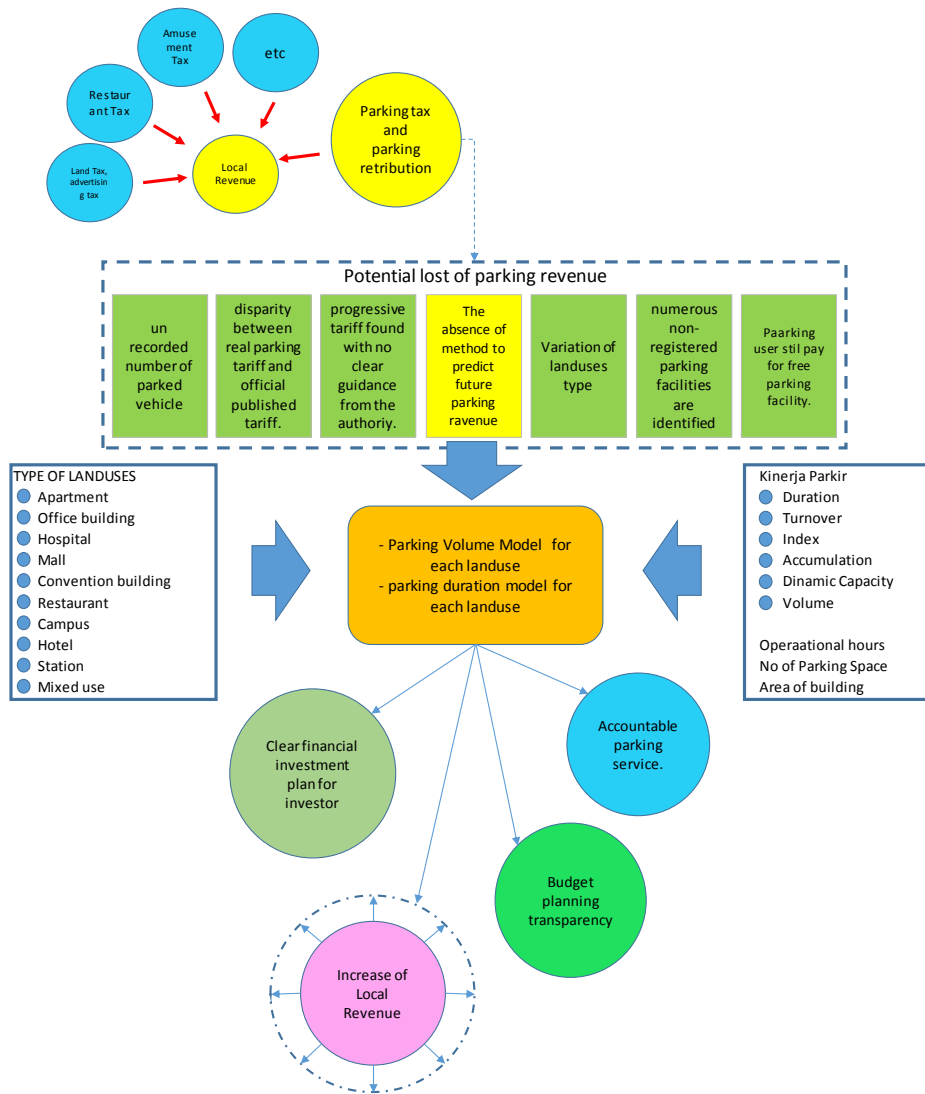

Figure 1. Conceptual Idea

analysis is carried out by optimization of spplying parking space, parking tariff, and parking operational cost (finding parking space cost, shuttle bus cost wih specific headway, capacity and utilization factor).

Different perspective regarding financial aspect of parking is shown by Arditia, R. dan D.A. Nuswantara (2013) in which the contribution as well as the efectiveness of local tax as the local revenue is analysed since parking tax is one of the local tax component. The contribution criteria is measured from Team of Litbang Depdagri-Fisipol UGM (1991) while the efectivenes is measured by standard value taken from Kepmendagri (Decree of Minister of Internal Affair Republic Indonesia) No. 690.900-327/1996.

2.5 Applied Technology in Parking service and operation

Many researchs regarding the applied technology of parking service and operation has been conducted, one of them is carried out by Birell et. al. (2015) discussing the impact of parking layout as well as driver behaviour to the position of wireless battery recharge aquipment when electrical car is used. The result shows that lateral position is better than longitudinal position in terms of accuracy of vehicle position. However, overall only 5% of vehicles is in their accurate position when they are recharged.

The other one is Renuka and Dhanalkshmi (2015) investigate the android based application to find vacant parking space together with the real time tariff accordingly. The finding process based on the slot allocation method while the payment method used is RFID (Radio Frequency Identification Device). Within this application, it is also possible to book available vacant parking space based on nearest location and the cheapest tariff.

Meanwhile, Banerjee and Al-Qaheri (2011) model the availability of parking space in small town, in this case Mauritius, in which they also develop software that can be installed in cell-phone so that parking user can easily find available parking space nearby.

2.6 Parking in Technical Point of Views

The technical performances of parking facilities according to Hobbs (1984) are as follows:

3. Turnover
4. Parking Index/Occupancy
5. Parking Duration
6. Capacity and Dynamic Capacity

2.7 Parking in Legal Point of Views of Indonesia

A. Traffic and Transportation Act No 22/1999

Art 43 explain about base regulation regarding parking issues, one of them is that the public parking space is only possible to be installed outside ROW of road, however it is possible to installed parking facility within the the ROW of the road but this is can only be applied to either Regency (*Bahasa: kabupaten*) road or village (*bahasa: desa*) road.

B. Surabaya's Major Decree No. 37/2015 regarding The Changing of Retribution for Parking Tariff

The changing of retribution for paring tariff in city of Surabaya is regulated by Major Decree No 37/2015 which can be summarised in **Tabel 1**.

III. PROPOSED CONCEPTUAL OF ANALYSIS

3.1 Parking performance analysis and type of landuses modelled

Before creating the model, the analysis of parking performance of each landuses must be carried out first. The parking performance analysis will include parking accumulation, parking volume, turnover parking, parking index, dynamic capacity and parking duration. They will cover these following types of landuses; mall, office, apartment, shopping-house, hotel, restaurant, hospital, station, convention building and mixed use. The analysis will be devided into two different group of day including weekday and weekend.

3.2 Model of Parking Performance (duration and volume) of each Landuse

As explained before that the number of parking revenue (retribution and parking tax) will depend on the two technical variables and the tariff of parking services. Those two technical variables are parking volume and parking duration. Since the tariff is only depending on the local authorities, therefore, these two variables will

Table 1. Parking Retribution

Type of vehicle	Description	Weight	Retribution, one utilization (IDR.)	
			lot/building/park and ride	Tourism area
Passenger Car and Logistic car	Sedan, Pick-up, minibus	≤3500kg	3000	5000
Passenger Car and Logistic car	Bus, truck, heavy vehicle	>3500kg	6000	20000
Motorcycle	-	-	2000	2000
Bicycle	-	-	1000	1000

Source: Major Decree of Surabaya No. 37/2015

1. Parking Accumulation
2. Parking Volume

be

Table 2. Summary of Research on Parking Facility

No	Author	Year	Type	Title	Discussion	Gap
1	Machsus and Mukafi	2011	Proceeding Seminar	Kajian Kebutuhan Ruang Parkir pada Mall Galaxy di Kota Surabaya	The performance of parking facility of Mall in Surabaya (Galaxy Mall)	No Model on parking duration and parking volume, other landuses type is not discussed. No discussion about parking revenue
2	Banerjee S. and Al-Qaheri H.	2011	Journal	An Intellegent Hybrid Scheme for Opimizing Parking Space: a Tabu Metaphore and Rough Set Based Approach	Model the availability of parking space in small town, in this case Mauritius city	No model on parking performance as well as no discussion about the revenue.
3	Kartika AAG and Himawan A.	2013	Proceeding Seminar	Studi Pendapatan dari Sektor Parkir Jalan Umum Kota Surabaya	Potential revenue of on-street parking for only year 2011 only.	model can not be applied when parking tariif is changed.
					Model developed based on the length of the parking facility on the street.	Various scenario of progressive tariff can not be accomodated
					the calculation of potential lost of revenue based on the different tariff between published official tariff and real tariff as well as only registered location is calculated	the model for off-street parking is excluded
						No parking model based on the parking performance is created so that can be used for the future .
4	Hidayah S., and Widyastuti H.	2014	Theses	Studi Potensi Pendapatan dari Sektor On-Street Parking dan Off-Street Parking di Kabupaten Hulu Sungai Tengah	Potential revenue of on-street and off-street parking for only year 2013 only.	model can not be applied when parking tariif is changed.
					Model developed based on the length of the parking facility on the street.	Various scenario of progressive tariff can not be accomodated
					Only discuss one landuse, in ths case market building.	No parking model based on the parking performance is created so that can be used for the future .
						The variable of parking space, operational hours and the area of building are not considered.
5	Sutapa IK, Suthanaya PA, and Suweda IW	2008	Journal	Analisis Karakteristik dan Pemodelan Kebutuhan Parkir Pada Pusat Perbelanjaan di Kota Denpasar	Analyse the technical performance of parking facility of mall in Denpasar	no discussing about paring revenue
					Analyse the adiitional need of parking space to meet the parking demand	No Model on parking duration and parking volume, other landuses type is not discussed..
					modelling the need of parking space based on these following variable; no of employee and part time employee	
6	Khalid UA and Hamsa AAK	2013	Proceeding Seminar	Parking Utilization and Ride Facility at Public Transportation Terminals	Analyse the technical performance of parking sacility at two LRT station in Malaysia	No Model on parking duration and parking volume, other landuses type is not discussed..
					Analyse the adiitional need of parking space to meet the parking demand which currently the parking index already achieve 90%	
7	Widhiastuti RE, Priyadi RE and Akhmadi	2013	Journal	Evaluasi dan Analisis Kebutuhan Ruang Parkir di Kampus Politeknik Negeri Pontianak	Analyse the technical performance of parking facility of campus	No discussion regarding parking tariff and revenue
					Analyse the adiitional need of parking space to meet the parking demand	No Model on parking duration and parking volume, other landuses type is not discussed..
8	Arditia R and Nuswantara	2013	Journal	Analisis Kontribusi dan Efektivitas Pajak Daerah Sebagai Sumber Pendapatan Asli Daerah Kota Surabaya	To discuss the contribution share of parking tax of all local tax as well as its effectiveness within the period of 2007-2011.	No discussion about how to determina the tax as well as no discussion about technical parking performance
9	Dirganakbari MI, NN Hayati dan H Suyoso	2015	Journal	Penyediaan Fasilitas Parkir pada Pusat Perbelanjaan Roxy Square di Kabupaten Jember	Discuss the diffrent need of parking space between weekday and weekend for mall in Jember	No Model on parking duration and parking volume, other landuses type is not discussed. No discussion about parking revenue
10	Rizki M, CM Kosakoy dan TB Joewono	2014	Prosiding Seminar	Eksplorasi Kesediaan Membayar Parkir Mahasiswa Menggunakan Stated Preference	Discuss about the willingness to pay of students regarding parking service in their university	No Model on parking duration and parking volume, other landuses type is not discussed. No discussion about parking revenue
11	Renuka R and S. Dhanalakshmi	2015	Journal	Android-Based Smart Parking System Using Slot Allocation and Reservations	Creating android based application to find parking space as well as the real time parking tariff accordingly.	No Model on parking duration and parking volume. No discussion about parking revenue as well as technical performance of parking facility
12	Luca Mantecchini	2015	Journal	Optimization of Airport Parking Facilities Size, Location and Construction	The analysis to decide best remote location of new parking facility of an airport in Italia. The analysis is based on economic point of views.	No Model on parking duration and parking volume, other landuses type is not discussed. No discussion about parking revenue
13	Birrell S.A., Wilson D., Yang C.P., Dhadyalla G., Jennings P.	2015	Journal	How Driver Behaviour and Parking Alignment Affects Inductive Charging Systems for Electric Vehicle	Discuss about the impact of parking layout and driver behaviour to the posisition of wireless battery charger equipment for electric car.	No Model on parking duration and parking volume. No discussion about parking revenue as well as technical performance of parking facility
14	Mudjanarko S. W, H. Sulistio, L. Djakfar, and A. Wicaksono	2013	Journal	Behaviour Model of Motor Cycle User in Selecting Parking Location (Case study in Surabaya City of Indonesia)	Discuss about the probability of choosing parking location for motorcycle. There are three possible options, including on-street parking, garage parking (off-street) and lot parking (off-street)	No Model on parking duration and parking volume. No discussion about parking revenue as well as technical performance of parking facility
15	Auckland Trasnport	2016	Guidance	Auckland Transport Price, Adjustment Policy Parking Buildings, Auckland CBD	To discuss parking facility as the instrument to restrict vehicle visitation to CBD	No detail discussion about technical parking performance.
16	Darmaningtyas	2011	Monograph	Parkir dan Pembatasan Mobil	To discuss parking facility as the instrument for trip restritcor	No detail discussion about technical parking performance.

Table 3 Dependent Variabel and Independent Variable.

Dependent Variable, Y		Independent Variables, Xi	
Volume parkir	Y	Turnover	X1
		Index	X2
		Dynamic Capacity	X3
		Avearge Duration	X4
		Accumulation	X5
		Parking space	X6
		Operational hours	X7
		Area of building	X8
Duration (% duration of total), Yi			
<5 min	Y1	Turnover	X1
5-120 min	Y2	Index	X2
2-3 hrs	Y3	Dynamic Capacity	X3
3-4 hrs	Y4	Volume	X4
4-5 hrs	Y5	Accumulation	X5
5-6 hrs	Y6	**Parking space**	X6
6-7 hrs	Y7	**Operational hours**	X7
7-8 hrs	Y8	**Area of building**	X8
>8 hrs	Y9		

modelled and used as the dependent variables. For volume model the independent variable will be turnover, index, dynamic capacity, average duration, accumulation as well as the physicaal variable (number of parking space and the area of building) and operational variable (operational hours).

Duration model will be in form of percentage of duration of each group of duration as the dependent variable to accomodate the progressive tariff that may occured, while the independent variable will be as follow; turnover, index, dynamic capacity, volume, accumulation as well as the physical variables (number of parking space and the area of building) and operational variable (operational hours). The independent and dependent variable for the model is summarised in Table 3. Regression of principal component will be used to create the models.

Based on Table 3 above the model made for each landuses, each landuses will have two model for weekdays and weekend. The bold independent variables (paking space, operational hours, area of building) can be easily identified while the others need to be found. By the existence of these models as well as the published official parking tariff, the local authority can easily predict the parking revenue annually so that the lost of parking revenue can be eliminated or at least can be minimised.

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