

Travel Emission Profile of Iskandar Malaysia Neighbourhoods from Pre-1980s to 2000s

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Abstract. Vehicle Miles Travelled (VMT), an indicator of travel levels on the roadway system mainly by private vehicles, has been widely used in urban planning to help indicate CO₂ emission due to changes in built environment. Bordering Singapore to the south, neighbourhood development has been constantly happening in Johor Bahru since 1980's. These neighbourhood developments are believed to have undergone a continuous layout design evolution affecting its land use distribution, road network design, and density. Thus, this paper investigates the quiet influence of neighbourhood design, as it evolves over the decades on VMT and eventually travel carbon emission. Twenty two residential neighbourhoods representing several decades from pre-1980s to the 2010s were selected and travel diaries of their randomly selected households were recorded. Findings from this study reveal that travel carbon emission for pre-1980s residential areas is only 8.7 kilograms/household/day with a daily travel range of 40 km/day. However, the amount increases up to 21.8 kilograms/household/day for 2010s houses with daily travel range of 100 km/day. Car usage among residents in Iskandar Malaysia is undoubtedly increasing as car ownership proportion increases from 0.8 in pre-1980s to 2.37 in 2010s. Number and distance of vehicles trip can be reduced by organizing activities in compact communities rather than in auto dependent suburbs. In addition, a carbon emission reduction of up to 10 percent may result from a change in land use approach alone while additional reductions will result from employing other strategies such as transit investment, fuel pricing, and parking charges.

1. Introduction

Road transport is one of the largest contributors to emissions of greenhouse gases (GHGs) [1]. In promoting greener lifestyle, neighbourhoods have been targeted for CO₂ emission reduction and this is true for neighbourhoods in Iskandar Malaysia (IM) too. Neighbourhood development in IM has always been reasonably active since 1960s and this is especially so when the Iskandar Malaysia Economic Region was announced back in 2007. Over the decades the steady growth in neighbourhood development brings with it the inevitable changes in the layout and physical design of a typical neighbourhood. Kassim [2] in her study, found that mixed-use neighbourhood as a type of development has been on the decrease over the decades. Proximity between houses to commercial center and the connectivity indexes of neighbourhoods are on the decrease too [3][4]. These changes

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in built environment encourage more automobile use by residents. Thus, higher Vehicle Miles travelled (VMT) and higher CO₂ emissions are generated. Studies found that changes in built environment's "Ds" factors can reduce VMT and CO₂ emission. The first "three Ds" are density, diversity and design [5]. Another two "Ds" are destination accessibility and distance to transit [6][7].

Therefore, the objective of this study is to see how travel carbon emissions in IM neighbourhoods as estimated from their VMTs differ with different designs of each particular neighbourhood. The different designs are described in terms of quantifiable characteristics including diversity index, connectivity index, proximity index, density index and intersection density of the neighbourhood according to the year each neighbourhood was established (from pre 1980s to 2000).

2. The Ds Factors as Measure of Built Environment

In travel research, the built environment to help moderate travel is known as the Ds factor. The original "three Ds," introduced by Cervero and Kockelman [5], are density, diversity, and design, followed later by destination accessibility and distance to transit [6][7]. Besides that, a few studies also include Demand management, which includes parking supply and cost, as a sixth D. Apart from that, demography is the seventh D that is not included as one of the built environment factors but controlled as confounding influences in travel studies.

2.1 Density

Density is measured as the variable of interest per unit of area. The area can be gross or net, and the variable of interest can be population, dwelling units, or building floor area. High densities neighbourhoods help create walkable neighbourhoods as the origin and destination distance is getting close with one another.

2.2 Diversity

Diversity is the functional variety of land use [8]. The practice of mixed land use allows for integration of commercial businesses and residential areas [9]. Cervero notes that mixed-use development is those with a variety of offices, shops, restaurants, and other activities intermingled among one another [10].

2.3 Design

Design includes street network characteristics within an area, varies from dense urban grids of highly interconnected streets to sparse suburban networks of curving streets forming loops and lollipops.

2.4 Destination Accessibility

Destination accessibility measures ease of access to trip attractions. It may be regional or local [11]. It is closely related to the number of jobs or other attractions reachable within a given travel time, which tends to be highest at central locations and lowest at peripheral ones. Accessibility refers to the proximity and density of goods and services available to residents via transportation networks.

3. Carbon Emissions and Built Environment

There is a significant impact of land-use patterns on energy and GHGs. Ewing *et al.* [7] in their travel study found that typically residents of compact neighbourhoods travel 20% to 40% lower compared to residents of sprawl neighbourhoods. The Growing Cooler study by Ewing *et al.* estimated that changes in land-use patterns to focus most new development into compact, walkable, transit-accessible communities could reduce total USA's transportation GHG by 7% to 10% from forecast levels by 2050, or urban VMT by 12% to 18% [12].

Polzin and Chu [13] from the Center for Urban Transportation Research (CUTR) in their VMT forecasting model, based on the 2001 National Household Travel Survey (NHTS) suggests that households in the highest-density neighbourhoods (over 10,000 ppsm) produce less than half the

annual CO₂ emissions produced by households in the lowest-density neighbourhoods (under 500 ppsm). This is because, high density neighbourhood lead to shorter trip lengths (destinations are closer together) and make transit more competitive as compared to automobile travel. In addition, the Transportation Research Board's (TRB) Special Report 298 found results in the same range [14]. This report estimated that the reduction in VMT, energy use, and CO₂ emissions are resulting from more compact, mixed-use development. It would be in the range of less than 1% to 11% by 2050. The estimated GHG reduction range is based on 25% to 75% of new residential development taking place at double the average density of new acres developed between 1987 and 1997. Development between 1987 and 1997 was significantly less dense than existing development [14].

4. Methodology

Twenty seven neighbourhoods located within IM were selected to participate in this study. Using ArcGIS shapefiles data and selected equations, the built environment factors comprise of the diversity, connectivity, proximity, density and intersection density index are calculated for each neighbourhood. Next, VMT data were collected by distributing travel diary and questionnaire in two methods. The first method involved distribution of travel diary and questionnaires to children of selected schools from targeted neighbourhoods, with assumption that these students come from the targeted neighbourhoods. The second method involved gathering of data by conducting a Home-to-Home household survey. In this method, the travel diary and questionnaires were given to the respondent's on day 1 and being collected on day 8, to allow them to fill out their one-week travel diary. Respondents who returned the travel diary and questionnaires were given RM5 petrol money as a token of appreciation. Finally, CO₂ emission factors for this study were calculated based on conversion factor on the average carbon content of each litre of fuel, as well as based on the emission factors of car type and fuel use per kilometer of driving. This was obtained from *The Car Fuel Use and Emission Factors: 1994 UK Petrol and Diesel Demand*, UK Transportation Research Laboratory with assumption that residents in IM own a medium-size car with speed between 40-65 mph (emission factor of 153 g/km) [15]. Below is the equation for CO₂ emission calculation used for this study:

$$\text{CO}_2 \text{ emissions (g)} = \text{emissions factor (g/km)} \times \text{vehicle kilometres (km)}$$

5. Results and Discussion

Based on travel diary of 367 respondents from 27 neighbourhoods, we can see that average household VMT increasing over the years (Figure 5.1). Lowest average VMT recorded was among the residents of Taman Tampoi (1969) with average value of 26.17 km/day. Meanwhile, the highest average VMT value recorded in this study was residents of Taman Setia Indah with an average of 106.21 km/day.

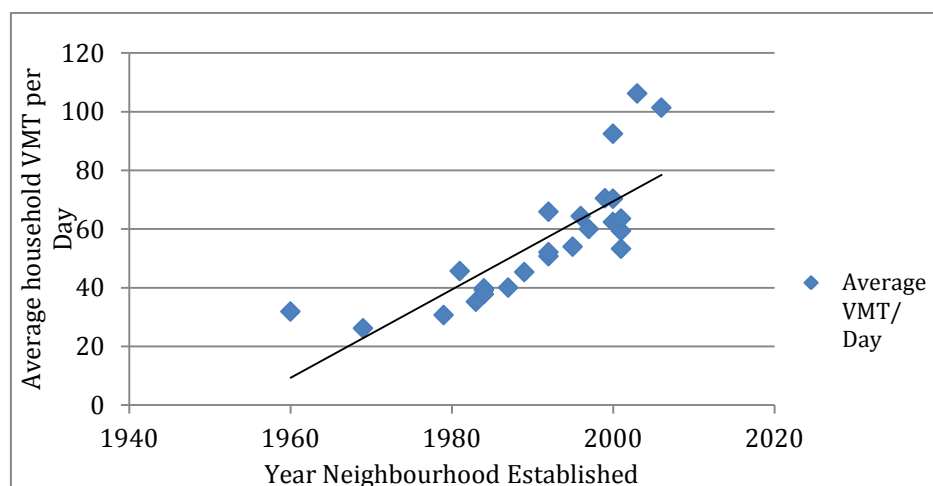


Figure 5.1: Average VMT is increasing from pre 1980s to the present time

Figure 5.2 below shows how CO₂ emissions were estimated based on average household VMT. From 1960 to 2006, there is gradual increase of CO₂ emission together with increasing in VMT. During pre-1980s, CO₂ produced was between 4-4.8 kilograms per day. The amount increased up to 6.9 kilograms per day in the 1980s and then up to 10.8 kilograms per day. The highest household CO₂ emissions by travel were by residents of Taman Setia Indah with 16.2 kilograms per day. However, even during the 2000s there are neighbourhoods that produce CO₂ emission as low as emission in the 1980s and 1990s. The amounts range from 8.1 kilograms to 15.5 kilograms.

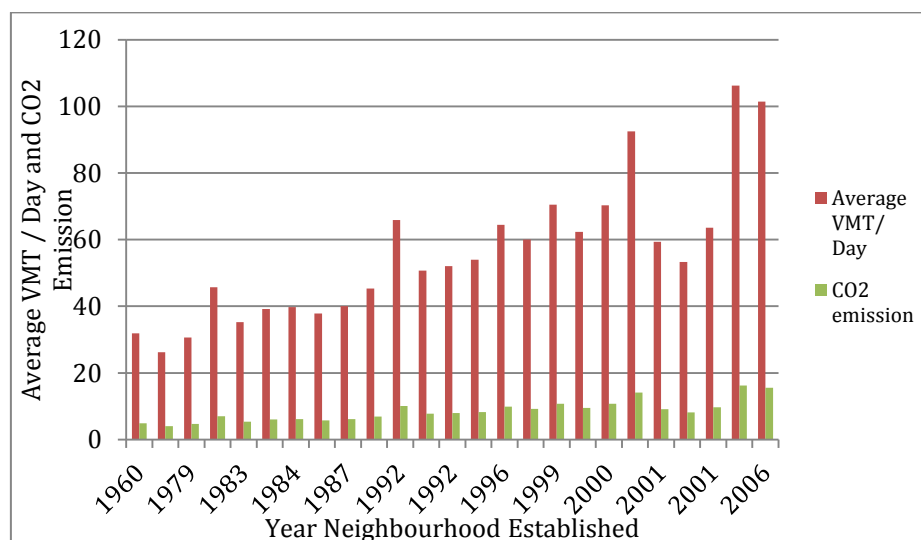


Figure 5.2. Average VMT and CO₂ emission is increasing from pre 1980s to the present time

If this trends continue, there is no doubt that the VMT and CO₂ emission will remain the same or maybe more than before (refer figure 5.3).

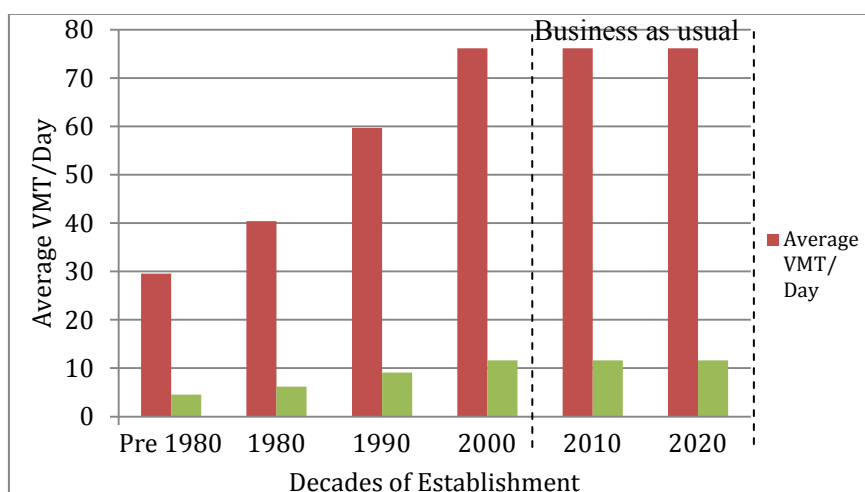


Figure 5.3. Average VMT and CO₂ emission according to decades of development

Next, a multiple regression analysis is conducted to identify which factors influence VMT the most. From Table 5.1, we can see that the R^2 value is .866. This concludes that all independent variables explain 86.6 percent of the variability of the average VMT in Iskandar Malaysia.

Table 5.1. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
dimension0 1	.930 ^a	.866	.782	9.67219

a. Predictors: (Constant), car_ownership, Housing_density, Diversity_index, Connectivity_index, household, Proximity_index, Intersection_density, Distance_to_CBD, license_ownership, income

Table 5.2 identifies three built environment factors that can influence VMT. They are housing density ($p = .027$), proximity index ($p = .000$) and diversity index ($p = .013$). The unstandardized coefficient, B, for housing density is 1.621. This means that for each percent increase in housing density, there is an increase in VMT of 1.621 kilometer per day. However, this finding is opposite with findings from previous scholars. High density neighbourhood development should encourage residents to walk along the neighbourhood since the location of houses, shops, restaurants and schools are near to each other. Proximity index and diversity index own the unstandardized coefficient, B, of -92.228 and -45.293 respectively. This means that for each percent increase in proximity and diversity, there is a decrease in VMT of 92.228 and 45.293 kilometer per day respectively. This support Sun, Wilmot and Kasturi (1998) that the proximity of residential to commercial areas determines the VMT of residents. Meanwhile, Khattak & Rodriguez (2005) stated that mixed use resulting in resident make shorter trips.

Table 5.2. Significant Table

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
1 (Constant)	104.379	19.538		5.342	.000
Distance_to_CBD	.299	.311	.115	.960	.351
Housing_density	1.621	.668	.280	2.426	.027
Proximity_index	-92.228	21.206	-.457	-4.349	.000
Diversity_index	-45.293	16.203	-.361	-2.795	.013
Connectivity_index	-9.532	13.788	-.075	-.691	.499
Intersection_density	-11.028	10.539	-.126	-1.046	.311
Income	.006	.003	.355	1.984	.065
No. of Household	3.284	2.078	.180	1.581	.134
License_Ownership	-7.536	9.315	-.123	-.809	.430
Car_Ownership	-1.917	6.409	-.035	-.299	.769

Thus, the general form of the equation to predict VMT from urban form factors is:

$$\text{VMT} = 104.379 + (1.621 \times \text{housing denisty}) - (92.228 \times \text{proximity index}) - (45.293 \times \text{diversity index}).$$

6. Conclusion

The most important finding from the study in terms of effort to minimize greenhouse gas emission is that household VMT in Iskandar Malaysia is on the increase, and CO₂ emissions too are on the increase. This can partly be attributed to the fact that neighbourhoods now are becoming less dense yet larger, less diverse in terms of land uses and increase distances between the different land uses in the area. As Iskandar Malaysia is looking into developing more and more neighbourhoods to cater for the estimated 3 million populations by 2025, the changing of neighbourhood design from compact and diverse to large and less diverse is becoming a concern. Steps need to be taken to ensure that all future neighbourhoods take into consideration the impact of its layout/physical design and land use components on travel CO₂ emissions. Using the above equation, future neighbourhoods can be developed with more sustainability aspects that produced lower VMT and CO₂ emissions. It can be achieved by improving the proximity and diversity of land uses development in neighbourhood.

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