The Effects of Land Use Characteristics on Passenger Ridership of Rail-based Transit Oriented Development in Kuala Lumpur

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Abstract: Urbanization has been a key driver of Malaysia's success in economic growth. Yet growing challenges in urban mobility dampen the benefits of urbanization and threaten Malaysia's ambitions of becoming a sustainable and inclusive high-income nation. Over the years, in big cities and towns, the mobility of people has been greatly affected because of significant upsurge in the number of private vehicles on urban roads. The annual survey on morning peak travel patterns carried out by Suruhanjaya Pengangkutan Awam Darat (SPAD) reflects that the modal share of public transport (PT) in the Klang Valley region for 2013 was at 20.8% or 1.2 million of the total 5.7 million trips. Ineffective and inefficient public transportation services including limited coverage, lack of integration between public transit modes and other supporting facilities and lack of integration between land use planning and rail-based public transportation system have only exacerbated the unabated problems of chronic traffic congestion and environmental degradation (Kuala Lumpur Structure Plan 2020). The primary field survey was conducted to collect data on land use density and diversity of mixed land use within 1000m radius around the 25 selected LRT station. Whereas, the passenger volume count method was used to count the passenger ridership on weekday covering both during peak hour and off-peak hour for twelve hours duration at the 25 selected stations.The method of analysis such as content analysis and descriptive analysis were applied. The main findings from the analysis on the effects of land use density and diversity on passenger ridership show a mixed result. In order to increase the use of public transport, other main components such as park and ride facilities, feeder bus services must also be considered in the planning of transit stations.

Keywords: Transit Oriented Development (TOD), Light Rail Transit (LRT), Land use density, diversity of mixed land use

1. INTRODUCTION

The increase of population and rapid urbanization have contributed to the increase of travel in major urban areas which leads to urban mobility problems such as traffic congestion. Over and over again, Klang Valley finds itself chocked by traffic snarls that threaten its future growth. With over eight million people living in the city, Klang Valley has experienced a staggering population expansion compared to more than six decades ago. Prior to 1957, there were approximately only 100,000 cars in Malaysia. But today, there are more than four million cars entering the city centre daily (PEMANDU, 2015).

To address the growing travel demand of the population, several initiatives and multiple efforts have been taken by the government to improve the public transportation system in Klang Valley. The ongoing construction of Mass Rapid Transit (MRT) and the extension of Light Rail Transit (LRT) in Klang Valley are some of the major public transportation projects which are undertaken to provide a travel solution through connectivity with other rail services and mode of public transport. In addition to that, Transit Oriented Development (TOD) concept will be promoted as the basis of urban planning to ensure the viability of public transport (NPP, Malaysia).

Public transport is one of the major modes of transportation especially in urban areas for mobility and accessibility for a greater population. The use of public transport can be seen in almost all the major cities in the world. However, the extent of the use of public transport varies between cities due to local internal and external factors. In Kuala Lumpur, the use of public transports stands at a very low level (only 20% of all trips) due to high vehicle ownership, relatively low fuel price, limited public transport options and coverage and sparse land use development.

Redesigning cities and expanding alternative transportation modes offer the best long-term means of reducing traffic congestion. Land use patterns which support the use of transit and transit systems are increasingly seen as an essential element in policy making which aim to encourage users to shift from private to public transport as well as to reduce traffic congestion. It is evident from studies that the success of the public transport use largely depends on how attractive the system is to the commuters especially in terms of the location of the stations, infrastructure at the stations, and the characteristics of the land use surrounding the station. Therefore, this research paper will focus more on the land use-transportation interaction, the impact of land use intensification, and mixed land use on transit use. The study on the effects of land use characteristics on passenger ridership of rail-based public transport is very important to grasp current and future travel trends as well as to enhancing the quality of public transport service in the future.

2. LITERATURE REVIEW

The expansion of towns and cities, due to increase in population, has shifted the growth in residential development outside the urban areas. But the employment and business centers are predominately concentrated within the urban areas which eventually increases the travel distance of the commuters from residential areas to offices and business activities. The increase in travel distance coupled with the affordability of owning private vehicles has induced commuters to use private transportation especially motorcars to accomplish work and business activities. The poor public transportation system in terms of lack of coverage, frequency, fleet size and exclusive bus infrastructure has further increases the use of private transport into the urban areas.

It is widely agreed that transit-oriented development can increase the use of public transit system through careful planning and design of public transportation system, pedestrian and bicycle facilities and high-density mixed-use development around the rail stations. The reduction in the number of trips, trip length (person and vehicle miles) by private transport and increase in passenger ridership by public transportation through transit-oriented development has been realized in many developed countries. In the recent past, transit-oriented development has gained momentum in many developing countries because of the benefits that it renders in relieving congestion, pollution and protecting from further environmental degradation.

The level of motorization has been increasing at an alarming rate over the years. In Malaysia (PEMANDU, 2015) has recorded 4 million cars entering the city center of Kuala Lumpur daily regardless of the comprehensive public transport network available. The government has invested about RM 33 billion in 2010 to 2015 in three major projects; LRT3, MRT, and BRT KL-Klang particularly to improve and increase public transit capacity in order to cater the future need of travel demand indirectly increase transit modal split in an urban area (PEMANDU, 2015). MRT is expected to contribute 20,000 per passenger hour per direction (pphpd) in the year 2017, followed by BRT KL-Klang, 25,000 pphpd in the year 2018 and LRT 3, 14,000 pphpd in the year 2020. By the end of the year 2020, public transit capacity in GKL/KV has a total additional capacity is 59,000pphpd, 61% increase from 2015 (PEMANDU, 2015).

The literature review about transportation and land-use interaction can be found in Badoe and Miller (2000) and also in Ewing and Cervero (2001). As reported in Stefano Gori, et.al. (2012), the reviews are conducted to understand if travel variables as trip frequencies, trip lengths, and mode choices are correlated with the built-in environment in the studies analyzed. The studies provide an example of the complexity of the connection between land use and transport system, involving a very large number of social, economic, technical and historical elements not easy to measure and to compare. About the opportunities provided by the public transport systems to develop a sustainable mobility, Bernick and Cervero (1996) and Cervero (1998) show, as reported in Stefano Gori, et.al. (2012), introducing the concept of the "transit metropolis", examples of transit services that provide respectable alternatives to travel by car. This is the case of Zurich and Melbourne, where the cities are formed by a unique central and compact business area or Stockholm and Copenhagen, where new urban areas have appeared concentrated around railway stations connecting them with the historic central nucleus.

Transit-oriented development (TOD) is a planning technique that aims to reduce automobile use and promote the use of public transit and human-powered transportation modes through high density, mixed-use, environmentally-friendly development within areas of walking distance from transit centers (Wann-Ming Wey and Yin-Hao Chiu, 2013). Transit-oriented Development (TOD) was introduced by Peter Calthorpe in the late 1980s ("TOD Diagram," 2010). He defined TOD as a development of a community in mix land uses near transit services purposely to reduce dependency on automobile use within 2,000-foot or 800 meters walking distance or 5 to 10 minutes walking time between a transit stop and a core commercial area (Ibrahim, Nik Ibtishamiah Mohamed Rehan Karim., Adji, 2011; "TOD Diagram," 2010). For TOD transit stations in a suburban area, the 800 meters walking radius can be extended as the density and diversity of land uses are much lower and supported by 400 meters feeder bus services and park-and-ride facility ("TOD Diagram," 2010). In a nut-shell, transit-oriented development is a compact, pedestrian-friendly high-density development near transit stations (Ming Zhang et.al., 2012). One of the keys in the definition indicates "an integrated, comfortable (in terms of the level of service), easily available and reliable mass rapid transit services" which may encourage shift from personal vehicles to mass rapid transit (Litman, 2009) as reported in Vimal Gahlot et.al., (2012).

Literature reviews on the impacts of TOD planning factors on Western cities, in general, give us an idea that urban design factors and a pedestrian-friendly design are positive planning factors in reducing automobile use through the reduction of automobile traffic speed and enhancing pedestrian accessibility to a transit center. Pucher and Dijkstra (2000), as reported in Wann-Ming Wey and Yin-Hao Chiu (2013), state that transportation and land use policies have made walking “less feasible, less convenient and more dangerous”. Research in the US has shown that residents of compact, mixed-use neighborhoods are three times more likely to walk (to a store, restaurant, or local park) than those living in more spacious automobile-oriented neighborhoods (Cervero and Radisch, 1996) as reported in Wann-Ming Wey and Yin-Hao Chiu (2013). Cervero and Gorham (1995), as reported in Wann-Ming Wey and Yin-Hao Chiu (2013), also hypothesized that transit-oriented neighborhoods generate more pedestrian and transit trips.

Most experts agreed that high land use density surrounding urban rail-based transit station can able to increase public transit ridership. (Loo et al., 2010; Srinivasan, 2000)for example, support the idea of high and compact land use density surrounding transit station as high density provides services to a community in terms of access from home to workplace, businesses, school, as well as recreation either by walking and cycling or efficient use of mass transportation . (Loo et al., 2010; Srinivasan, 2000). In the context of an urban area, there are two major land uses; residential and commercial which are crucial in determining public transit patronage as to accommodate high travel demand of work trip during peak hour on weekdays (R. T. Dunphy & Fisher, 1996; Gahlot, Swami, Parida, & Kalla, 2012; Gori et al., 2012; Kurauchi & Schmöcker, 2010). The authors apparently stated rail-based transit stations in the high-density urban area are usually a few, located at strategic locations supported by feeder bus services. Perhaps the standard benchmark for land use density surrounding transit station can be based on (Stefano Gori, Marialisa Nigro, & Marco Petrelli, 2012) idea ranging from 50,000 to 100,000 population at 40 to 200 persons per hectare.

In Malaysia, public transit ridership initiative is highly concentrated in the Central Business District (CBD) of Kuala Lumpur. The CBD area which located in the central core is a plan for high density with a public transit modal split of 50 to 60 followed by 35 to 50 and 20 to 25; the farther the stretches of development from the central core CBD, the lesser modal split expectation in terms of public transit would be (SPAD, 2011).

Another aspect of determining transit ridership in the context of land use is diversity level. The literature shows that high diversity of land uses does encourage transit ridership and walking, reduce pollution, fuel consumption, and social segregation ((Cervero, 2002; Cervero & Kockelman, 1997; Loo et al., 2010; Wey & Chiu, 2013). Many experts believed a diversity of land uses among three major categories such as residential, commercial and institutional within the walking radius of transit station are able to accumulate transit ridership (Colonna et al., 2012; Ozbil, 2009; Srinivasan, 2000). In fact, high land use diversity is a pre-requirement for Transit-oriented Development (TOD) design according to (CUTA, 2006).

Other than land use characteristics, pedestrian infrastructure design also does contribute to transit ridership. The primary purpose of pedestrian infrastructure design in the context of rail-based urban public transit is to complement transit services (Colonna et al., 2012; Loo et al., 2010; Ozbil, 2009). It connects residential, commercial retail, banks and shops, service transfer stations, shopping malls, sports stadiums and off-street parking to the transit station and vice versa (Cervero & Kockelman, 1997; Daamen & Hoogendoorn, 2003; Srinivasan, 2000). It provides pedestrian connectivity to transit station between 0.4 to 0.8 km radius, particularly to boost transit ridership (Gori et al., 2012). Examples in California show that enhancement of pedestrian infrastructure design such as pathways, landscaping, and street lighting upgrades have all attracted private investment in the Transit-oriented Development (TOD). Continuous connectivity of walkways with roof and shades, provisions of the crosswalk, traffic lights, pedestrian signage, benches, lighting, landscapes and security camera are determinants of good pedestrian infrastructures (Shankar, Sittikariya, & Shyu, 2006).

3. DESCRIPTION OF THE SELECTED LRT STATION

The Ampang Line is a light rail transit (LRT) system network in Klang Valley operated by RapidKL, a subsidiary of Prasarana Malaysia. The Ampang Line system network with a total length of 34.4 km consists of 29 stations which are eleven stations along the Sentul Timur as common stations, seven stations along the LRT Ampang Line and elevens stations the LRT Sri Petaling Line (Figure 1). Ridership on the Ampang Line has steadily increased with the passage of time. In 2013, the system carried 60.2 million passengers, with over 130,000 to 150,000 passengers per day on weekdays and an average of 120,000 per day on weekends ("Transport in Kuala Lumpur" n.d.). For this study, 25 stations from the total of 29 Ampang Line stations were selected as a study area. Meanwhile another 4 station such as Awan Besar, Muhibbah, Alam Sutera, and Kinrara BK5 LRT station excluded from this study as these 4 stations are the new extension stations and not existed when this study conducted. These 25 selected LRT stations surrounded by different characteristics of density and diversity levels. Thus, the presence of different degree of land use diversity and density within this 25 station catchment area will give a different result on the passenger ridership volume which indirectly give a better understanding of this study.

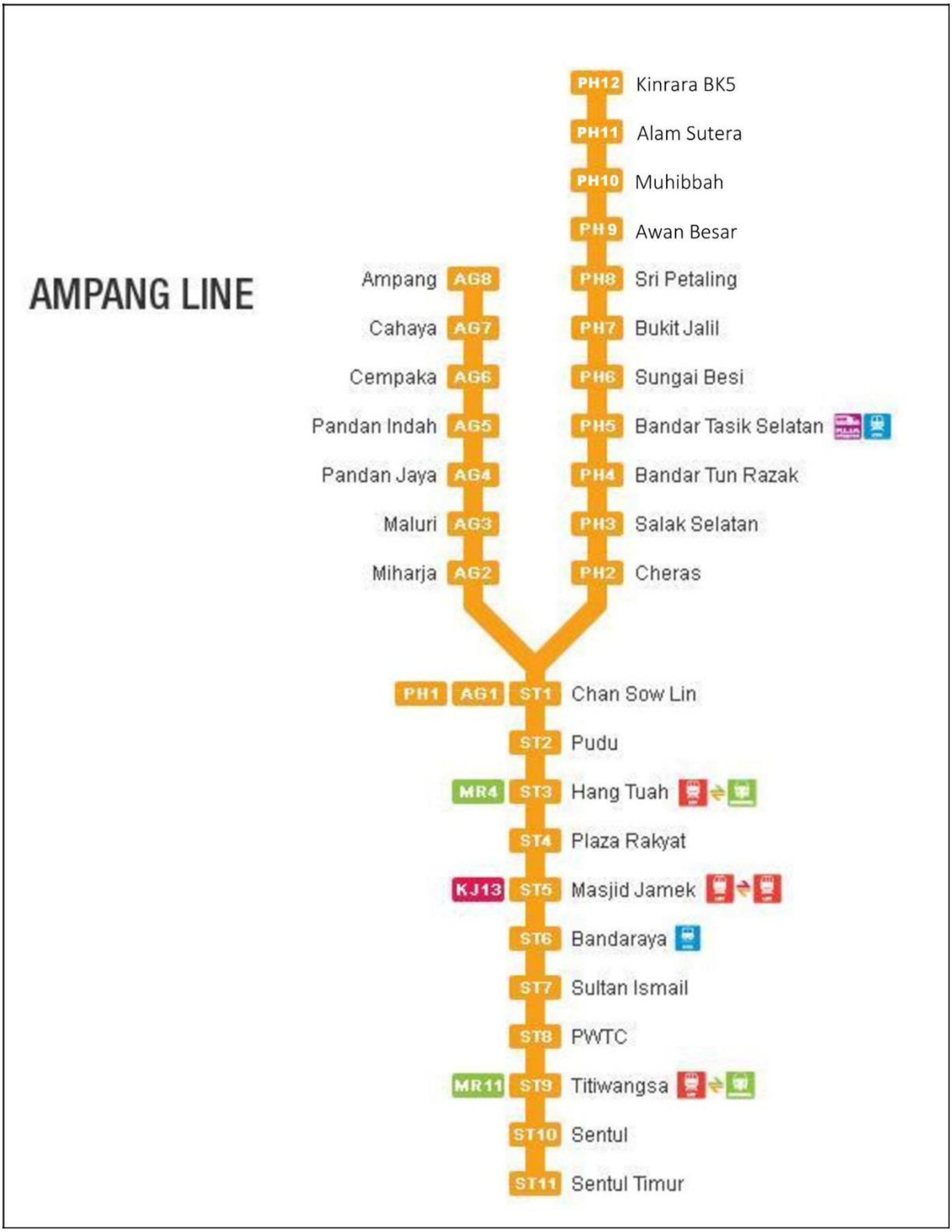

Figure 1. The 29 LRT stations in Ampang Line

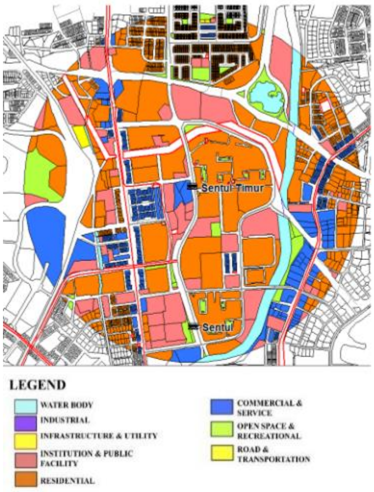

Figure 2. Sentul

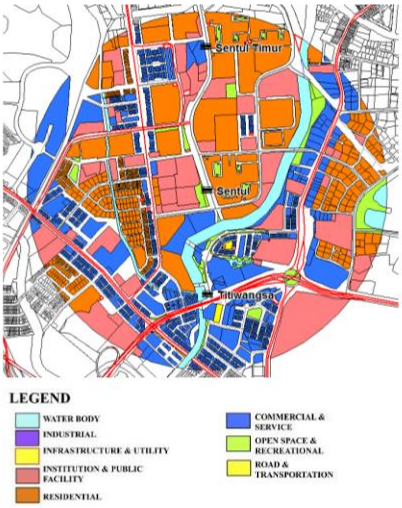

Figure 3. Sentul

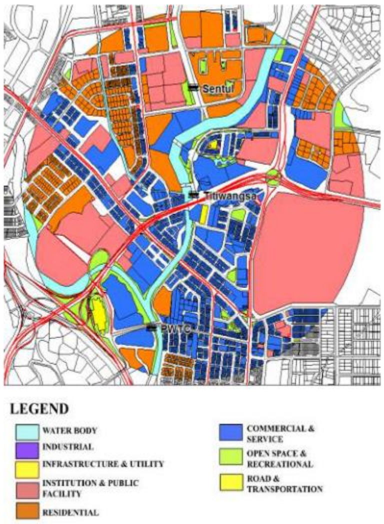

Figure 4. Titiwangsa

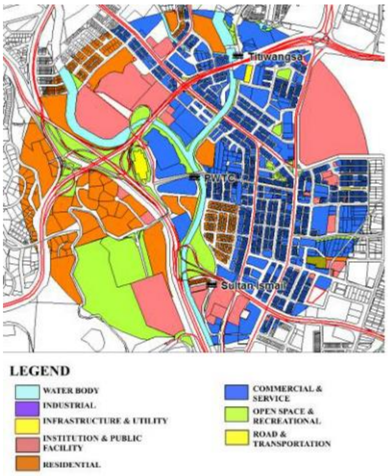

Figure 5. PWTC

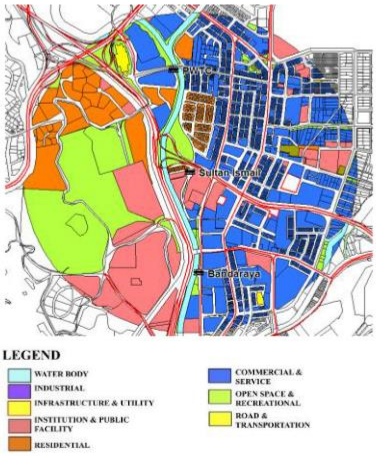

Figure 6. Sultan Ismail

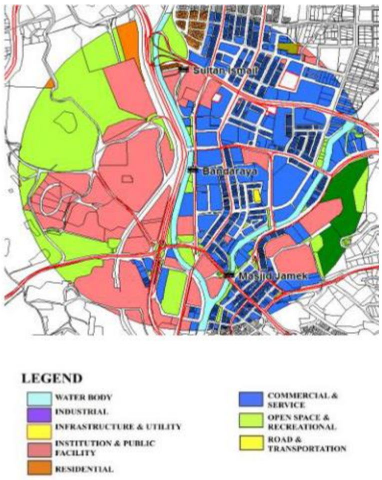

Figure 7. Bandaraya

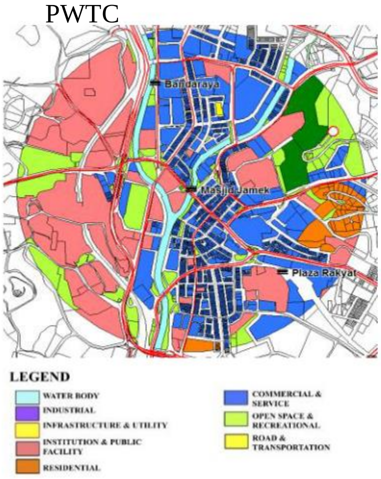

Figure 8. Masjid Jamek

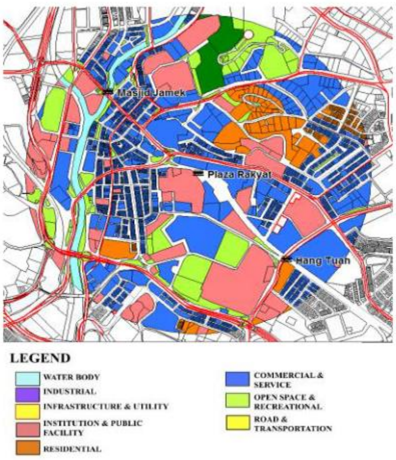

Figure 9. Plaza Rakyat

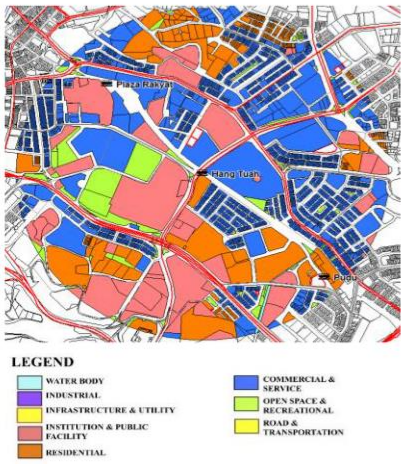

Figure 10. Hang Tuah

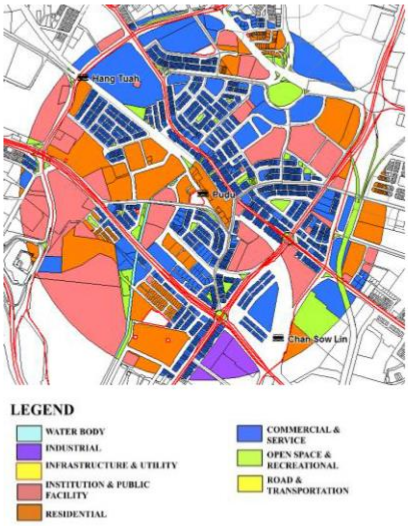

Figure 11. Pudu

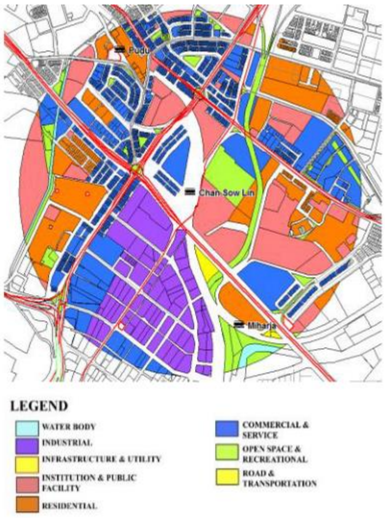

Figure 12. Chan Sow

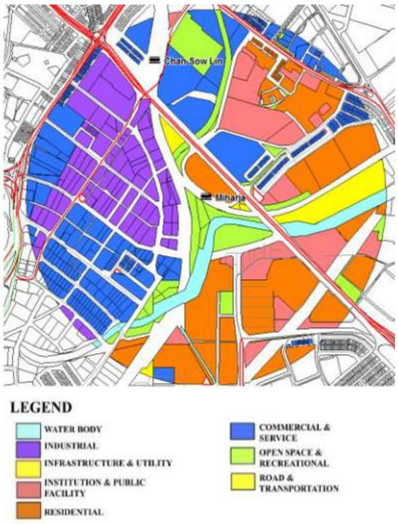

Figure 13. Miharja

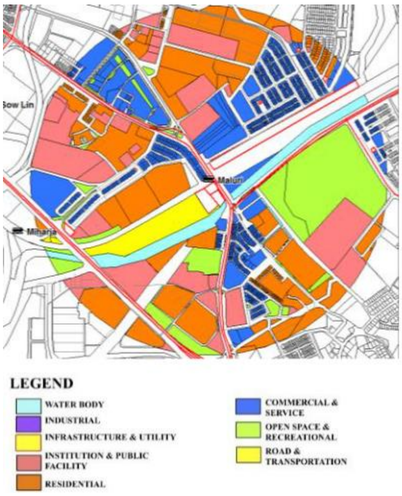

Figure 14. Maluri

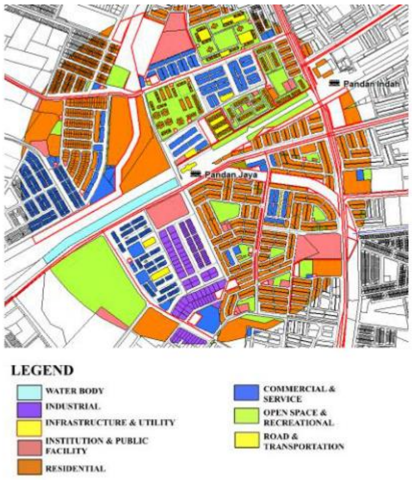

Figure 15. Pandan Jaya

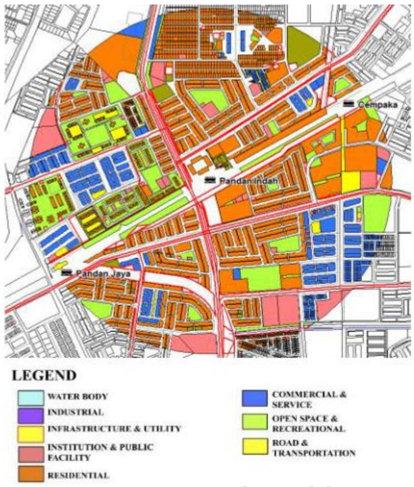

Figure 16. Pandan Indah

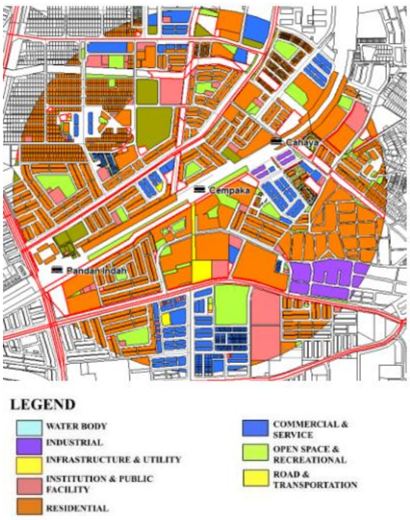

Figure 17. Cempaka

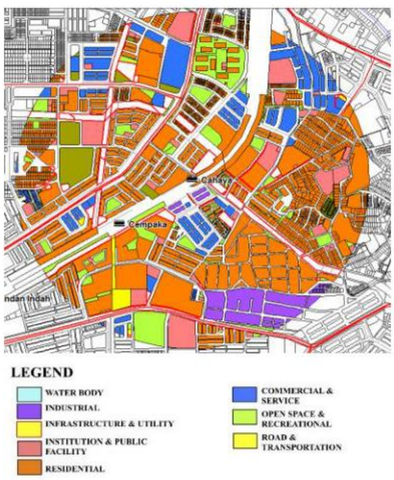

Figure 18. Cahaya

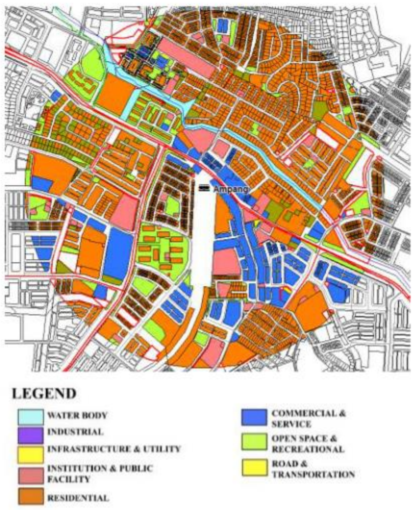

Figure 19. Ampang

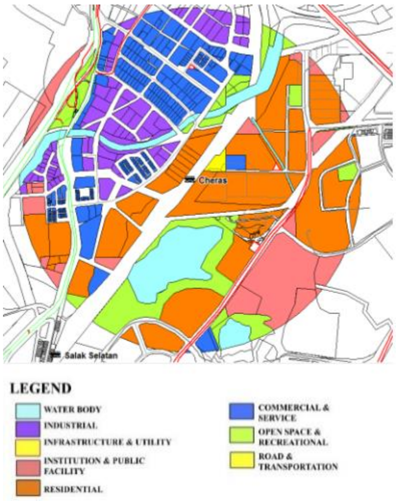

Figure 20. Cheras

Figure 21. Salak Selatan

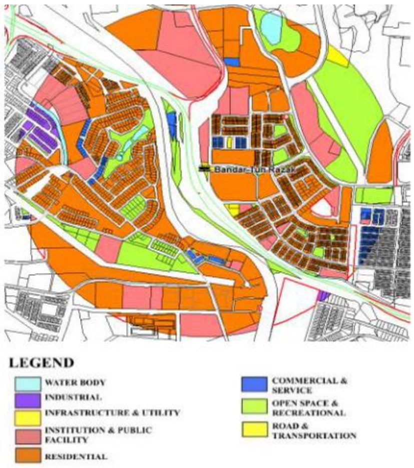

Figure 22. Bandar Tun

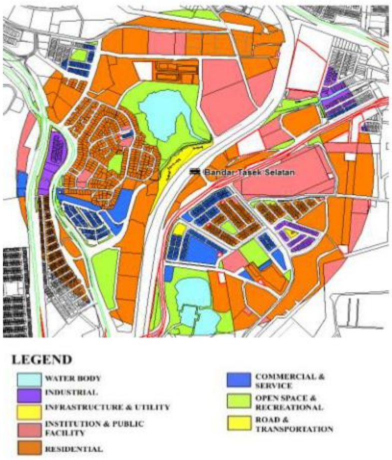

Figure 23. Bandar Tasik Selatan

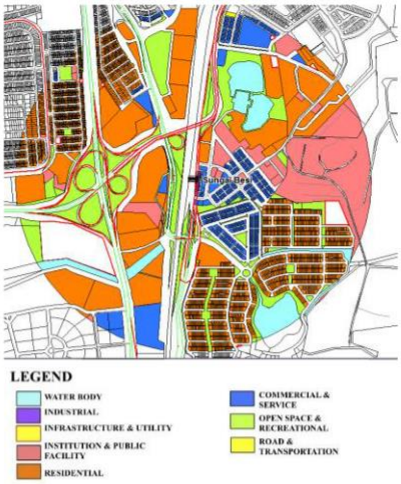

Figure 24. Sungai Besi

Figure 25. Bukit Jalil

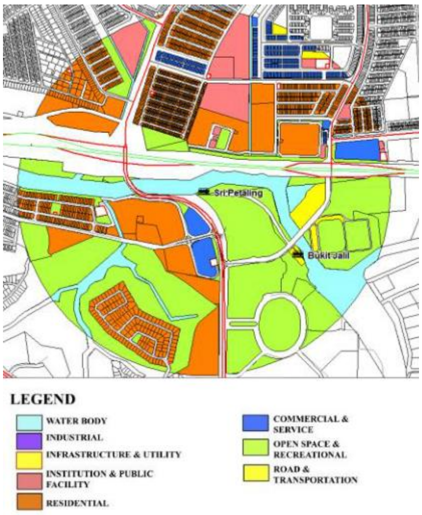

Figure 26. Sri Petaling

4. RESEARCH METHODOLOGY

4.1 Data Collection

Land uses characteristics surrounding transit station is needed in the study in order to relate land use characteristics and transit ridership. Thus, by selecting 25 stations at Ampang LRT line, the one-kilometer radius land uses characteristics are to examine. The breakdown characteristics such as residential, commercial, institutional, water body, infrastructure, and utility, vacant land, open space and recreational, road, population density and Simpson's index of diversity are to identify. The data on each of these elements of the primary field survey will be verified with the help of a secondary land use map. Enumerators were appointed to collect all the required land use data within the chosen radius of the area from each of the selected transit stations.

The use of public transportation will be assessed with the help of passenger ridership. Primary passenger count survey was conducted at points of entry to and exit from each transit station to determine the number of passengers using the station at different time period (morning peak-hour, evening peak-hour, and off-peak-hour). The 12-hour transit ridership volume at 25 selected transit stations is calculated from 7 am to 7 pm daily in two consecutive days in weekday. The average transit ridership volume for two days at each respective transit station constitutes the average daily transit ridership volume at each respective transit station. The data is used as to represent the total transit ridership at each particular transit station. These data will be checked with the daily and hourly passenger ridership collected from the rail transport authorities.

4.2 Method of Data Collection

In this study, the primary field survey focused on the characteristics of land use that is referring to the location of land use, type of land use, distribution of land use and land use mix. The data on land use was collected by identifying transit stations along the existing Ampang LRT lines. The selection of 25 stations was earmarked with a radius of 1000 meters (the ideal walking distance of the pedestrians to and from the station) from the station for the collection of land use characteristics.

The survey started at the beginning of October 2015 within the catchment area covered the land use by 1000 meters radius buffer surrounding at 25 different stations along the Ampang Line. In this field survey, the total of 50 enumerators is selected which are responsible for getting the land use details surrounding the transit station. By referring to the land use map, the land use details which include the type of land use (residential, commercial, institutional, industrial) and a number of units of each land use were recorded in a land use survey form in order to measure the intensity of land use density.

This primary passenger count survey was administrated by positioning two to four enumerators at automated ticketing access point which depend on the number of entrance and exit of the stations. The 12-hour transit ridership volume at 25 selected LRT station was counted from 7 am to 7 pm (morning peak-hour, evening peak-hour, and off-peak-hour) in two consecutive in weekday. The manual traffic counter is the equipment used by the enumerators by pressing the keys according to the number of people who enter and exit the station regardless of sex and ages.

4.3 Methods of Data Analysis

There are basically two methods of analysis conducted in this study; content analysis and descriptive analysis. Terminologies such as land use density, land use diversity, pedestrian infrastructure design, transit ridership, transit- oriented development (TOD) are discussed in Literature review chapter using content analysis. The land uses characteristics and transit ridership is analyzed using descriptive statistics. All these land use characteristics data and transit ridership are presented by suitable tabular data presentation and graphical data presentation to evaluate the individual effects of land use density and diversity on the use of public transport system. The extent to which each of the land use characteristics affects the use of public transport will be analyzed.

5. DATA ANALYSIS AND FINDINGS

The area of each type of land use and land use density around each of 25 selected LRT transit station is discussed in this section. The land use characteristics are important to understand its effects on the use of the transit station.

Land use density data is very important in order to find any relationship to rail-based transit ridership. For this study, a one-kilometer radius of rail station is a parameter to measure land use density surrounding rail station. The land use density for this study refers to the number of population within a kilometer radius of all stations at Ampang lines. One of the data used to calculate population density is the number of residential units which is multiplied by the standard household size in Kuala Lumpur equalling to four based on PLAN Malaysia. The residential units refer to detached, semi-detached, terrace, as well as strata home-based units within a kilometer of selected rail stations.

In this research, three major land uses such as residential, commercial and institutional land uses were used to calculate land use Diversity Index (LUDI) of a mixed land use surrounding three selected LRT station. The land use Diversity Index (LD) was calculated by using Simpson's diversity index. It measures both the distribution and the evenness of the individual land uses within the mix of land uses. The formula used to calculate this index is explained as follows: the square of the individual land use areas (a) divided by the square of the total area (A) is the measure of the individual (Ia) land use to the whole; the sum of these individual measures is the inverse of the diversity measure. Subtracting the inverse measure from 1 gives the land use diversity index of the total area [radius of 1000m from the station]. The greater the value of Land Use Diversity greater the mix of land use in the area. The values range from 0 to 1, where 1 denotes maximum possible diversity.

Land Use Diversity Index (LUDI) = 1- [Sum (Ia1, Ia2, Ia3, …….Ian)]

Individual areas = Ia1….. Ian = (a1)2 /A2 , (a2)2 /A2 , (a3)2 /A2 , …….(an)2 /A2

5.1 Land Use Distribution

Figure 27 shows the land use distributions (in hectare) within the one-kilometer radius (313.3 hectares) at each of the 25 selected transit stations. The land use area occupying residential was the highest around Ampang, Cahaya, Cempaka, and Sentul Timur LRT Station. Meanwhile, a commercial activity was the highest around Plaza Rakyat, Hang Tuah and Sultan Ismail LRT station. The land area occupying institutional within the one-kilometer radius was highest around Masjid Jamek, Bandaraya, and Titiwangsa LRT Station. No industries within one-kilometre radius around stations such as Sentul Timur, Sentul, Titiwangsa, PWTC, Sultan Ismail, Bandaraya, Masjid Jamek, and Plaza Rakyat as all of these stations located much closer to Kuala Lumpur central business district (CBD).

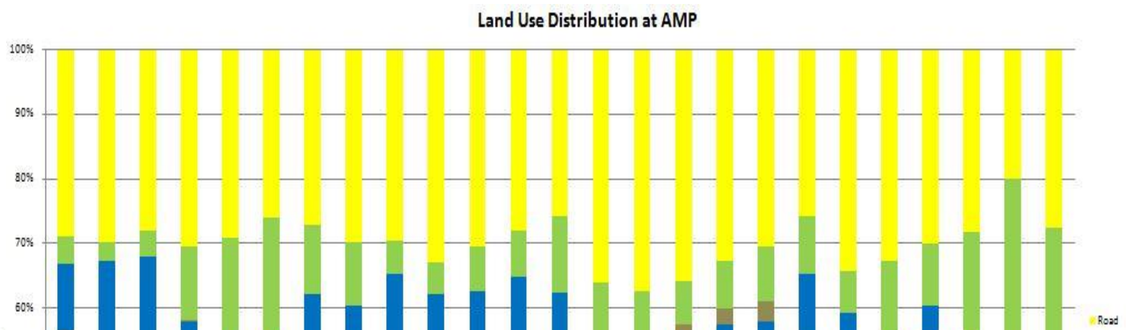

Figure 27. Land use distribution at Ampang Line LRT Station

5.2 Land Use Diversity

There are many different types of land use within the 1000 meter radius of the 25 selected LRT stations. Within the catchment of these selected stations, there are mixed development that consists of the residential area, commercial area, institutional, open space, and infrastructure. The land use diversity is categorized into three categories; high diveristy, medium and low. 11 stations in Ampang Line LRT fall into high-diversity category namely Titiwangsa, Chan Sow Lin, Sentul, Salak Selatan, Pudu, Maluri, PWTC, hang tuah, Miharja, sultan Ismail, and Cheras. The low-diversity stations along the Ampang Line are Ampang, Cahaya, Cempaka, Bandar Tun Razak, Sri Petaling, Bukit Jalil, and Pandan Indah.

Table 1. Land use diversity surrounding 25 LRT stations at Ampang Line

Station	Simpson's Index of Diversity
Sentul Timur	0.56
Sentul	0.66
Titiwangsa	0.66
PWTC	0.65
Sultan Ismail	0.60
Bandaraya	0.54
Masjid Jamek	0.55
Plaza Rakyat	0.56
Hang Tuah	0.64
Pudu	0.65
Chan Sow Lin	0.65
Miharja	0.63
Maluri	0.65
Pandan Jaya	0.50

Pandan Indah	0.44
Cempaka	0.39
Cahaya	0.42
Ampang	0.43
Cheras	0.59
Salak Selatan	0.61
Bandar Tun Razak	0.42
Bandar Tasek Selatan	0.50
Sungai Besi	0.52
Bukit Jalil	0.36
Sri Petaling	0.42

5.3 Land Use Density

The population density is categorized into three categories; high density, medium and low. 5 stations in Ampang Line LRT fall into high-density category namely Titiwangsa, Chan Sow Lin, Plaza Rakyat, Sentul and Cahaya. The low-density stations along the Ampang Line are Masjid Jamek, Pandan Indah, Bukit Jalil and Bandaraya.

Table 2. Categorical of Population Density along the Ampang Line

Station	Population Density (per hec)	Scale
Titiwangsa	921.15	
Chan Sow Lin	851.58	
Plaza Rakyat	850.89	High Density (701 and above)
Sentul	755.28	
Cahaya	719.85	
Ampang	697.56	
Miharja	669.20	
Cempaka	666.30	
Sultan Ismail	614.99	
Sentul Timur	609.90	
Pandan Jaya	603.17	
Hang Tuah	598.85	
Bandar Tasek Selatan	583.90	Medium density
Salak Selatan	547.62	(401 until 700)
Pudu	547.20	
Maluri	542.23	
Bandar Tun Razak	534.41	
Cheras	508.08	
PWTC	482.50	

Sungai Besi	459.53	
Sri Petaling	437.45	
Masjid Jamek	399.89	
Pandan Indah	388.97	Low Density
Bukit Jalil	322.10	(0 until 400)
Bandaraya	169.37	

5.4 Passenger Ridership

For Ampang line, Masjid Jamek station has a significantly very high number of passenger ridership when compared with other stations. This transit station is located at the city center and it is an interchange transit station connecting to another LRT line namely Kelana Jaya line. Hang Tuah, Bandaraya, Plaza Rakyat and Bandar Tasik Selatan have had recorded a high number of passenger ridership. The other transit stations along this line, however, have recorded low passenger ridership (refer to Table 3).

Table 3. Ampang line passenger ridership, June - August 2015

Station	June 2015	July 2015	August 2015	Total Ridership
Ampang	166,671	168,115	168,525	503,311
Cahaya	123,690	123,958	124,755	372,403
Cempaka	172,953	171,698	174,083	518,734
Pandan Indah	106,068	105,427	107,897	319,392
Pandan Jaya	152,889	160,317	157,941	471,147
Maluri	181,813	181,795	183,159	546,767
Miharja	75,144	75,754	78,994	229,892
Chan Sow Lin	89,281	86,703	90,125	266,109
Pudu	166,420	169,760	168,286	504,466
Hang Tuah	583,249	591,355	587,204	1,761,808
Plaza Rakyat	267,075	271,840	272,208	811,123
Masjid Jamek	1,168,181	1,170,405	1,153,503	3,492,089
Bandaraya	379,264	387,187	376,419	1,142,870
Sultan Ismail	82,748	77,543	81,328	241,619
PWTC	152,779	171,623	175,760	500,162
Titiwangsa	119,090	117,894	122,549	359,533
Sentul	99,546	103,460	102,539	305,545
Sentul Timur	143,968	144,265	144,770	433,003
Cheras	113,353	110,056	113,203	336,612
Salak Selatan	140,219	137,392	139,825	417,436
Bandar Tun Razak	109,280	107,293	109,125	325,698
Bandar Tasek Selatan	381,532	377,080	378,971	1,137,583
Sungai Besi	114,705	110,829	115,452	340,986
Bukit Jalil	176,166	186,187	187,707	550,060
Sri Petaling	104,600	103,465	103,604	311,669

Total	5,370,684	5,411,401	5,417,932

Source: Prasarana 2015

5.5 Relationship between Major Land Use and Passenger Ridership

Based on the analysis of this study, there is significant association between major land use such as residential, commercial, and institutional around Ampang Line LRT Station. Shown in Table 4, there is a significant positive association between ridership and commercial/institutional land use at Plaza Rakyat and Hang Tuah. Surprisingly, residential land use is significantly negatively associated with ridership at Sentul Timur, Cempaka, and Ampang LRT station.

Table 4. Major land use distribution and average LRT Passenger ridership

Station	Institutional	%	Residential	%	Commercial	%	Average LRT ridership per month
Sentul Timur	43.02	13.7	113.31	36.2	33.14	10.6	142850
Sentul	53.23	17.0	76.92	24.6	65.23	20.8	100321
Titiwangsa	77.74	24.8	47.13	15.0	71.08	22.7	119477
PWTC	43.65	13.9	47.34	15.1	76.49	24.4	167800
Sultan Ismail	42.84	13.7	29.63	9.5	88.88	28.4	79609
Bandaraya	74.25	23.7	5.79	1.8	72.95	23.3	369930
Masjid Jamek	82.94	26.5	9.62	3.1	82.01	26.2	1151497
Plaza Rakyat	52.94	16.9	19.37	6.2	101.92	32.5	271983
Hang Tuah	58.62	18.7	46.87	15.0	97.13	31.0	583775
Pudu	57.19	18.3	46.88	15.0	82.89	26.5	167436
Chan Sow Lin	39.72	12.7	50.11	16.0	67.77	21.6	88728
Miharja	28.93	9.2	74.65	23.8	50.87	16.2	77616
Maluri	51.49	16.4	81.34	26.0	45.75	14.6	180861
Pandan Jaya	14.19	4.5	77.38	24.7	25.42	8.1	155139
Pandan Indah	15.99	5.1	96.1	30.7	21.11	6.7	106759
Cempaka	15.04	4.8	113.04	36.1	19.67	6.3	172022
Cahaya	18.13	5.8	114.3	36.5	21.12	6.7	123924
Ampang	16.44	5.2	116.95	37.3	27.42	8.8	165926
Cheras	30.5	9.7	86.71	27.7	36.64	11.7	111900
Salak Selatan	48.6	15.5	81.41	26.0	28.2	9.0	138452
Bandar Tun Razak	39.64	12.7	117.2	37.4	4.97	1.6	108439
Bandar Tasek Selatan	38.6	12.3	105.16	33.6	15.42	4.9	374632
Sungai Besi	32.41	10.3	96.41	30.8	19.89	6.3	114209
Bukit Jalil	11.53	3.7	73.15	23.3	8.36	2.7	183977
Sri Petaling	14.79	4.7	76.01	24.3	11.93	3.8	101684

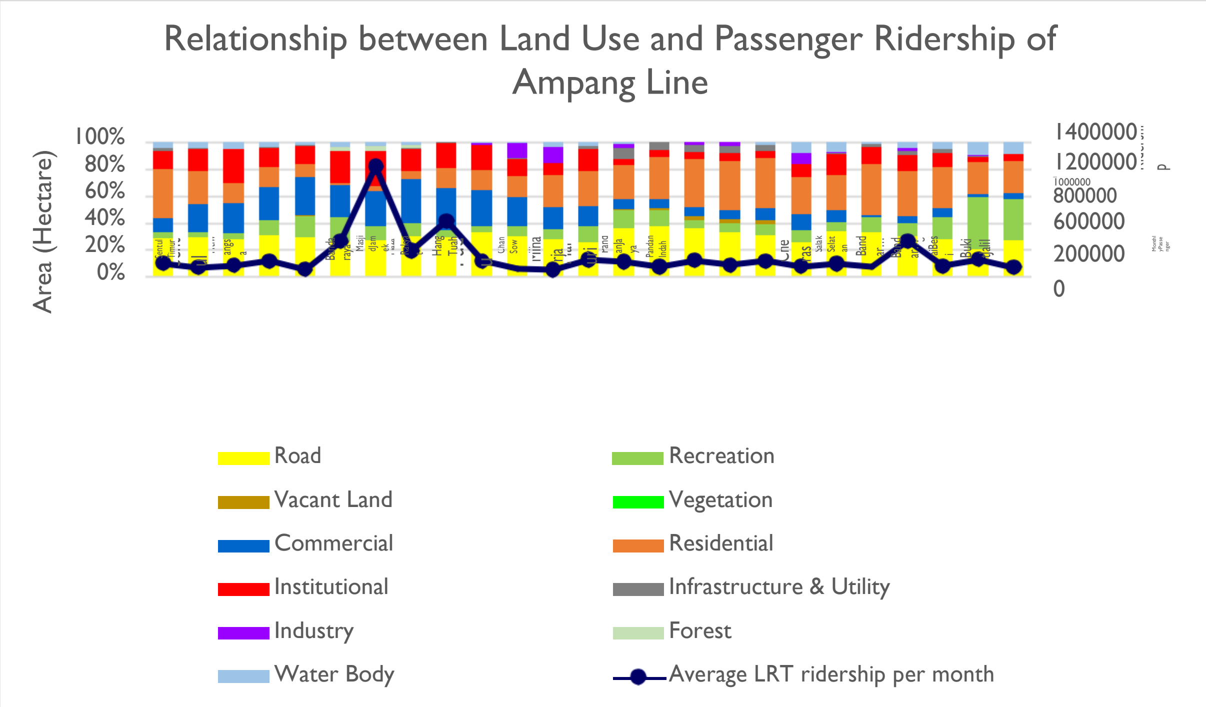

Figure 29. Relationship between Land Use and Passenger Ridership of Ampang Line

Based on the figure 2.9, ridership only fluctuates when land uses share changes. The stations that are close to Kuala Lumpur Central Business District (CBD) have fewer residential compared to the stations that are located far from the city centre. Stations with a higher share of residential use (on the right) have less ridership, while stations with more commercial/office use (on the left) have higher ridership. The stations on the left which are started from Pandan Jaya station to Sri Petaling station are all located far from the city centre of Kuala Lumpur. Most of the high passenger ridership along Ampang Line is generated by the commercial/office use in surrounding stations that closer to the City Centre.

5.6 Relationship between Land Use Diversity, Density, and Transit Ridership

Table 5 shows findings on population density and diversity within a one-kilometer radius from LRT stations and average monthly ridership of all stations along Ampang lines. Areas with higher density and diversity likes Titiwangsa, Chan Sow Lin, and Sentul have low levels of ridership but its contrast with Bukit Jalil. Bukit Jalil has an area of lower density and diversity but have a higher of ridership levels. Besides that, Pandah Indah shows the lower density, diversity and ridership. Maybe, the possibility of a distance factor between LRT stations contributes to lower ridership rates at Pandan Indah station. The nearest LRT station is Cempaka and Cahaya.

High LRT ridership was identified to be in the urban centers of Kuala Lumpur except for Bandar Tasik Selatan (average ridership 374632 per month). This station, however, has the highest number of station infrastructures. It shows that station infrastructures have influenced on increasing ridership at the rail station and there is medium in land use density and diversity.

The LRT stations which have low ridership at stations for Ampang lines are generally not located in central business district areas. These stations were found to be provided with low station infrastructures elements. Hence, difficulties in accessing the neighboring land use by walking were encountered although the stations are located in the center of Kuala Lumpur having high land use density such as, Chan Sow Lin, and Sentul.

Table 5. Relationship between landuse diversity, density, and transit ridership

Transit Station	Population Density (per hectare)	Simpson's Index of Diversity	Average LRT ridership per month
Sentul Timur	609.9	0.56	142850
Sentul	755.28	0.66	100321
Titiwangsa	921.15	0.66	119477
PWTC	482.5	0.65	167800
Sultan Ismail	614.99	0.60	79609
Bandaraya	169.37	0.54	369930
Masjid Jamek	399.89	0.55	1151497
Plaza Rakyat	850.89	0.56	271983
Hang Tuah	598.85	0.64	583775
Pudu	547.2	0.65	167436
Chan Sow Lin	851.58	0.65	88728
Miharja	669.2	0.63	77616
Maluri	542.23	0.65	180861
Pandan Jaya	603.17	0.50	155139
Pandan Indah	388.97	0.44	106759
Cempaka	666.3	0.39	172022
Cahaya	719.85	0.42	123924
Ampang	697.56	0.43	165926
Cheras	508.08	0.59	111900
Salak Selatan	547.62	0.61	138452
Bandar Tun Razak	534.41	0.42	108439
Bandar Tasek Selatan	583.9	0.50	374632
Sungai Besi	459.53	0.52	114209
Bukit Jalil	322.1	0.36	183977
Sri Petaling	437.45	0.42	101684

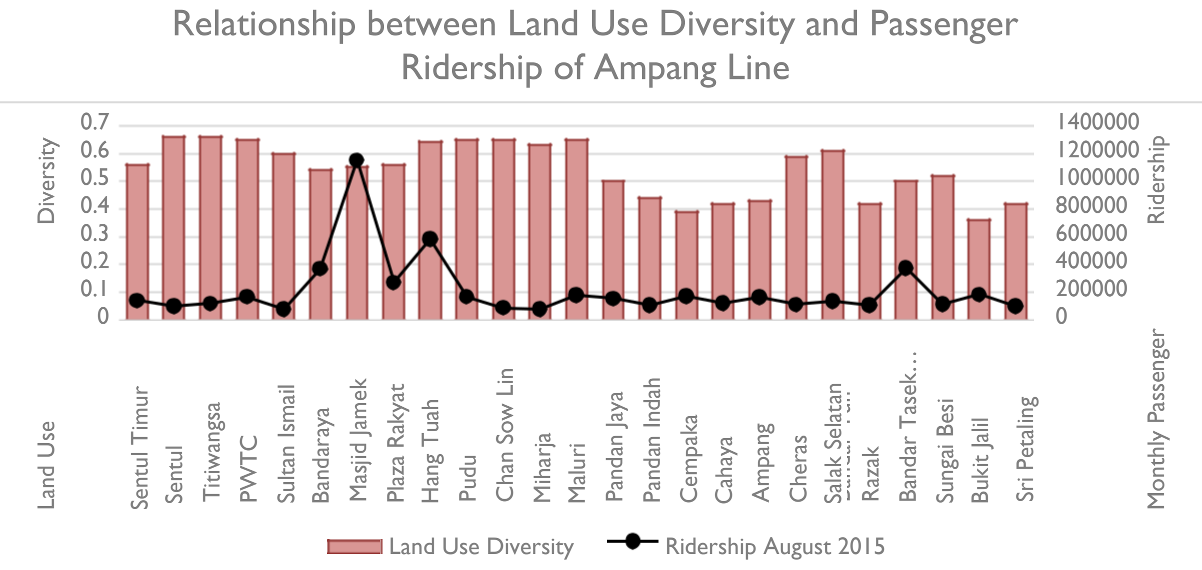

Figure 30. Relationship between Land Use Diversity and Passenger Ridership of Ampang Line

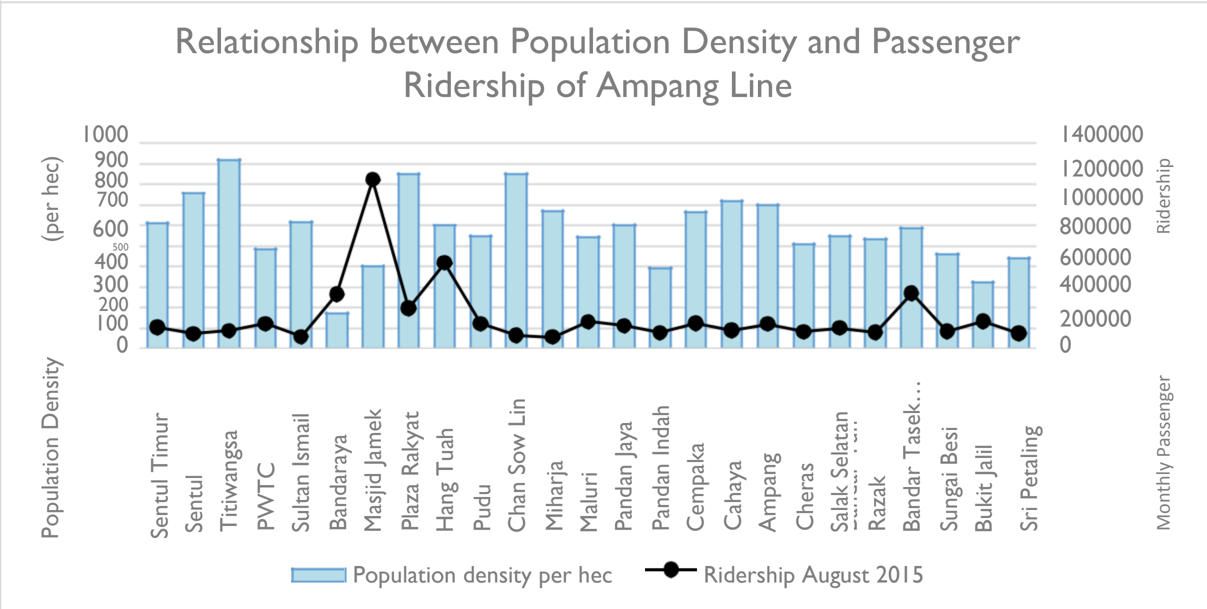

Figure 31. Relationship between Population Density and Passenger Ridership of Ampang Line

6. CONCLUSION

The main focus of this research is to evaluate the effects of land use density and land use diversity on rail-based transit ridership. From the previous literature, it is well known that the three main components such as density, diversity and design would have adverse effects on transit ridership – the higher the land use density, diversity, and good pedestrian infrastructures, the higher the increase in the transit ridership. It is understandable that public transport plays a vital role in enhancing the urban mobility and accessibility to different activities in urban areas.

The main findings from the analysis on the effects of land use density and diversity on passenger ridership show a mixed result. Generally, the findings concurent with the previous literature in which the transit stations having high land use density and diversity were patronizing high passenger ridership and similarly lower passenger rideship at transit stations with low land use density and diversity. Nevertheless, the findings also showed that some other transit stations along the selected LRT line having high land use density and diversity were found to be patronizing low passenger ridership. Similarly, some other transit stations having low land use density and diversity were found to be patronizing high passenger ridership. The likely reasons for high land use density and diversity but low passenger ridership are inappropriate location of transit stations, and absence of feeder bus services from the neighboring residential areas to the transit station. On the other hand, the likely reasons for low land use density and diversity but high passenger ridership are presence of park and ride facilities at the transit station and regular provision of feeder bus services. The findings from this study are expected to contribute towards realizing the public policies in improving the use of public transport in major cities in Malaysia. Undoubtedly, public transport has a significant role in eradicating the level of traffic congestion in many major cities. The alignment of future transit line especially the transit station should be located at places where the surrounding development is at least having medium land use density and diversity. Additionally, the provision of well-connected pedestrian infrastructures connecting the transit station to the surrounding land use also increases rail transit ridership. To complement the increase in the use of public transit, other main components such as park and ride facilities, feeder bus services must also be considered in the planning of transit stations.

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REFERENCES

Badoe, D. A., & Miller, E. J. (2000). Transportation-land-use interaction: Empirical findings in North America, and their implications for modeling. *Transportation Research Part D: Transport and Environment*, *5*(4), 235–263. https://doi.org/10.1016/S1361-9209(99)00036-X

Billings, S. B. (2011). Estimating the value of a new transit option. *Regional Science and Urban Economics*, *41*(6), 525–536. https://doi.org/10.1016/j.regsciurbeco.2011.03.013

Calgary City Council. (1995). *Transit Friendly Design Guide*. *Transportation*. Calgary, Alberta: Calgary Transit Division Transportation Department The City of Calgary P.O. Box 2100, Stn. M. Calgary, Alberta T2P 2M5.

Cervero, R. (1994). Transit-based housing in California: evidence on ridership impacts. *Transport Policy*, *1*(3), 174–183. https://doi.org/10.1016/0967-070X(94)90013-2

Cervero, R. (2002). Built environments and mode choice: toward a normative framework. *Transportation Research Part D: Transport and Environment*, *7*(4), 265–284. https://doi.org/10.1016/S1361-9209(01)00024-4

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment*, *2*(3), 199–219. https://doi.org/10.1016/S1361-9209(97)00009-6

Colonna, P., Berloco, N., & Circella, G. (2012). The Interaction between Land Use and Transport Planning: A Methodological Issue. *Procedia - Social and Behavioral Sciences*, *53*, 84–95. https://doi.org/10.1016/j.sbspro.2012.09.862

Dunphy, R., Myerson, D., & Pawlukiewicz, M. (2003). *Ten Principles for Successful Development Around Transit*. Washington, D.C.: Urban Land Institute.

Dunphy, R. T., & Fisher, K. (1996). Transportation, congestion, and density: New insights. *Transportation Research Record*, (1552), 89–96. https://doi.org/10.3141/1552-12

Gori, S., Nigro, M., & Petrelli, M. (2012). The impact of land use characteristics for sustainable mobility: The case study of Rome. *European Transport Research Review*, *4*(3), 153–166. https://doi.org/10.1007/s12544-012-0077-6

Kurauchi, F., & Schmöcker, J. D. (2010). Special issue on transit planning, operation and management in densely populated areas. *Transportation*, *37*(5), 705–707. https://doi.org/10.1007/s11116-010-9288-7

Ozbil, A. (2009). *Walking To the Station: the Effects of Street Connectivity on Walkability and Access To Transit*. *College of Architecture*. Georgia: College of Architecture, Georgia Institute of Technology.

PEMANDU. (2015). KL Travel Dmend Management. Kuala Lumpur: PEMANDU.

Peterson, D. (2011). *Transit Ridership and the Built Environment*. North Dakota State University: Small Urban & Rural Transit Center Upper Great Plains Transportation Institute.

Shankar, V. N., Sittikariya, S., & Shyu, M.-B. (2006). SOME INSIGHTS ON ROADWAY INFRASTRUCTURE DESIGN FOR SAFE ELDERLY PEDESTRIAN TRAVEL. *IATSS Research*, *30*(1), 21–26. https://doi.org/10.1016/S0386-1112(14)60152-7

SPAD. (2011). *Greater Kuala Lumpur/ Klang Valley. Public Transport Master Plan*.

SPAD. (2013). Land Public Transport Master Plan GREATER KUALA LUMPUR / KLANG VALLEY 7, (November).

Srinivasan, S. (2000). Linking land use and transportation: measuring the impact of neighborhood-scale spatial patterns on travel behavior. *Area*. Retrieved from http://web.mit.edu/uis/theses/sumeeta_phd/diss1.pdf

Stefano Gori, Marialisa Nigro, & Marco Petrelli. (2012). The Impact of Land Use Characteristics for Sustainable Mobility: The Case Study of Rome. *European Transport Research Review*, (4), 153–166.

Sung, H., & Oh, J. T. (2011). Transit-oriented development in a high-density city: Identifying its association with transit ridership in Seoul, Korea. *Cities*, *28*(1), 70–82. https://doi.org/10.1016/j.cities.2010.09.004

TOD Diagram. (2010). Retrieved from http://bettercities.net/images/17929/tod-diagram

Wey, W. M., & Chiu, Y. H. (2013). Assessing the walkability of pedestrian environment under the transit-oriented development. *Habitat International*, *38*, 106–118. https://doi.org/10.1016/j.habitatint.2012.05.004

Zhang, M., Mulholland, K., Zhang, J., & Gomez-sanchez, A. J. (2012). *Getting the Parking Right for Transit-oriented Development*. *Research Report SWUTC/12/161027-1*. University of Texas at Austin, USA.: Centre for Transportation Research.