The Effect of Land Use and Pedestrian Infrastructures Design on Pedestrian-based transit ridership (PBTR) at Urban Rail Transit Station. A Case Study in Kuala Lumpur, Malaysia

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Abstract: PEMANDU, a governemnt secretariat involves in improving public transit has recorded 80.4% private trip are made daily in Kuala Lumpur as end of 2015. It creates congestion on the road especially during morning and evening peak hours. Government has spent billions of ringgit in providing road-based infrastructures in order to overcome high travel demand. Apparently, travel demand is keep increasing year by year. Thus, transit ridership is one of viable solutions in addressing the tremendous increase in travel demand particularly in urban areas. However, public transit usage is not encouraging in major car-oriented cities in Malaysia including Kuala Lumpur. Ampang line urban rail transit is one of two Light Rail Transit (LRT) available providing services to Greater Kuala Lumpur (GKL) dwellers. Sentul, Pandan Jaya, and Bukit Jalil are three of 25 transit stations available along the line as at end of 2015. These urban rail transit stations experiencing imbalance proportion of ridership which lead to economic loss and supress the optimum use of transit line. Therefore, increasing urban rail transit ridership at transit stations are important to avoid economic loss and optimizing uses of transit line. Literature shows that PBTR at transit station can be increased by land use planning and provision of pedestrian infrastructures design surrounding transit station. Thus, this paper is to study to the effect of land use and pedestrian infrastrucutres design on PBTR at transit station at urban rail transit station by selecting Kuala Lumpur, Malaysia as a case study.

Keywords: *PBTR, land use density, land use diversity, land use characteristics, pedestrian*

infrastructures design.

1 . INTRODUCTION

The purpose of this paper is to study the effect of land uses and pedestrian infrastructures design on pedestrian-based transit ridership (PBTR) at urban rail transit station. Literature has mentioned on the potential relationship between land use, pedestrian infrastructures and transit ridership. By using selective quantitative data, land use and pedestrian infrastructures data are presented in tabular as well as figure forms based samples taken from three selected transit stations; Sentul, Pandan Jaya, and Bukit jalil. Land use and pedestrian infrastrcutures design data are correlate to the PBTR data for the selected stations. By using SPSS, any significant correlations among variables are recorded. Discussion section is slotted in to review on the finding before arriving at a conclusion.

2 . LITERATURE REVIEW

In the context of relationship between land use characteristics and transit ridership, many experts treat land use characteristics using density and diversity parameter. (Badoe & Miller, 2000; Billings, 2011; Cervero, 1994, 2002; Dunphy, Myerson, & Pawlukiewicz, 2003; Gori, Nigro, & Petrelli, 2012; Ibrahim, Nik Ibtishamiah Mohamed Rehan Karim., Adji, 2011; Loo, Chen, & Chan, 2010; M.A Mohd Din, M.R Karim, n.d.; MoUD Goverment of India, n.d.; Ozbil, 2009; Peterson, 2011; Sung & Oh, 2011) for instance, promote high and compact land use density surrounding transit station to provide accessibility to workplace, business, school, and recreation either by walking, cycling or good transit system. Calgary Transportation Plan stated that high density land uses are designed along transit line in the city particularly to solve traffic congestion (Calgary City Council, 1995). Thus, high density development does promote transit ridership and reducing number of vehicles on road.

Land use diversity similarly, has proven able to increase transit ridership by combination of major land uses such as residential, commercial and institutional within walking distance (Badoe & Miller, 2000; Cervero, 2002; Loo et al., 2010; Ozbil, 2009; Sung & Oh, 2011). Even though land use density and diversity are two major stated variables in predicting transit ridership by literatues, the individual land use type and size are also contributed to transit ridership.

Besides land use, some literature states that pedestrian infrastructures design do influence on transit ridership. One of transit services major components is provision of pedestrian infrastructures design (Colonna, Berloco, & Circella, 2012; Loo et al., 2010; Ozbil, 2009). It helps connecting residential, commercial, institutional and stand-alone parking space to transit station or vice versa (Cervero & Kockelman, 1997; Daamen & Hoogendoorn, 2003; Srinivasan, 2000). Literature suggests that pedestrian linkages connecting land uses and transit staion has a catchment around 400 meters to 800 meters particularly to attract PBTR at transit station (Gori et al., 2012). Studies taken in California found that improvement of pedestrian infrastructures design such as walkways, landscaping, and street lighting are able to encourage transit ridership. (Shankar, Sittikariya, & Shyu, 2006) have agreed that pedestrian infrastrucutres design such as connected walkways either with roof or shades, crosswalk, traffic lights, pedestrian signage, benches, lighting, landscapes and security camera are determinants of good pedestrian infrastructures.

3 . METHODOLOGY

Method used consists of three parts: data requirement, method of data collection, and data analysis. For data requirement, digital mapping and land use size of land use distributions within a-kilometre radius of three selected transit stations; Sentul, Pandan Jaya and Bukit Jalil are important secondary data. The selection of three transit stations is based on different in characteristics of density and diversity levels (refer to Table 1).

Table 1: Selection of three urban rail transit stations based on density and diversity levels

Transit Station	**Density Level**	**Diversity Level**
Sentul	High	High
Pandan Jaya	Medium	Medium
Bukit Jalil	Low	Low

Source: Kuala Lumpur city hall MapInfo digital mapping data 2010

Land use types considered in this study such as residential, commercial and service, industrial, water body, infrastructure and utility, institutional and public facility, open space/ recreational and vacant land, and road/ transportation. However, only residential, commercial, and institutional are useful for correlation and regression model. The digital mapping and land use size of land use distributions within a-kilometre radius of three selected transit stations retrieved from Kuala Lumpur city hall in MapInfo digital mapping.

The total transit ridership at transit station, PBTR, and non-PBTR are dependent variables. These variables are counted at three selected transit stations; Sentul, Pandan Jaya, and Bukit Jalil. The transit ridership volume signifies number of transit user at transit station, embark and disembark of train within 12-hour from 7a.m. to 7p.m. including morning and evening peak hours. The PBTR refers to transit users who walk to access transit station whereby non-PBTR refers to transit users who access transit station using motor vehicles.

Transit ridership is count at automated ticketing access gate based on the number of passenger cross in and out at the gate. PBTR is count at each particular transit station at different points of pedestrian access pathway counting the number of people cross by from and to transit station. Since the survey is steering simultaneously, the different in the number of transit ridership and PBTR at three different transit stations represent the number of non-PBTR. Table 2 shows all variables used under this study.

Table 2: Types and categories of variables taken at three selected transit stations

Independent variables		Dependant variables
Land use data (within a-kilometre radius of transit station	**Pedestrian infrastructures design data**	**Ridership data**
1.Residential (in hectare) 2.Commercial (in hectare) 3.Institutional (in hectare) 4.Population density per hectare 5.Simpson's diversity index of land uses	1. Average Walkways Width 2. Walkways distance 3. Direct connectivity to land use 4. No. of crosswalk 5. Distance of roof and shades 6. No. of benches along walkways 7. Distance of pedestrian walkways with lighting 8. No. of pedestrian signage 9. No. of pedestrian traffic lights 10. No. of obstruction object along walkways 11. Distance of pedestrian walkways planted with landscape 12. No. of security camera along walkways	1. 12-hour transit ridership 2. 12-hour PBTR 3. 12-hour non-PBTR

Source: Kuala Lumpur city hall MapInfo digital mapping data 2010 and Field-counting survey in December 2015

For the analysis, land use data, pedestrian infrastructures design data, and ridership data of three selected transit stations are present and analyse in tabular and graphical forms. As the purpose of this paper to study on the relationships of independent variables and dependent variables, all values are entered in SPSS spread sheet. Finally, correlation coefficients of all variables are generated using SPSS software. For any statistically significant correlated variables are further discussed and observed.

4 . LAND USE CHARACTERISTICS OF THREE SELECTED TRANSIT STATIONS

Table 3 shows land use distributions (in hectare) within a-kilometre radius (313.3 hectares) of three selected transit stations. Based on the finding, land use surrounding of Sentul and Pandan Jaya transit stations dominated mainly by road/ transportation and residential. Pandan Jaya transit station surrounding has the least size of water body land and no available industry within a-kilometre radius of Sentul transit station. Bukit Jalil transit station however has very different surrounding. Open space/ recreational/ vacant land are the main core land use followed by residential and industrial land is the smallest area within a-kilometre radius. All three selected transit stations are located in suburban areas, but in relative Sentul are much closer to Kuala Lumpur central business district (CBD).

Table 3: Land use are (in hectare) within a kilometre radius from selected transit stations

Type of Land use	**Land use area (in hectare) within a-kilometre radius from transit station**		
	Sentul	**Pandan Jaya**	**Bukit Jalil**
Water Body	14.78	4.48	31.53
Industrial	0	9.23	1.56
Infrastructure & Utility	0.72	26.98	2.79
Institution & Public Facility	53.23	14.19	11.53
Residential	76.92	77.38	73.15
Commercial & Service	65.23	25.42	8.36
Open Space/ Recreation/ Vacant land	9.66	43.18	121.8
Road & Transportation	92.76	112.44	62.58
Total Area	313.3	313.3	313.3

Source: Kuala Lumpur city hall MapInfo digital mapping data 2010

Table 4 shows population density and Simpson's diversity index of three selected transit stations land use within a-kilometre radius. Sentul transit station has the highest density and diversity followed by Pandan Jaya transit station with medium density and diversity. Bukit Jalil has the lowest density and diversity levels in relative to three selected transit stations within a-kilometre radius.

Table 4: Land use density and diversity within a-kilometre radius from each selected transit stations

Transit Station	**Population Density (per hectare)**	**Simpson's Index of Diversity**
Sentul	755	0.66
Pandan Jaya	603	0.50
Bukit Jalil	322	0.36

Source: Kuala Lumpur city hall MapInfo digital mapping data 2010

All three selected transit stations have less than a-kilometre to the next transit station. Sentul Timur and Titiwangsa are two stations within the catchment of a-kilometre radius of Sentul station. Pandan Indah station similarly is about a-kilometre from Pandan Jaya station and Sri Petaling station is just about a half kilometre from Bukit Jalil station. All these transit stations are operating at the same transit line and supported by feeder buses connecting different land uses and transit stations.

5 . PEDESTRIAN INFRASTRUCTURES DESIGN AT THREE SELECTED TRANSIT STATIONS

Pedestrian infrastructures design observed in the study based on suggestion by literature. Table 5 shows types of pedestrian infrastructures design recorded at three selected transit stations. According to the table, in terms of connectivity, Bukit Jalil Station has the longest span of pedestrian walkways followed by Sentul and Pandan Jaya stations. Sentul station has pedestrian walk connected directly to land uses, longest roof or shade pedestrian walk, more lighting and landscape but high number of obstructions along the walkways. Bukit Jalil has the highest number of crosswalks, pedestrian signage and pedestrian traffic lights. Pandan Jaya station provides highest unit of benches along the pedestrian walk and security camera. It seem that Sentul station has better pedestrian infrastructures design than Bukit Jalil and Pandan Jaya.

Table 5 : Pedestrian infrastructures design at three selected transit stations

Pedestrian Infrastructures Design	**Urban Rail Transit station**		
	Bukit Jalil	**Pandan Jaya**	**Sentul**
Walkways average width (in meter)	2.24	2.15	2.12
Connected walkways distance (in meter)	3229.2	1878.4	4837.8
Direct connectivity to land use (unit)	5	10	15
Crosswalk (unit)	16	3	2
Roof and shades (in meter)	1382.7	696.7	1458.1
Benches along walkways (unit)	6	9	2
Pedestrian walkways with lighting (in meter)	2112.7	1586	4767.8
Pedestrian signage (unit)	3	0	1
Pedestrian traffic lights (unit)	10	0	0
No. of obstruction along walkways (unit)	10	5	90
Pedestrian walkways planted with landscape (in meter)	517.1	480.7	1855.3
Security camera along walkways (unit)	1	2	0

Source: Kuala Lumpur city hall MapInfo digital mapping data 2010

6 . THE AVERAGE 12-HOUR TRANSIT RIDERSHIP, PBTR, AND NON-PBTR PER DAY AT THREE SELECTED TRANSIT STATIONS

Table 6 shows the average 12-hour counting survey in two days of transit ridership, PBTR and non-PBTR. Pandan Jaya has the highest number of transit ridership in relative to other transit stations, which is mostly pedestrian-based. Bukit Jalil has the next highest transit ridership, and almost all generated by non-pedestrian. Sentul has the lowest number of transit ridership in relative to other transit stations with balance distribution between pedestrian and non-pedestrian ridership. However, pedestrian ridership shows higher number than non-pedestrian ridership.

Table 6: The average 12-hour transit ridership per day at three selected transit station

Transit station	Average 12-hour PBTR per day	Average 12-hour non-PBTR per day	Average 12-hour transit ridership per day
Sentul	3405	1538	4943
Pandan Jaya	6486	1075	7561
Bukit Jalil	914	6484	7398

Source: Field-counting survey in December 2015

7 . ANALYSIS OF LAND USE AND PEDESTRIAN INFRASTRUCTURES DEISGN ON PBTR AT TRANSIT STATION.

This study is to understand the effect of land use and pedestrian infrastructures design on PBTR. All variables under land use and pedestrian infrastructures design are included in the SPSS application. Pearson coefficient correlation between any independent values with dependant value; the volume of average 12-hour PBTR are assess and analyse.

Figure 1 shows variables which are correlated with average 12-hour PBTR at transit station and other independent variables. The R-value refers to Pearson's coefficient corelation and (sig) stands for signifant value <.05 . There are three major outputs can be observed from the figure. First, number of obstruction along pedestrian walkways has positive pearson coefficient correlation with distance of pedestrian walkways (R =1 ; sig .019) and Distance of pedestrian walkways with landscape (R = 1 ; sig .019) but has negative correlation with Average 12-hour pedestrian ridership per day (R = -1 ; sig .002).

Secondly, Distance of pedestrian walkways has negative relationship with Number of security camera installed near to transit station (R = -.999 ; sig .032) and Number of benches along pedestrian walkways (R =-.999 ; sig .02).

Thirdly, Average 12-hour pedestrian ridership per day has negative relationship with Number of obstruction along pedestrian walkways (R = -1 ; sig .002) and Distance of pedestrian walkways with landscape (R = 1 ; sig .019).

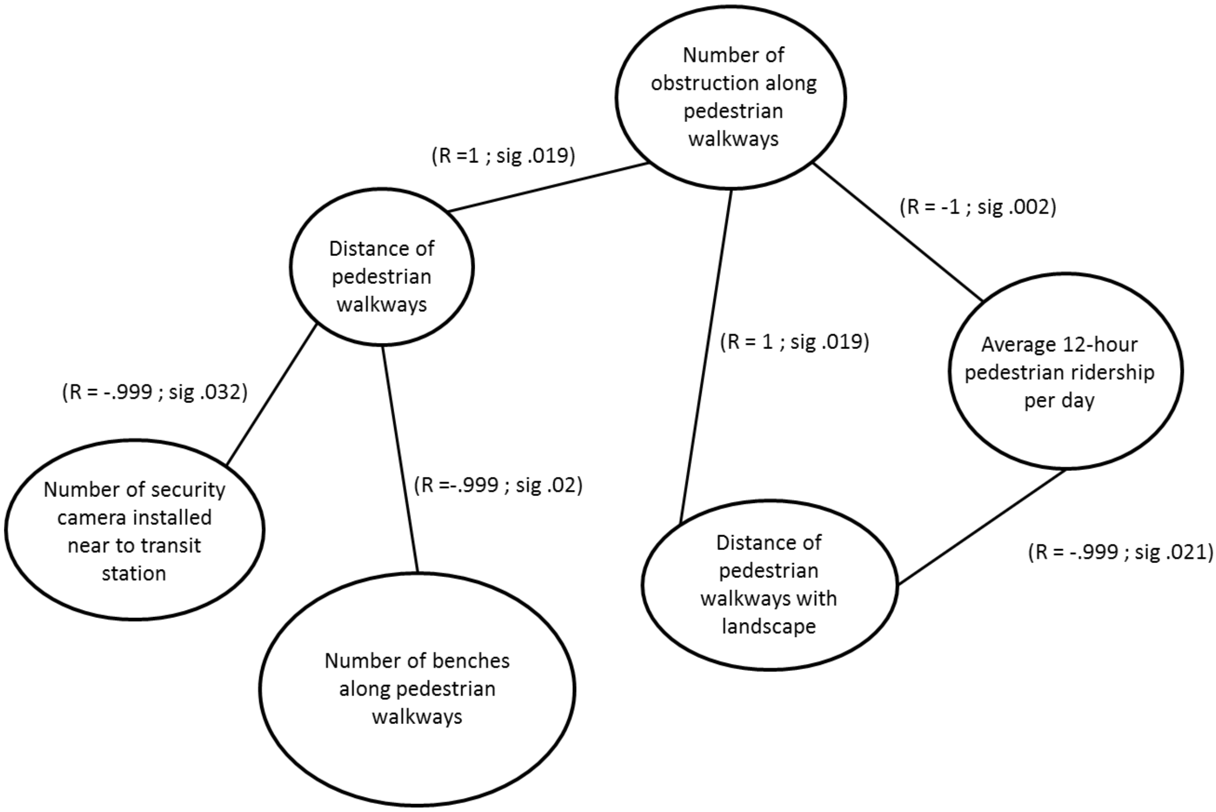

Figure 1: Variables that correlated with PBTR

Source: SPSS computer generated data

8 . DISCUSSION

Based on Figure 1, number of obstruction along pedestrian walkways have correlations with three other variables; distance of pedestrian walkways, distance of pedesrian walkways with planted landscape, and average 12-hour pedestrian ridership per day. The number of obstruction may increase if the pedestrian walkways connecting transit stations with or without planted landscape are longer. After all, if obstruction and landscape along pedestrian walkways are less, it may increase PBTR at station.

Distance of pedestrian walkways in addition has recorded negative pearson coefficient with the other two variables; number of security camera installed and number of benches along pedestrian walkways. It illustrates that longer walkways discourage installation of benches and security cameras along the walkways.

Authors can simplify that in order to increase PBTR at transit station. Pedestrian walkways should free from any harm. Potholes or other kind of obstructions should be avoided and proper landscaping with enough lighting for instance are able to increase PBTR. The key issue probably is safety of the users to walk to transit station. As provision of benches and security camera are inadequate for long distance pedestrian walkways, the provision of these infrastructures are necessary for assure safety and convenience of the users.

9 . CONCLUSION

The output of this paper is significant for planning a future transit station particularly in encouraging PBTR at urban rail transit station. The uses of motor vehicles can be reduced if the constrcution of future transit station emphasize on pedestrian walkways with appropriate landscaping and benches along the walkways at strategic location. It is important for urban planning whereby land uses are placed closer to transit station. Therefore by providing good pedestrian infrastructures, there would be more ridership at transit station contribute by PBTR. Land uses around transit stations are convinced by literature have some impact on ridership. Therefore, further studies is necessary to explain these relationships in a bigger samples size which desirable before making general conclusion.

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