simultaneous acquisition of kinematic variables, localization and emissions data have been used. Some results relative to kinematic data analysis are presented. An aspect under investigation is the fact that nowadays cars have a strong individual behaviour in the emission production, thus driving cycles must be as more representative of real use as possible. Resulting global driving cycles built for Path A and for Path B, however, are specific of different kinematic conditions and summarizes information related to road/driver/traffic conditions more frequently experienced in real use. Following this approach, the identified global cycles could have different kinematic characteristics in terms of average speeds, length and distance traveled, idling time, running time, distributions of gear use and acceleration/deceleration. Results regarding this activity obviously are a preliminary indication but also a strong starting point for reflection on the real representation of the cycles currently used for type approval, fuel consumption and emissions evaluation. Moreover, they could be useful to both policy makers and vehicle manufacturers in developing future emission policy/technology strategies.

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Summary on the effect of density, diversity and pedestrian infrastructure on the use of rail-based urban public transport

M. F. J. Sidek, N. N. A. N. Othman, A. A. K. Hamsa, N. M. Noor & M. Ibrahim
Department of Urban and Regional Planning,
Kulliyyah of Architecture and Environmental Design,
International Islamic University Malaysia, Malaysia

Abstract

The high increase in travel demand, particularly in the urban areas requires continuous provision of new road and related infrastructure. However, provision of new road infrastructure is not always feasible due to constraints on the availability of limited resources and adverse negative impacts on the environment. Thus, public transit is one of the viable solutions that can be considered in addressing the increase in travel demand especially in urban areas. However, the patronage on public transit is not encouraging in major car-oriented cities in Malaysia including Kuala Lumpur. The rise in the private vehicle ownership, disaggregated spread of major land use activities, low public transit network coverage and limited public transit services are some of the main reasons for this trend. The aim of this paper is to synthesise and critically evaluate the effects of land use Density, Diversity and pedestrian infrastructure Design (3Ds) on rail-based urban public transport ridership from literature review. This paper analyses the existing literature on Transit-Oriented Design (TOD), its elements and characteristics as well as its successful application in few selected countries to ascertain the extent of land use characteristics effects on the use of rail-based public transit. This paper also draws attention to opportunities for further studies and its benefit for future selection of transit station.
Keywords: public transit, travel demand, land use density, land use diversity, pedestrian infrastructure design, transit-oriented design.

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1 Introduction

The purpose of this paper is to explain the effect of land use characteristics in terms of density and diversity as well as pedestrian infrastructure design on rail-based urban public transport based on literatures. First, this paper detailed the individual effect of land use density and land use diversity on rail-based urban public transport followed by pedestrian infrastructure design. As the three elements in determining the use of rail-based urban public transport are closely related to Transit-oriented Development (TOD), this paper then discuss the elements, characteristics and its applications. TOD has been introduced in the late 1980s initially to reduce dependency on automobile uses by concentrating development in high density and diversity around transit station in urban area. It gives pedestrian infrastructure design provision a priority in its concept to serve connectivity among land uses and encourages public transit ridership. This paper is concluded by summarizing the important highlights of the paper followed by setting directions for future studies.

2 Public transit and private vehicle usage in urban area: a case study of Kuala Lumpur

Travel demand may increase due to increase in the number of trip and population. In Malaysia [1] has recorded 3 million cars entering the city centre of Kuala Lumpur daily regardless of the comprehensive public transport network available. Figure 1 shows the continuous increase of private trips from 2009 to 2014 made by private vehicles each year in Greater Kuala Lumpur (GKL)/ Klang Valley (KV) with a cumulative average growth rate of 15% in six years [1]. The same report in which is a part of Government Transportation Programme initiatives prepared by PEMANDU – a government appointed authority in improving urban public transport in Malaysia, show the increase in the number of registered vehicles in GKL/ KL with a cumulative average growth rate of 3% in six years (refer to Figure 2).

As a result, the Centre Business District (CBD) of Kuala Lumpur is congested, buses travel at low speed, and obstructed traffic flow. Some of the affected major roads are Jalan Kuching, Jalan Sultan Ismail, Jalan Raja Laut, Jalan Ampang, Jalan Raja Chulan, and Jalan Tuanku Abdul Rahman [1]. The report has recorded 80.4% of trip made are generated by private trips (modal splits) as end 2015. Government through public-private partnership has invested billion of ringgit to build road infracstructure in order to cater the on-going increase of private trip. Lebuh raya Lembah Klang Utara (NKVE), Lebuh raya Persekutuan, Lebuh raya Damansara Puchong (LDP), Lebuh raya Sprint, Lebuh raya Lingkaran Tengah 2 (MRR2), Lebuh raya Pantai Baru (NPE) and Lebuh raya Shah Alan (KESAS) are some of the highways in Kuala Lumpur [2]. The government has recently realised that trip generation in future should concerntrated on rail-based public transit.

Thus, 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

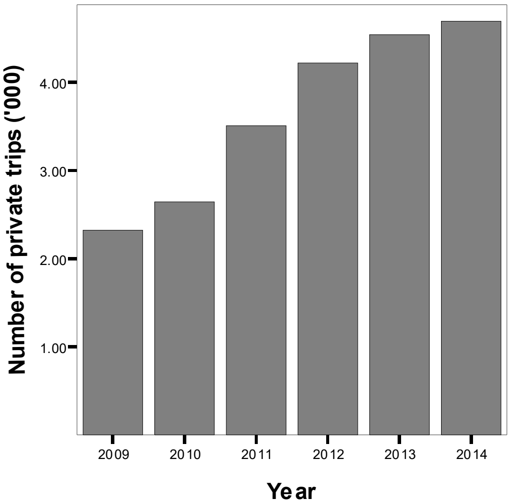

Figure 1: Private vehicle daily travel in Greater Kuala Lumpur/Klang Valley. (Source: GTP2.0 Lab analysis; JPJ, S.P.A.D., PEMANDU NKPI Survey 2011, SPAD Annual Traffic Survey.)

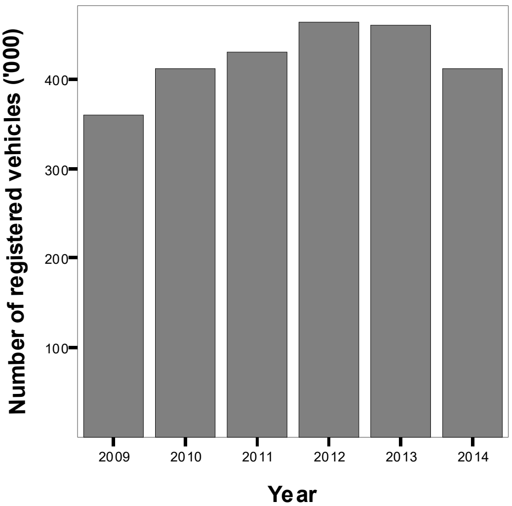

Figure 2: Number of newly registered vehicles in Greater Kuala Lumpur/Klang Valley. (Source: GTP2.0 Lab analysis; JPJ, S.P.A.D., PEMANDU NKPI Survey 2011, SPAD Annual Traffic Survey.)

indirectly increase transit modal split in urban area [1]. MRT is expected to contribute 20,000 per passenger hour per direction (pphpd) in year 2017, followed by BRT KL-Klang, 25,000 pphpd in year 2018 and LRT 3, 14,000 pphpd in year 2020. By the end of year 2020, public transit capacity in GKL/KV has a total additional capacity is 59,000pphpd, 61% increase from 2015 [1].

For example, a major highway to city centre of Kuala Lumpur MRR1 has recorded 1.2 million person trips created daily which equivalent to 765,000 vehicles daily based on 1.6 person trips per car, by 2020, an additional capacity of 59,000 pphpd of public transit service is generated by LRT3, MRT & BRT may potentially take 295,000 vehicles off the road during morning peak hour approximately 40% of current volume in MRR1.

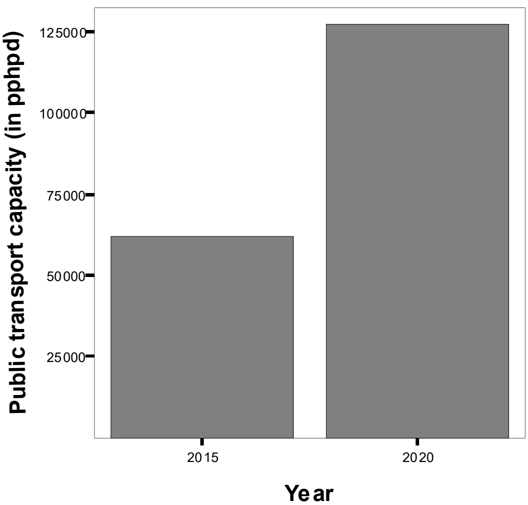

Figure 3: Public transport capacity in 2015 and 2020 (estimated). (Source: Operator data, S.P.A.D.)

3 Effect of land use density, diversity and pedestrian infrastructure design on rail-based urban public transport

Most experts agreed that high land use density surrounding urban rail-based transit station is able to increase public transit ridership [3, 4]. 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. 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 in peak hour on weekdays [5–8]. The authors apparently stated rail-based transit stations in 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 [9] idea ranging from 50,000 to 100,000 population at 40 to 200 persons per hectare.

The Canadian city of Calgary has a comprehensive initiative in replacing automobile uses to public transit as specified in Calgary Transportation Plan in which high density land uses are designed along transit line in the city particularly to solve traffic congestion [10]. Another study by [11] found that each Metrorail station along Rosslyn-Ballston corridor in Arlington county represents an urban village with medium to high density mixed uses and surrounded by low-to-moderate density neighborhoods. 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 would be [12].

Another aspect of determining transit ridership in the context of land use is diversity level. The literatures show that high diversity of land uses does encourage transit ridership and walking, reduce pollution, fuel consumption, and social segregation [3, 13–15]. 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 [4, 16, 17]. In fact, high land use diversity is a pre-requirement for Transit-oriented Development (TOD) design according to [18].

Research in southern California estimated that mixed-use suburban work settings increased transit usage by, on average, 3.5 percent relative to otherwise comparable single-use workplace [15]. However, it is quite difficult to separate the effect of land use density and land use diversity on transit ridership. A study conducted in Vermont and Ventura Corridor by Tridib Banerjee and his colleagues used Simpson's diversity index in 2000 and found that transit ridership increases as land use diversity or land use mix increases. In Asia, studies conducted in Taipei, Hong Kong and Seoul show in terms of land use diversity, it is imperceptibly correlated to rail-based transit ridership [19].

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 [3, 16, 17]. It connects residential, commercial retail, banks and shops, service transfer stations, shopping malls, sport stadiums and off-street parking to transit station and vice versa [4, 13, 20]. It provides pedestrian connectivity to transit station between 0.4 to 0.8 km radius, particularly to boost transit ridership [6]. 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 crosswalk, traffic lights, pedestrian signage, benches, lighting, landscapes and security camera are determinants of good pedestrian infrastructures [21].

4 Transit-oriented development elements, characteristics and application in determining land use effect on the use of rail-based urban public transit

Transit-oriented Development (TOD) was introduced by Peter Calthorpe in the late 1980s [22]. 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 [2, 22]. For TOD transit stations in 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 [22].

[23] In addition, refer TOD as any official legal arrangement by either public, private or both in improving physical development potential and value generated by public transit facility. High density and diversity land use development have a significant relationship to TOD. [24] claimed that TOD has comprised land use density and diversity as well as encourage walking and cycling into its concept. As time fly, TOD elements have changed to cater travel need and facilitate commuters. In 2013 Wey and Chiu suggested TOD to fulfill seven requirements; provision of open space, pedestrian and sidewalk circulation, facility, paving and landscape, traffic settings, building and environment [14].

A study conducted by [3] on TOD in New York and Hong Kong found that station characteristics looked relatively crucial than transit patronage. Since the study steered in different socio-economic context, therefore it is slightly difficult to claim a solid effect of transit patronage. Car ownership is found significant to transit patronage as car ownership encourages pick-ups, drop-offs, and park-and-ride activities. Cost (including parking charges), safety, speed and reliability of public transit are other variables influenced transit patronage. Figures 4 and 5 show the difference in railway networks for both countries. Hong Kong transit development is much concentrated to its center core whereby New York is well dispersed towards the whole city.

5 Discussion

As refer to the literature, most of the experts agreed that public transit services particularly rail-based are the best mechanism dealing with traffic congestion, high travel demand, and other related issues in an urban area. Thus, reducing dependency on automobile use and increasing transit ridership is a major goal in urban transport services. Development should focus on high density surrounding transit station in an urban area. As high land use density usually incorporated with mixed-use and diversified land uses according to most literature, development of high density and good pedestrian infrastructures at transit station is a priority in determining high transit ridership. These are basically the features of TOD. Therefore, developing high density land use equipped with pedestrian infrastructures at urban transit station is ultimately developing TOD.

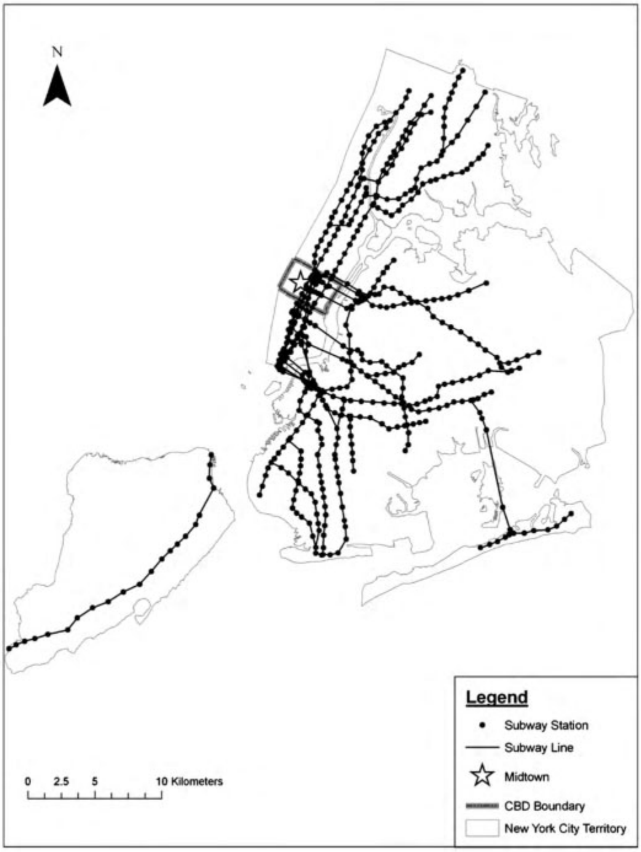

Figure 4: The railway network in New York. (Source: Loo *et al*. [3, p. 204].)

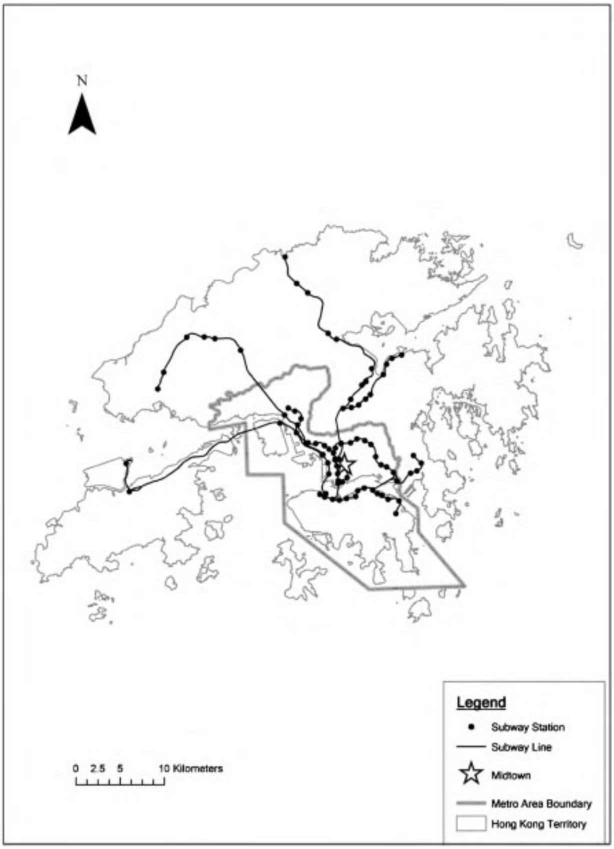

Figure 5: The railway in Hong Kong. (Source: Loo *et al*. [3, p. 204].)

6 Conclusion

Overall, the increasing travel demand should be absorbed into public transit patronage. The development of transit station in the future has to concentrate at high land use density and diversity supported by good pedestrian infrastructure as these three elements are core factors in determining transit ridership. The concept of TOD has to be inserted into transit station development as TOD has proven its role in increasing transit ridership. Perhaps, the future study on the best TOD application can be done especially in a local context in achieving the optimum volume of transit ridership.

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