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Determining the Relationship between Land Use Characteristics and Passenger Ridership of Light Rail Transit Lines in Kuala Lumpur

Determinación de la relación entre las características del uso del suelo y el número de pasajeros en las líneas de tren ligero de Kuala Lumpur

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transit-oriented development; land use diversity index; pedestrian infrastructure design; regression model

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Abstract

This paper determines the relationship between land use characteristics and passenger ridership of Light Rail Transit lines in Kuala Lumpur, Malaysia. Two LRT lines, namely Kelana Jaya line and Ampang line were selected. Data on the type of land use, land use mix, size of land use and population size within one KM radius from each transit station along the two selected LRT lines were collected. Data on passenger ridership at each transit station was also collected. The relationship between land use characteristics and passenger ridership of each selected LRT line was determined. Additionally, the effects of the factors related to land use characteristics, pedestrian infrastructure design (PID) and LRT station characteristics on passenger ridership of the two selected LRT lines were examined by using multiple linear regression (MLR) model. The results of the relationship between land use density and passenger ridership, land use diversity and passenger ridership show that there is no clear association exists between these components. However, the high land use density and medium land use diversity at most of the transit stations along the Kelana Jaya LRT line attracted high passenger ridership but high land use density and medium land use diversity along Ampang LRT line attracted low passenger ridership. The results of the MLR model show that only one factor namely "residential land use" was influential in affecting the passenger ridership of the two selected LRT lines.

Palabras clave:
desarrollo orientado al transporte; índice de diversidad de uso de suelo; diseño de infraestructura peatonal; modelo de regresión

Resumen

Este artículo determina la relación entre las características del uso de suelo y el número de pasajeros de las líneas de Tránsito de Tren Ligero en Kuala Lumpur, Malasia. Se seleccionaron dos líneas de Tránsito de este tren, la línea Kelana Jaya y la línea Ampang. Se recopilaron datos sobre el tipo de uso de suelo, la mezcla de usos de suelo, el tamaño del uso de suelo y la población en un radio de un KM de cada estación de tránsito a lo largo de las dos líneas de Tránsito de Tren Ligero seleccionadas. También se recopilaron datos sobre el número de pasajeros en cada estación de tránsito. Se determinó la relación entre las características del uso de suelo y el número de pasajeros de cada línea del Tren Ligero seleccionada. Además, se examinaron los efectos de los factores relacionados con las características del uso del suelo, el diseño de la infraestructura peatonal (PID) y las características de la estación de Tránsito de Tren Ligero en el número de pasajeros de las dos líneas de Tránsito de Tren Ligero seleccionadas utilizando un modelo de regresión lineal múltiple (MLR). Los resultados de la relación entre la densidad del uso de suelo y el número de pasajeros, la diversidad del uso del suelo y el número de pasajeros muestran que no existe una asociación clara entre estos componentes. Sin embargo, la alta densidad y la mediana diversidad de usos del suelo en la mayoría de las estaciones de transporte público a lo largo de la línea LRT de Kelana Jaya atrajeron un alto número de pasajeros, mientras que la alta densidad y la mediana diversidad de usos del suelo a lo largo de la línea LRT de Ampang atrajeron un bajo número de pasajeros. Los resultados del modelo MLR muestran que solo un factor, el "uso residencial del suelo", influyó en el número de pasajeros de las dos líneas LRT seleccionadas.

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1. Introduction

The use of private vehicles in many cities in Malaysia has been increasing over the years causing severe traffic congestion and associated traffic delays during both morning and evening peak hours of the working day. The high use of private vehicles is directly attributed to low coverage of public transit networks, non-adherence to public transport schedules, especially road-based, fuel subsidies, good and upgraded road infrastructure, ample availability of parking spaces in CBD and low parking charges. Increasing the coverage of public transit network is one of the strategies being applied by the local authorities to induce a shift from using private transport to public transit. As part of this strategy, various measures including transit-oriented development (TOD) were vigorously considered by the local authority. The global trend toward urbanization has spurred the widespread adoption of transit-oriented development (TOD) (Gu et al., 2024). Transit-oriented development (TOD) is a planning strategy that places a greater emphasize on physical development along the public transit lines or corridors. It allows the residents or workers both easy and direct access to the transit station for the use of the transit line. The type of development along the public transit corridor in TOD is specifically planned for medium to high density land use and mixed-use development. More specifically, medium to high density residential, commercial and institutional land uses are primarily developed near transit stations to facilitate the occupants of these land uses to use public transit as a major mode of transport for their daily use. It is well-known that transit-oriented development is based on 3-D concept, namely density, diversity and design (Cervero & Kockelman, 1997) which means developing high density (density), mixing land uses (diversity) and planning for pedestrian and bicycle friendly oriented facilities (design) near the transit stations.

Transit-oriented development can be either bus-based or rail-based. Studies have shown that the medium to high density development coupled with mixed land uses near the transit stations would increase the number of passengers boarding at these stations. Since the introduction of transit-oriented development by Calthorpe in the late 1980s, the definition of TOD has not been altered significantly by different researchers over time (Gahlot et al, 2012; Ogra & Ndebele, 2013; Phani Kumar et al., 2020; Peng, et al, 2017; Loukaitou-Sideris, 2010; Loukaitou-Sideris and Banerjee, 2000; Loo et al, 2010; Wey & Chiu, 2013; Wang, Xi & Zhang, 2012). TOD is a land-use planning approach that provides seamless walking and cycling accessibility from and to transit stations, and that maximizes the existing transit usage (Phani Kumar et al., 2020).

It is widely agreed that transit-oriented development can increase the use of public transit through careful planning and design of public transportation systems, pedestrian and bicycle facilities and high-density mixed-use development around the rail stations. The reduction in the number of trips, trip length (person-kms and vehicle-kms) 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 traffic congestion, air pollution and protecting from further environmental degradation of the urban areas. In Malaysia, new initiatives and multiple efforts have been taken by the government authorities to improve the public transportation system under the National Key Result areas (NKRA) especially in Kuala Lumpur to shift from the use of private transport to public transport. The ongoing construction of Mass Rapid Transit (MRT), Bus Rapid Transit (BRT) in Klang Valley regions including Kuala Lumpur, extension of existing Light Rail Transit (LRT) lines is some of the major public transportation projects undertaken by the transport authority to address the growing travel demand of the urban population and better mobility options to commuters. Additionally, TOD has been gaining popular among the major property developers in recent years in Malaysia which are clearly encapsulated by the widespread application of TOD concept in the many major mixed use property developments in and around Kuala Lumpur.

The location of transit stations around pre-determined land use is very crucial when expanding and building new public transit lines to attract public transport users. One of the pull factors for an increase in the use of public transport is the presence of concentration of users living or working near to the transit station. It implies that the concentration of medium to high density development and mixed-use development near the transit station would increase the use of public transport. This paper examines and determines the relationship between land use characteristics and passenger ridership of two existing LRT lines in the greater Kuala Lumpur area. The land use characteristics such as density and diversity near each transit station of these two LRT lines were analysed and subsequently correlated with the passenger ridership at each LRT transit station to determine how they are knitted with each other and what lessons that can be learned from their relationships. Additionally, the effects of factors related to land use characteristics, pedestrian infrastructure design and LRT station characteristics on passenger ridership of the two selected LRT lines were examined by applying multiple linear regression (MLR) model.

2. Literature Review

Transit-oriented development (TOD) has been gaining popularity in many cities in Asia because of easy accessibility, attractiveness and convenience in using public transit. TOD is a planning technique which helps lessen the use of private cars but upsurges the use of public transit, bicycle and walking modes through high density, mixed use, environmentally friendly development within areas of walking distance from transit centres (Wey & Chiu, 2013). When TOD was proposed in the late 1980s, some planners and academics had perceived it as an effective measure to reduce urban sprawl and they also considered it as an effective strategy for smart growth and development (Calthorpe, 1993; Cervero, 1993; Bernick & Cervero, 1997). Improving transit-oriented development (TOD) practices include adopting market-friendly zoning, allowing mixed land uses, allowing higher densities, promoting multi-modal streets with wide sidewalks and proper traffic management and ensuring adequate public space to support a walkable and transit-oriented urban environment (Ardila Gomez et al., 2024).

It is significant to stress the importance of the relationship between land use and transport system to know how TOD has been gaining popularity and the impact it induces on society and environment. Recently, the relationship between land use and transport systems has been determined by the research community at large. In this section, the results of some analysis about the relationship between land use characteristics (such as urban densities, neighbourhood design schemes and mixed land-use) and transit ridership are narrated. Uniform land use in areas is a dominant factor for asymmetric ridership pattern – passengers are inevitably concentrated in peak hours if a certain land use is predominant (Kim & Jang, 2022). The review on the relationship between land use and transport can be seen in Badoe and Miller (2000) and in Ewing and Cervero (2002). These reviews were undertaken to understand whether trip variables namely trip frequencies, trip lengths and mode choices are correlated with the built-in environment (Gori, et al., 2012). These studies set examples to show how complex the relationship between land use and transport systems is by involving a very large number of social, economic, technical and historical elements which are not easy to measure and compare.

When looking at the opportunities by the public transport systems in developing a sustainable mobility, Bernick and Cervero (1997) and Cervero (1998) introduce the concept of the "transit metropolis" which are perfect examples of providing transit services to travel over private car. The cities of Zurich and Melbourne, where they were formed by a unique and compact central business area, or the cities of Stockholm and Copenhagen, where new urban areas have concentrated around the railway station, it is important to connect them with the historic central nucleus. In the case of Munich, Ottawa and Curitiba, the realization of an efficient transit system through "hybrid schemes" was focused. It balances the urban development along the main corridors of the public transport services and adapting public transport services to serve the spread-out suburb communities. In these examples, the success of transit services is characterized by strong relationship between the land use policy and the transport system planning. Similar conclusions on the requirements for successful transit services were also drawn by Beimborn et al. (1992). On the other hand, density and diversity are the least suitable criteria for TOD planning in Delhi, India (Phani Kumar et al., 2020).

The significance of high-quality access to transit stops is underlined by Schlossberg and Brown (2004). The level of car and public transport use was explained by the population and densities of activities through extensive debates. High residential density was closely associated with a higher number of bus stops, indicating the importance of transit accessibility in densely populated areas (Vichiensan et al., 2025). Sinha (2003) demonstrates that an upsurge in transit boardings had primarily happened by high urban population density through the collection of different data from 46 cities in United States, Australia, Canada, East Europe and Asia. The transit boardings per capita per year increase with the rise in the number of persons per hectare and the car-kilometres of travel per capita per year decline. About the impact of the density, an important observation was highlighted by Eidlin (2005). According to his study, the critical issue was the distribution of density values within an urban area, not density values itself. This finding was drawn from Los Angeles city where the average density of activities and residences was higher than many other cities in America, but these values were correlated with one of the lower levels of transit share. When compared with the data from New York and San Francisco which were characterized by the largest level of transit use in the US but by an average value of population density lower than Los Angeles, it allows to underscore that this condition was drawn from the low variation of population and activities density within the territory, which author defines as "the worst of all worlds".

Mees (2009) when comparing relationship between urban densities and transport mode shares of Australian, Canadian and United States reports variations in density with little or no relationship to transport modes share despite those Australian cities having similar urban densities to those of Canadian cities and the more densely populated US cities. This differing finding was the result of more closely related different transport policies. These findings suggest the need for a radical rethinking of transport policies because they are bound to be different from those on which existing urban policies are based. Other interesting contribution on the determinants of the mode choice is from Buehler (2011) when comparing the results of national travel surveys conducted in Germany and in the USA. The findings show that the Germans are considerably more likely to walk, bike, and use public transport than the Americans despite having similarity in the socio-economic, demographic and spatial development variables. It clearly shows that travel behaviour choice was more related to factors such as transport, land-use policies and cultural preferences as well.

Banister (2000) and Banister (2005) had revealed a synthesis of the main characteristics that could identify a sustainable city especially in the European context, where the scarcity of space and the protection of non-built-up space are key issues. The total population level (ranging from 50,000–100,000 inhabitants) must be distributed to guarantee medium densities (40–200 persons per hectare), as shown by empirical studies. Mixed-use developments orienting along public transport accessible corridors and near to public transport interchanges were also suggested. Moreover, Banister (2000; 2005) underlines the importance of applying suitable and relevant policies for developing high-quality liveable cities which act as the rudiments for sustainable urban development. Density is considered as one of the elements to identify the role, importance and the impact of the interaction between land use policy and transportation planning. High density is a prerequisite to concentrate trips along a high capacity, high speed and high reliable transit service and increase the accessibility at the start and at the end of the trip which as a result increases the door-to-door travel speed (Stefano Gori, et al., 2012).

Arlington county in Virginia, USA has one of the most outstanding TODs in the United States (Zhang et al., 2012). In this county, each Metrorail station aligned along Rosslyn-Ballston corridor reflects an urban village with medium to high density, mix land uses and they are surrounded by low-to-moderate density neighbourhoods (Zhang et al., 2012). These urban villages are supported by various multi-modal transportation facilities which include pedestrian pathways, bicycle lanes, bus services and the Metrorail.

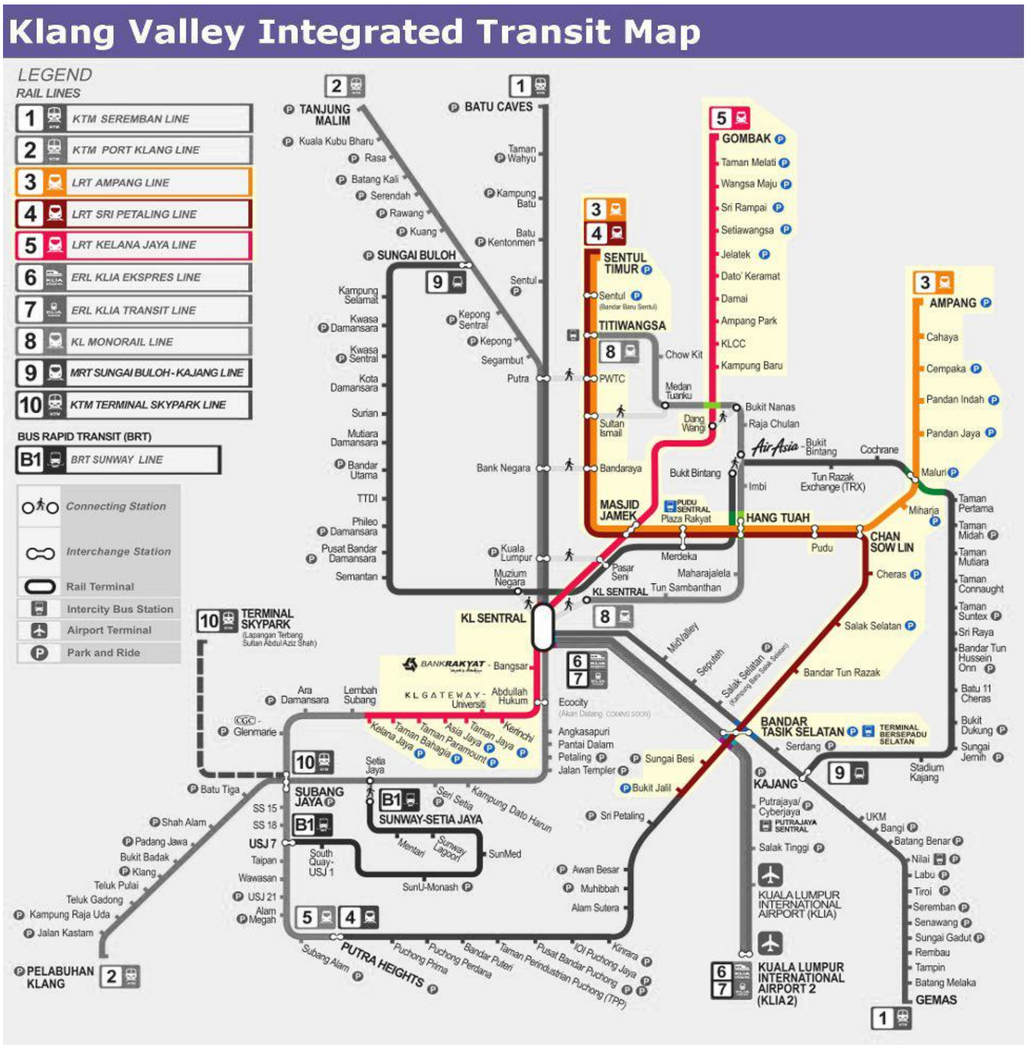
As a result of these development in the urban villages, the Metrorail stations experience high transit ridership (Cervero, 2006; Zhang et al. 2012). The presence of office-retail development in and around and at walking distance from the Metrorail stations has attributed to an increase in transit ridership. The Models used in this study had shown that every 100,000 square feet of additional office and retail floor development would increase average daily boardings at transit stations by around 50 commuters (Cervero, et al., 2004). A decrease of nearly 770 lane miles and reduction of daily vehicle-miles travelled of 10 to 12 million or by 3.5 to 4.5 person-miles traveled per person was reported along the portion of a congested road in one of the regions in USA (Zhang, 2010). This magnitude of reduction in congestion during peak-hour commuting has clearly indicated that considerable savings in highway investments through the practice of TOD could be realized. TOD's role as a congestion mitigation strategy has particularly focused on the concentrated high-density development that normally shortens average trip length and hence results in less vehicle-miles traveled (VMT) and person-miles traveled (PMT) than low-density development.

Several studies have clearly demonstrated an increase in transit ridership because of high-density development and mixed land use near the transit stations (Cervero, 1996; Ewing & Cervero. 2002; Ewing and Cervero, 2010). Study showed that office workers constituted the highest number of transit passengers, followed by those working in hotels and commercial/retail and residential users. It was noted that optimizing the design of the TOD can increase the number of daily LRT passengers by up to 55% (Mohammed Ali Berawi et al., 2020). The high-density development and mixed land use near KL sentral and Terminal Gombak station (along Kelana Jaya LRT line) in Kuala Lumpur, Malaysia has substantially increased transit ridership (Mustapha, 2011). Transit Planning Zones are also pursued in Johor Bahru and Nusajaya city centre in Malaysia by promoting commercial and housing development on the same site to support the strategy of encouraging city living and transit-oriented development (Ho & Fong, 2011). A study on the relationship between transit-oriented development and transit ridership conducted in Seoul has suggested focusing attention more than in increasing density in strengthening the transit service network, growing the mixed land-use and creating a more pedestrian friendly around rail stations and working on urban design and street networks (Sung and Oh, 2011).

3. Research Approach

The public transit system that is involved in transit-oriented development can be either road-based or rail-based. This research considers rail-based public transit systems because of the higher frequency of services, strict adherence to the running schedule, long distance routes and having potential for high passenger ridership due to its exclusive right-of-way over road-based public transit system. Two existing LRT lines, namely Kelana Jaya line and Ampang line were selected in this research. Each LRT line runs over a distance of about 28 km serving 24 transit stations. Ampang LRT line, an integration of Ampang line and Sri Petaling line, is aligned along north-west and north-south direction and Kelana Jaya LRT line along north-south direction. Figure 1 shows the selected Kelana Jaya LRT line and Ampang LRT line. Both LRT lines were running in Klang Vally region which include Kuala Lumpur.

Figure 1. Kelana Jaya and Ampang LRT line



Source: Klang Valley Integrated Transit Map 2015.

3.1. Data & Data Collection Method

Data and data collection is an important stage of research. The land use characteristics such as land use type and land use size near each transit station of the two selected LRT lines were collected by using field observation survey technique. These data were collected within one kilometre radius from each transit station by employing 11 enumerators. A one-km radius serving distance from each transit station was chosen because studies had shown that it is the ideal walking distance for the pedestrians from the adjoining land use to the transit station.

Each enumerator was given a GIS MapInfo land use map to check and verify the type of land use within a radius of one kilometre from each transit station. The google map application tool on each enumerator's mobile phone was used to identify and guide the enumerator's current location as they started to stroll along the roads and pathways to check and verify the existing land use by GIS MapInfo land use maps.

The enumerators had spent about 4 months completing the land use survey involving all 48 transit stations of two LRT lines. Population density data representing land use density was collected from GIS MapInfo prepared by the City Hall of Kuala Lumpur (DBKL). Three major land uses, namely residential, commercial and institutional were chosen to measure the land use diversity index in and around each transit station. The three types of land use were chosen based on the suggestions made by Colonna et al. (2012), Comer and Greene (2015) and Ozbil (2009) claiming that these three types of land use are the main land uses that are responsible and contribute to passenger ridership.

Passenger ridership at a transit station is the number of transit users boarding or alighting at that station over a period of time. The time period could be daily, weekly, monthly or yearly. In this study, the monthly passenger ridership data was collected from the local transit operator as it is the only data available by them. The passenger ridership data at each transit station of two LRT lines was collected for a period of three months.

3.2. Data Analysis

The data collected was analysed by using different analysis methods. Population density was measured in persons per hectare (pph) as stated in the previous literature (Jun et al., 2015, Kupke, et al., 2012, Rodriguez et al., 2009, Gori et al., 2012 and Tong & Wong 1997). Population density was calculated by multiplying number of residential units with the standard household size and divided by the total residential land use size. The standard household size was 4 in Kuala Lumpur (Standard and Guidelines of Plan Malaysia). The land use diversity index (LUDI) was calculated by using the following expression (Hunter and Gaston, 1988):

$$LUDI = 1 - \frac{1}{N(N-1)} \sum_{j=1}^{s} n_j(n_j - 1)$$

Where LUDI = land use diversity index; N = total size of the selected land use; s = number of the selected land use types; nj = land use size that belongs to the type of land use "j".

The land use diversity index ranges between 0 and 1 where '1" indicates maximum possible land use diversity and "0" indicates no land use diversity. Due to unavailability of daily passenger ridership data, the three-month passenger ridership data obtained from the local LRT operator was converted into average daily passenger ridership by dividing the total three-month passenger ridership by the total number of days. The land use within one-km radius from each transit station along both Ampang and Kelana Jaya LRT lines was related with passenger ridership to ascertain the pattern and trend of its relationship. Similarly, land use density within one-km radius from each transit station was related with passenger ridership along both LRT lines. The relationship between land use diversity within one-km radius from each transit station and passenger ridership was also determined and analysed.

4. Results & Discussion

The results of the analysis of land use characteristics, passenger ridership and relationship between land use characteristics and passenger ridership are discussed in this section.

4.1. Land use characteristics at urban rail stations

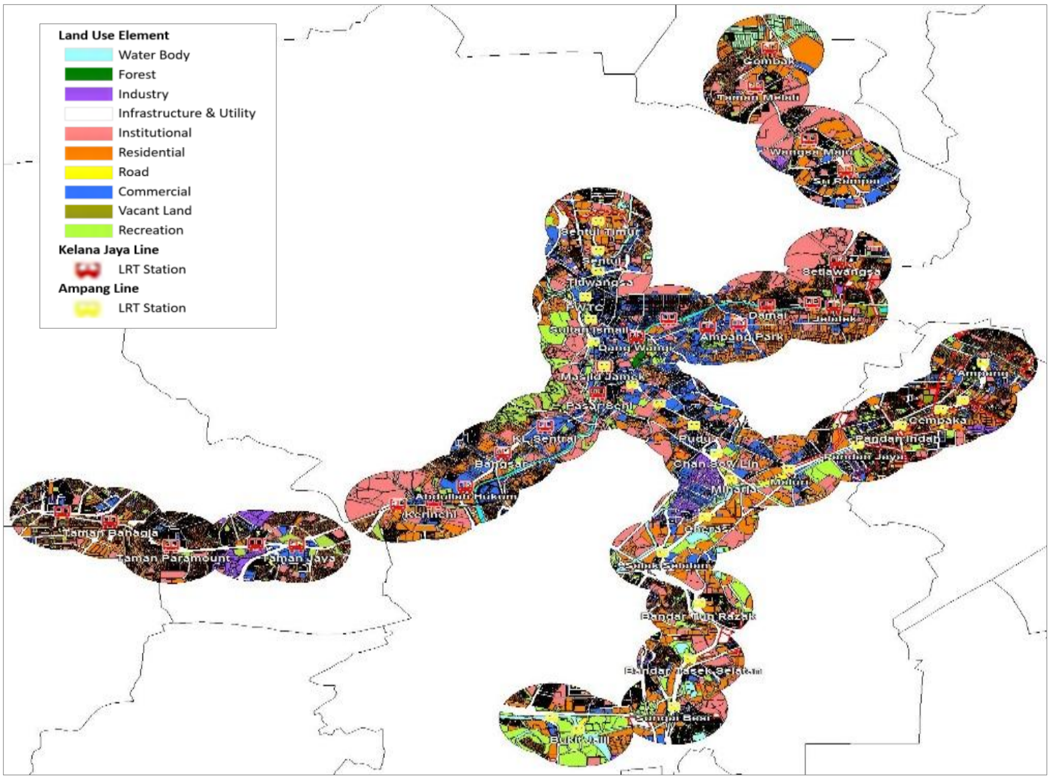
The Kelana Jaya and Ampang LRT line were the selected urban rail lines in this study. The land use characteristics and their distributions within one-kilometre radius from each LRT station along each of these two selected LRT lines were analysed. These two LRT lines are interconnected at Masjid Jamek interchange rail station at the central area of Kuala Lumpur.

4.1.1. Land use type and distribution around the transit station

A detailed analysis on the type of land use and distribution of land use within one-kilometre radius from each transit station along the Kelana Jaya and Ampang LRT line was conducted.

Each LRT line was represented by a total of 24 transit stations constituting a combined total of 48 LRT stations along both LRT lines. Figure 2 shows the distribution of land uses at each LRT station along both LRT lines. Unsurprisingly, commercial land use is the major land use type that was found surrounding the LRT stations located at the central area of Kuala Lumpur. It is followed by institutional land use, which was also widely distributed at the central area of Kuala Lumpur. These two land uses are the main trip generators contributing towards passenger ridership. On the other hand, the land uses surrounding the LRT stations that were located away from the central area of Kuala Lumpur are mostly residential land use followed by recreational land use. The major land use surrounding the transit stations along the Kelana Jaya LRT line were residential (29.09%), followed by road (25.54%), institutional (17.47%) and commercial (15.95%) whereas along the Ampang LRT line, road (29.76%), followed by residential (23.02%), commercial (15.02%) and institutional (12.80%).

Figure 2. Land use at LRT stations along Kelana Jaya and Ampang line



Source: Primary Survey and Analysis, 2015.

4.1.2. Land use density

The land use density at each transit station along the Kelana Jaya LRT line was determined. The findings show that many transit stations (16 stations) were in the category of "high density". The land use density of only two transit stations namely "Dang Wangi" and "Kampung Bharu" stations were found to be "very high density" and the remaining stations were "medium density". Similarly, the land use density at each transit station along the Ampang LRT line was also determined. Only one station namely "Bandaraya" station is categorised as "medium land use density". Other stations (23) are categorised as either "high land use density" or "very high land use density". Only "Titiwangsa" station is categorised as "very high land use density". This shows that the land use density around the transit stations along the Ampang LRT line are generally higher than that of Kelana Jaya LRT line. The findings also show that most of the transit stations along both LRT lines were categorised as "high density" and "very high density".

4.1.3. Land use diversity

The land use diversity index adopted by Ritsema van Eck and Koomen (2008) was used in classifying the land use diversity index at each transit station along both LRT lines. A land use diversity index below 0.5 is considered as low, 0.5- 0.74 as medium, and 0.75 and above as high. By using this classification, the land use diversity index at each transit station along Kelana Jaya LRT line was determined. A total of nine transit stations were in the category of "low land use diversity index" and the remaining 15 transit stations were "medium land use diversity index". No transit station is categorised as high land use diversity index. The land use diversity index at each transit station along the Ampang LRT line was also determined. Similar to the Kelana Jaya LRT line, it was found that none of the transit station along the Ampang LRT line is categorized as high land use diversity index.

A total of seven transit stations was found to be in the category of "low land use diversity index" and the remaining 18 LRT stations in the category of "medium land use diversity index".

4.2. Passenger ridership at the selected LRT Lines

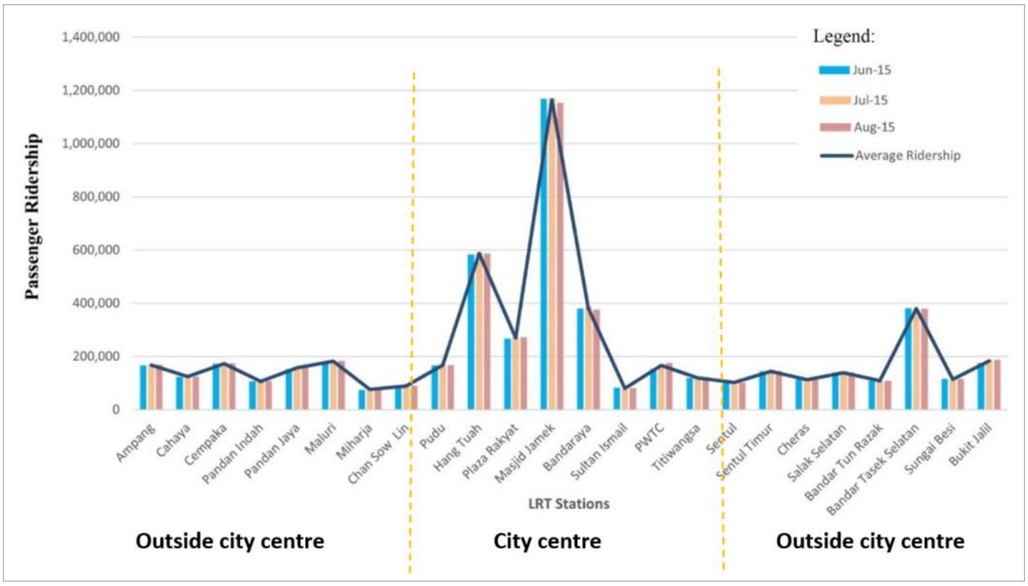
The passenger ridership data is important to gauge both the ridership pattern at each transit station of the two selected LRT lines and to ascertain its relationship with land use characteristics. The passenger ridership at each transit station was collected from the local transit operator namely Prasarana.

- *Ampang line*

Figure 3 shows the monthly passenger ridership trend of Ampang LRT line and the average passenger ridership over three months' period. Figure 3 shows the average daily passenger ridership of transit station along Ampang LRT line that falls between high, medium and low ridership. The findings show that the Masjid Jamek station, located in the central area of Kuala Lumpur, has a very high passenger ridership (21.56%) as compared to other transit stations. Hang Tuah station, another transit station located in the central area of Kuala Lumpur has the second highest passenger ridership (10.88%).

Five transit stations namely Masjid Jamek, Hang Tuah, Bandaraya, Bandar Tasek Selatan and Plaza Rakyat stations were combinedly accommodating about 52% of the total average number of passengers along the Ampang LRT line. It clearly demonstrates that the five transit stations which are located at the central area of Kuala Lumpur carries close to 50% of the total number of passengers from all 24 transit stations.

Figure 3. Passenger ridership trend along Ampang line by station

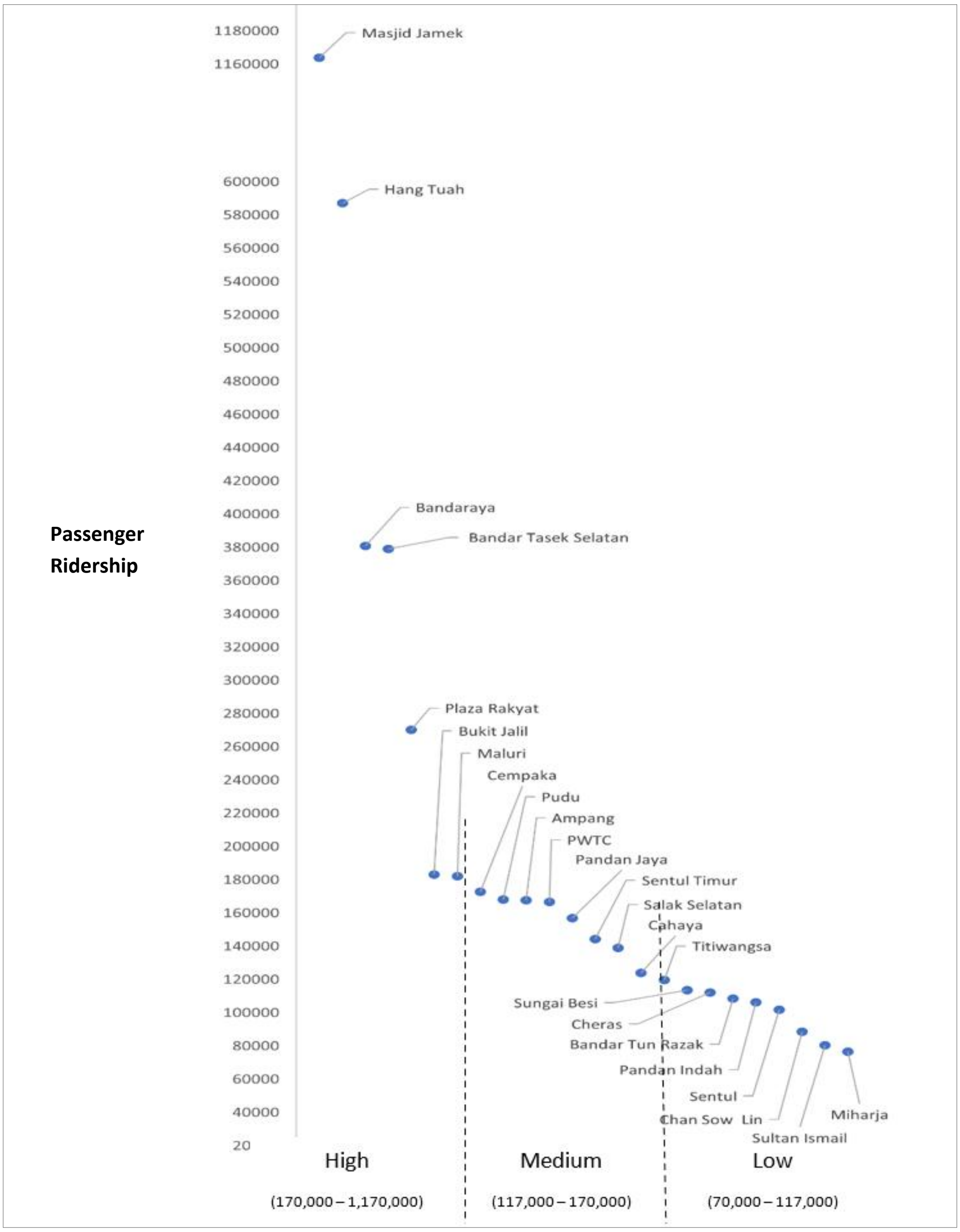


Source: Prasarana Passenger Ridership Database 2015.

Figure 4 also depicts that closer the transit station to the central area of Kuala Lumpur, higher the number of passengers who had used these transit stations. On the profile of the transit users, 58% were female and 42% male, 64% were ethnic Malays, 19% ethnic Chinese and 11% ethnic Indian. Most of the transit users (55%) were 18-24 years old.

About 64% of the transit users belong to less than RM1000 (USD200) monthly income bracket. About 72% of the transit users were having no private vehicles. About 20% of the transit users were involved in education trips, 17% work trips, and 11% shopping trips. Most of the transit users were using this LRT line daily especially for work and educational trips.

Figure 4. Range of average daily passenger ridership along Ampang LRT line



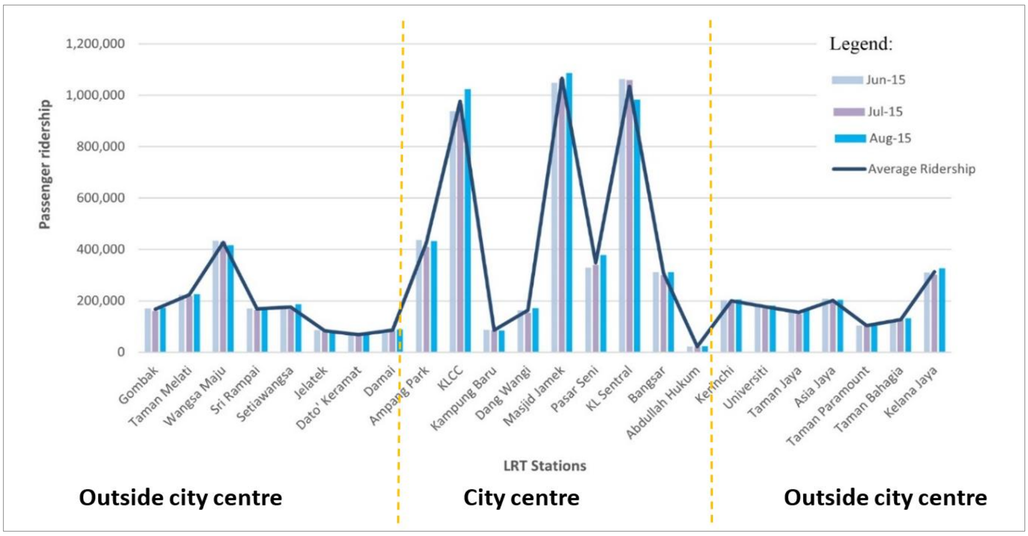
Source: Prasarana Passenger Ridership Database 2015.

- *Kelana Jaya line*

Figure 5 shows the monthly passenger ridership trend of Kelana Jaya LRT line and the average passenger ridership over three months' period. Figure 6 shows the average daily passenger ridership of transit station along Kelana Jaya LRT line that falls between high, medium and low ridership. The findings show that the Masjid Jamek (15%), KL Sentral (14.56%) and KLCC (13.73%) stations were recorded the highest average daily passenger ridership. Masjid Jamek and KL Sentral stations are the interchange stations located in the central area of Kuala Lumpur. On the other hand, KLCC station which is not an interchange station but recorded a very high passenger ridership. This is due to the location of many high-rise commercial office buildings and shopping complexes near to this station. Like the Ampang LRT line, the passenger ridership along Kelana Jaya LRT line shows that the transit stations located near to the central area of Kuala Lumpur were recorded higher passenger ridership than the stations located away from the central area. On the profile of the transit users, 57% were female and 43% male, 55% ethnic Malays, 27% ethnic Chinese and 17% ethnic Indians. About 35% of the transit users were 18-24 years old. About 28% of the transit users belong to less than RM1000 (USD200) monthly income bracket. About 62% of the transit users were having no private vehicles. About 44% of the transit users were involved in work trips, 11% shopping trips and

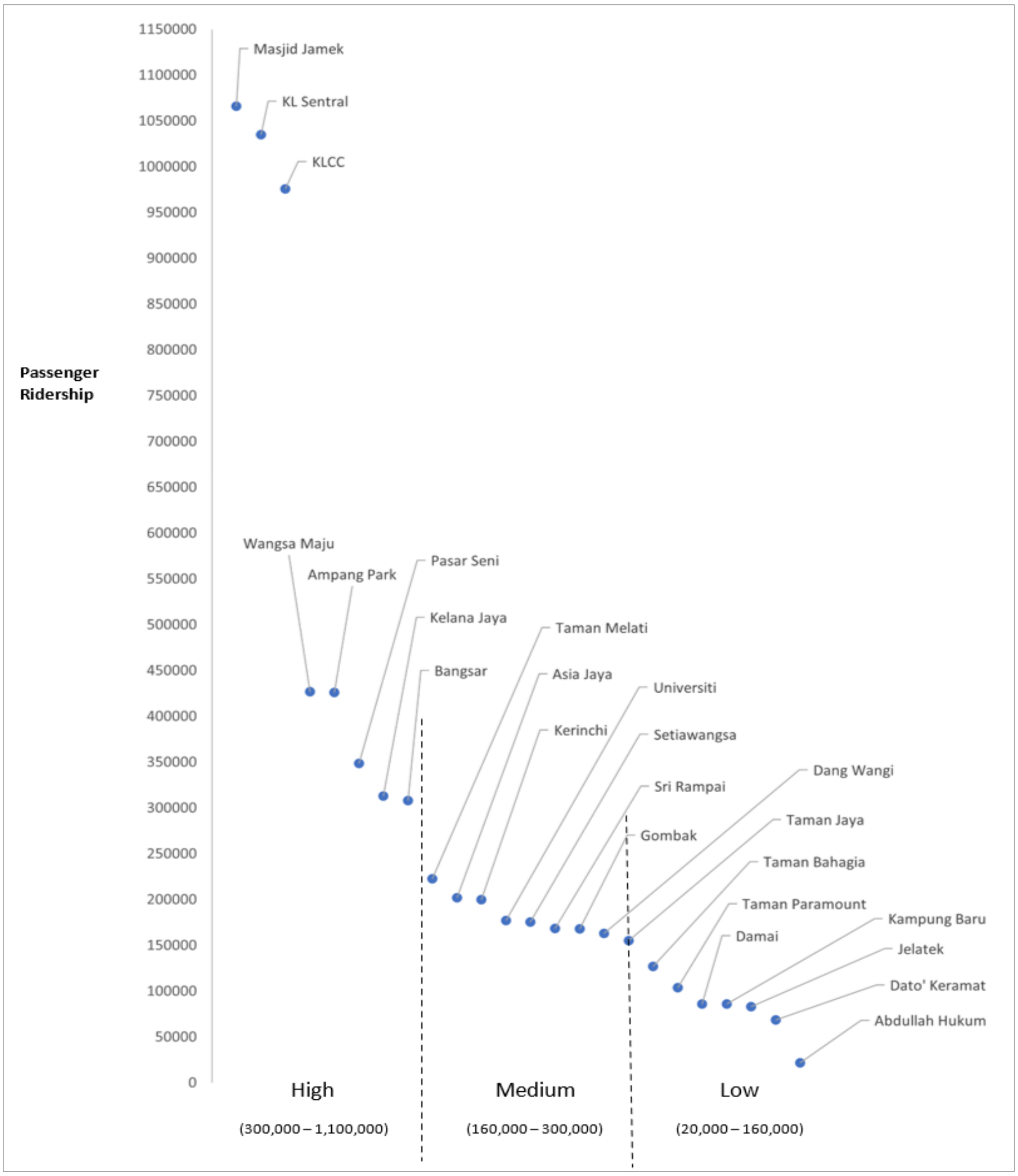
10% education trips. Most of the transit users were using this LRT line daily especially for work and educational trips.

Figure 5. Passenger ridership trend along Kelana Jaya LRT line by station



Source: Prasarana Passenger Ridership Database 2015.

Figure 6. Range of average daily passenger ridership along Kelana Jaya line



Source: Prasarana Passenger Ridership Database 2015.

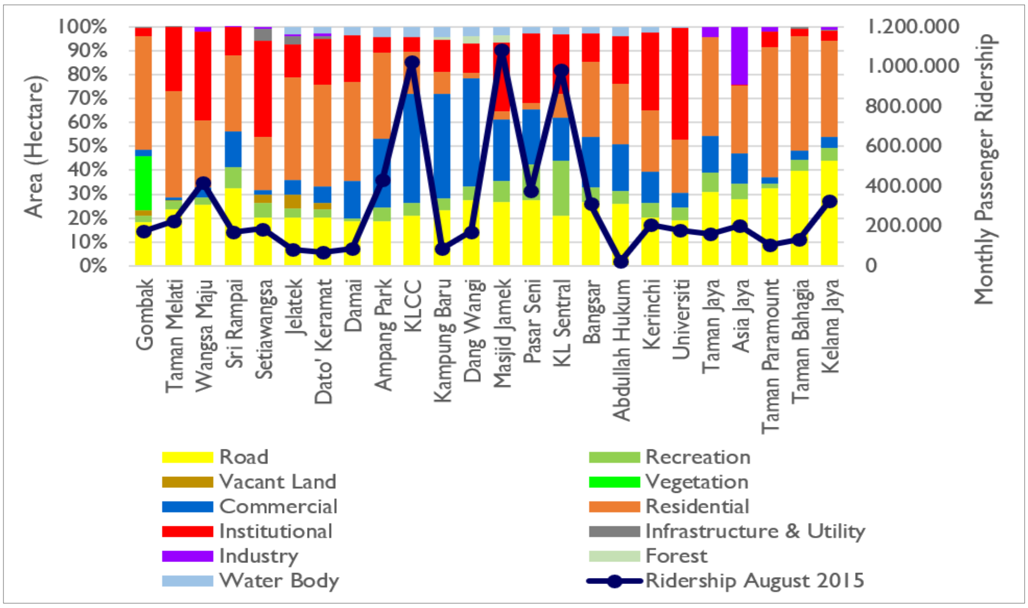
4.3. Relationship between Land Use Characteristics and Passenger Ridership

The relationships between land use characteristics and passenger ridership along both Kelana Jaya and Ampang LRT lines were evaluated and discussed in this section.

4.3.1. Relationship between land use types and passenger ridership

Figure 7 shows the relationship between land use types and passenger ridership at each transit station along Kelana Jaya LRT line. The commercial, residential and institutional are the three land uses which were predominant along the Kelana Jaya LRT line. Generally speaking, the transit stations surrounded with high commercial activities such as KLCC, Masjid Jamek and KL Sentral had a very high passenger ridership. The commercial core, institutional and residential areas have clear morning and evening peaks in terms of number of boarding and alighting passengers indicating a significant commuting activity in both directions (Merkebe et al., 2022). Evidently, many high-rise office buildings, major shopping malls, internationally renowned hotels, and retail shopping districts were located near to these transit stations. The location of large-scale commercial activities near to these transit stations has evidently attracted to use this LRT line and thus recorded a very high passenger ridership at these transit stations. On the other hand, the Kampung Bharu and Dang Wangi transit station, though has large-scale commercial activities near to these stations has recorded a low passenger ridership. Unlike KLCC, Masjid Jamek and KL Sentral transit stations, it was found that the Kampung Bharu station was located at an inaccessible location and less conspicuous area whereas Dang Wangi station was located near to the KLCC station where most of the LRT users were unsurprisingly attracted to KLCC station rather than Dang Wangi station. Moreover, KLCC station has underground pedestrian connections to the surrounding shopping complexes and office buildings which additionally makes this station more attractive for passengers who use LRT line. Figure 6 also shows that Jelatek, Dato' Keramat and Damai transit station were recorded a low passenger ridership along the Kelana Jaya LRT line. The predominant land uses surrounding these three stations were found to be residential land use.

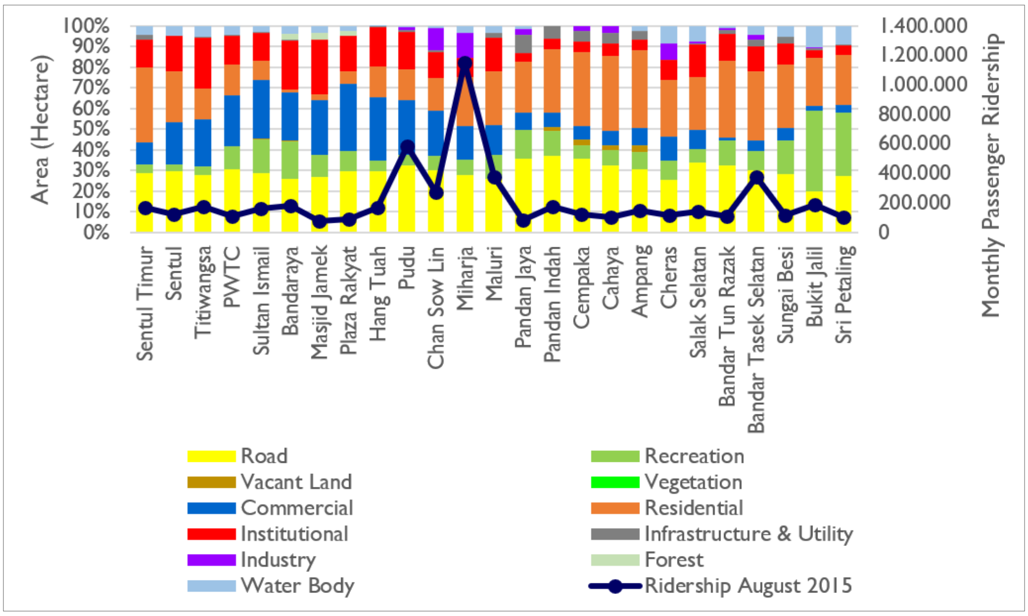
Figure 7. Relationship between land use types and passenger ridership along the Kelana Jaya LRT line



Source: GIS MapInfo Kuala Lumpur 2010 and Prasarana 2015.

Figure 8 shows the relationship between land use types and passenger ridership at each LRT station along the Ampang line. This chart shows that the Miharja LRT station has the highest passenger ridership followed by Pudu LRT station and Bandar Tasik Selatan LRT station. Bandar Tasik Selatan is an interchange station. The highest passenger ridership at Miharja LRT station was contributed to the presence of mega shopping mall located less than 500 meters from this LRT station. It demonstrates again that big commercial activities such as shopping malls would eventually attract users to use rail-based public transport system to visit the mall when located close to the mall. Pudu LRT station is located in the central area of Kuala Lumpur, and it is surrounded by large-scale commercial areas. On the other hand, Bandar Tasik Selatan LRT station is located in an integrated transport terminal complex which undoubtedly attracts a high passenger ridership. Other LRT stations along this line have recorded a low passenger ridership which is below 300,000 monthly.

Figure 8. Relationship between land use types and passenger ridership along the Ampang LRT line

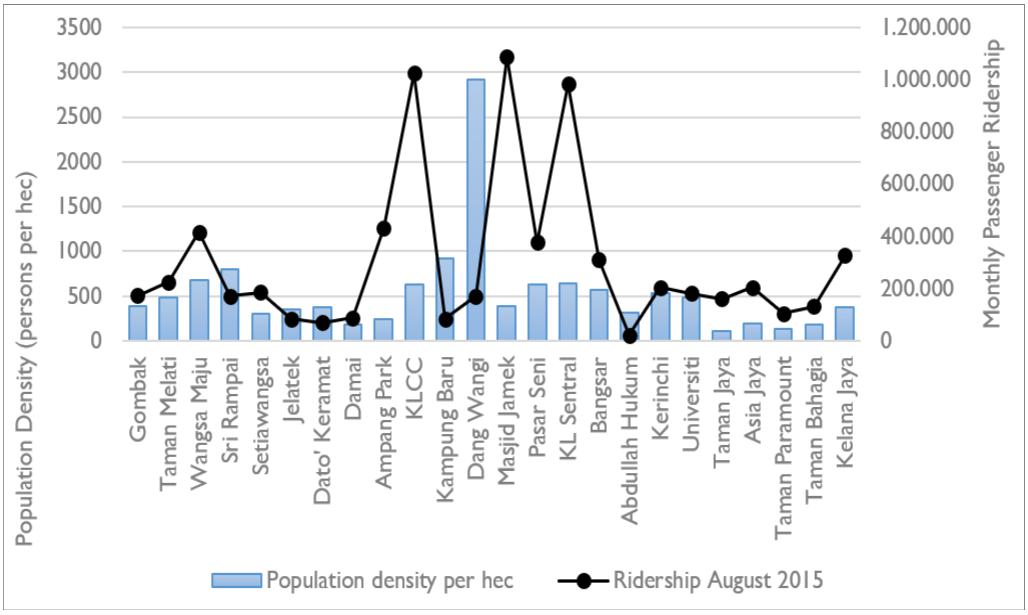


Source: GIS MapInfo Kuala Lumpur 2010 and Prasarana 2015.

4.3.2 Relationship between land use density and passenger ridership

Figure 9 shows the relationship between land use density and passenger ridership along the Kelana Jaya LRT line. There is no clear relationship between land use density and passenger ridership along this LRT line. The findings from this chart show that the low land use density is parallel with passenger ridership except for the LRT stations located in the Kuala Lumpur central areas such as Ampang Park, KLCC, Masjid Jamek, Pasar Seni and KL Sentral. It also shows that although Dang Wangi station has a high land use density (more than 2500 pph), but it has recorded a low passenger ridership. KL Tower, Sunway Tower, Concorde Hotel and other high-rise buildings are located within one kilometer radius from this LRT station. Though these buildings have contributed towards high land use density around this LRT station, however, the absence of pedestrian infrastructures and direct access to these buildings has attributed to low passenger ridership at this LRT station. On the other hand, the transit station with relatively high land use density such as Wangsa Maju, Setiawangsa, Kerinchi, Asia Jaya and Kelana Jaya station had contributed towards increase in passenger ridership as compared to other transit stations.

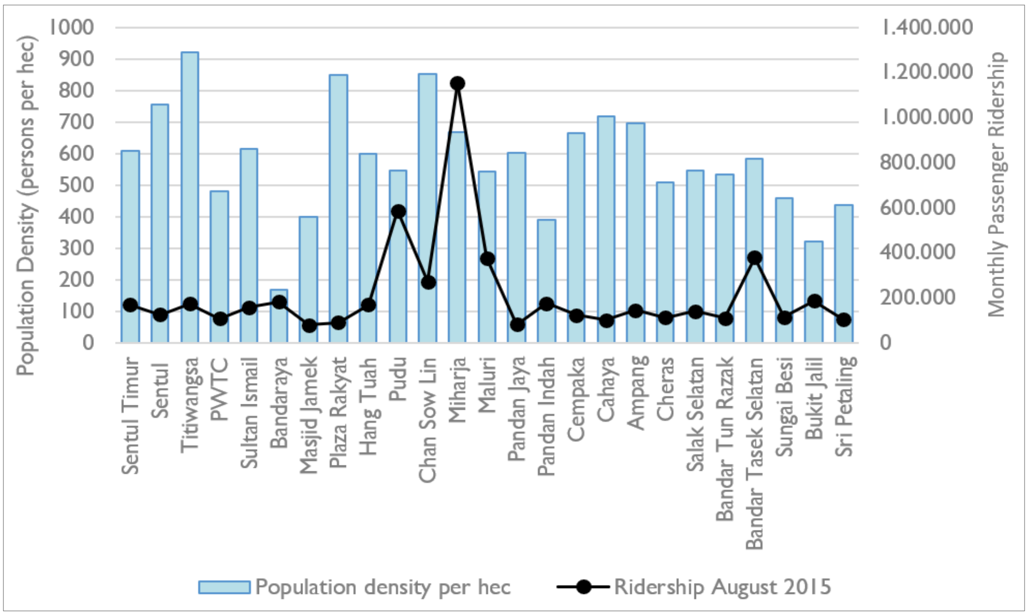
Figure 9. Relationship between land use density and passenger ridership along the Kelana Jaya LRT line



Source: GIS MapInfo Kuala Lumpur 2010 and Prasarana 2015.

Figure 10 shows the relationship between land use density and passenger ridership along the Ampang LRT line. Similar to the Kelana Jaya LRT line, the findings show that there is no obvious relationship between land use density and passenger ridership along the Ampang LRT line. Generally, the LRT stations such as Pudu, Miharja, Chan Sow Lin which are located at the central area were surrounded with high-rise office buildings and attracted a high passenger ridership. Some of the transit stations surrounded with high density residential land use such as Titiwangsa, Sentul, Pandah Indah, Bukit Jalil were attracted with an increase in passenger ridership. Density is one of the prominent variables for TOD planning in Dhaka, Bangladesh (Haque, 2025). Nonetheless, the evidence showing medium to high land use density development would lead to medium to high passenger ridership is inconclusive in this study.

Figure 10. Relationship between land use density and passenger ridership along the Ampang LRT line

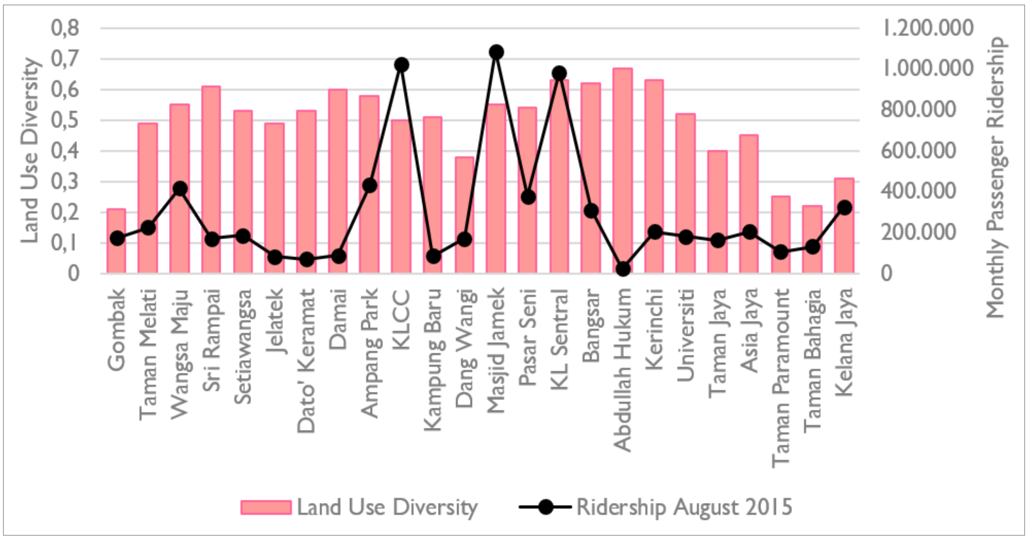


Source: GIS MapInfo Kuala Lumpur 2010 and Prasarana 2015.

4.3.3 Relationship between land use diversity and passenger ridership

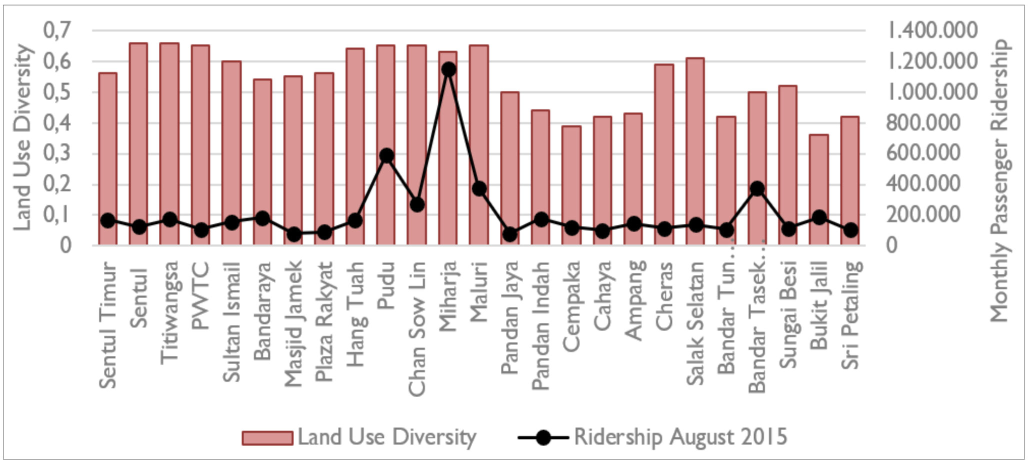
Figure 11 and Figure 12 show the relationship between land use diversity and passenger ridership along the Kelana Jaya and Ampang LRT line respectively. The findings from these two charts show that there is no apparent relationship between land use diversity and passenger ridership along both LRT lines. Other studies have shown that higher the land use diversity, higher the passenger ridership. A high land use mix at the transit station supports higher off-peak ridership and provides access to a wide range of activities and uses (Merkebe et al., 2022). However, this cannot be verified from the findings of this study.

Figure 11. Relationship between land use diversity and passenger ridership along the Kelana Jaya LRT line



Source: GIS MapInfo Kuala Lumpur 2010 and Prasarana 2015.

Figure 12. Relationship between land use diversity and passenger ridership along the Ampang LRT line



Source: GIS MapInfo Kuala Lumpur 2010 and Prasarana 2015.

4.4. Examining the effects of factors on the passenger ridership of Kelana Jaya and Ampang LRT line by using multiple linear regression model

The effects of land use and other factors on passenger ridership of the two selected LRT lines by multiple linear regression (MLR) model were examined in this section. This model was chosen because of the linear relationship that each independent variable has shown with dependent variable when analysed separately. A total of 29 exploratory variables related to land use characteristics, pedestrian infrastructure design and LRT station characteristics were used in the model. Based on Krieger (2018) & Osborne & Waters (2002), linear regression assumptions, violated variables and finalized exploratory variables are shown in Table 1.

Table 1. Assumptions of linear regression; violated variables and finalised independent variables

Assumptions of linear regression; violated variables			
No.	Normality	Skewness	Kurtosis
1.	*"total number of parking bays"*	3.715	14.337
2.	*"number of OKU parking bays"*	4.714	21.615
3.	*"number of female-only parking bays"*	4.863	23.018
4.	*"availability of parking bays provided by others"*	3.732	12.449
5.	*"interchange to KTM"*	3.732	12.449
6.	*"interchange to ERL"*	4.737	21.323
7.	*"interchange to monorail"*	3.732	12.449
8.	*"interchange to MRT"*	4.737	21.323
9.	*"interchange to the intercity bus station"*	6.928	48.000
10.	*"industrial"*	3.269	11.078
11.	*"open spaces and recreational"*	2.466	8.969
12.	*"population density per hectare in a one-kilometre radius"*	4.288	24.922
	Linearity; Residual scatterplot	-	
	Multicollinearity	-	
	Homoscedasticity	-	
	Independent; Durbin-Watson test	>1.5, 2.309, <2.5	

Table 1. Assumptions of linear regression; violated variables and finalised independent variables (continuation)

Finalised independent variables		
No.	**Variables**	**Category**
1.	*“walkway width of 1.5 metres or more”*	Pedestrian infrastructure designs (PID)
2.	*“at least one walkway stretches for more than a 200-metre radius of the rail station”*	
3.	*“at least one walkway has direct connectivity to a building”*	
4.	*“at least one walkway has links to a crosswalk”*	
5.	*“fully roof/shade walkways”*	
6.	*“the availability of a park-and-ride facility”*	Station characteristics
7.	*“existence of an interchange to other modes of public transport”*	
8.	*“number of interchanges to other modes of public transport”*	
9.	*“connecting stations”*	
10.	*“bicycle rack availability”*	
11.	*“feeder bus total ridership in January to August 2017”*	
12.	*“water body”*	Land-use characteristics
13.	*“infrastructure and utility”*	
14.	*“institution and public facility”*	
15.	*“residential”*	
16.	*“commercial and services”*	
17.	*“road and transportation”*	
18.	*“Simpson’s Diversity Index”*	

Source: SPSS data, 2017.

Kline (2005) has suggested that the skewness and kurtosis's values should be between -7 to +7. Table 1 shows 12 variables were found to violate the normality test, which are: “total number of parking bays” (3.715, 14.337), “number of OKU parking bays” (4.714, 21.615), “number of female-only parking bays” (4.863, 23.018), “availability of parking bays provided by others” (3.732, 12.449), “interchange to KTM” (3.732, 12.449), “interchange to ERL” (4.737, 21.323), “interchange to monorail” (3.732, 12.449), “interchange to MRT” (4.737, 21.323), “interchange to the intercity bus station” (6.928, 48.000), “industrial” (3.269, 11.078), “open spaces and recreational” (2.466, 8.969) and “population density per hectare in one-kilometre radius” (4.288, 24.922). Because of the violation of normality test by these variables, they were removed from the MLR model.

Hox (1995), as cited in Krieger (2018) has stated that the result of a model involving relationship between the independent variables and the dependent variable is not accounted for if the model is non-linear. Kivilu (2003), Osborne and Waters (2002) and Stevens (2009), as cited in Krieger (2018) has suggested to use a residual scatterplot to figure out the linearity of a model. All variables were almost linear in trend except for the dummy coded variables. These variables are dummy coded as “0” and “1” for regression model purposes.

Therefore, no independent variables were removed from the regression model. Collinearity statistics based on values of tolerance and VIF were referred to check for multicollinearity further. It has been suggested that multicollinearity violations applies if the tolerance value is more than “1” and a VIF value is more than “10”. Table 1 shows that none of the variables had violated the test and therefore they were not deleted from the regression model.

Table 2. Final Regression Model

Category	Variable	*B*	SE	Beta Coeff.	*t*	Sig.
Constant		15.874	2.5		6.351	0
Land use characteristics	Residential	-0.09	0.027	-0.439	-3.317	0.002
	Water body	-0.093	0.140	0.045	-.664	.510
	Infrastructure and Utility	-0.131	0.136	-0.226	-.960	.342
	Institution and public facility	0.091	0.146	0.256	.624	.536
	Commercial and services	0.09	0.191	0.357	.470	.641
	Road and transportation	-0.133	0.133	-0.182	-1.001	.322
	Simpson's index of diversity	-0.141	0.153	0.114	-.923	.361
Pedestrian infrastructure designs (PID)	Walkway width 1.5 meter or more	-0.075	0.141	0.071	-.531	.598
	At least one walkway stretches more than 200-meter radial of rail station	0.176	0.138	0.294	1.275	.209
	At least one walkway has direct connectivity to building	0.063	0.134	.111	.470	.641
	At least one walkway has linked to crosswalk	-0.024	0.135	.042	-.177	.860
	Fully roof/ shade walkways	-0.08	0.134	-.111	-.596	.554
Station characteristics	The availability of park-and-ride facility	-0.133	0.150	-0.312	-.885	.381
	Existence of Interchange to other mode of public transport	0.208	0.163	0.395	1.280	.207
	Number of interchanges to other mode of public transport	0.106	0.138	0.217	.766	.448
	Connecting stations	0.111	0.160	0.322	.693	.492
	Feeder bus total ridership in January to August 2017	0.068	0.147	-0.119	.464	.645
	Bicycle rack availability	-0.08	0.156	-0.283	-.513	.611
R		.439				
R Square		.193				
Adjusted R Square		.175				

Source: SPSS data, 2017.

Osborne and Waters (2002) and Stevens (2009), as cited in Krieger (2018) has stated that the homoscedasticity indicates that the variance of errors is equal and constant at all levels of the variables. The assumption is made when the residual is randomly scattered around the horizontal line ri=0. The Normal P-P Plot and homoscedasticity scatterplots for the dependent variable "average daily ridership". The variance of errors is equal and constant at all levels of the variables. Stevens (2009), as cited in Krieger (2018) has stated that all errors were independent between the actual and the estimated scores and non-correlated. Krieger (2018) has suggested the use of Durbin-Watson test. The magnitude result should be between 1.5 and

2.5 to indicate that the variables are non- correlated. The Durbin-Watson value is >1.5, 2.309, <2.5. Therefore, the actual and estimated scores in the model have no serial correlations and they are independent. The finalised 18 variables were entered into the SPSS system to predict the dependent variable namely "average daily ridership". Table 1 shows the details of these variables. Five of the variables represent the PID: "walkway width of 1.5 metres or more", "at least one walkway stretches for more than a 200-metre radius of the rail station", "at least one walkway has direct connectivity to a building", "at least one walkway has links to a crosswalk" and "fully roof/shade walkways". Six variables represent LRT station characteristics: "the availability of a park-and-ride facility", "existence of an interchange to other modes of public transport", "number of interchanges to other modes of public transport", "connecting stations", "bicycle rack availability" and "feeder bus total ridership". Another seven variables-"water body", "infrastructure and utility", "institution and public facility", "residential", "commercial and services", "road and transportation" and "Diversity Index" represent land-use characteristics.

The 18 exploratory variables and a dependent variable were added to the regression model; only one variable namely "residential" land use was found to be significant affecting passenger ridership in the case of both Kelana Jaya and Ampang LRT line. Table 2 shows the results of the final regression model. A significant regression equation was found (F (2, 21) = 2.159, p .002 < .05), with an R value of .439 and R2 of .193. The Adjusted R square value is .175. The output shows that the "average daily ridership" was decreased to 90 people for each hectare of "residential" land use within one kilometre radius from an LRT station. "Residential" land use was a significant predictor in predicting "average daily ridership" in the case of both Kelana Jaya and Ampang LRT line. The model has explained that an increase in the non-residential area within one kilometre radius from urban rail stations could increase passenger ridership. It also can be read that other land uses, such as institutional, commercial and services, might potentially generate additional ridership to urban rail stations. It might encourage a mixture of land uses within a one-kilometre radius of the urban rail stations instead of increasing the residential area. Heidari (2015) has supported this statement, stating that TOD should consist of a mixture of residential and commercial land use as compared to only residential development to increase public transit ridership at rail stations. Ramachandran (2017) also added that horizontal residential expansion's growth is not improving public transit commuting. The study probably encourages a reduction in the residential area but proposes a higher density building with diversified land uses. However, this cannot be confirmed statistically based on the results of the regression model produced.

5. Conclusions

Transit-oriented development has been rapidly growing in many newly built mixed-use developments in many major cities in Malaysia. The promotion of this concept by the developers and approval by the local authorities has clearly shows how important it is to attract the residents who will live in these new developments to use public transport system to reduce the pressure created by private transport on many city roads and other road-related infrastructure. The overall current use of public transport stands only at 20% in Kuala Lumpur (Structure Plan of Kuala Lumpur, 2020) which is considered very low when compared with other cities in the Asean region. To promote the use of public transport in Kuala Lumpur, it is important to gauge the relationship between land use characteristics such as land use density and land use diversity and passenger ridership. It is apparently evident from studies in countries like US, Japan, Hong Kong, Taiwan and Singapore that the land use density and land use diversity around the transit stations plays an important contributing role in increasing the passenger ridership of transit system. Studies in these countries show that high land use density and land use mixes would have high passenger ridership.

The main purpose of this paper is to determine the relationship between land use density, land use diversity and passenger ridership of the two existing LRT lines in Kuala Lumpur, Malaysia. Additionally, this paper also examines the effects of land use and other factors on passenger ridership by multiple linear regression model. The land use density and diversity were measured within one KM radius from each transit station of the two selected LRT lines namely Kelana Jaya LRT line and Ampang LRT line. The findings of this study show that there is no clear relationship between land use characteristics and passenger ridership along the two LRT lines. However, some of the transit stations along both LRT lines had represented mixed findings indicating the high land use density around these transit stations show high passenger ridership and low to medium land use diversity high passenger ridership. These findings contradict to that of findings from other studies stating that the commercial core, institutional and residential areas have clear morning and evening peaks in terms of number of boarding and alighting passengers indicating a significant commuting activity in both directions (Merkebe et al., 2022). It is due to higher use of private vehicles especially for work purpose over the years as it stands at 80% of all trips made in Kuala Lumpur (Structure Plan of Kuala Lumpur, 2020). The output of the regression model shows that the "average daily ridership" was decreased to 90 people for each hectare of "residential" land use within one kilometre radius from an LRT station. "Residential" land use was a significant predictor in predicting "average daily ridership" in the case of both Kelana Jaya and Ampang LRT line. The model has explained that an increase in the non-residential use within one kilometre radius from urban rail stations could increase passenger ridership. Study showed that office workers constituted the highest number of transit passengers, followed by those working in hotels and commercial/retail and residential users. (Mohammed Ali Berawi et al., 2020). It explains that a mixture of land uses within a one-kilometre radius of the urban rail stations instead of increasing the residential land use would encourage the use of public transit system.

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Authorship

Author 1 has curated data, data analysis, investigation, project administration and writing of original draft of the manuscript; Author 2 has conceptualized, acquired fund, developed methodology, provision of resources, supervision and writing including reviewing and editing.

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