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THE RELATIONSHIP BETWEEN URBAN POPULATION DENSITY AND TRANSPORTATION FUEL CONSUMPTION IN MALAYSIAN CITIES

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Abstract
This paper describes an exploratory study to analyze the relationship between urban population density and transportation energy consumption in the context of urban planning. Urban population density is used because it is commonly accepted as "proxy" for urban form pattern analysis in terms of degree of centralization. This paper reviews sustainable urban form, relationship between urban transportation and urban population density. Based on the secondary data, multi regression analysis on the relationship between urban population density and transportation fuel consumption on Malaysian cities are carried out. In this analysis, three main variables are explored: population density, private vehicle ownership and transportation fuel consumption. In order to understand the relationship between population density and transportation energy consumption, other selected global cities are used as benchmarks in relation to selected Malaysian cities.
Keywords: Urban Population Density, Transportation Fuel Consumption, Urban Form, Private Vehicle Ownership

INTRODUCTION

The future of our cities lies in the actions we make today. Achieving sustainable cities are crucial in the urbanization of the world. This is reflected with the increase of population in settlements known as the urban areas. In 1950, 30% of the world's population lived in urban areas. By year 2008, these figures would have dramatically risen to almost 50%. According to the United Nations *Report of the World Summit on Sustainable Development 2002*, approximately 61% of the world's projected population will be urban by the year 2030. Almost all will take place in developing

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URBAN POPULATION DENSITY PATTERN ANALYSIS

The degree of centralization among the selected cities is analyzed, using the urban population density of the metropolitan area as a parameter of comparison (person per km2). Two sub parameters are analyzed to determine the densities of population among selected cities. The greater metropolitan area is used to study the degree of *distribution* density, given the definition of each boundary area and population of the selected cities. The Inner City Centre is used to study the degree of *concentration* located within the core of the metropolitan. Table 1 shows the urban population density pattern analysis among selected cities in year 2000. The data on the urban density of metropolitan and inner city centre have to be obtained from various sources as shown in the endnote. Definitions of metropolitan and inner city centre boundary to determine the urban population density are based on the official sources of the report.

TOTAL URBAN POPULATION DENSITY OF THE GREATER METROPOLITAN AREA VERSUS INNER CITY CENTRE

Table 1 shows city island states such as Hong Kong and Singapore have the highest population density of more than 5,000 persons per sq km at metropolitan level. Georgetown city has the highest urban population density of about 4,700 persons per sq km among the Malaysian cities at metropolitan level. Most of the other selected cities are 1,000-2,500 persons per sq km at metropolitan level. However, urban population density at inner cities can be very different if compared with metropolitan level between cities.

The metropolitan area of Georgetown in Penang exhibits a higher density in comparison to other Malaysian cities within the greater metropolitan area of 4,683 persons per km2. This indicates the existence of a denser population structure beyond the population density of inner city centre (3,384 persons per km2). This would suggest the existence of an urban structure which leads towards suburbanization, as reflected by the distribution pattern of the population density.

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Table 1: Urban Population Density Patterns Analysis in Selected Cities, 2000

SELECTED CITIES	URBAN FORM PATTERNS	
	GREATER METROPOLITAN AREA	INNER CITY CENTRE
	Urban Population Density (person per km2)	Urban Population Density (person per km2)
[1,12] **Kuala Lumpur**	**1,050.62**	**5,694.69**
[2,13] **Georgetown**	**4,682.89**	**3,383.96**
[3,14] **Johor Bahru**	**2,180.05**	**3,475.83**
[4] Singapore	5,884.96	6,858.64
[5] Hong Kong (Hong Kong Island)	6,104.28	16,693.36
[6] Sydney	2,075.87	6,581.88
[7] Melbourne	1,520.19	1,982.78
[8] Adelaide	1,374.49	1,136.80
[9] New York	2,515.89	6,813.68
[10] Los Angeles	2,379.39	2,982.63
[11] San Francisco	2,130.56	1,238.62

Note: The hedged population data shows that inner city centre population density is 50% more than metropolitan population.
(Source: Adapted from various resources, 2008. Refer to endnotes on the detail of the sources)

The Metropolitan area of Kuala Lumpur indicates an otherwise reverse urban form pattern which shows a dense urban density in the inner city centre of 5,695 persons per km2 in comparison to 1,050 persons per km2. This could be explained that there is a similar pattern which exists in proportion of the employment density located in the city centre of Kuala Lumpur. Studies have shown that employment density increases with the location of the business district centre or central area of the particular city *(Chung et. al)*. This may also be the case for Kuala Lumpur. Further research could be implemented to research the pattern of employment density between greater metropolitan area and inner city centre.

Hong Kong shows the highest population density among the selected cities, both in terms of the greater metropolitan area (6,104 persons per km2) and inner city centre (16,693 persons per km2). Hong Kong Island is a highly urbanized metropolitan in comparison with Malaysian cities. This is reflected by the equal distribution of population in proportion of the urban structure of the greater metropolitan area.

While other cities in the likes of Melbourne, Adelaide and Los Angeles also indicate a constant distribution in greater metropolitan area and inner city centre, the figures also shows that Hong Kong comprise the densest of the selected cities. This suggests that Hong Kong is increasingly becoming "vertical" in both physical development and population distribution.

TRANSPORTATION ENERGY CONSUMPTION PATTERN ANALYSIS

In transportation planning, the use of private vehicles is related to the intensity of urban activities and how cities provide for its automobile and non-automobile modes *(Newman, 1989)*. Usage of private vehicles also strongly correlates with fuel use. Therefore, energy consumption of end use fuel products is essential to understand consumptions of vehicles among selected cities. Supported by two variables using private vehicle ownerships per capita and transportation fuel consumption (derived from national average population data), energy consumption patterns are studied to correlate with urban form patterns using regression analysis. Table 2 shows transportation energy consumption pattern analysis among selected cities in year 2000.

PRIVATE VEHICLE OWNERSHIP PER CAPITA

Private vehicle ownership represented in total private vehicle ownership per capita shows that Malaysian cities, comprising of Kuala Lumpur, Georgetown and Johor Bahru are among the highest among selected cities, with Georgetown being the highest figure at 2.52 vehicles per person. This is equivalent of one person having 2 private vehicles. Whereas the comparison among selected cities shows that Hong Kong indicates the lowest vehicle ownership per capita with 0.08 vehicles per person, equivalent of 12 people sharing one private vehicle (which includes automobiles and motorcycles).

TRANSPORTATION FUEL CONSUMPTION PER CAPITA

With reference to Table 2, fuel consumption of private vehicles represents the intensity of urban and human activities which takes place in the metropolitan area. The data derived from the private vehicle patterns and fuel consumption variables covers the context of the greater metropolitan area. With relation to private vehicle ownerships per capita, the measurement of fuel consumption are also supported by other transportation factors such as passenger trips, split modals by types of vehicles and trip distribution according to human activities *(Newman, 1989)*. This would justify

the complex relationship which exists between human activities and fuel consumption and thus the regression analysis to correlate between these variables.

Table 2: Transportation Energy Consumption Pattern Analysis in Selected Cities, 2000

SELECTED CITIES	TRANSPORTATION ENERGY CONSUMPTION PATTERNS		
	PRIVATE TRANSPORTATION	FUEL CONSUMPTION	
	Private Vehicle Ownership per Capita (vehicle per person)	Transportation Fuel Consumption (MJ)	Transportation Fuel Consumption per Capita (MJ per person)
Kuala Lumpur	**0.71**	**538,573,115,380**	**128,012.01**
Georgetown	**2.52**	**78,818,035,071**	**56,611.17**
Johor Bahru	**1.82**	**135,280,395,786**	**202,188.93**
Singapore	0.2	282,302,703,392	70,086.79
Hong Kong (Hong Kong Island)	0.08	131,326,388,202	11,275.59
Sydney	0.82	1,039,337,485,882	296,784.60
Melbourne	0.68	938,430,933,854	296,784.43
Adelaide	1.09	297,377,544,504	296,783.03
New York	0.38	10,394,997,890,468	527,343.69
Los Angeles	0.75	7,292,635,238,803	527,343.08
San Francisco	1.3	2,805,468,180,666	527,342.82

(Source: Newman, 1989 and Researcher's Study, 2008- based on several sources as noted in the endnotes)

Among Malaysian cities, Johor Bahru records the highest of fuel consumption per capita with 202.19 X 10^3MJ per person in comparison to Georgetown's 56.61X10^3 MJ per person. Given the comparison in terms of private vehicle ownership and usage of fuel use, the variations in the intensity of fuel consumption per capita is independent of the private vehicle ownership per capita. Despite having the highest ratios of vehicle ownership of 2.52 vehicles per person, Georgetown remains one of the lowest fuel consumers per capita among Malaysian cities, which is 56.61 X 10^3MJ.

With regards to the variations for the measurement of transportation energy consumption patterns, two main points are to support the use of the parameters. Firstly, the private vehicle ownerships are used to measure the extent of balance of automobiles between the dependency of private and public transportation. Secondly, fuel consumption allows the study of vehicle usage intensity by human activities and how it correlates with urban structure of cities. The next analysis will explore correlations between both parameters and position Malaysian cities in this relationship among selected cities.

RELATIONSHIP BETWEEN URBAN POPULATION DENSITY AND TRANSPORTATION ENERGY CONSUMPTION PATTERNS

Regression analysis between urban density (population density) patterns and transportation energy consumption patterns are compared among selected cities. The study will explore the characteristics which each city portrays using greater metropolitan area and inner city centre as the constant of the analysis. With context to Malaysian cities, the characteristics that the benchmark cities carry will then be deduced towards planning implications in Malaysia.

Based on Figure 4, the regression line shown describes the position of Kuala Lumpur, Georgetown and Johor Bahru among selected cities. Based on the range of densities portrayed by the proximities of selected cities, four distinctive clustering of cities may be identified, in correlation with the total private vehicle ownership per capita, as shown in Table 3.

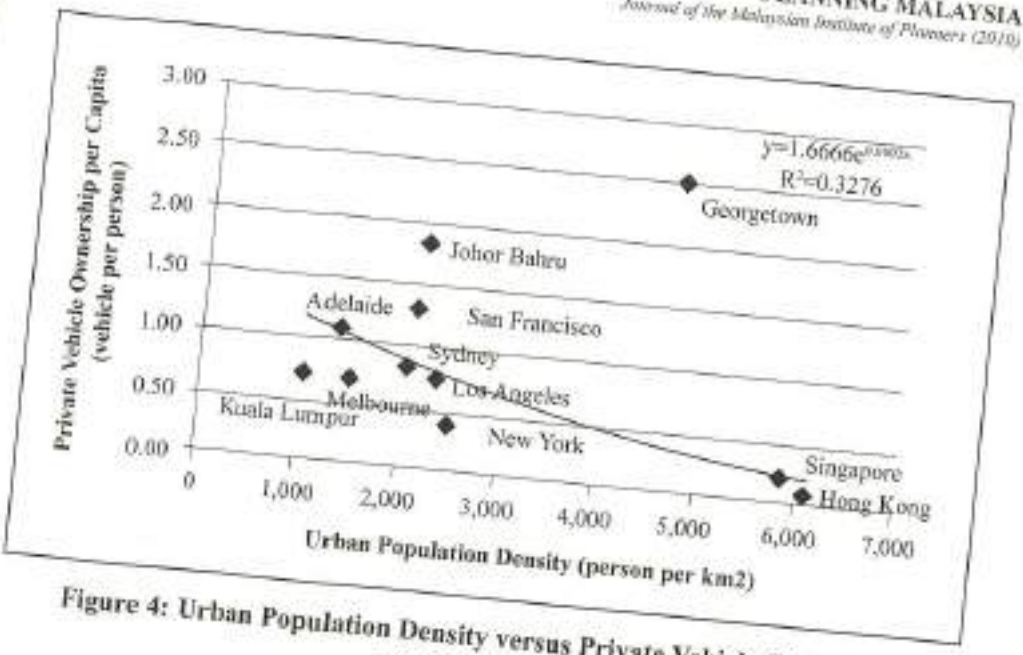

Figure 4: Urban Population Density versus Private Vehicle Ownership per Capita, 2000

(Source: Researcher's Study, 2008)

Table 3 features the range of clustering which allows the analysis of pattern of relationship between urban population density and private vehicle ownership to be analyzed. Based on the total average of densities among selected cities, the average point of 3000 person per km2 is chosen. The selection is used as a breakeven point to determine "High" or "Low" for urban population density. One vehicle per person is used as breakeven point for private vehicle ownership. From this analysis, relatively speaking, Georgetown represents the high density – high private car ownership, while Johor Bahru represents the low density – high private vehicle ownership. Kuala Lumpur represents the low density– low vehicle ownership.

In relative terms, the four (4) clusters shows the degree of compactness of the city measured by the population density and private vehicle usage shown by private vehicle ownership data. In the case of Malaysian cities, Georgetown is the most compact among the other 3 Malaysian cities but it is still a very private vehicle dependence urban centre. On the other hand, Kuala Lumpur is less compact but it has a lower private vehicle ownership as compared with Georgetown. This may be explained with better provision and more choices of public transportation.

Based on Figure 5, there is a pattern of clustering among the selected cities, based on the total fuel consumption. Based on the regression analysis, we have assumed

that since there are no specific standards to comply in determining the proximity range of urban densities in the greater metropolitan area an assumption of 3000person per km2 is used, based on the average density among the selected cities. Similarly, the measurement of 2.0 X 10^{12}MJ per person is used for the total fuel consumption energy. This value may vary based on the number of cities used in the measurement or throughout time period. Based on the range of densities situated within close proximity among the selected cities, four distinctive clustering of cities may be identified, in correlation with the total fuel consumption, as shown in Table 4. Table 4 shows that all the 3 Malaysian cities are categorized as low fuel consumption in relative to other selected cities.

Table 3: Clustering of Selected Cities based on Proximity of Private Vehicle Ownership per Capita

Range of Clusters		Pattern of relationship Density- Private Vehicle ownership	Selection of Cities	CLUSTER	
Urban Density (person per km2)	No. of Private Vehicles per Capita (vehicle/person)				
>3000	<1.0	High – Low	Singapore, Hong Kong	1	***Compact and lower private transport oriented***
>3000	>1.0	High - High	Georgetown	2	Compact and higher private transport oriented
<3000	<1.0	Low - Low	Kuala Lumpur, Melbourne, Sydney, Los Angeles, New York	3	Less compact and lower transport oriented
<3000	>1.0	Low - High	Johor Bahru, Adelaide, San Francisco	4	Less compact and higher private transport oriented

(Source: Researcher's Study, 2008)

From this analysis, Georgetown, together with Hong Kong and Singapore fit into the theory of compact city having lower fuel consumption or the higher the density the lower fuel consumption relation. However, the result in Table 4 shows that low density have lower fuel consumption in the case of Kuala Lumpur, Johor Bahru, Sydney, Melbourne and Adelaide contradict the compact city theory. Based on the theory less compact city or lower density city usually have higher private car ownership and lower public transport usage. Hence this will contribute to higher fuel consumption.

The possible explanation of the low fuel consumption of the 3 Malaysian cities may be influenced by factors such as in relative terms there is a greater use of public transport and non motorized vehicles, trip frequency and shorter trip distance. Whereas in the case of New York, Los Angeles and San Francisco, in relative terms trip frequency and trip distance may be higher than the Malaysian cities.

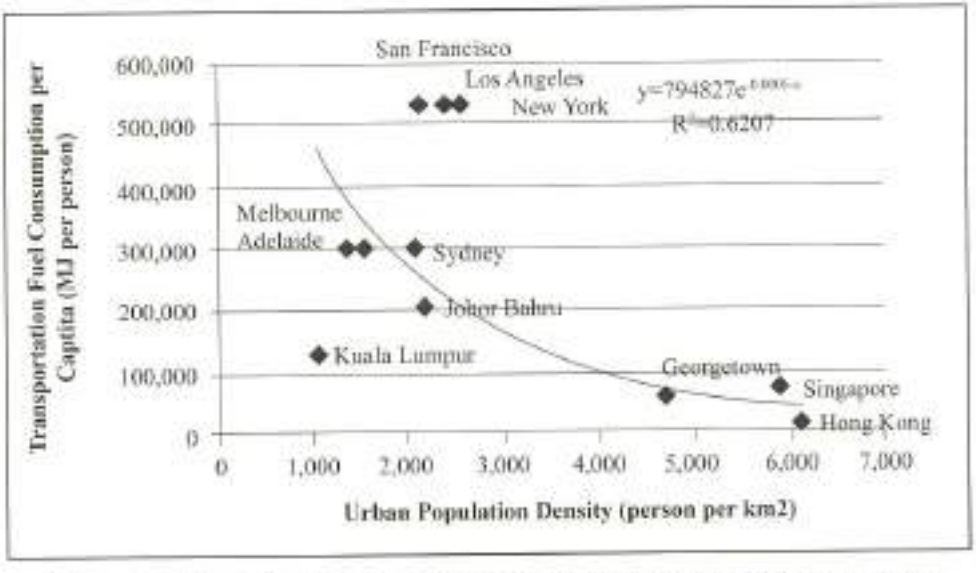

Figure 5: Urban Density versus Total Fuel Consumption per Capita, 2000
(Source: Researcher's Study, 2008)

Table 4: Clustering of Selected Cities based on Proximity Range of Total Fuel Consumption (MJ)

Range of Total Fuel Consumption (MJ)		Pattern of relationship between Population Density and fuel consumption	Selection of Cities	CLUSTER	
Urban Density (person per km2)	Total Fuel Consumption (MJ per person)				
>3000	<2.0 X 10^{12}	High– Low	*Georgetown*, Hong Kong, Singapore	1	*Compact and low fuel consumption*
>3000	>2.0 X 10^{12}	High - High	Nil	2	Compact and high fuel consumption
<3000	< 2.0 X 10^{12}	Low - Low	*Kuala Lumpur, Johor Bahru*, Sydney, Melbourne, Adelaide	3	*Less compact and low fuel consumption*
<3000	>2.0 X 10^{12}	Low - High	New York, Los Angeles, San Francisco	4	Less compact and high fuel consumption

(Source: Researcher's Study, 2008)

CHARACTERISTICS OF CORRELATION BASED ON URBAN FORM PATTERNS

As mentioned in the regression analysis, we will examine the characteristics of these relationship, mainly urban density patterns and transportation energy consumption patterns. The study will examine existing urban form and land use planning theories in the context of Malaysian cities. Specifically, this study will benchmark Malaysian cities to compare efficient correlation, i.e. efficient urban density against the selected cities. This form of classification allows benchmarking of the current position of Malaysian cities in terms of energy efficient cities and thus allowing decision makers to make progressive and optimum decision making towards effective sustainable planning implementation.

Table 7: Ideal Characteristics of Correlation for Private Vehicle Ownership Per Capita

IDEAL CLASSIFICATION	Private Vehicle Ownership Per Capita	
Urban Density (Greater Metropolitan Area)	HIGH density – HIGH vehicle ownership	HIGH density – LOW vehicle ownership
	LOW density – HIGH vehicle ownership	LOW density – LOW vehicle ownership

Note: Hedged column is ideal situation
(Source: Researcher's Study, 2008)

Table 8: Ideal Characteristics of Correlation for Total Fuel Consumption

IDEAL CLASSIFICATION	Total Fuel Consumption	
Urban Density (Greater Metropolitan Area)	HIGH density – HIGH fuel consumption	HIGH density – LOW fuel consumption
	LOW density – HIGH fuel consumption	LOW density – LOW fuel consumption

Note: Hedged column is ideal situation
(Source: Researcher's Study, 2008)

Table 7 indicates the ideal classification of the correlation between urban density and private vehicle ownership per capita. This is the qualitative classification based on existing theories on the correlation given. It is commonly assumed that high urban density or compact city will have lower fuel consumption because of better modal split of public transport users. Table 8 indicates the ideal classification of the relationship between urban density and total fuel consumption. Hence, a higher density or compact city will promote better use of public transport and pedestrianization and hence consume less fuel for transportation. Although both projects similar traits of characteristics in terms of the correlation, other complex transportation factors intercept this relationship.

Table 9 describes the summary of characteristics of Malaysian cities with reference to urban form patterns. An example of a correlation is that fuel consumption for urban density (greater metropolitan area) would be a high density – low consumption for Penang as well as low density –low consumption in the case of Kuala Lumpur and Johor Bahru cities (as highlighted in Table 9). When comparison is made between Table 8 and Table 9 to benchmark the position of Malaysian cities among these characteristics, we will then determine suggestions available to decision makers.

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ENDNOTE

**With Reference to the Source of Researcher's Study*

Population in Metropolitan Area

1 **KUALA LUMPUR:** Adapted from Structure Plan of Kuala Lumpur (RSKL) 2000–2020, Chapter 6.1: Land Use and Development Strategy http://www.dbkl.gov.my/pskl2020/english/land_use_and_development_strategy/index.htm.

2 **GEORGETOWN:** Adapted from Laporan Interim Rancangan Tempatan Majlis Perbandaran Pulau Pinang (RTMPPP) Mei 2006 pg 32, population trend in North East and South West Area of MPPP jurisdiction

3 **JOHOR BAHRU:** Adapted from Laporan Pemeriksaan Rancangan Struktur Negeri Johor 2001 – 2020 pg 70, Population for Urban Area in Johor Bahru (MBJB Jurisdiction, inclusive of Kulai)

4 **SINGAPORE:** Adapted from the Singapore Census of Population 2000: Geographic Distribution and Travel, population trend of Singapore http://www.singstat.gov.sg/pubn/popn/c2000sr4/cop2000sr4.pdf

5 **HONG KONG:** Adapted from the Population by Census Office, Census and Statistical Department of Hong Kong, Population by District Council District, last updated 22 Feb 2007