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JOURNAL OF THE MALAYSIAN INSTITUTE OF PLANNERS
B-01-02, Jalan SS7/13B, Aman Seri, Kelana Jaya,
47301, Petaling Jaya, Selangor Darul Ehsan, MALAYSIA
Tel: +603 78770637 Fax: +603 78779636
Email: pmjournal@gmail.com or mip@mip.org.my

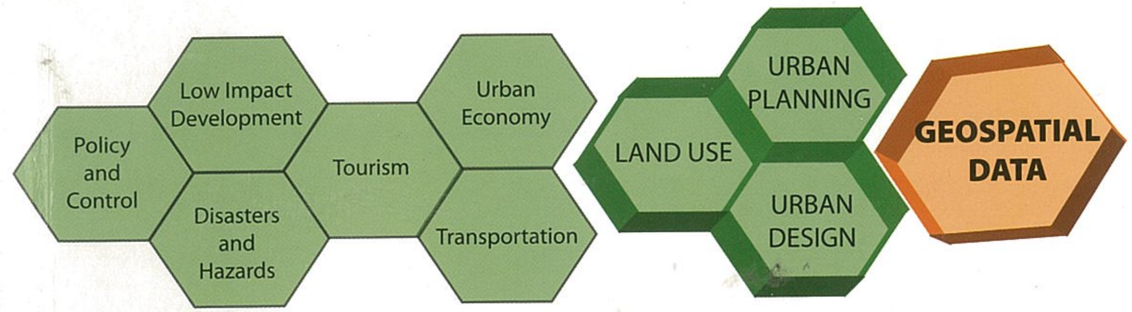
ISSN 16756215
9 771675 621005

PLANNING MALAYSIA
Journal of the Malaysian Institute of Planners
Special Issue II, 2013

PLANNING MALAYSIA

JOURNAL OF THE MALAYSIAN INSTITUTE OF PLANNERS

GEOSPATIAL ANALYSIS IN URBAN PLANNING



MALAYSIAN INSTITUTE OF PLANNERS
SPECIAL ISSUE II - 2013 [ISSN 1675-6215]
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All articles were reviewed by two or three unanimous referees identified by the Institute (MIP).

Published By
Malaysian Institute of Planners

ISSN Number
1675-6215

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developing new residential areas close to transit stations, and also to locate new transit stations along the transit lines.

Connecting transit stations to residential areas also demand for other support facilities such as for a convenient, safe and well-designed pedestrian facility. Numerous studies have been done and continuously been improved to determine the pedestrians' Level of Services (LoS). Pedestrian Index (P-Index) rated through star rating formats can be used to evaluate the quality of pedestrian services. With the availability of free geospatial data such as Google Maps, ratings of pedestrian facilities can be made public and encourage public participatory planning approach to improve these services.

In addition, TOD which is characterised by high density and mixed-use development can also generate environmental and social issues. Energy consumption and carbon emissions within this area are expected to be relatively higher than other parts of the city. Therefore, there is a need to develop a new method in assessing potential urban development parameters that can help reduce energy consumption in development (residential) areas. The findings are important for urban planners to formulate effective policies on land use and building control to promote a sustainable environment within the cities.

Malaysia is relatively safe from earth quakes and tsunamis due to its geographical location and blessed with natural defence mechanism. However, most cities located along the coastal lines are susceptible to other natural hazards for example rising sea level, coastal flooding and possibly will be impacted by earthquakes or tsunamis in the neighbouring countries. It is important to understand the effect and impact of this disaster to enable affected areas to be better prepared in the wake of such disasters. The research on seismic micro-zonation at post-disastrous earthquake and tsunami in Banda Aceh City can be a useful input for the planners at the coastal cities in Malaysia.

The publication of this journal is made possible due to an excellent collaboration between the Malaysia Institute of Planners (MIP) and the Centre for Innovative Planning and Development (CIPD), Faculty of Built Environment, Universiti Teknologi Malaysia. It was agreed by MIP and CIPD that the theme of this Special Edition was the use of present technological know-how and tools in urban planning. It reflects our continuous efforts towards promoting sustainable urban development and strengthening the planning profession in Malaysia. CIPD has continuously encouraged their staff and researchers to carry out innovative, fundamental and ground-breaking and problem solving oriented research that lay the foundations for further research.

We wish to express our deepest gratitude to Planning Malaysia editorial board for giving valuable inputs to improve the manuscripts. Our special thanks are also to Malaysia Institute of Planners' Council for giving us the opportunity to publish the output of our research. We also extend our appreciation and thanks to all our research sponsors and data providers, which we could not possibly list all and, UTM that made

this special edition journal possible. I hope this publication will be useful for planners, urban managers and practitioners.

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PLANNING MALAYSIA
Geospatial Analysis in Urban Planning
Volume **II** (2013), Page 1 - 22

IMPACTS OF URBAN LAND USE ON CRIME PATTERNS THROUGH GIS APPLICATION

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Abstract

Land use planning plays a crucial role in creating a balance between the needs of society, physical development and the ecosystem. However, most often poor planning and displacement of land uses particularly in urban areas contribute to social ills such as drug abuse and criminal activities. This research explains the spatial relationship of drug abuse and other criminal activities on urban land use planning and their implications on the society at large. Spatial statistics was used to show patterns, trends and spatial relationships of crimes and land use planning. Data on crime incidents were obtained from the Royal Malaysia Police Department whilst cases of drug abuse were collected from the National Anti-Drug Agency (AADK). Analysis of the data together with digital land use maps produced by Ampang Jaya Municipal Council, showed the distribution of crime incidents and drug abuse in the area. Findings of the study also indicated that, there was a strong relationship between petty crimes, drug abuse and land use patterns. These criminal activities tend to concentrate in residential and commercial areas of the study area.

Keywords: Drug abuse, land use planning, GIS/spatial statistics, criminal activities

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INTRODUCTION

Fear of crime and insecurity are realities of urban life. Criminal activities and drug abuse in particular, continue to raise concerns in most developing countries. Between 1980 and 2004, the total crime index in Malaysia increase by 90% and most of which are related to properties (Sidhu 2006). Malaysia is ranked 50 out of 60 countries in terms of total crime per capita with an average of 6.97 per 1,000 people (Nations Master 2010). Vasudevan (2004) ranked the top 6 issues in Malaysia to be crime and public safety (46%), followed by social and moral problems (12%), economy (9%), domestic policies (7%), unemployment (4%) and education (4%).

Cities as socioeconomic hubs attract people of diverse interests and backgrounds including those susceptible to perpetrate criminal activities. Criminal activities are complex phenomena, and researchers agreed that there is a link between criminal activities with physical and social space. Opportunity theory implies that crime density and population density are conceptually related, in that the probabilities of predatory interactions between individuals and their property increase as a function of persons per unit area (Harries 2006). Crime opportunity takes place when the offender finds a target in suitable situation without a capable guardian in the urban physical environment (Tabagin *et al.* 2008; Chainey and Ratcliffe 2005; Klinkenber 2008). Criminal pattern theory reveals that offenders tend to concentrate in areas familiar to them and through their day-to-day activities watch for an easy target and an open space for a quick and easy escape route before committing a crime. Population density and total area are expected to influence the influx of crime incidence in housing scheme. This fact is supported by Gymfi (2002) through a crime pattern study in Ghana where crime is highest in developed and densely populated regions. Hence, there is a relationship between crime, the offender and the environment.

Generally, it is a criminal activity to use, own, produce or distribute drugs classified as having the potential to be abused. Drug abuse is closely related to crime due to its consumption without legal prescription. It affects individual behaviour and/or habit, and is potential for violence and petty crimes such as snatch theft. Drug abuse and unemployment are among the driving factors for the increase of snatch theft crime (Allen 2005). In fact, 50% of snatch thefts that occurred in Kuala Lumpur in 2009 are believed to be committed by drug addicts (Utusan Online 2009).

Due to the increasing rate of crime each year, the Malaysian government in January 2012 has introduced and launched Government Transformation Programme (GTP). This programme is designed to provide all Malaysians the

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access to improved public services irrespective of race, religion and region. GTP is created based on public concerns about some major issues that affected the nation. The focus of attention under GTP is the implementation of the National Key Result Area or NKRA. NKRA involves 7 key areas and the performance of each area is evaluated through specific Key Performance Index (KPI). In order to measure and improve the efficiency and quality of government services, one of the NKRA initiatives is on reduction of crime.

Following the NKRA initiatives, the Federal Town and Country Planning Department introduced a Safe City Programme and embrace Crime Prevention through Environmental Design (CPTED) concept with the objectives to reduce crime incidence and improve the quality of life (JPBD 2010). Under this programme, the safe city is defined as a city that is free of any threats physically, socially and mentally, and is a protected environment. While, CPTED basically emphasises on the idea that proper design and effective use of the built environment can lead to a reduction of crime incidence (Schneider & Kitchen 2013).

Hence, this research attempts to evaluate the relationship and influence of land use planning on the distribution patterns of drug abuse and criminal activities. Spatial statistics techniques are used to generate spatial analysis model and hotspot areas. Ampang Jaya Municipal Council (AJMC) is selected as the study area because it has one of the highest population densities in Selangor. This study focuses on theft and snatch theft with the assumption that these crimes are often drug related crimes.

THE RELATIONSHIP BETWEEN CRIMINAL ACTIVITIES, DRUG ABUSE AND LAND USE

Suryavanshi (2001) contends that there is a relationship between land use, urban form, routine activities and crime. Figure 1 shows the relationship between land use and opportunities for crime through two other important factors namely routine activities and urban form.

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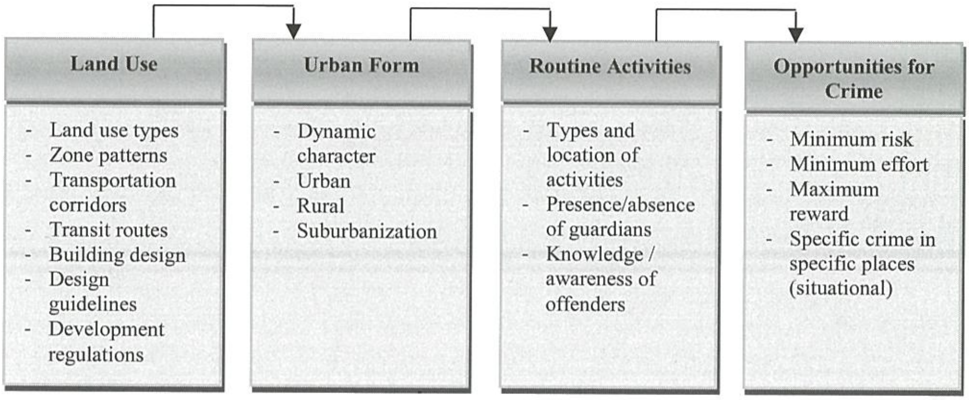

Figure 1: Theoretical Relationship between Land Use and Opportunities for Crime

Source: Suryavanshi (2001)

Drug Abuse and Criminal Activities

Brochu (1995) and Fisher *et al.* (1999) observed that individuals whom have developed an extreme dependency on drug tend to be involved in criminal activities such as prostitution, theft of property and fraud. Karofi (2005) argued that drug abuse and criminal behaviours are closely related to subculture, socio-economic factors and rural-urban migration. He further explained that subculture is a situation where an individual lives among drug addict friends that later ends up in drug trafficking and consumption. Thus, for a continuous supply of drugs, criminal acts are committed as an easy earning. In addition, socio-economic factors such as poverty, broken homes, environment and urbanization, and rural-urban migration also contribute to criminal acts. The pressure of life coupled with the increasing standard of living in urban areas has resulted in these individuals to choose the easy way out in fulfilling their needs regardless of the impact and consequences of their actions on the community.

Criminal Activities and Land Use

As land use change with new development and redevelopment, the structure of urban form will change as well (Brantinghams 1981; Felson 1987). Urban forms are dynamics; any change in land use may bring about other changes to nearby areas. For instance, the development of a new community facility may change the routine activities of the community involved. According to Felson (1987) routine activities would create crime opportunities for the offender. Property crimes are higher at places where there are dispersed shopping and strip commercial developments. Commercial areas in cities have been found to be prone to burglaries and thefts while residential areas are conducive to crimes such as sexual offence and murders. Studies have also indicated that child-sex offences and juvenile crimes are much higher near areas where high schools are located (Suryavanshi 2005).

GIS Application in Crime Pattern Analysis

Crime patterns can be analysed and explained using GIS because it offers a medium to analyse criminal activities data for a better understanding of the factors that influence crime offenders. It could also be used to generate a model that would predict potential crime spots. GIS could be applied for the analysis and the mapping of crime data for both academic research and practical law enforcement (Murray *et. al*. 2001). This is more so because it offers tools for the modelling of statistical surfaces that facilitate approximate visualisations of point densities (Harries 2006). The level of analysis achieved using GIS could determine even the density of crime within every spatial scale. Spatial statistics function can be utilized to help authorities such as the police department to map crime scene. This would further assist the authority to understand crime behaviours and find the best action to prevent crime. The methodology employed could assist authorities to better understand the pattern of crime spatially and predict potential crime. Thus, preventive measures can be taken through proper physical planning for new development areas while 'target hardening' measures can be taken for existing developed areas. GIS provide an alternative tool that can aid policy makers, decision makers and the security operatives in particular discharge their core responsibility of ensuring peace and security in the society. The integration of spatial statistics technique and GIS can assist local authorities and police departments to identify hotspots for crime incidence.

CASE STUDY: MAJLIS PERBANDARAN AMPANG JAYA

The study area, Majlis Perbandaran Ampang Jaya (MPAJ) or Ampang Jaya Municipal Council covers Mukim Ampang, Mukim Hulu Kelang and part of Mukim Setapak, and is approximately 14,350 hectares. The adjoining councils include Dewan Bandaraya Kuala Lumpur, Majlis Perbandaran Selayang and Majlis Perbandaran Kajang. The map showing MPAJ and its neighbouring municipalities is shown in Figure 2. The population of MPAJ is estimated at 600,000 people in 2007 (Department of Statistics, Malaysia) or 12.7% of the total population of Selangor. The district consists of four planning blocks as shown in Table 1. MPAJ together with Kuala Lumpur has one of the highest population densities in Malaysia due to concentration of economic and institutional activities.

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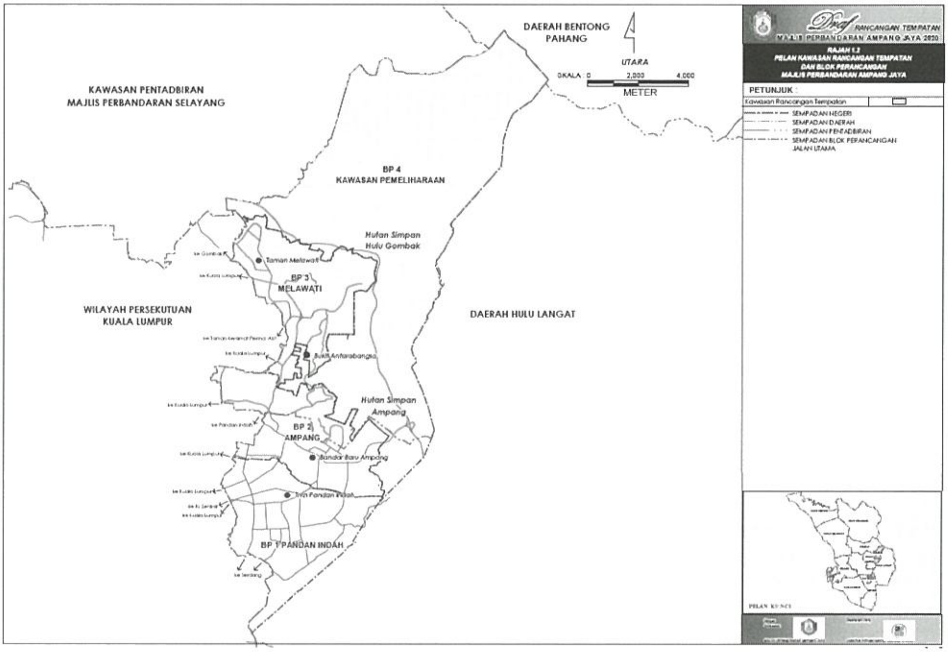

Figure 2: Location of Ampang Jaya Municipal Council

Source: Draft Local Plan of Ampang Jaya Municipal Council 2020

Table 1: Majlis Perbandaran Ampang Jaya by Planning Blocks (BP)

Planning Blocks	**Area (Hectare)**
BP 1 : PANDAN INDAH	2,056
BP 2 : AMPANG	1,880
BP 3 : TAMAN MELAWATI	1,823
BP 4 : CONSERVATION AREA (Hulu Gombak Reserve Forest)	8,591
Total	**14,350**

Source: Draft Local Plan Majlis Perbandaran Ampang Jaya 2020

Ampang Jaya has a population of 608,030 people in 2007 (Dept of Statistic, Malaysia). The district registered a relative increase in population from 478,613 in 2000 to 577,828 people in 2005. Table 2 shows the population distribution by planning blocks for 2000, 2005 and 2007.

Table 2: Population in Ampang Jaya District

Planning Block	**2000**	**2005**	**2007**
Pandan Indah	239,437	284,060	296,678
Ampang	168,554	206,274	218,246
Taman Melawati	60,474	75,376	80,289
Conservation Area	10,148	12,118	12,817
Total	**478,613**	**577,828**	**608,030**

Source: Draft Local Plan Majlis Perbandaran Ampang Jaya 2020

METHODOLOGY

Data Collection

Digital data on land use were obtained from MPAJ, while data on crimes were acquired from the Police District Headquarters of Ampang Jaya. Data on drug abuse were obtained from National Anti-Drug Agency (AADK). A total of 2,062 cases of crime recorded in 2008 were plotted manually using ArcGIS 9.2 as an individual point, geocoded by X and Y coordinates with the necessary attributes. Estimates on locations were made when the exact location of the crime were not recorded. Beyond these coordinates each point has additional attributes illustrating time, date, day, type of crime, type of drugs, location, small planning block and housing scheme. Figure 3 shows the spatial distribution and the patterns of crime incidents in MPAJ. These are classified into four crime incidents namely, (i) theft, (ii) snatch theft, (iii) night time burglary, and (iv) day time burglary.

Based on the recorded crime data, theft accounts for one-third (or 36%) of the total crimes reported in 2008. Therefore, this study assumed that drug abusers tend to commit theft and snatch theft compared to night and day time burglary based on opportunity to commit crime, easy target and easy planning.

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Influencing factors analysis

This analysis was executed based on the results from the hotspot analysis for theft, snatch theft and drug abuse. Figure 4 show the land use verification of Taman Pandan Indah based on Google Earth image. Taman Pandan Indah consists of 40% residential area and 60% commercial. The hotspot locations of theft, snatch theft and drug abuse is overlaid with the Google Earth image to facilitate the analysis of influencing factors to criminal incidents.

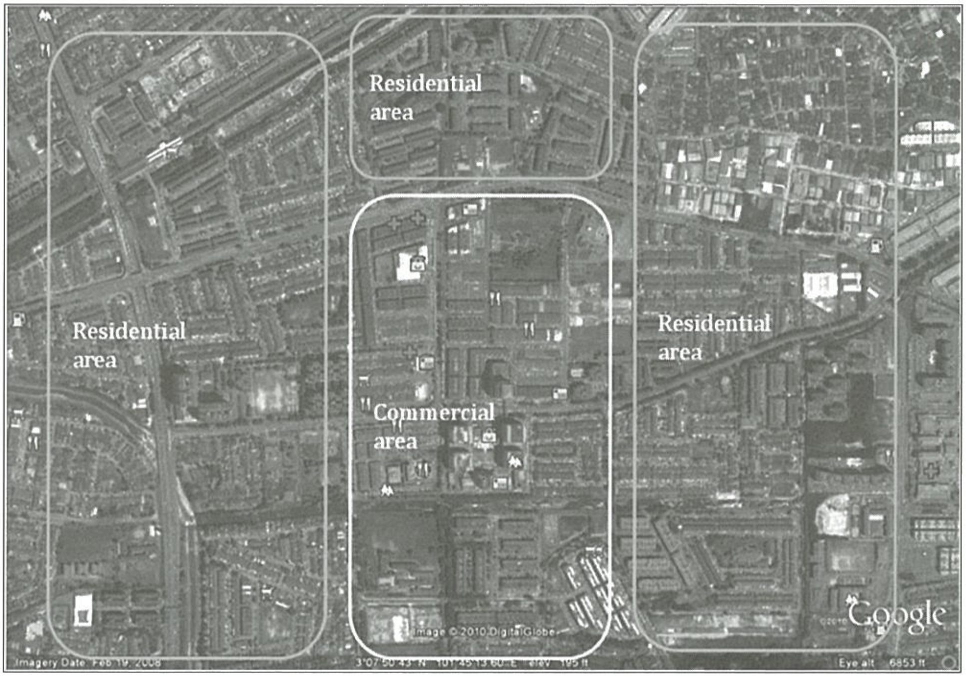

Figure 4: Land Use of Taman Pandan Indah

Source: Google Earth Image

Movement Pattern Analysis

The movement analysis is conducted using Mean Centre and Standard Deviational Ellipse (SDE) technique. The mean centre is the point whose coordinates are the mean x-coordinate and mean y-coordinate for all the features in the study area. The SDE technique is a measurement of the difference between the average distance and the distance from a given feature to the mean centre. Based on reported offences, SDE would identify the direction criminal offenders select their target area. The measurement can be obtained using equation (4):

$$SD = \sqrt{\frac{\sum_i (X_i - \bar{X})^2}{n} + \frac{\sum_i (X_i - \bar{X})^2}{n}} \qquad \text{Eq. (4)}$$

The SDE is employed to indicate the geographic centre, distribution, orientation and directionality that exist for each crime, especially in understanding how the crime trans-change overtime in day and time categories. Standard deviation ellipse is a logical extension of the standard distance circle (Furley 1927) which can capture the directional bias in a point distribution (Wong & Lee 2005). In movement pattern analysis, both theft and snatch theft are analysed by day and time categories. Day category is divided into two subcategories which are weekdays and weekends, whilst time categories are divided into five subcategories in 24-hour time format as shown in Table 3.

Table 3: Time Frame Subcategories

ID	**Time Frame**
1	0000-0359
2	0400-0859
3	0900-1659
4	1700-1959
5	2000-2359

FINDINGS

Most of the hotspot areas for theft, snatch theft and drug abuse were detected in the southern region of MPAJ especially in Pandan Indah, whilst, the cold spot areas are distributed in the north of study area as shown in Figure 5. A further hotspot analysis was executed based on overall reported cases of theft and snatch theft in Taman Pandan Indah area to identify the hotspot location (Figure 6).

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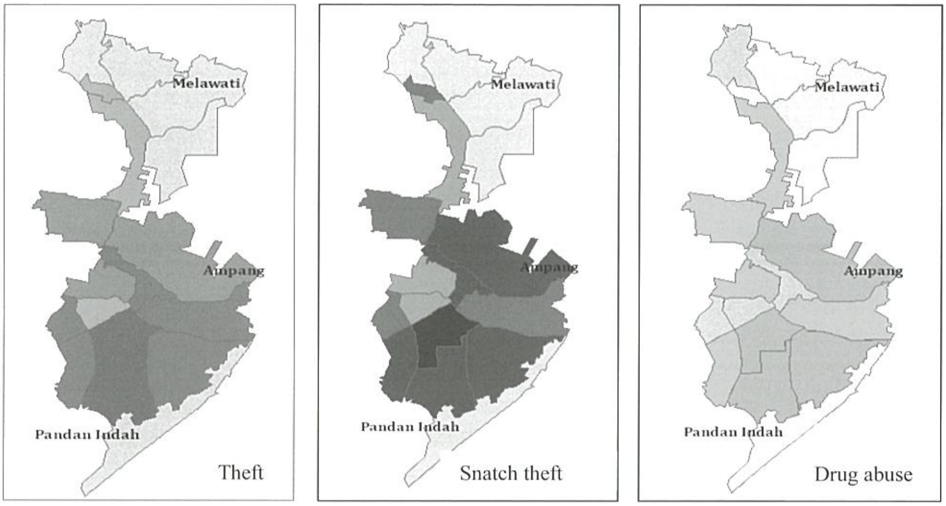

Figure 5: AJMC Hotspot Areas of Theft, Snatch Theft and Drug Abuse

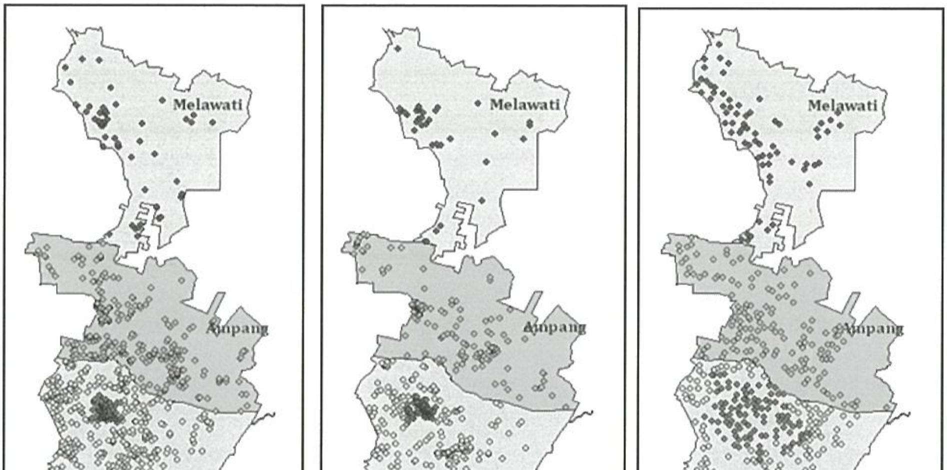

Figure 6: Hotspot Location based on overall reported Theft and Snatch Theft in MPAJ

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Based on the results of the hotspot analysis for theft, snatch theft and drug abuse, the influencing factor analysis was conducted on Google Earth image of Taman Pandan Indah. Taman Pandan Indah was selected due to the high number of reported cases recorded for the entire MPAJ. In Figure 7 and 8, the hotspot location of crimes are indicated as cross marks and drug abuse distributions are indicated as small circle dots. The hotspot area is in the commercial centre comprising of banks, clinics, restaurants, and a shopping mall. A feature with a high value may denote some form on concentration in crime incidence, but may not be a statistically significant hotspot.

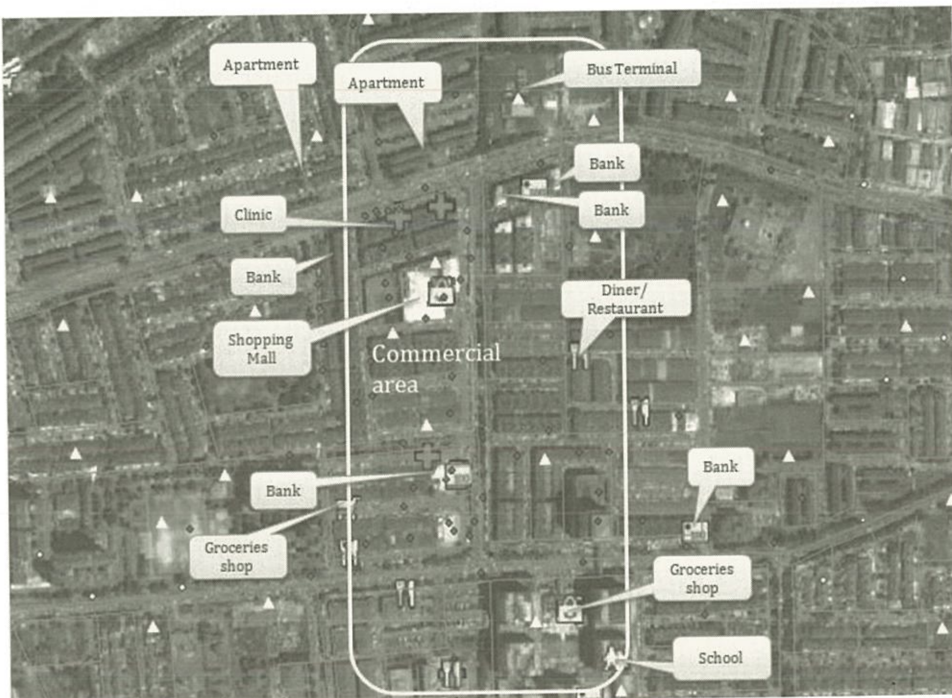

Figure 7: Theft occurrence based on land use and drug abuse overlay of Google Earth image

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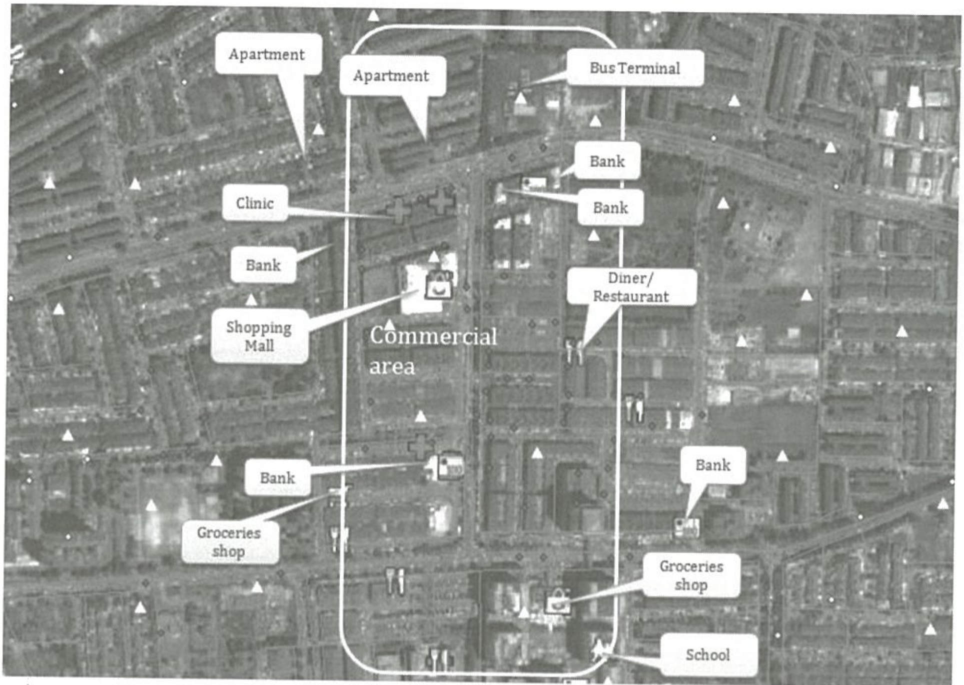

Figure 8: Snatch Theft Occurrence based on Land Use and Drug Abuse factor overlay of Google Earth Image

Based on the influencing factor analysis, planning of the land use is a major contributing factor other than the likely availability of a victim. The findings of the study indicate that, drug abuse and criminal patterns are related to land use. The movement pattern analysis indicate that crime patterns in MPAJ tend to concentrate more in Pandan Indah and Ampang planning block.

As shown in Figure 9(a) and (b), the current tendency for all crimes are in the southern region of the ellipse. Similarly, the pattern of drug abuse distribution was found to be near theft and snatch-theft locations. This supports the contention that, there is a relationship between drug abuse, crime and land use. Main roads, pedestrian bridges, commercial facilities such as banks, shopping complexes, bus stands and restaurants appear to be the preferred locations for criminals to find their victims. The direction and concentration of crime as indicated by the SDE for both crimes seem to disclose that busy traffic and large crowds which present a high possibility of likely victims in open and strategic areas are relative opportunity elements for crime incidents.

Both theft and snatch theft are more frequent on weekdays compared to weekends, where 563 theft and 322 snatch theft cases are reported during 2008.

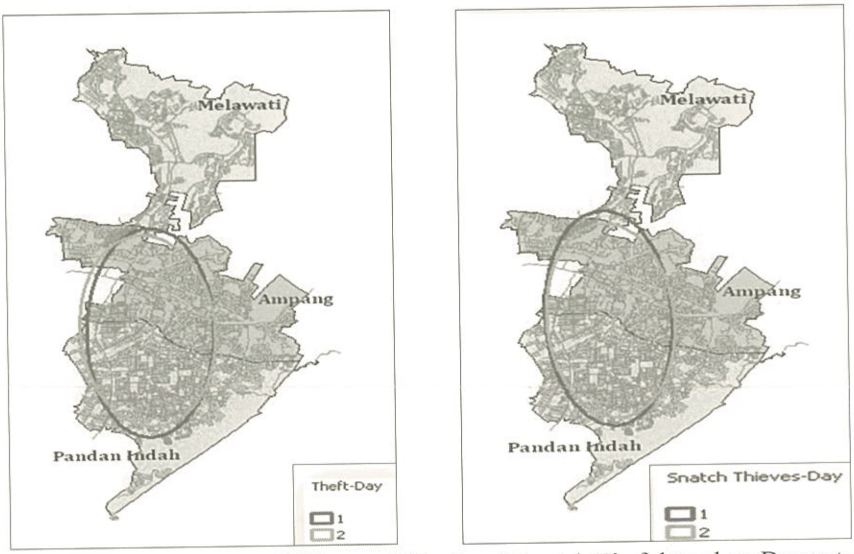

Figure 9(A): The Direction of Ellipses of Theft and Snatch Theft based on Day category

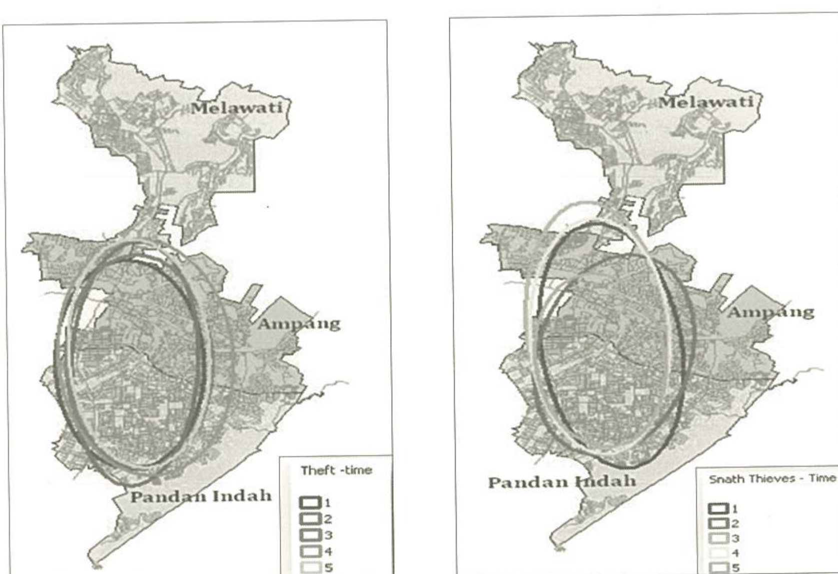

Figure 9(B): The Direction of Ellipses of Theft and Snatch Theft based on Time Frame Category

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The mean centre technique clearly defined the movement pattern of theft and snatch theft by time. As the daily activities of likely victims change the hotspots from crime incidence also changes. Figure 10(a) shows the movement pattern of both theft and snatch-theft during weekdays and weekends.

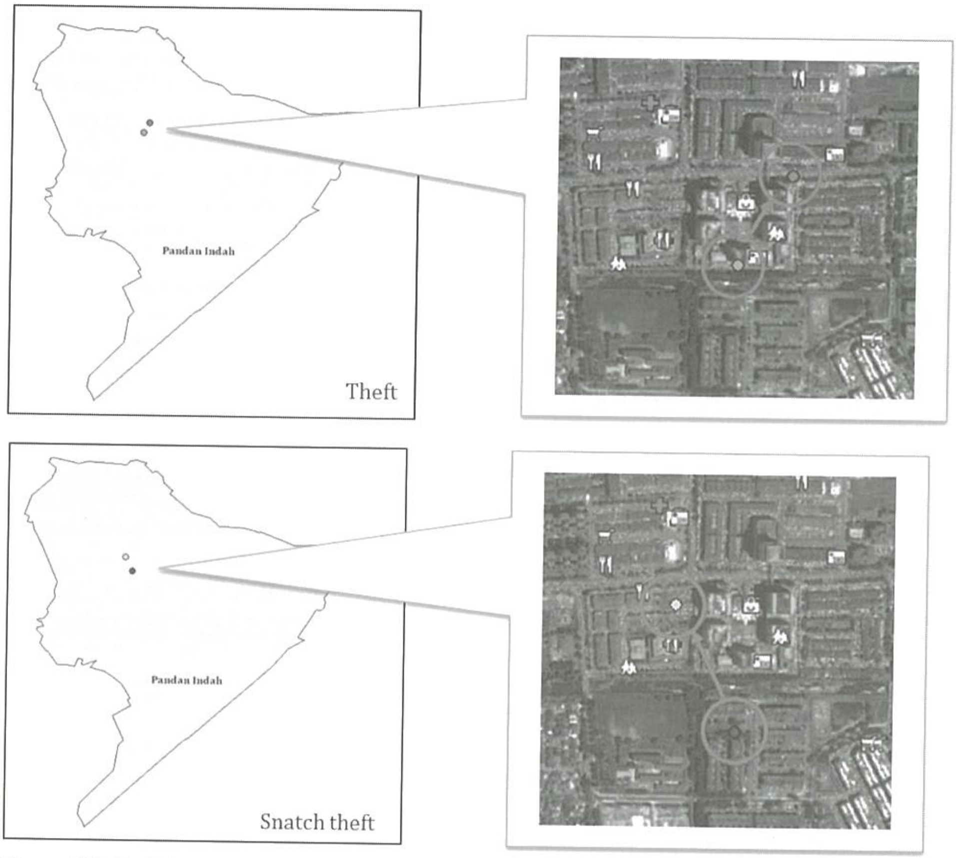

Figure 10(A): Mean Centre Movement of Theft and Snatch Theft based on Day Category

The time subcategories data indicate that, the highest number of theft took place between 4:00 am to 8:59 am, whilst snatch-theft occurred between 9:00 am to 4:59 pm. The movement pattern of both criminal activities as shown in Figure 10(b) is based on the mean centre, calculated according to the time frame subcategories. The movement pattern begins from time frame 1 (00:00 – 03:59) to time frame 5 (20:00-23:59) as shown in Table 3.

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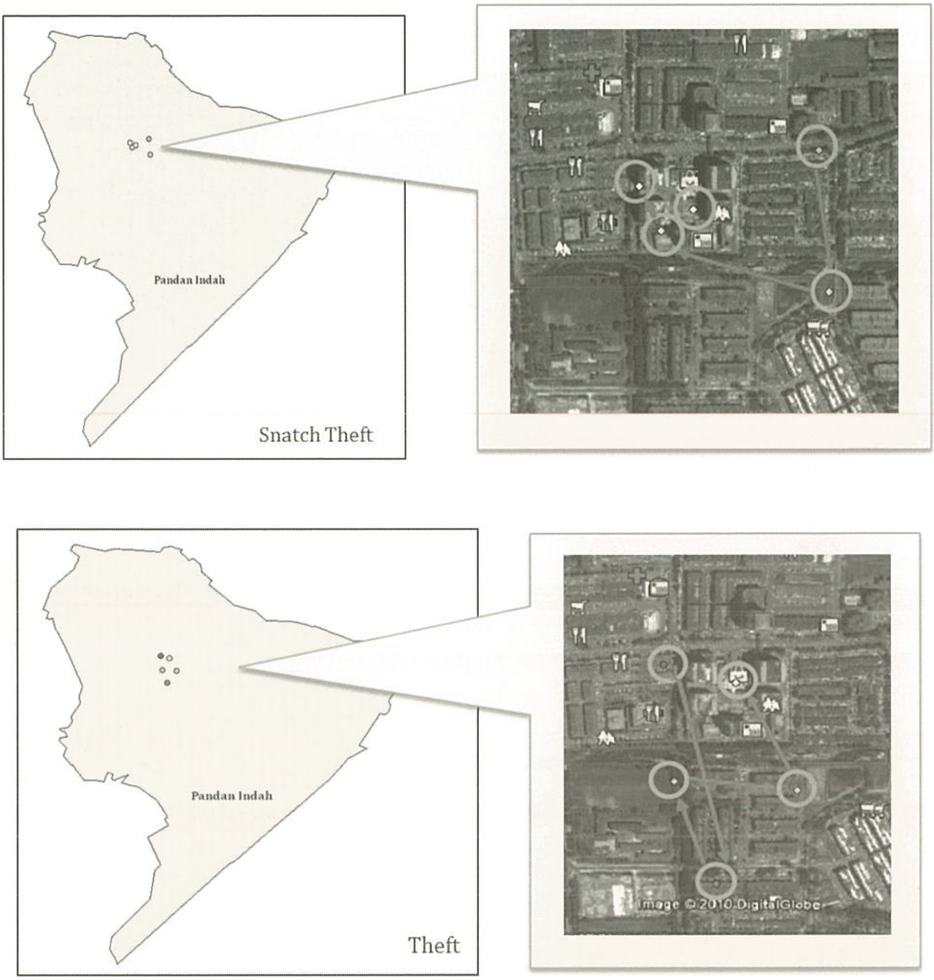

Figure 10 (B): Mean centre movement of theft and snatch theft based on time frame subcategories

The movement patterns in Figure 10(b) indicate that the occurrence of both criminal acts originates at residential area close to target spot (restaurant or bank) and as the night progresses to daylight (04:00-08:59), the offenders target the residential area. The offenders then shift their target area to a bigger area of likely victim located mostly in commercial centre and its surrounding during daylight (09:00-16:59). As the night progresses (20:00-23:59), the criminal acts are centred in the commercial areas. From the analysis, it is concluded that the offenders tend to change their target area based on the crowd and land use. The offenders select target areas that are relatively near to commercial centre such as banks, schools, diners or restaurants and residential areas.

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CONCLUSIONS

This study shows that there is a measurable link between criminal activities and physical or social space. It supports the opportunity theory which implies that crime density and population density are conceptually related. The mean centre of each crime distribution for MPAJ also identifies with this suggestion. The mean centre of crime is located in Taman Pandan Indah, an urban area with a dense population. The analyses were carried out for each crime based on categories and subcategories. Each category is further split into groups that are weighted. Each day category is weighted according to week-day and weekend subcategories, and the time category is weighted into five subcategories or time frame.

The crime distribution in MPAJ displayed a highly clustered pattern for every crime type. Clustered means crime rates are concentrated in a certain area. The spatial result showed that crime patterns in the study area are clustered with high value and the land use has a correlation with crime activities. Results from the analysis according to time frame also resulted in significant change of crime pattern. These findings revealed the spatial correlation between types and patterns of criminal activities and land use namely commercial (banks and shopping malls) and residential areas. The opportune spots for criminals are at roads with heavy traffic, pedestrian bridges and bus stops. The temporal GIS dimension of the study has provided a clearer understanding on the pattern of crimes and drug abusers in relation to land use planning.

The integration of spatial statistics and GIS can assist local authorities and police departments in particular, to identify hotspots for crime incidence. Implementation of the safe city initiative by the Government and CPTED in residential layout design is potentially a more effective way to combat urban crime and insecurity of the Malaysian urban society.

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PLANNING MALAYSIA
Geospatial Analysis in Urban Planning
Volume **II** (2013), Page 23 - 38

ESTIMATION OF RESIDENTIAL IMPERVIOUS SURFACE USING GIS TECHNIQUE

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Abstract

Urban impervious surface in the form of rooftops, street pavement, parking lots, etc. is an important contributor to water pollution, urban heat island, flash floods and other environmental degradations. While studies on the extent of impervious surface are common in advanced countries, few have been carried out in developing countries. This paper discusses a study on the nature of impervious surface coverage in a southern city in Malaysia. The study focuses on impervious surface in several residential areas, looking at the relationship between impervious surface and housing density as well as the source of the surface. Remote sensing images combined with some GIS techniques were employed for this purpose. The percentage of impervious surface measured ranged from 40–95%, well above the values indicated from similar studies overseas. While density was a factor in the amount of impervious surface, it was not the only factor. Other factors such as policies on impervious surface control were also important as illustrated by comparison of the results of this study to similar studies reported in the USA. Based on these findings, the paper offers several steps towards reduction of impervious surface in residential areas.

Keywords: Impervious surface, remote sensing, GIS, residential imperviousness.

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INTRODUCTION

Any material covering the ground that prevents infiltration of water into the soil can be classified as an impervious surface (Arnold & Gibbons 1996). While it is not a single homogeneous quantity, when impervious surface is used as a landscape indicator it is typically presented as a percentage of the land that is covered with impervious materials. The word *imperviousness* is also regularly used to refer to the extent of this percentage.

Impervious surfaces come in different types such as paved surfaces (roads, parking lots, sidewalks, etc.) and building rooftops that fall unambiguously under the definition of impervious surface. Yet there are also traditionally pervious surfaces, man-made and natural, that are so heavily compacted that they become functionally impervious. Examples of these are compacted soil in construction areas, dirt roads, bedrock outcrops and, even to a certain extent, grass turf in our residential areas. This paper, however, focuses on the earlier category of impervious surfaces, i.e. paved surfaces and building rooftops.

It is a fact that urbanisation carries with it a series of environmental concerns such as water and air pollution as well as increase in temperature and occurrence of flash floods. On many occasions have these been linked to the extent of impervious surface, an indicator that defines urbanisation. As development alters the natural landscape, the percentage of land covered by impervious surface also alters, i.e. it increases. Increase in urban impervious surface has been identified by many studies as an important contributor to a host of urban problems including water pollution, urban heat island, flash floods and other environmental degradations (Hammer 1972; Booth 1991; Schueler 1994; Arnold & Gibbons 1996).

While studies on the extent of impervious surface are common in advanced countries, only a few have been carried out in developing countries. Lacking empirical local values, guidelines or manuals requiring the use of impervious surface estimate simply adopts values from overseas such as the case of Manual Saliran Mesra Alam or MSMA adopting values from Australia (MSMA 2012). The justification for such action comes into question given our different approach towards development. In view of that, this paper discusses a study on the nature of impervious surface coverage in Johor Bahru, Malaysia. The study focuses on impervious surface in several residential areas, looking at the relationship between impervious surface and housing density as well as the

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source of the surface. Remote sensing images combined with GIS techniques were employed for this purpose.

IMPERVIOUS SURFACE IN HOUSING AREAS

There have been very few studies (if any) on the amount of impervious surface per unit urban area in Malaysia, even though impervious surface has been recognised as an important indicator of urbanisation and its associated impact on the environment. The parameters concerning impervious surface that have been adopted for local uses, in runoff estimation for example, are those from developed countries such as Australia and the USA. One example of empirical values obtained from overseas is those reported by the Soil Conservation Services (SCS) in the USA listed in Table 1. The validity of such values for usage in Malaysia is however questionable due to several factors. Our more compact housing areas would in theory lead to higher percentage of impervious surface per unit area. The maximum density of single-family housing in Malaysia which can reach up to 30 units per acre, for example, is much more than the maximum depicted in the table. Other factors such as building design, street standards, and subdivision regulations are also different from those in the USA and would definitely influence the amount of impervious surface. Thus, it has been long overdue that we know exactly the extent of our impervious surface and its relationship to urbanisation.

Table 1: Impervious surface according to urban land use (SCS, USA)

Urban Land Use	Average Impervious Surface (%)
Commercial Area	85
Industrial Area	72
Housing Area (According to Density):	
8 units/acres or more	65
4 units/acres	38
3 units/acres	30
2 units/acres	25
1 units/acres	20
1/2 units/acres	12

The relationships between the characteristics of housing areas, particularly density and design, and the amount of impervious surface have been studied extensively in developed countries (see Majid 2005; Stone Jr. 2004; Capeilla & Brown 2001). Majid (2005), for instance, showed that the amount of impervious surface was correlated to density and design in a non-linear manner

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(Figure 1). The gross densities calculated in his study were however relatively low compared to what is prevalent in Malaysia, i.e. 0.5-6 units/acre in contrast to about 4-30 units/acre in Malaysia. Thus the impervious surface percentage of between 10-40% reported by him would be well below what is expected for housing areas in Malaysia whose densities are higher.

In addition to density, the design of housing layout also plays an important role in determining the amount of impervious surface. In the same study, Majid (2005) also reported that conventional layouts (where the whole development parcelled out into individual housing lots) resulted in higher imperviousness than cluster layouts (conservation layouts that leave some open space for conservation). The difference in imperviousness level between the two layout types is shown in Figure 1 while Figure 2 highlights the many advantages of a cluster layout over a conventional one. Though originally promoted for conservation of critical open spaces, cluster layouts have lately been promoted more as an alternative design to reduce imperviousness (Arnold & Gibbons 1996; Schueler 1996; Arendt 1996).

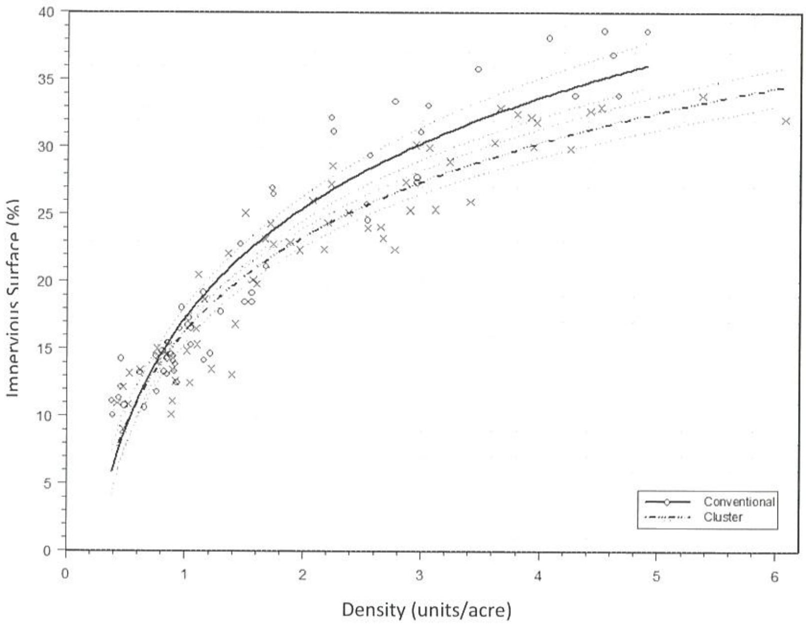

Figure 1: Impervious surface vs housing density in North Carolina, USA

Source: Majid, 2005

Depending on lot size and the road network, Schueler (1996) claims that cluster development can potentially reduce site imperviousness by as much as 10-50%. In *density-neutral* provision for cluster development, a developer is still committed to the total units as in conventional development but has the flexibility to place them in a way that is more responsive to the physical characteristics of the site. In spite of more open space, density is maintained by allowing smaller lots than the conventional developments. Smaller lot size that results in narrower and shallower lots also helps reduce the lineal length of streets and total length of driveways. Clustering lots closer together also results in shorter roads.

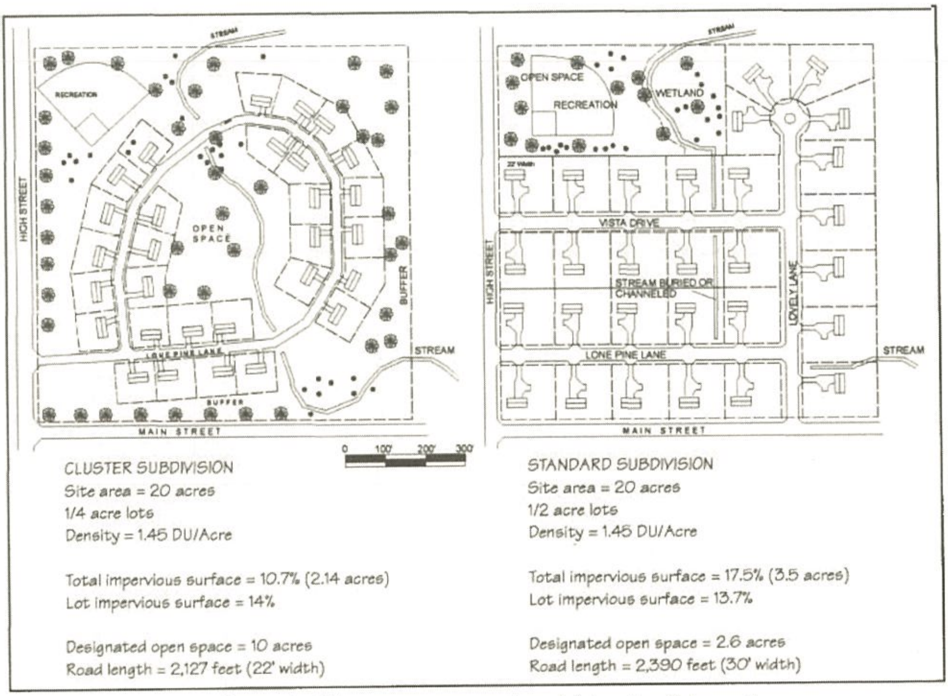

Figure 2: Cluster vs conventional (standard) layout
Source: Arnold & Gibbons 1996

Cluster housing layout as practised in the United States (Figure 2), however, is rare in Malaysia. Without specific regulations requiring it, housing developers in Malaysia are more content to turn the whole development into housing or commercial lots, leaving only 10% of the area for open space as required by law. Even for the conventional layouts, there are still vast differences between housing layouts in Malaysia and those in developed

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countries. Different street designs, for example, might contribute to the difference in the overall impervious surface amount. In addition to that, a peculiar Malaysian penchant for paved compound around their houses, that is to a certain extent encouraged by lack of specific regulations concerning impervious surface limits, does also contribute to the amount of impervious surface.

REMOTE SENSING AND QUANTIFICATION OF IMPERVIOUS SURFACE

Remote sensing is a method which records the information of an object or a phenomenon on earth surface from afar by using electromagnetic wave. It is usually done through image interpretation gained from afar by using the satellite or aircraft. Most remote sensing image interpretation now uses satellite images of various brands and resolution due to low cost and high resolution. Some of the currently popular images in accordance to resolution are AVHRR (low resolution), Landsat TM and SPOT (medium resolution), and IKONOS as well as Quickbird (high resolution).

The study of the relationship between impervious surface and land use has long begun since 1970's in the field of urban hydrology (Brabec et al. 2002). According to Brabec et al.(2002), the total size of impervious surface can be measured through four methods; 1) identifying impervious surface in the aerial photo and made measurements by using planimeter (example Stafford et al. 1974; Graham et al. 1974); 2) by placing grids on the aerial photo and count the number of squares covered by Impervious surface and other land uses (example: Gluck and McCuen 1975; Hammer 1972; Ragan & Jackson 1975); 3) using the method of remote sensing image classification (example: Ragan and Jackson 1975); 4) corresponding the percentage of urbanisation rate with the percentage of impervious surface (example: Morisawa & LaFlure 1979). Several studies also show that there is a significant difference between the relationship of impervious surface percentage and demographic factors including population density, household size and number of job opportunities (Stankowski 1972; Graham *et al.* 1974; Gluck & McCuen 1975). However, these studies depend solely on the study areas chosen, and are unsuitable to be implemented for all urban areas.

The early mapping of impervious surface by using remote sensing images has begun by interpreting visual aerial photos but this method is complicated and time consuming when a large area is involved. Besides, the manual method is subject to a high tendency of human error, even by skilled personnel. The aerial photos are also taken on different dates and scales, which need further rectification, digitation and time consuming interpretation. The establishment of Landsat Multispectral Sensor Satellite in year 1972 has provided the digital satellite image world with full view of the earth surface. By using these images, exclusive computer programs and impervious surface measurement through spectral analysis method begin to produce outputs comparable to that of the manual method – within a shorter time (Ragan & Jackson 1975).

Compared to aerial photo, remote sensing images covers a larger area and produce a more consistent output – which can also be used in GIS. After the classification procedure has been determined for a certain image, all the remaining images shall be classified using the same procedure in a shorter amount of time, as compared to the manual method. Other special attribute of remote sensing image is that is has spectral wires which resembles various types of land cover spectral reflectance. For instance, the Landsat TM Image has six (6) spectral wires, comparing to coloured aerial photos – which only have three (3), and black and white aerial photos – which only have one (1).

The weakness of remote sensing image is its large pixel size for certain cheap images; Landsat TM with 30m x 30m pixel, for instance. However, there are expensive small pixel images such as IKONOS (4m x 4m for multispectral, 1m x 1m for panchromatic), Quickbird (2.4m x 2.4m for multispectral, 60cm x 60cm for panchromatic), Geoeye-1 (1.65m x 1.65m for colour and 0.41m x 0.41m for black & white) and Worldview-2 (0.46m x 0.46m for panchromatic images). Large sum of monetary cost would be required if used on a wide area by using these high resolution images because it implicates a large number of images to be produced. For the current study, Quickbird Image shall be employed for the area of Johor Bahru Tengah Municipality (MPJBT) and Kulai Jaya Municipality (MPKJ).

The earlier method of impervious surface measurement using spectral information from remote sensing images are classification method and other clustering, thresholding and modelling methods (see Wu and Murray 2002; Rashed et al. 2003). The outputs are usually presented in the form of maps which shows the existence of impervious surfaces in certain pixels. Forster (1985) reminded about the inaccuracy of this method due to the large pixel size in representing a land use or, it is impossible for a whole area to be covered with impervious surface, and vice versa. However, this statement was done based on the pixel size of Landsat TM image, which is known to be large (30m

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x 30m). The current high resolution satellite images such as IKONOS and Quickbird will produce a more accurate output by using the same method. The current methods are used for the purpose of improving this weakness by combining machine learning algorithms and spectral mixture analysis to get impervious surface at the sub-pixel levels. This method is more accurate and has been proven by Flanagan & Civco (2001), Wang et al. (2000), Ji & Jenson (1999), Wu & Murray (2002), Ward et al. (2000), Rashed et al. (2003) and Yang et al. (2003). Based on the early visual checks, it shows that the content of impervious surface in the study is high. Hence, the current study shall employ the method of classification based on pixel; not sub-pixel for the purpose of impervious surface measurement. The high content of impervious surface and high resolution images used has been predicted to be able to provide accurate information on the real content of impervious surface in a certain housing area.

ESTIMATION OF IMPERVIOUS SURFACE AREA

Motivated by the lack of specific information on the amount of impervious surface in urban housing areas in Malaysia and the desire to compare this amount to those reported by studies carried out in other countries, the authors set out the study with the following objectives: 1) to quantify the amount of impervious surface in urban housing areas in Malaysia using remote sensing images (Quickbird images); 2) to establish the relationship between the amount of impervious surface as the dependent variable and density of housing as the explanatory or independent variable; and 3) to compare the extent of residential imperviousness in Malaysia to those in other countries.

The study was carried out through the following four steps:

Step 1: Identifying residential areas with different densities to measure the total size of impervious surface;
Step 2: Processing Quickbird Satellite Images by integrating various remote sensing techniques with GIS in order to calculate the total size of impervious surface;
Step 3: Generating a regression model, which is able to forecast the total size of impervious surface based on the densities of the residential areas; and
Step 4: Recommending policies and planning guidelines which are able to minimize the total size of impervious surface. The following section introduces the study area and discusses the detailed steps involved.

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Study area

Since the study was to investigate the percentage of impervious surface in housing areas, its unit of analysis was urban housing areas located in two municipalities in the southern part of Johor. The two municipalities were Johor Bahru Tengah Municipality and Kulai Jaya Municipality. Johor Bahru Tengah Municipality covers an area of 339 km^2 with a population of roughly 525,351 while Kulai Jaya Municipality has a population of 130,000 within an area of 747 km^2. A total of 11 housing areas were randomly selected for the study and Figure 3 below shows their locations. The housing areas come in various sizes from as small as a few hundred acres to as large as close to a thousand acres. The age of the housing areas varies from as old as 30 years (Taman Jaya, Taman Aman) to as young as less than 10 years (Taman Pulai Emas, Taman Pulai Jaya). The gross density of each housing area too varies but what is of interest here is the density of each housing type which would in the end determine the amount of impervious surface.

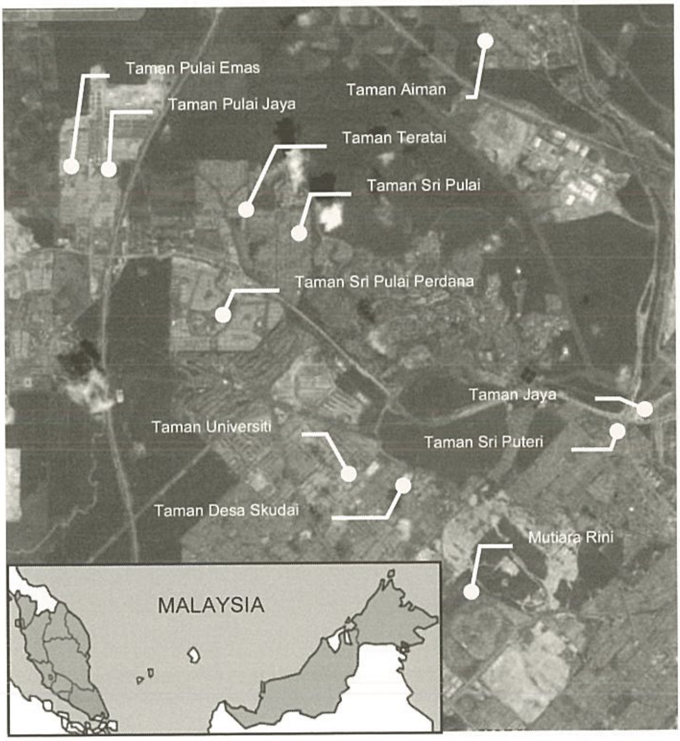

Figure 3: Study Area Showing Sampled Housing Estates

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Data and Image Processing

The study used two forms of raw data, i.e. QuickBird 0.6m remote sensing images of the study area and digital layout plans delineating the housing lots and boundaries of the housing areas. All of the processing work was done on ERDAS Imagine and ArcGIS 9.2. Pre-processing of the satellite images using a geometric correction technique was first carried out on the images before they could be used. Rectification of the satellite images to the local coordinates, Rectified Skewed Orthomorphic (RSO) coordinates, was carried out with the help of a GPS receiver for collection of ground control points within the study area.

The following stage involved classification of the images in order to distinguish impervious surfaces from previous ones. The classification process involved both unsupervised and supervised classifications. The results of the classification process were classified images that had only two types of land surfaces, i.e. impervious and pervious surfaces. The classified raster images were then converted into vector format in ArcGIS 9.2 for quantification of the amount of impervious surface. In order to do this, the vectorised classified images were overlaid with the digital layout plan before the images for each of the 11 housing areas were clipped out. Figure 4 shows one such housing area with the impervious and pervious surfaces classified.

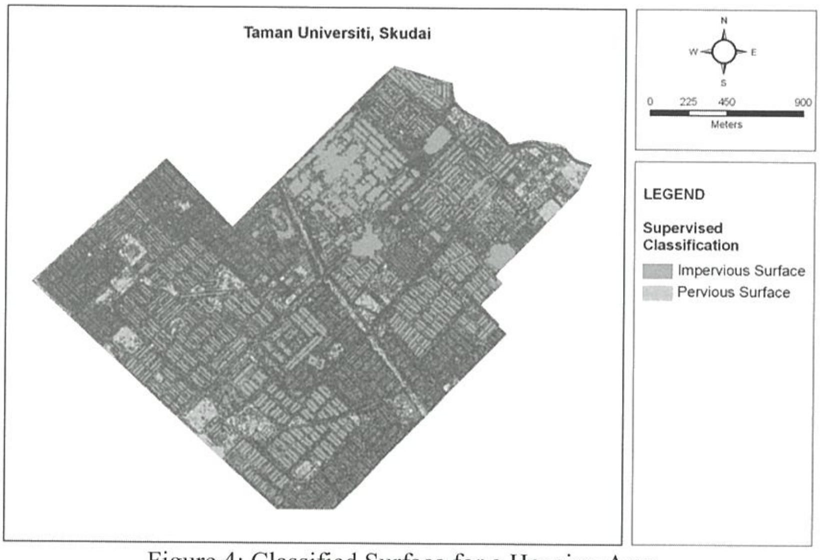

Figure 4: Classified Surface for a Housing Area

The trend of urban housing development in Malaysia is that each housing area or estate would have a mixture of houses built in zones differentiated by house types. Thus, in a housing estate one would normally find bungalows in a zone separated from semi-detached (semi-D or duplex) houses which are in their own zone separated from terraced (linked) houses and so on. In order to capture the whole range of housing densities, the study made use of these existing housing categories for sampling of house groups to calculate the amount of impervious surface. Figures 5 shows typical house types in Malaysian housing estates. A total of 28 housing samples from the selected housing estates were randomly chosen for analysis. For each of these housing samples, the percentage of impervious surface was computed using zonal summary technique of ArcGIS 9.2.

Figure 5: Typical housing types: linked, semi-detached and bungalows (left to right)

RESULTS AND DISCUSSIONS

The ensuing discussion will highlight the relationship between degree of imperviousness and housing density. Before looking into the relationship between the two variables, however, it is appropriate that we look at the basic statistics of the variables collected in the study areas. This will give us an overview of the characteristics of the housing areas studied, especially those concerning intensity of development and impervious surface.

For the three housing types that are the subject of this study, Table 2 gives the details of their densities. In general, densities of the houses cover quite a range from as low as 3 units per acre for bungalows to as high as 30 units per acre for linked houses. These densities seem to double from one type to another of higher density. The mean density of linked houses, for example, is twice that of the semi-detached houses which itself is about twice the mean density of the bungalows. Overall, it is evident that housing densities in Malaysia are much higher than those in the developed countries where previous studies on impervious surface had been carried out (see Stone 2004; Majid 2005; Capeilla

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& Brown 2001). Bungalows and semi-detached in the USA, for instance, are built in densities of 2-3 and 4-6 units per acre respectively. It is difficult to find the density of linked houses in the USA as this type of housing is not popular there.

Table 2: Statistics of density and impervious surface of housing types

	Density (units/acre)			**Impervious Surface (%)**		
Statistic	Bungalow	Semi-Detached	Linked	Bungalow	Semi-Detached	Linked
Minimum	3.0	6.0	14.0	40.4	51.4	60.8
Maximum	10.0	15.0	30.0	96.6	93.4	99.2
Mean	5.9	10.4	19.3	69.4	76.9	88.2
Median	5.3	10.0	19.5	70.4	79.0	89.8
Std Dev.	2.9	2.9	4.6	24.1	14.1	8.9
Sample (n)	4	7	17	4	7	17

Table 2.0 also includes the statistical summary of the percentage of impervious surface for each housing type. They range from as low as 40% for bungalows to as high as 99% for linked houses. As expected, the higher the density the more the impervious surface. The linked houses have the highest impervious surface percentage that ranges from the minimum of 61% to the maximum of almost 100%, with the mean of 88%. Given the density of this kind of housing that can go up to 30 single-family units per acre, the high percentage of impervious surface is expected. What is not expected is the high percentage of impervious surface for the bungalows. At the mean density of 6 units per acre, the mean impervious surface percentage of these bungalow areas are at 69% which exactly doubles the impervious surface percentage of American bungalows at the same density (See Figure 1).

Among the factors that contribute to the higher percentage of impervious surface in Malaysia are the road design standards that allow for excessive pavement, the practice of converting green compounds into paved ones by some house owners and of course, since we are comparing to overseas planning regulations, lack of regulations in Malaysia that set the limits on the percentage of impervious surface. Of the two major components of impervious surface studied, rooftops made up on average 70% of the total amount of impervious surface while road pavement made up 25%. The remaining 5% consisted of driveways, footpath, etc.

Figure 6.0 plots the relationship between imperviousness and density. The nonlinear fitted curve shows how impervious surface increases rather dramatically from density of 1 unit/acre to 10 units/acre and then starts to taper

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off from there on to about 90%. Ninety percent is the ultimate impervious surface percentage due to the regulations in Malaysia that require 10% of housing areas should be open spaces, and open spaces in most cases in Malaysia mean green vegetation. Comparing the curve of Figure 6(a) to that of Figure 1 for the same density range showcases a contrast in term of how impervious surface predominates the housing landscape in Malaysia. It is no wonder that some of these housing estates are experiencing various environmental consequences brought about by this style of urban development. Among the environmental consequences are urban heat island, water quality deterioration, flash floods and transformation of beautiful natural streams into disgraceful urban concrete drains.

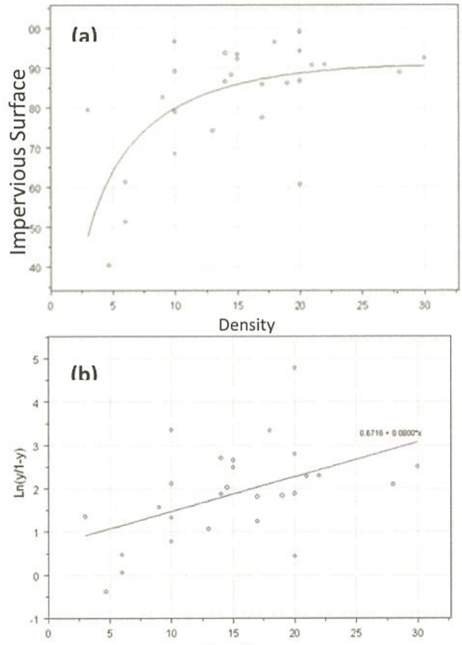

Figure 6: Impervious surface vs density: (a) Nonlinear; (b) Linear

Logit transformation of the dependent variable in the relationship gives us the linear regression model of the percentage of impervious surface and housing density. The linear model is given by

$$\ln(y/(1-y)) = 0.6716+0.08x \quad \text{(Eq. 1)}$$

where:

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y = proportion of impervious surface.
x = housing density (units/acre)

Statistical tests indicate that the relationship is significant ($p<0.01$) with a rather low multiple R-squared of 0.25.

The results of the study show that impervious surface is directly correlated to density. This confirms the trend observed overseas. What is more important in this study is the fact that the amount of impervious surface in our housing areas is relatively too high. Too high that it causes a lot of environmental problems previously alluded to in the beginning of the paper. The amount of impervious surface calculated, 40-90%, cannot sustain any form of lives in the streams as studies by various researchers (Schueler & Claytor 1997; Booth 1991; Booth & Jackson 1997) have shown that watershed with impervious surface between 20-60% will kill the stream.

CONCLUSIONS

Reducing the amount of impervious surface would be easy if only the authority were determined enough to do so. There are several ways to achieving lower impervious surface. Among them are: 1) imposing a limit on the percentage of impervious surface per subdivisional lots or per development; 2) reviewing of existing road standards that are outdated and very generous on pavement – skinny streets are now the trend; 3) encouraging more cluster development and vertical density – the two types of development that would have any chance of conserving the environmentally sensitive areas while being neutral on density (Richards, Anderson and Santore 2003); 4) regulating renovation of the houses – renovation that increases the amount of impervious surface within a lot should be tightly regulated; and 5) more usage of porous materials for pavement or interlocking blocks that encourage water infiltration. There are of course numerous other steps to either reduce the amount of impervious surface or to reduce the impact of impervious surface.

ACKNOWLEDGEMENT

The author acknowledges the funding support for this research provided by the Ministry of Higher Education, Malaysia through Universiti Teknologi Malaysia under the Fundamental Research Grant (FRGS) Programme (Vot78161).

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PLANNING MALAYSIA
Geospatial Analysis in Urban Planning
Volume **II** (2013), Page 39 - 56

GREEN SPACE AUDITS ON ITS ACCESSIBILITY IN PASIR GUDANG

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Abstract

Green space is an essential element in a city that serves outdoor recreational place for the community. It helps generating the economic and social values and promoting a healthy lifestyle for local community. The aim of the study is to audit the green spaces in Pasir Gudang Municipality and promote the strategies to improve the use of green space in the study area towards better quality of life of the citizens. The study classifies the existing green spaces in Pasir Gudang in terms of size, function, use, quality, area, accessibility and facilities provided in the green space areas. Two key points have been identified as a basic reference before any development of green spaces take place in Pasir Gudang. The study reveals that present green space areas in Pasir Gudang Municipality are able to serve most communities in the municipality. However, still about 35% of the municipality area is not presently served by the existing green spaces. Thus quantity, quality and accessibility of the green space areas need improvement. This study also shows the potential network of the access that will be able to improve the approachability of all existing green space areas by the citizens to contribute to their quality of life.

Keywords: green space auditing, accessibility, geographic information system, quality of life.

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INTRODUCTION

Green space is defined as any piece of land covered with vegetation. It usually refers to parks, golf courses, sports fields and other open land within the built-up area, whether publicly accessible or not. In many countries, open spaces are nowadays regarded as integral part of land use planning decisions. However, approaches to open space planning vary, and there is no general agreement on the desirable planning criteria as to how much open space is needed, where open spaces should be located or how they should be used (Maruani and Cohen 2007). In Malaysia, green space considered as open space. According to Department of Town and Regional Planning under the Town and Regional Planning Act (Amendment) 1995 (A933), open space is defined as any land either gated or not, which had been specifically and fully reserved or a part of it, to be used as garden, public park, football field, public recreation area or as public place. Also, the hierarchy and characteristic (size and catchment area) of open space can be classified as national park (no limitation on size, all countries), regional park (100 hectares, all regions), town park/urban Park (40 hectares, 50,000 people and above), local park (8 hectares and above but not exceed 40 hectares, 12,000 to 50,000 people), neighbourhood park (2 hectares and above but not exceed 8 hectares, 3,000 to 12,000 people), play field (0.6 hectares and above but not exceed 2 hectares, 1,000 to 12,000 people) and play lot (0.2 hectare and below, 300 to 1,000 people).

The distribution and catchment area for different type of green spaces are shown in Figure 1. It shows that green space concerns with any development. However, with the rapid land use change, it is necessary to revisit the functionality of existing green space. Besides that, green space it also provides a 'Green Lung' for a city, serve as focal points that can break monotony of concrete jungle, promote healthy society by providing spaces for recreational, social and leisure activities and also counterbalance the harsh reality of a hectic urban life. A well-distributed green space can influence the quality of life of people (Federal Department of Town and Country Planning 2005).

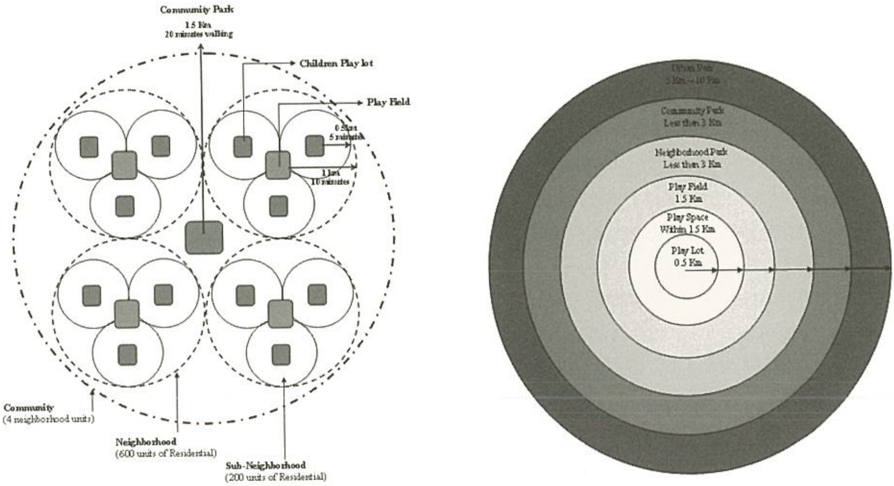

Figure 1: Distribution of (a) catchment area (b) green spaces according to Malaysia's Planning Standard

Source: Guideline and Planning Standard for Recreation and Open Space, Department in Town and Regional planning, Peninsular Malaysia.

Meanwhile the amount of provision, the distribution of green space and the ease of access to such spaces are key contributors to social and ecological functions in urban environments (Barbosa et al. 2007). Parks and green spaces have a major contribution to the liveability of city centre by creating informal recreation which serve as an outdoor recreational place and provide leisure activity for social groups.

The presence of greenery area can also help to protect natural environment, improve air quality and ensure the urban dwellers have access to recreational site. The health policy in the United Kingdom, for example, has been increasingly advocating the use of outdoor green space to improve health and there has been a growing emphasis on the health improvements connected with use of the natural environment (Kessel and Green 2009). Other than that, green spaces serve as protective elements to the unique character of rural communities which might otherwise be absorbed by expanding suburbs area. It also functioning as a place for local community to learn and experience outdoor environment. Therefore, there is a strong reason that green spaces contribute towards promoting social inclusion on health and well-being of the community and act as important local education resources.

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Green space becomes more and more important element of a city for its psychological role in community well-being. People who live in urban areas with more green space tend to report greater well-being than city dwellers who do not have parks, gardens, or other green space nearby (White et al. 2013). They also assert that living in an urban area with relatively high levels of green space compared to one with relatively low levels of green space was associated with a positive impact on well-being equivalent to roughly a third of the impact of being married vs. unmarried and a tenth of the impact of being employed vs. unemployed.The above study suggests that while urbanization is a potential threat to mental health and well-being, living closer to urban green spaces such as parks, is associated with lower mental distress. This shows the importance role of green space in improving quality of life of the citizens.

Green spaces might act as the 'glue' which binds the city together. They are part of a larger cohesive network of individual spaces which include the transport arterials, streets, lanes, street intersections, parks and squares. The availability of green space in the living environment may be an important environmental factor that moderates the relationship between stressful life events and health (Berg et al. 2010). Meanwhile, urban green spaces are universally valued as amenity-recreation venues, wildlife refuges and essential liveable-city ingredients (Jim and Chen 2003). The various benefits of green space had been identified through various studies established by many researchers. These benefits are generally much dependent on the way that the green spaces are planned, designed and managed by authority where it belongs. It is important to ensure that all these resources have strong impact on quality, accessibility and adequate quantity to serve local community.

Geographic Information Systems is one of the best tools to implement environmental analysis. The most importance of GIS is about its capability to handle spatial and attribute data (Ahris 1994). The integration of the GIS and Remote Sensing will contribute to better results. It enhances the research results through the improvement of the interpretation of the earth surface. The application of planning standard for green spaces distribution and catchment areas with GIS is beneficial to understand the current issues. There are many advantages in GIS that can be used in analysing the real world system. GIS can be applied to analyse line and point features based on topology rules. It is a useful tool in analysing water distribution, stream flows, and traffic flows, whereby centres, links, nodes, and impedance are key elements in that analysis (Kyushik and Seunghyun 2007). It also provides network-based spatial analysis, such as routing, fleet routing, travel directions, closest facility, service area, and location-allocation.

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Green space audit is carried out to identify how extent the green space areas exists, including its distribution and accessibility. Due to the rapid development and land use changes, it is then necessary to look at the functionality of green spaces. The goal of this study is to identify and evaluate the green space areas in Pasir Gudang Municipality. There are two objectives in this study. First: to audit various types of green spaces in the study area, and second: to look at the function of green space areas in terms of coverage and accessibility. This audit is carried out to see whether or not the selected area has sufficient coverage and quality of the green space areas for local community, as well as to establish an accurate view of the service level of the green space areas and proposed fundamental strategies to improve the connectivity and accessibility of the green space areas. Green space audit in this study covers several assessments particularly with respect to its quantity (area) and accessibility.

STUDY AREA

The study area is area under the administrative unit of Pasir Gudang Local Authority or Majlis Perbandaran Pasir Gudang, Johor (MPPG) as exhibited in Figure 2. The area was selected because of its potential future development under Iskandar Malaysia Development Region. Pasir Gudang becomes one of the key components of development of Iskandar Malaysia that is put under the Eastern Gate Development and Special Economic Corridor (SEC). Eastern Gate is the industrial and manufacturing hub in the southern region of Peninsular Malaysia. This hub encompasses 31,132 ha in Pasir Gudang Municipality.

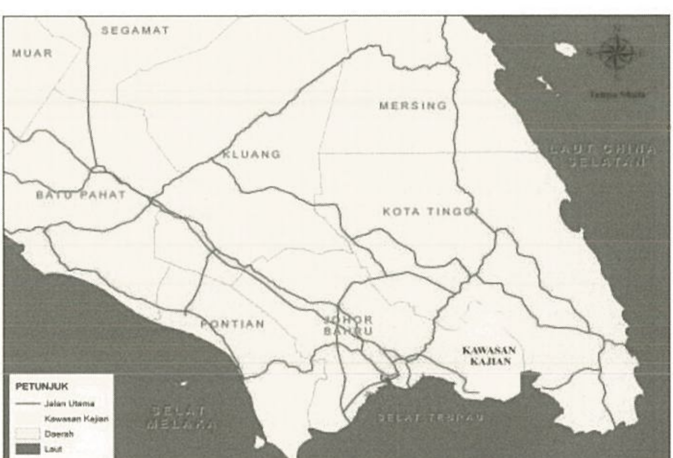

Figure 2: Location of the Study Area

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The complexity of the development issues and the increase of population are seemingly the fundamental issues that contribute to the environmental sustainable matters in the Pasir Gudang Municipality. This study attempts to understand the greenery as one of the key components to improve quality of life towards the sustainable livelihood in Pasir Gudang Municipality. It is believed that the presence of sufficient green space areas with adequate accessibility in the city contributes to the happiness of the citizens towards sustainable quality of life.

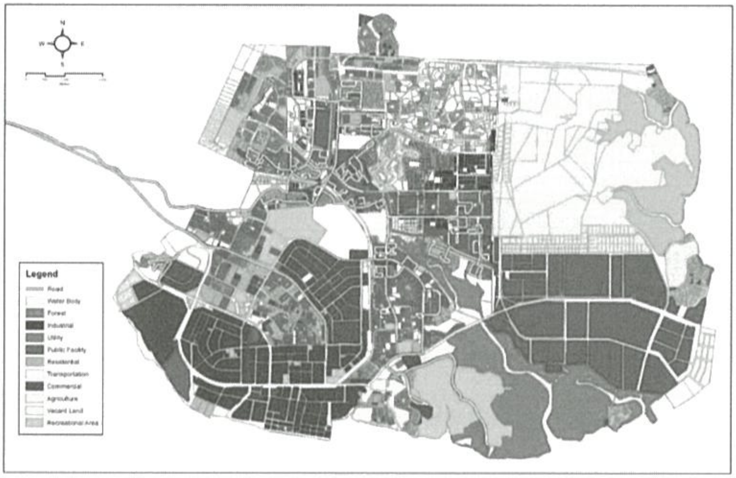

Figure 3: Land Use of Pasir Gudang

Table 1: Area and Percentage of Land Use in the Study Area

Land use	Acreage (Hectare)	Percentage (%)
Housing	578.23	4.39
Commercial	38.09	0.29
Industry	1,296.41	9.84
Institution	192.17	1.46
Open Space and Recreation Area	222.86	1.69
Vacant Land	4,113.70	31.23
Forest	772.55	5.86
Agriculture Land	3,697.31	28.07
Water bodies	930.75	7.07
Utility	322.20	2.45
Street and Transportation	1,009.73	7.66
Total	**13,174.00**	**100.00**

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The main components of the land use of Pasir Gudang are agricultural land, open space, industrial and residential areas as shown in Figure 3 and quantitatively reflected in Table 1. Major economic activities in the Pasir Gudang area are electrical and electronic, chemical, oleo-chemical, chemical biofuels, plastic and food products, engineering-based industries, ports and logistics, warehousing, as well as research and development. The study area is mainly characterized by mix land use development, as shown in Figure 4. Most of the green spaces exist in this zone is at scattered manner.

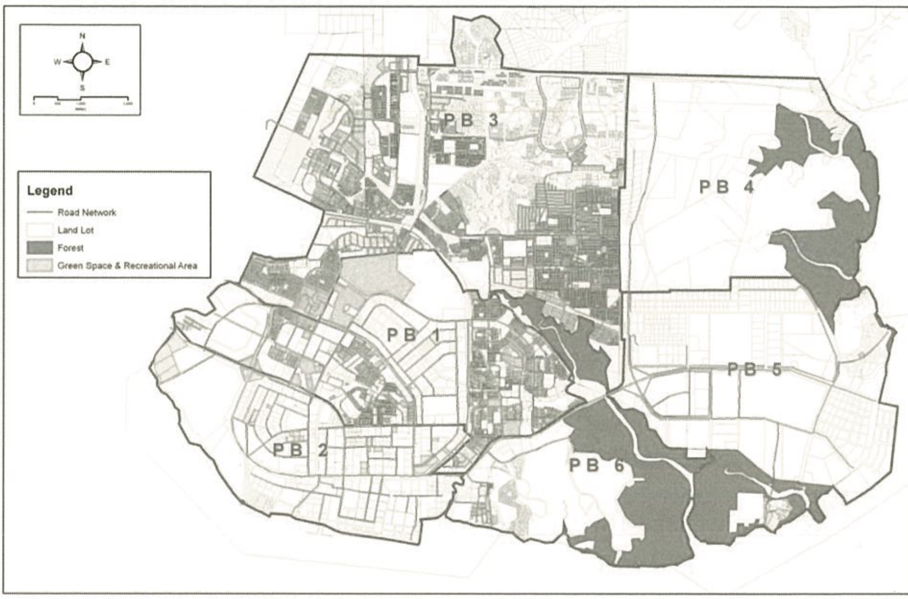

Figure 4: Distribution of Green Spaces in the Study Area

The accessibility of the existing green space areas in Pasir Gudang seems adequate, since they have no barriers to free entry such as round-the-clock access, no admission charge applied, available road access from community centres to the green space areas, and sufficient parking lots for the visitors. However, room for improvement with respect to accessibility is still there. The improvement can be, among other, done through enhancement of the accessibility of the green space areas and connectivity between the users i.e. community centres and the green space areas. This study attempts to understand this issue by means of employing geographic information system as a tool for analysis and appropriate methods of study.

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METHODS OF STUDY

The study applies the integration of several techniques in data collection and analysis. A database was developed to accommodate the spatial data input. The Ikonos Satellite Imagery and vector data obtained from the Local Authority are the main component in this study, since the analysis was based largely on this source. Updating data and ground verification on land use and land cover have been made to ensure that the existing data and information are up-to-date. The ground verification of land use data and land cover was done by walking-through the existing green space areas and other relevant land use categories.

Data collection and analysis are two most essential stages towards best results with the support of data accuracy and suitable technique of analysis. Table 2 shows the sources, types and components of data collected and used in the study. For the accuracy of the data verification, the study area was visited several times and the measurement of the data was made with the support of Global Positioning Systems instrument. The additional data, which is necessary to support the study, were also collected and verified by using same instrument and technique.

Study uses satellite imageries. The purpose of using satellite imageries is to identify the existing green space areas and its land cover towards the acceptable level accuracy. The satellite imagery that shows "present" land use of Pasir Gudang area is shown in Figure 5. However, due to the delay time of the image, the image might not reflect the current condition of the green spaces in the study area. That is why the ground verification was undertaken. The satellite image is also very useful to identify both natural and artificial green space areas and get information on it in terms of geographical location, area and shape. The images are classified according to type of land use or land cover and also by greenery and built-up areas. There are two methods to classify the images, which are Supervised Classification and Unsupervised Classification. The study employs Supervised Classification method, as Richard and Jia (1993) asserted that the supervised classification is the essential tool used for extracting quantitative information from remotely sensed image data. By using this method, the analysis can be done in smoother manner since sufficient known pixels to generate representative parameters for each class of interest.

The classification process of land use and land cover was done by using image processing software. The first result of the classification has been used as a reference for the second classification in determining the green space areas in Pasir Gudang Municipality.

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Table 2: Components and Sources of Data Collection

Component	Data	Shape	Source
Administration	State Boundary	Polygon	MPPG
	District Boundary	Polygon	MPPG
	Mukim Boundary	Polygon	MPPG
	Cadastral Lot	Polygon	MPPG/JPBD
Land Use	Existing Land Use	Polygon	MPPG/JPBD/Field Work
	Future Land Use	Polygon	MPPG/JPBD
Water Body	River	Polygon	MPPG/JPBD/Field Work
	Lake	Line	MPPG/JPBD/Field Work
Building	Existing Building	Image	MPPG/JPBD
Transportation	Road Network	Line	MPPG/JPBD/Field Work
Pedestrian Network	Pedestrian Network	Line	Field Work (GPS)
Recreational Area	Recreational Area	Point	Field Work (GPS)
	Recreational Area	Polygon	Satellite Image
Green Space	Green Space	Point	Field Work (GPS)
	Green Space	Polygon	Satellite Image

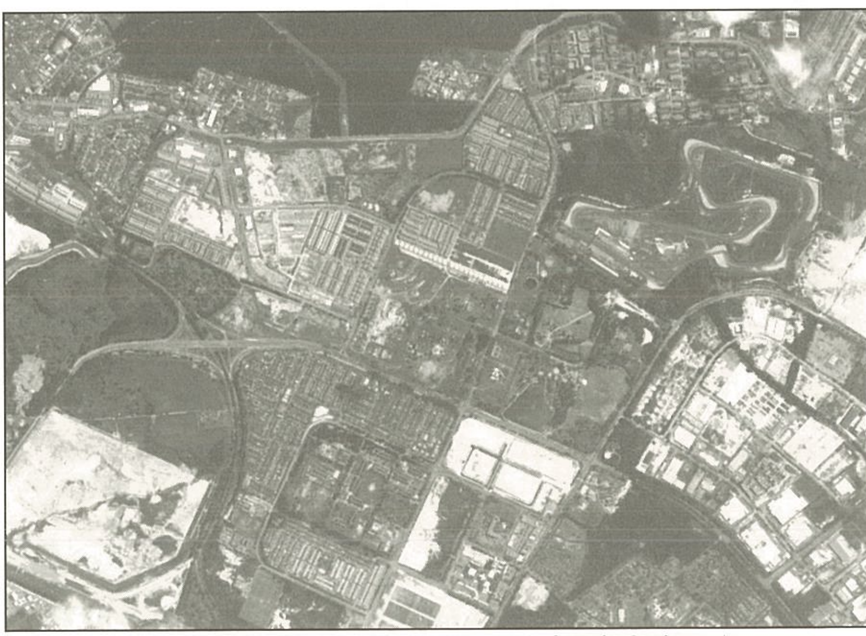

Figure 5: The Ikonos Satellite Imagery of Pasir Gudang Area

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Evaluation on the accessibility level and the coverage of service area of green space in Pasir Gudang was done by using GIS software. The analysis is based on the distribution of green spaces, roads and pedestrian networks. The connectivity and coverage of the green spaces was evaluated by following the Guidelines provided by Jabatan Perancangan Bandar dan Desa. The evaluation was done with the support of GIS functions. The service area of the green spaces was considered basing on its typology and function of its category. To identify the best network i.e. connectivity of the green space areas with the community centres as well as connectivity among green space areas, a network analysis has also been done with the support of same GIS function. The analysis results reveal that connectivity of the green space areas and community centres, as well as connectivity among the existing green space areas need improvement. Looking at this connectivity status, recommendations on the integration and connectivity of all green space areas and accessibility by the community centres in Pasir Gudang are proposed.

RESULTS AND DISCUSSION

This study largely focuses on the distribution and relation of green space typology on the accessibility and connectivity of green spaces network.

Green Spaces Typology and Accessibility

Study area has a wide range of open space with respect to size, function and use. It is also certain that some communities have been provided with easily accessible green space better than others in terms of quality, quantity and facilities of the green space areas. This issue should not appear when equal quality of life would be promoted for the whole citizens in the study area.

Satellite imageries and ground verification reveal that six planning blocks in the study area have significant provision of green space areas with respect to quality, size and facilities. The Planning Block 1 and 3 contain the most numbers of green space areas compared to other blocks, particularly in the eastern part of Pasir Gudang. The eastern part was actually planned to be the main industrial area of Johor Bahru, and thus contains less green spaces. Also, the residential areas in Pasir Gudang are concentrated in the western part of the Municipality. It is realistic then to have more green spaces in the western part.

The audit process identifies 1,531.62 hectares of green space in the study area. This is quite significant figure in comparison to other areas in Johor Bahru. The auditing process was then done throughout this area. The total

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amount of green space areas in Pasir Gudang Municipality were then identified and quantified.

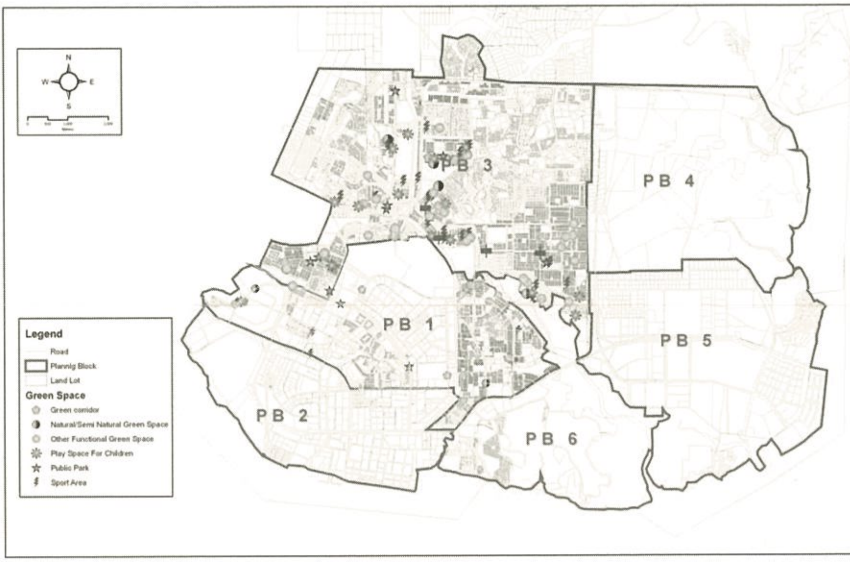

Figure 6: The Distribution of Green Space by Its Typology

Figure 6 shows all sites plotted and presented with respect to its green space typology. This figure reveals that the concentration of green space areas is in Planning Block 1 and 3. The primary function of these two blocks was residential areas. In the remaining planning blocks, the number of green space areas is not significant amid the growing increase of residential development in these parts particularly Planning Blocks 4, 5 and 6. The primary function of these three blocks was industrial areas.

Table 3: The Area and Percentage of Green Space according to Its Typology

Typology	**Area (ha)**	**Percentage of Total (Area)**
Public Park	68.15	4.45
Private Ground	688.31	44.94
Amenity Garden	-	-
Play space	18.38	1.20
Sports Area	199.72	13.04
Green Corridors	34.22	2.23
Natural/Semi natural Green Space	522.99	34.15

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Other functional Green Space	-	-
Total	**1,531.62**	**100.00**

Some land use conflicts would perhaps arise in future when residential and industrial developments will be equipotentially promoted. Thus, authorities should be cautious on this latent issue. A number of green space areas with similar quality with other planning blocks i.e. Planning Blocks 1 and 3 seems necessary to develop, with an argument that still industrial development would need sufficient greenery. The green space typology is shown in Table 3.

Table 3 shows the area of various typologies of green space areas and percentage in Pasir Gudang. It shows that private ground, which is currently greenery area, is predominant. This type of greenery is very vulnerable to land conversion since it is mostly owned by private companies or individuals. When the land owners convert them to be built-environment, the greenery is then easily gone. A clear and suitable development control that promotes socio-economic development while conserving environment should be appropriately implemented in this area.

Table 4: Green Space Coverage in the Study Area

Coverage	**Area**		**Percentage**
	In Acre	**In Hectare**	
Inside coverage	21,430.63	8,672.67	64.79
Outside coverage	7,544.65	3,053.21	35.21

Table 4 shows the total amount of green space within the whole study area. It shows that the total area of green spaces is 1,531.62 hectares or equivalent to 11.66 % from total area of Pasir Gudang. The most common green space typology identified in the study area is private ground, which is accounting for 44.94 % of the total area of Pasir Gudang. Natural and artificial green spaces occupy 522.99 hectares in the study area. This is identified as the second largest green space in Pasir Gudang. This size is equivalent to 34.15 % of size of study area. Sports area had covered 199.72 hectares or equivalent to 13.04 %. Green corridors that consist of buffer area and river reserve cover only 34.22 hectares of land.

The ability of people to access green spaces easily is very important to promote health and well-being. It is important that residents are able to access green spaces within a reasonable, or even, walkable distance from where they live or work. This is to encourage the visits of communities surrounding on foot or by bicycle, and thus, reducing emissions.

Accessibility can be expressed through, among others, distance thresholds, which represents the maximum distance that a typical user can reasonably be expected to travel. However, the attractiveness of the parks and green spaces might also be essential factor for the citizens to visit and enjoy the parks, even though the distance beyond the threshold. For green space evaluation in Pasir Gudang, the threshold represents the distribution and distance. The threshold was derived, based on the Guideline and Planning Standard for Recreation and Open Space, Department in Town and Regional planning, Peninsular Malaysia. The baseline of the threshold is that people willing to walk to their nearest accessible green spaces. This study measures the threshold for the purpose of development of green spaces strategy. The standards of distance should be set to reflect how far people prepare to travel to different typology of green spaces.

The service area was evaluated based on the typology and distribution of green spaces. The availability and accessibility of roads and pedestrian networks are the criteria for evaluation. The analysis was executed using a function in GIS. The study found that a largest part of Pasir Gudang is served by the green spaces catchment area (Figure 7). The total catchment area of all green spaces is 8,672.67 hectares or 64.79% of the total area of Pasir Gudang. On the other hand, the area outside of the catchment is 3,053.21 and 35.21%. Figure 8 shows that the eastern part of study area is mostly outside green spaces service area. The eastern part is planned for new industrial development area, and thus there will be insignificant green space in this area.

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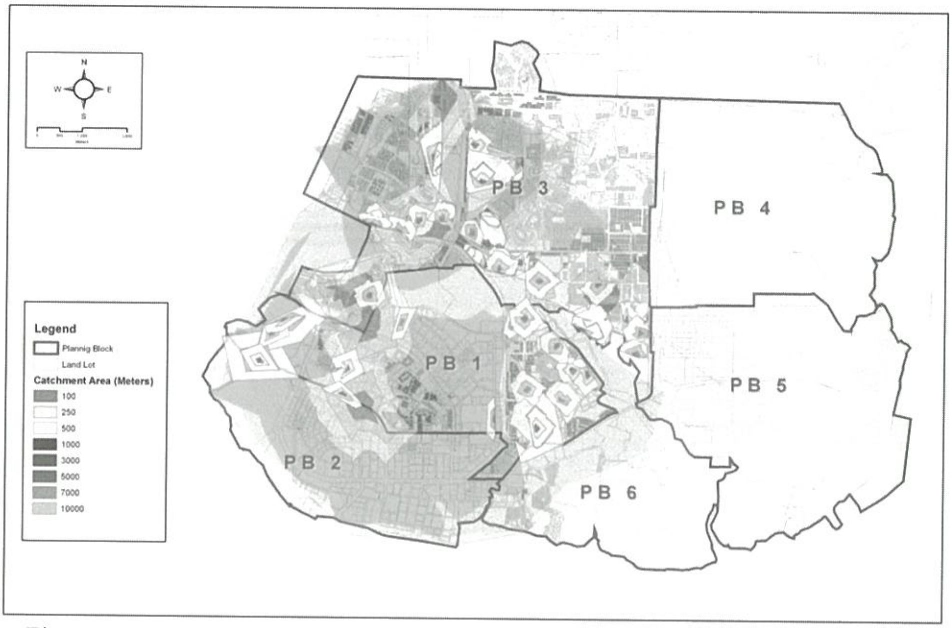

Figure 7: The Coverage Distances of All Green Spaces in Pasir Gudang

The study reveals the present catchment area of the green spaces in Pasir Gudang based on the distance and its distribution. It is obvious that almost all of the residential area in Pasir Gudang are within the catchment or service area, and therefore conveniently served by the green spaces. The service area was measured and accordingly the level of accessibility of the green spaces was identified. The town parks and community parks are the main green spaces that give a full service to the whole communities in Pasir Gudang. Nevertheless, the number and distribution of play field are quite limited for small neighbourhood.

Upgrading and Enhancing Green Space Network

Apart from the analysis of accessibility and service area, the second part of analysis is to identify the optimum network of all the green spaces. The purpose of the analysis is to look at the potential network that can enhance the connectivity of all the green spaces in Pasir Gudang. People will be able to move conveniently from one to another green space. A network analysis has also been done with the support of GIS function. Figure 8 shows selected roads for the purpose of enhancing green space network based on their distribution and distance. This network should be improved to create better connection of the green spaces.

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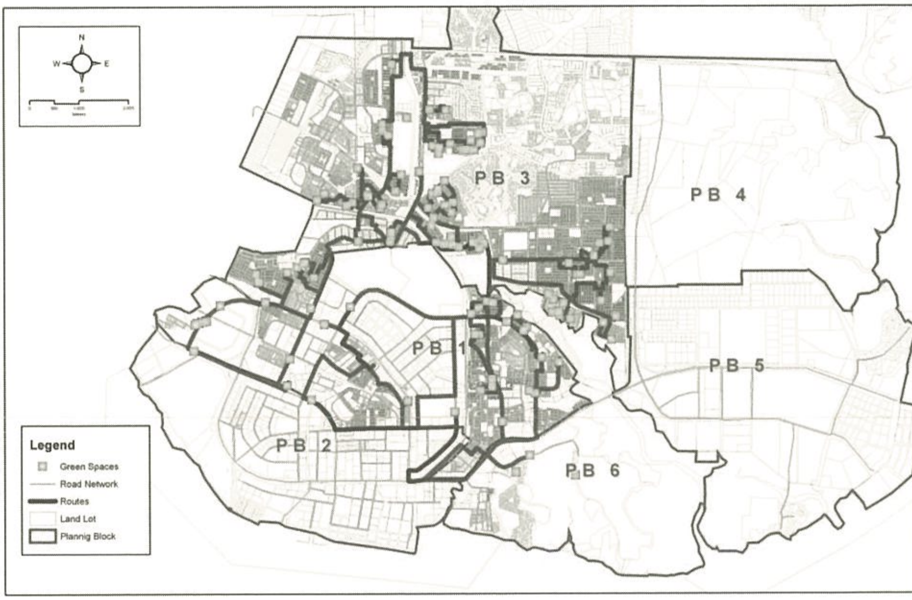

Figure 8: Selected Network for the Enhancement of the Green Space Connectivity

The network as shown in Figure 8 interconnects the green spaces and parks and may also reflect the shortest possible distance of the existing green spaces and parks from surrounding community centres i.e. residential areas. The citizens can pass through a certain pathway in the network to arrive at any green spaces or parks safely and conveniently. The pathways along the network can be improved with respect to convenience and safety for the citizens to access the green spaces. Some connections of the green space areas and residential areas are presently inconvenient for pedestrian access since pedestrian facilities are seemingly not adequate to support safety and convenience.

Upgrading of the network i.e. connectivity is very important to create high accessibility and safe access to green space through high quality networks. In this case, a high quality network must be reflected in its safety and convenience for access by various mode of transport i.e. both pedestrians and motorized transports. A "green corridor" that connects existing green spaces is a good concept, and therefore can be applied in selected networks in the study area. The green corridor should have good vegetation and greenery sense along the paths with high safety level for pedestrian. Some of the existing roads in the study area have already provided pedestrian networks but still improvement of safety, pavement, shading and connection is needed. The conflict between vehicles and pedestrians also need to resolve by improving meeting points along

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the pedestrian network. For instance, zebra crossing, pedestrian crossing bridges or tunnels, lighting and green barrier should be provided along the green corridor. This will encourage people to use the pedestrian network effectively.

By considering the results of network analysis of the green space areas, this study suggests the following key strategies to improve the accessibility of green space areas by putting safety and convenience first. The key strategies include:

- Establishment of clearly defined and well-used network of accessible routes that connect communities to local green and open spaces.
- Assurance that new and enhanced green spaces are designed to have good internal access with clear entrances, good signage and clearly defined paths.
- Maximizing the opportunities for people to walk or travel to their nearest green space. A 500m in distance can be adopted for local access standard in Pasir Gudang. This can be considered as the maximum distance that people should have to walk or travel to their nearest greenery area. This standard can be applied to both new and existing neighbourhood development.
- Provision of safe road crossings and easy access point to encourage people to walk or cycle to nearby green space. Busy roads may act as barriers, thereby reducing access for nearby residents.
- Increasing accessibility of communities to presently inaccessible green spaces for recreation.
- Development of new accessible green spaces. Where there are no suitable sites for new green space development, then the accessibility of existing green spaces should be enhanced and improved.
- Development of convenient links between green spaces and the surrounding neighbourhoods to encourage people to undertake more local journeys on foot or bicycle.
- Provision of a 500m maximum walking distance standard, which is equivalent to a 10 minute walk. The proposed standard reflects the need of ensuring equity and also ensures that the play spaces provided are well maintained. This distance standard means that every child will be able to access an equipped playing space within 500m or less of where they live.
- Provision of easily accessible playing and recreation opportunities will enable children, young people and adult to connect with the world around them, provide essential facility for healthy and inclusive communities, and provide opportunities for safe social interaction.

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CONCLUSION

The Green Space Strategy for Pasir Gudang, as revealed by the study, is part of the audit results. It sets out the objectives for the way in which green spaces in Pasir Gudang are maintained and improved. It should be accessible, sustainable and continue to perform a range of functions that brings benefit the whole community besides the good provision of green spaces area.

The recommendations made in this study, however, require additional resources and further investigation for implementation. This strategy can be achieved over several years through consistent approach to improve the management of existing resources and encourage greater involvement of local communities in the development as well as management of green spaces. The recommendation could be incorporated in the development plan of Pasir Gudang Local Authority.

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PLANNING MALAYSIA
Geospatial Analysis in Urban Planning
Volume **II** (2013), Page 57 - 74

FIRM DYNAMIC ANALYSIS FOR URBAN LAND USE AND ECONOMIC GROWTH MODELLING

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Abstract

In urban growth processes, urbanisation is highly influenced by economic growth which triggers the dynamics of economic agents and land uses. This is consisted of complex subsystems which need sophisticated methods like agent-based modelling and simulation to understand the pattern, behaviour and scale of multiple actors. The objective of this paper is to identify the behaviour, pattern and the scale of impact of firms on market in the region in order to foster an accurate agent-based modelling. The Geographic Information System is utilized to geocode the entrance and exit of firms to the market in Greater Kuala Lumpur region. This study has also carried out a temporal analysis considering 18 years performances of the firms from 1990 to 2007. The findings in this paper show sector 9 (i.e. Financing) has highest percentage of establishment with 35.1 %. In addition, Sector 3 (i.e. Mining) and Sector 5 (i.e. Electricity) have the lowest percentage of establishment with 0.3 %. The result of this study will be a foundation to facilitate developing an agent-based modelling and simulation which helps town planners and decision makers to understand the relationship and interaction between economic growth and dynamic land use patterns in their region.

Keywords: Regional Economic Growth, Geographical Information System, Urban Sprawl, Firm Demography.

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INTRODUCTION

Urban planning and transportation modelling have in common a long history of modelling urban dynamics. These disciplines have however used to some extent different modelling approaches. The integrated land use transportation models have been dominant in transportation research. The core of this modelling approach is a transportation demand model that is applied to a given spatial configuration of land uses. It results in a distribution of traffic, travel times and perhaps congestion. These travel times are then used as input to measure accessibility. Land use change is then modelled as a function of changing accessibility, and iteratively urban dynamics are then simulated.

It may be argued that the integrated land use transportation models include a richer set of behavioural principles. However, the location decisions of firms which are mainly based on the concept of accessibility do little justice to the results of empirical studies in regional science and economic geography. This suggest that the location decisions of firms are part of their overall business model and influenced by a larger set of considerations, some of which are related to preferences, others to constraints. To avoid these problems, multi-agent models have been advocated as an alternative to these dominant modelling approaches. An agent in this context represents a decision maker that makes location decisions, party independently, partly in reaction to the location decisions of other agents. The philosophy behind this modelling approach is that urban growth patterns emerge as the cumulative effects of these individual decisions. In that sense, multi-agent models are assumed to better allow investigating urban land use as a complex system. Models are built in order to understand urban dynamics since these tools, in mimicking part of the urban system, can provide valuable information on the system's behaviour to planners. Despite the potential of agent-based models to simulate urban dynamics, very little progress has been made, especially if ignoring those models claiming to be multi-agent models but which in reality stay very close to conventional integrated land-use transportation models. This is possibly the result of the lack of basis for identifying the characteristics of multiple actors. This paper therefore, prepares a foundation for an agent-based modelling and simulation of urban dynamics while understanding the pattern, behaviour and scale of multiple actors. The paper considers firms entrance and exit in Greater Kuala Lumpur, Malaysia, where the economic growth and urbanisation trend is rapid and attracted a great number of literature (Morshidi 2000).

In achieving sustainable development in Malaysia, urban planning activities have changed from simple objectives to a more complex exercise improving comfort living conditions. This is due to the government initiative to introduce development programs to accelerate economic growth and elevate income levels to improve the quality of life of people. Furthermore, with the new trends of economic regional development in Malaysia, it may be relevant to develop a model which simulates growth within the region. Economic growth can be described as changes or increments in the level of production of goods and services in the economy of a country over a period of time. To the extent that economic growth is reflected in urban growth, it is often manifested in changes in land use patterns. In general, some amount of growth can be captured in the existing building stock and associated land use patterns, but increasing growth tends to induce land use change. The problem and difficulty is how to incorporate economic growth in agent-based models. This paper aims to answer this question in the following sections.

URBAN LAND USE AND ECONOMIC GROWTH MODEL

Understanding Urban Land Use

Understanding urban and regional growth is important in order to model it since it involves several actors with different patterns of behaviour (Cheng 2003). Urban growth can be defined as the process of growth and decline of urban areas. These urbanization processes tend to be strongly linked to economic development processes. The pattern of concentration of economic activity and its evolution has been found to be an important determinant of the structure of cities, the organization of economic activity, and national economic growth. Yet, urban growth affects the efficiency of production and economic growth, and the way agents interact and live in cities. Urban growth is related to land use in cities. In order to understand these land use pattern, models have been built to make these relationships explicit.

Early urban models were formulated in the 1950s. However the first operational model of urban land use is widely considered to be developed by Lowry (1964) and is known as "Model of Metropolis". This model was the first generation of models that is based on theories of spatial interaction. The spatial interaction models framework was continued to be developed through the early 1960s to the mid-1980s when they became mainly replaced by models grounded on random utility theory and an econometrics framework (Iacono *et al*. 2008). This shift also meant a changing focus from aggregate, spatial analysis to disaggregate non-spatial analysis. Starting in the early 1990s, researchers have dedicated their effort to develop comprehensive urban micro-simulation models, and cell based models which reflect the dynamics of change in urban environments. These modern era models backed with advances in computing

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technology and efficiency, allow researchers to undertake a more complex series of model development, for instance, through the integration of new technology such as GIS to create a new generation of models. Figure 1 shows the chronological development of land use and transportation models.

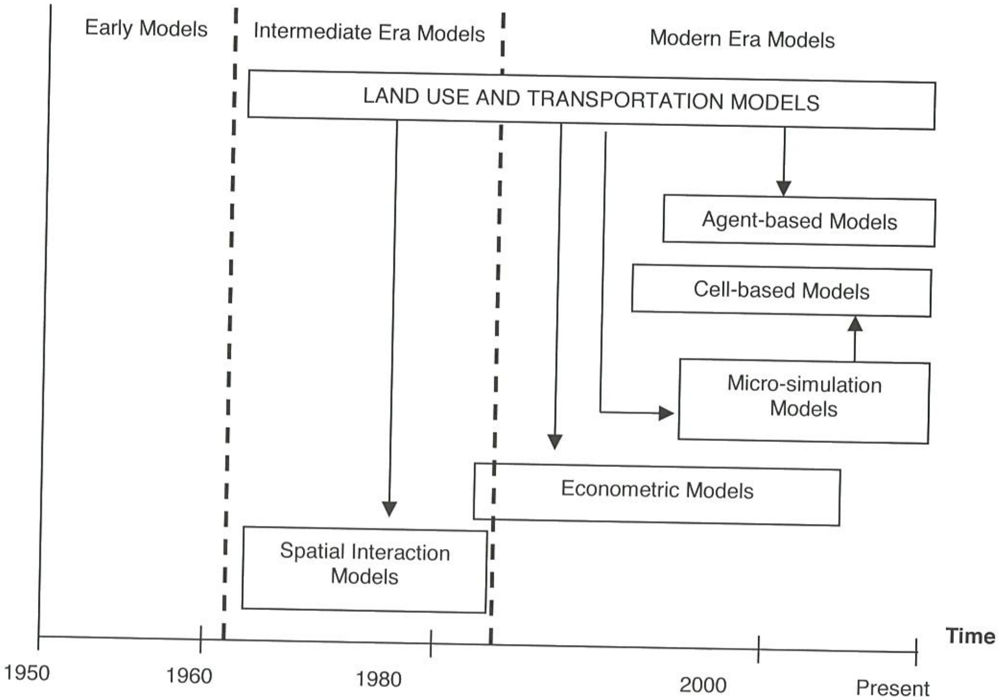

Figure 1: Chronological Development of Urban Land Use and Transportation Models
Source: Modified from Iacono et al. 2008

How to Incorporate Economic Growth?

To address the issues of incorporating economic growth in land use change model, several cellular automata and agent-based models have been develop (Batty & Xie 1994; Yeh & Li 2001; Li & Liu 2008). Although there are differences between models, integrated land use transportation and cellular automata models typically first estimate a model of economic growth such as a spatial input-output model, sometimes linked to assumptions or a model of external urban growth. These models then predict the impact of change in the economy in one sector or region on other sectors in other regions. This change is assumed to reflect a changing demand for land use. Finally, this additional demand is allocated across locations as a function of accessibility and suitability. The mechanism of including economic growth into these models is hierarchical and aggregate and far removed from the premise of agent-based modelling of behavioural realism. The question then is what alternative approach may be employed?

Based on the notion that location decisions are part of their business model and its inherent dynamics, it has been argued that perhaps the demography of firms or firm demography may be valuable approach (van Wissen 2002). This concept focuses on the demographic transformation of firms in the region and its correlation with land use changes. Firm demography can be defined in terms of the lifecycles of a firm which are similar to human lifecycles that consist of birth, death, and changes in the number of employees of the firm. Seminal work on this concept goes back to David Birch's study on 'job generating processes' in the USA (Birch 1979). He advocates that the economic development of a region consists of birth, death, and migration of firms which can be considered as the basic components of development (Van Dijk & Pellenbarg 2000b). In recent years, firm demography has caught some attention in organisational sociology (Carroll & Hannan 2000), economics and economic geography (van Wissen 2002), industrial organization (Geroski 1995; Audretsch *et al.* 1997); (Caves 1998), regional science (Van Dijk & Pellenbarg 2000a) and transportation (Moeckel 2005). This study decided to use the concept of firm demography, but the concept probably needs some elaboration. Existing models have basically used the concept only to have an accounting system that predicts the future number of firms in particular segments and their size as a function of births, deaths and relocations. To the extent these drivers of change are predicted, often again the well-known aggregate models are used. This remains far from a richer theoretical framework. Hence, the challenge is how to model decisions about growth/decline, start and closure and relocations as a function of external factors. Identifying the special links between firm dynamics and urban dynamics will give firm demography the connotation of an intermediate concept linked with economic growth.

Malaysia's Urban Planning System and Economic Growth

Urban planning activities in Malaysia has evolved from the simple objective of improving living conditions to a more complex exercise of facilitating the achievement of sustainable development in the country. This is due to the intensity of development activities that require determining issues such as those relating to location, size and patterns of land utilization.

Table 1 shows Malaysia's Vision and National Planning System from the year 1947 until now. The vision is the revolutionize government development. The national planning development plan is a written policy document that includes supportive statistical data to define Malaysia's terms of development and that sets the agenda for socio economic change (Bruton 2007). This vision and

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development plan emphasise Malaysia planning strategies for generating sustained economic growth to ensure that the benefits of growth can be shared among all Malaysians in an equitable manner.

Table 1: Malaysia's Vision and National Level Planning System

Plan Content	1947-1957	1958-1970	1971-1990	1991-2000	2001-2010
Vision	British Colonial	Old Economic Policy	1. New Economic Policy 2. Outline Perspectives Plan 1	1. New Economic Policy 2. Outline Perspectives Plan 2	National Vision Policy
Planning at National Level	Plans for Economic Development	Plans for Economic Development	Development Plans Plans 1-5	Development Plans Plans 6-7	Development Plans Malaysia Plans 8-9 National Physical Plan

Source: Modified from Bruton (2007)

The Malaysian economy has generated an average Gross Domestic Product (GDP) of 6.2 % per annum from 1991 to 2005 and was expected to grow at a healthy rate of 8.5 % a year between 2006 until 2010 (Parliament of Malaysia 2006). With the previous and current economic situation in the country, it explains the relation to firm performance in a later part of the paper. Although this research is not directly related to an economic study, the economic indicators and government policy need to be taken into consideration because firm demography is influenced by these.

GIS AND ABM INTEGRATION

Currently, the employment of Information and Communication Technology (ICT) is seen as an evolving approach to improve urban governance. GIS is a tool for decision making and for providing planning information. GIS tools have the ability to build complex and interesting spatial models that represent patterns of urban development, although that may take some effort as their script languages are not necessary the best in this regard. At the very least, however, geographic information systems are highly appropriate for spatial data handling and visualization of model output (Davis 2001). Geo-reference is the most important feature of GIS and this functionality is very useful for spatial modelling. Applications based on spatial reference will create better agent-based models

(Benenson & Torrens 2004). Meanwhile, agent-based model have the capability to represent the processes underlying a particular phenomenon or activities.

According to Cheng (2003), agent-based modelling (ABM) can be defined as a collection of interacting autonomous agents, each with their own capacities and goals but related to a common environment that can involve communication, such as passing of information from one agent and environment to another. He also claims that agent-based simulation is ideally suited to explore the implications of nonlinearity in system behaviour and also lends itself to models that are readily scalable in scope and level. In urban systems, Multi Agents are also a useful tool for representing mobile entities in urban environments such as people, households and vehicles (Benenson & Torrens 2004). They have been used in urban contexts to simulate pedestrian movement in urban environments (Kerridge *et al.* 2001) and relocate households (Benenson 1998). It is unlikely that a model of urban evolution will need that level of detail, but in any case these examples of agent-based model do indicate that these systems are more appropriate to include a wide variety of behavioural principles and co-evolutionary decision strategies. Therefore, the relation and interaction of firm dynamic and land use changes can be simply detected using agent-based modelling.

GIS technologies are very useful for this study because GIS allow agent-based modellers to relate agents to actual geographic locations. Therefore, the integration of GIS and ABM will enhance the capability of urban simulation techniques (Brown *et al.* 2005; Parker 2005, Torrens & Benenson 2005). The integration of ABM and GIS enables exploring how heterogeneous individual decisions of agents translate it into aggregate rates of a phenomenon (Mathur 2007).

Integration of GIS and ABM in the urban dynamics domain has been studied before in several aspects. Gonçalves et al. (2004) for example, recommended a conceptual environment for coupling GIS and ABM simulation tools. Their ABM -GIS model was used to study the impact of a particular policy by modelling the behaviour of industrials under certain circumstances. A Shell for Simulated Agent Systems (SeSAM) was developed as a tool that provides a generic environment for modelling and experimenting in agent-based simulation (Schüle *et al.* 2004).

The integration of GIS and ABM would allow the simulation of urban dynamic development and has potential to simulate, display, analyze and present data using a common platform. Multi-agent models have the potential advantage that simulations can be more based on the behavioural of the actors as opposed to statistical data related to spatial units of observation. Relatively, it also will help

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urban development actors (policy makers and urban planner) and other professionals and administrators that are involved in the whole process of implementation to understand and make a clear decision in urban planning development.

STUDY AREA

The development of economic regions is one of the forms of the national mission in Vision 2020 motivated by Malaysia's former Prime Minister Dr. Mahathir. The initiative of economic development areas was inspired by the successful Klang Valley region development which is known as the heartland of Malaysia's industry and commerce. With diverse development concepts, it aims to achieve the goal of accelerating economic growth and development, and improving the quality of life for the people in these regions. Five new economic development corridors throughout the country were initiated and are being developed since 2005: Iskandar Development Region (IDR), North Corridor Economic Region (NCER), East Corridor Economic Region (ECER) Sabah Development Corridor (SDC) and the most recent The Sarawak Corridor of Renewable Energy (SCORE). Thus, with these economic development regions, it is realistic to develop a model that simulates growth within these regions. Yet, after considering data availability, it was decided to focus on the Klang Valley region and specifically on Kuala Lumpur as the study area.

Location

Klang Valley is a region in Malaysia which is comprised of Kuala Lumpur and its fringes and neighbouring cities and towns in the state of Selangor. Klang Valley has no official boundary, yet it is currently comprised of six districts which are Kuala Lumpur, Putrajaya, Gombak, Hulu Langat, Klang and Petaling (Figure 2). The physical site of the area was encouraged by the development of commercial, industrial and residential activities which made Klang Valley grow rapidly. With a population of 5.78 million people (Department of Statistics Malaysia, 2008) and areas covering up to 2,826 km^2, Klang Valley has the most urbane transportation hierarchy in Malaysia. Rather than a road system, integrated rail transport which consists of monorail, electrified commuter, light rail transit (LRT) and Express Rail Link (ERL) are built for Klang Valley's residents and workers to commute within the region which make it the most important region in Malaysia. This region is also served by two airports: the Kuala Lumpur International Airport (KLIA) in Sepang, which is the main international airport for Malaysia, and Sultan

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Abdul Aziz Shah Airport in Subang, which handles general aviation and turbo-prop domestic flights (2010).

Figure 2: Klang Valley Region

GIS DATABASE DESIGN AND DEVELOPMENT

Data Source

This study will utilize data from various sources, including GIS spatial and attribute data. The land use data of Klang Valley is obtained from Klang Valley Federal Territory (KVFT), demographic data from the Department of Statistics Malaysia and firm data which consist of companies registered in Malaysia are acquired from Company Commission of Malaysia (CCM). Other data to support the application such as transportation, administration and physical data are obtained from KVFT. The data are collected by visiting the targeted agency. In order to get accurate and precise data, every single spatial data is required to have a standard geo-reference. Thus, the data needs to be edited and manipulated. Attribute data were collected from various sources such as compilation of scientific reports, collections from site surveys, various digital forms data in multiple formats such as database, spreadsheet tables, and internet as well as raw data. All these data were adapted to a standard format and stored in a relational database management system which has the ability to relate to other databases.

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Data Classification

The structure of the GIS database for this study is focused on the needs of this study: land use development. For this study, there are several data layers in the database (Figure 3).

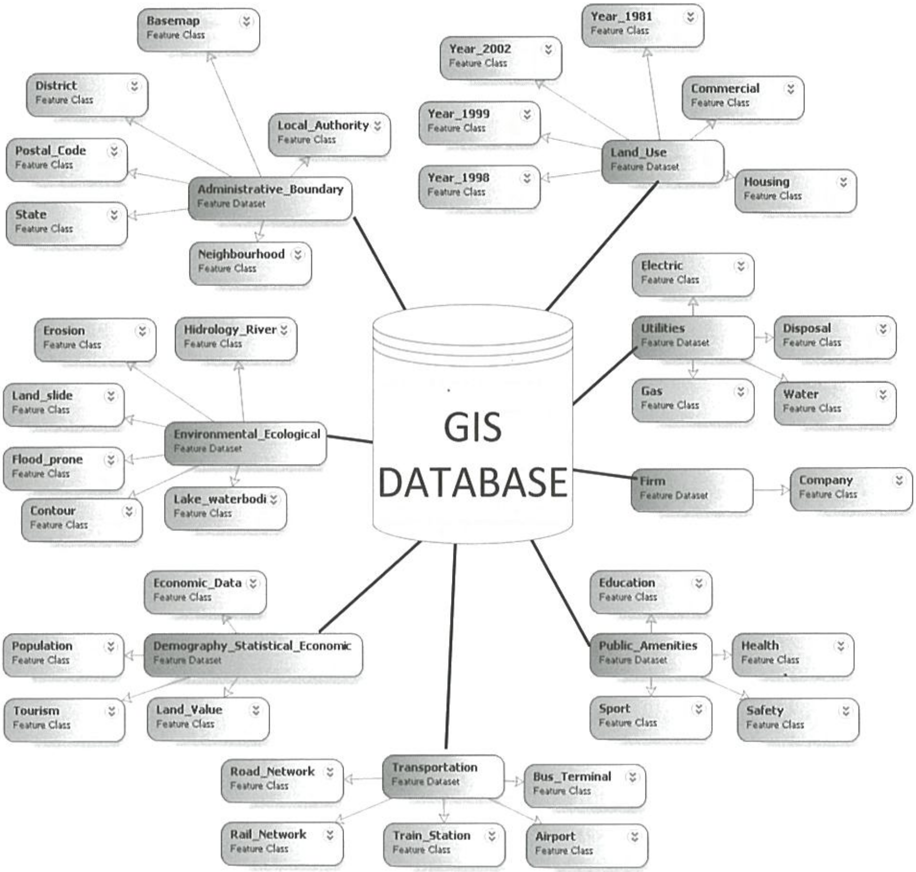

Figure 3: GIS Database

FIRM DATA ANALYSIS

The first stage of firm data analysis was conducted for the years 1990 until 2007. This preliminary analysis served as a guide to decide on the method that will be used for later periods of firm data.

Geocoding Firm Addresses

The firm data which were obtained from CCM were in spread sheet format. In order to display firm locations in spatial environments, geocoding was used. Geocoding or address matching is the process of assigning a location, usually in the form of coordinate values, to an address by comparing the descriptive location elements in the address to those present in the reference material (ESRI 2003). Based on the data, addresses come from common address formats of a company premise number followed by the street name, postal zone and area. Geocoding the address is based on a linear interpolation of an address based on the street segment in a reference of street file. In this study we geocode 62,605 firm addresses in the database. Addresses were geocode to the street name and assigned longitude and longitude coordinate using Kuala Lumpur street address locator which was created using ArcGIS software version 9.2. To geocode addresses, company data were the input and road information were the key field for matching the address. Addresses were matched using a minimum score of 10, spelling sensitivity of 10 and side offset of 10. With ArcGIS, the result of unmatched geocoding can be rechecked by using interactive re-matching function where the address can be reviewed and corrected on a case by case basis. Results with a match rate of greater or equal (>=) were positively accurate.

Result

From the 62,605 firm in the database, a match rate of 86 % (n = 53,626) match with score 80 to 100, 14 % (n = 8,979) match candidate with score not more than (<) 80 were discovered. From the overall matching process, 17 % (n = 10,394) are matched with candidate ties. In general, it can be concluded that most of the geocoded address fall close to the reference data locations.

FIRM DYNAMIC AND PRODUCTIVITY

This analysis covers firms in the Kuala Lumpur area between 1990 and 2007. Figure 4 shows the dynamic performance of firms operating between 1990 and 2007. In total, there are 62,605 firms including unknown type of firms in the Kuala Lumpur area. An unknown type firm in this study is described as a firm which is not adequately define by CCM. As can be seen in Figure 4, there were three peak years of firm growth: 1995, 2000 and 2004. From year 1995 onwards, the growth of new firms started to decline especially from 1997 to 1999 due to the global financial crisis. Unknown type firms have shown a rise and decline similarly to the trends observed for new firm's birth.

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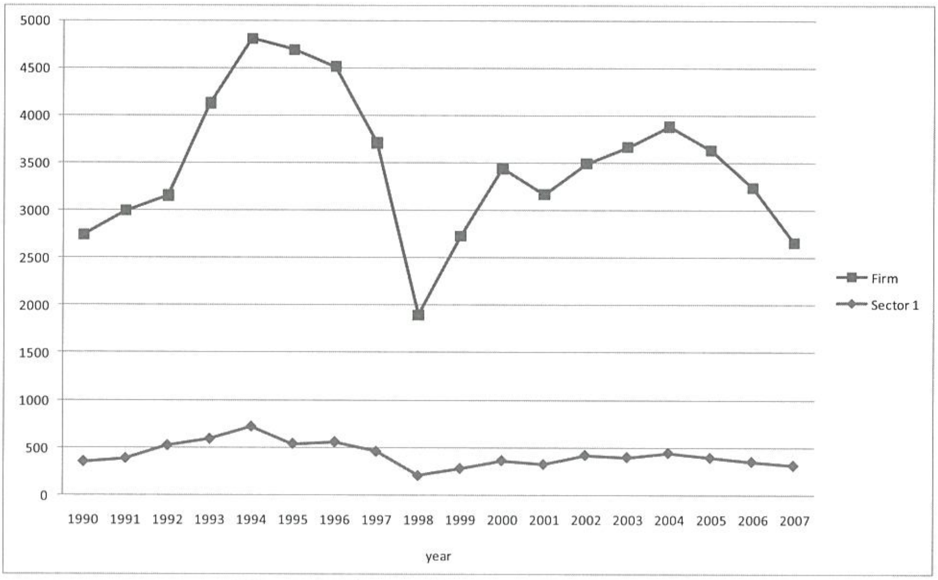

Figure 4: Firm performance from 1990 to 2007

The trade sector including firms, playing a role in generating output, income, employment and foreign exchange earnings which contributed to excellent economic performance. As shown in Figure 4, from the year 1990 until 2007, the number of births of firms increased every year in the study area. The increases of new firms are in line with Malaysia's Business Cycle Turns between 1990 and 2007 as shown in Figure 5. The business cycle is influenced by cyclical fluctuations in economic activities or processes, whereby these economic activities or processes can have widely conflicting temporal relationships to the business cycle (Department of Statistics Malaysia 2009).

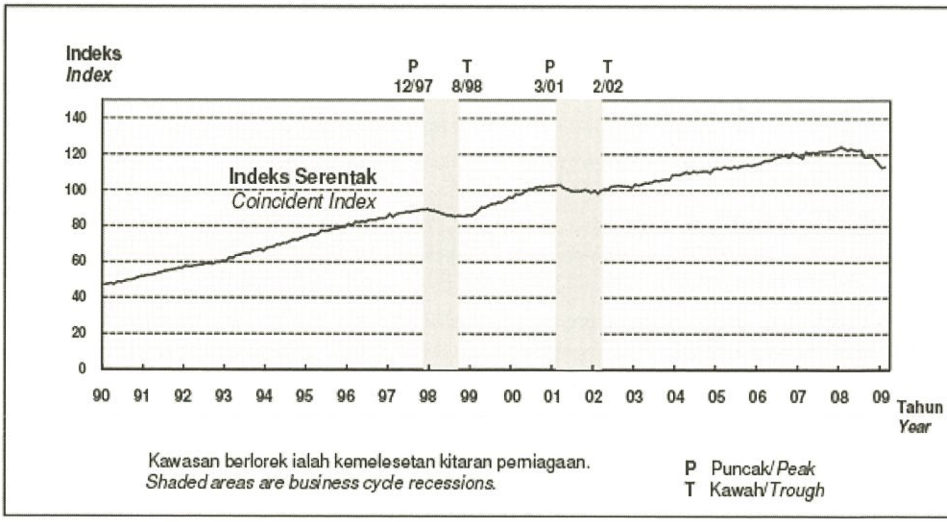

Figure 5: The Coincident Index and Malaysia Business Cycle Turns 1990-2009.
Source : Department of Statistics Malaysia 2009

From 1990 to 2007, Malaysian economic development was under The Sixth to Ninth Malaysia Plan and Second Outline Perspective Plan. The trade sector including firms, playing a role in generating output, income, employment and foreign exchange earnings which contributed to excellent economic performance.

From Figure 6, it can be seen that sector 9 (Financing, Insurance, Real Estate, Investment and Business Services) encompasses the largest share of new firms (35.1 %) which provided the impetus for economic growth during 1990 to 2007, followed by sector 7 (Wholesale and Retail trade, Restaurant and Hotel) with 30.1 %, sector 10 (Community, Social and Personal Services) with 6.6 %, sector 6 (Construction) with 6.3 %, sector 4 (Manufacturing) with 4.3 %, sector 8 (Transportation and Communication) with 4.5 % and sector 2 (Agriculture, Hunting, Forestry and Fishing) with 0.5 %.

Sectors 9 and 7 which make up the service sector cover 65 % of firms, which are more than two-thirds of overall firm births in Kuala Lumpur. The rapid expansion of these sectors was due to the growth of four service industry groups in Malaysia—finance, insurance, real estate and business services; estate and business services; wholesale and retail trade, hotels and restaurant; and transport, storage and communications—which accounted for more than 60 % of all new jobs in Kuala Lumpur (Morshidi 2000). Firm births in Sector 3 (Mining and Quarrying) and sector 5 (Electricity, Gas and Water) shows a very modest growth

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in this period of only 0.3 %. Although firm births in sector 5 are small, it is the country's engine of growth. Other sectors, especially sector 2, remain significant and an important component of the Malaysian economy.

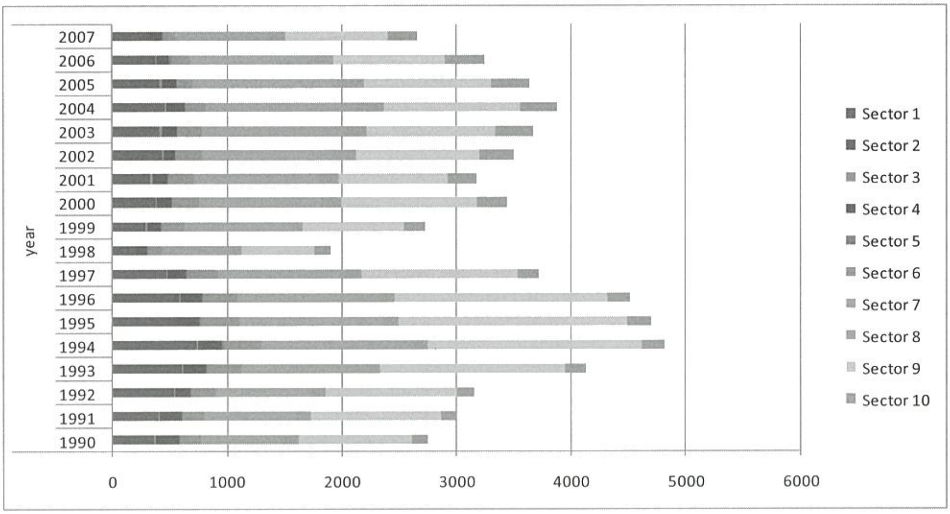

Figure 6: Firm Performance by Sector (1990-1997)

CONCLUSION AND DISCUSSION

This study is carried out with the objective of preparing a foundation for an agent-based modelling and simulation of urban dynamics while understanding the pattern, behaviour and scale of multiple actors. Using the findings of this study, the model will be developed using data of the Greater Kuala Lumpur. In general, the success of multi-agent model will among other factors depend on data availability and richness of behavioural concepts. In the early stage of development, there are needs to explore these issues and make strategic decisions. This paper documents this process by discussing some general literature, database development and initial analysis of the available data. The existing literature suggest that agent-based modelling is a reliable alternative to more commonly used cellular automata models and integrated land use transportation models in the sense that in principle they allow for richer behavioural principles and the treatment of interdependent location strategies of multiple actors and stakeholders.

For this study, the use of GIS tools assisted in data handling and visualization, while the trend of developing planning support systems based on GIS technology can also be supported. The very integration of GIS and ABM will have great impact on the process. A main problem of developing this system, the modelling of economic development as a bottom-up development process has been emphasised. It is not immediately clear how this problem may be solved in a non-traditional way, but perhaps the concept of firm demography may provide the key to a solution. Finally, model opportunities are limited to data availability. The data sources collected from different authorities and the data fusions described and planned, however, suggest that for the present study area, an interesting set of (temporal) data is available.

Acknowledgment

The authors would like to thank the Klang Valley Federal Territory, Universiti Teknologi Malaysia and Department of Statistics Malaysia for their permission to use the data for this research paper.

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Volume **II** (2013), Page 75 - 100

ASSESSMENT OF NEIGHBOURHOOD AFFORDABILITY BASED ON HOUSING AND TRANSPORTATION COSTS IN KUALA LUMPUR, MALAYSIA

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Abstract

One of the primary aims of transit-oriented development (TOD) is to reduce auto dependency, especially for low-income as well as senior residents. This study aims at providing some guiding principles for development of affordable housing with respect to TOD concept. As such, the study employed an index called Affordability Index (AI) and adapted for the study area to assess the neighbourhoods' affordability. It is composed of housing cost, household transportation cost, and household income. The analyses were conducted on three neighbourhoods in Kuala Lumpur, Malaysia. The results reveal that the AI is lower for both owners and renters in the neighbourhood farther away from the LRT station, where there is less public transit facility, despite the existence of more affordable housing. On the contrary, the index is high in the neighbourhood where the distance to LRT station is shorter, connectivity index is higher, and there are more public transport facilities, despite the presence of high- and medium-cost housings. These findings can be used to plan for suitable public transport facilities in view of neighbourhood affordability.

Keywords: TOD, Affordability Index, Transportation Cost, Housing Cost, Kuala Lumpur

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INTRODUCTION

Smart growth has been defined as a set of goals, and policy mechanisms to achieve them, which serves as an alternative to sprawl (Aurand 2010). Smart growth is considered as one of the new urban development concepts in which a great opportunity for pleasant, hospitable, and economically beneficial conditions for living, working and recreation is desired (Weitz and Waldner 2002). According to The American Planning Associations' 2002 policy guide, the smart growth focuses on a compact, transit accessible, pedestrian-oriented, and mixed-use development patterns. Refocus of smart growth on inner parts of the cities in order to reduce the share of growth that occurs on newly urbanizing land, existing farmlands, and in environmentally sensitive areas is recently appreciated by governments.

Transit-oriented development (TOD) is instrumental in achieving the smart growth initiatives. TOD is often defined as higher-density mixed-use development within walking distance of transit stations. It aims at creating high density, pedestrian-oriented communities living in a mixed-used urban context (Litman 2007). TOD which promotes public transport will be most beneficial if combined with affordable housing (Mu and Jong 2012). Contemporary planning has not incorporate the cost of transportation in the provisions of affordable housing, although it has become one of the larger share of the household budget (Department Of statistics Malaysia 2011). However, the current land use development pattern generates more urban journeys. According to Centre for Transit Oriented Development & Centre for Neighbourhood (2006), U.S. families living in neighbourhoods with greater residential density, a greater diversity of land uses and transit services spend less than 10% of their income on transport as compared with 19% by the average U.S. household.

As such, the efficacy of TOD in reducing individual's auto use is directly related to accommodating the residents who are not able to use private cars. Two main groups are mainly considered in this regards, namely, low-income households and senior citizens. The combination of mixed-income housing and TOD is regarded as a possible solution to this issue (Belzer et al. 2007). However, there are barriers in joining mixed-income and transit-oriented neighbourhoods. The current literature on US cities suggests that the social equity goals of TOD have not been achieved in most cases.

A large and growing body of literature has been published on the impact of TOD on property value and demand. Some of the main issues are related to the complicated and expensive nature of TOD (Debrezion et al. 2007, Hess and Almeida 2007). Others, argued that the demand for housing near transit stations should be socially desirable and increase the number of residential units in a TOD project (Cervero and Duncan 2001, 2002a,b; Winston and Maheshri 2007). Hence, the synergy between economic, land use, transportation, environment, housing, equity goals and TOD is not automatically achievable. Due to demographic, institutional and geographical differences, it is however difficult to generalize these studies (Duncan 2011). This study reviews the TOD and affordable housing in the context of Kuala Lumpur (KL), Malaysia, as an example of rapidly growing city.

This paper is divided into four parts. The first part deals with theoretical debates on TOD, affordable housing, and affordability index. The second part describes the design of affordability index model in Kuala Lumpur context. The third part presents the results of developed model in three KL neighbourhoods and evaluates the model by discussing the findings. The concluding remarks are presented in the fourth part of the paper.

TRANSIT-ORIENTED DEVELOPMENT

Transformation of cities through innovative public transport systems aims at providing more services to residents (Rimmer and Dick 2009). The literature suggests several reasons for developing urban public transit systems. Those reasons are declining traffic congestion, stimulating development, serving the central parts of the city, and improving the environment (Kim et al. 2007). Furthermore, these systems provide service to a wide range of residents by different income, age, gender as well as other urban activities such as commercial, institutional, and recreational.

Public transit potentially delivers congestion relief, reduces energy consumption, air quality improvement, and economic development (Litman 2012). In the US, several groups such as community-based developers, planners, and business leaders have already embraced TOD. It is also admired by advocates of transit and smart growth as a viable strategy that creates opportunity and accessibility for low-income households, and urban revitalization (PolicyLink 2008). It is believed that a community or a city, which is designed adhering to TOD principles, is able to move more passengers with lower spatial requirements (Mu and Jong 2012).

Preliminary work on TOD was undertaken by Calthorpe (1993) drawing on the future trajectories of American cities. He provided new planning guidelines as alternatives to housing, traffic, environmental, and social issues

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caused by urban sprawl. Therefore, many American cities such as San Diego, San Francisco, and Boston have adopted TOD principles (Kahn 2007; Duncan 2011; Hess and Almeida 2007). There is a vast literature on good practices of TOD in European and Asian cities (Mu and Jong 2012). However, the synergy between all goals of TOD such as economic, land use, transportation, environmental, housing and equity are not achieved in most cases (PolicyLink 2008).

Many claimed to be TOD projects are not fundamentally different from traditional residential suburban developments. They are not well-integrated with the station or the surrounding community, and they are neither mixed-use nor mixed-income. For instance, Cervero and Duncan (2001), who investigated the land value effects of proximity to light and commuter rail stations on Santa Clara County, California, highlighted a substantial capitalization benefits for commercial lands. Similar study conducted on Buffalo, New York by Hess and Almeida (2007), indicated that a home located within one-quarter of a mile radius of a light rail station earns more compared with that of the city's median home value. Other studies (Cervero and Duncan 2002a,b; Duncan 2011) also conclude the likelihood that TOD housing will be unaffordable to low-income households. In other words, TOD can produce gentrification, which replaces the affordable housing and low-income residents by high-end residential, commercial, or offices (Kahn 2007). For instance, Cho-yam Lau (2011) reported a spatial mismatch caused by redevelopment of central area into business district in Singapore. The low-income residents have to spend a considerable percentage of their income and time going to work.

One question that needs to be answered, however, is to what extent the proximity to transit infrastructure reduces the overall household expenditure. A variety of influential factors for implementing an equitable TOD is reported in numerous academic and government documents. Among these factors, governance (including tax incentives and alternative transport service coordination) (Levine 2005; Cho-yam Lau 2011), land use (including density and diversity) (Cho-yam Lau 2011; Kim et al. 2007; Chakraborty and Mishra 2013), urban design (including pedestrian friendly design, designs with human scale characteristics, safety and security) (Jacobson and Forsyth 2008), urban policy (protection from displacements, and securing local communities' benefits of TOD) (Cervero 2007; Winston and Maheshri 2007), expanding multi-centric developments and management of real estate market (Cervero and Duncan 2002b, Debrezion et al. 2007) are considered as priorities in achieving an equitable TOD principle.

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AFFORDABLE HOUSING

Generally, housing affordability involves the capacity of households to consume housing services; specifically, it involves the relationship between household incomes and housing expenditure. If expenditure on housing relative to income is reasonable or moderate, it is considered as affordable (Kutty 2005). Affordability is commonly measured based on the ratio of housing costs to income. The rule of thumb in US, Australia, and most of Europe is that households exceeding 30% of the expenditure on housing, are identified as having an affordability problem (Nelson et al. 2002; Kutty 2005).

This approach, however, does not consider whether the income available after the housing expenditure is adequate to meet other household needs, such as transportation, food, cloth, education, and health care. In recent years, there has been an increasing criticism on this approach because of its normative and arbitrary nature (Hulchanski 1995; Kutty 2005; Mulliner et al., 2012; Stone 2006; Seelig and Phibbs 2006). In contrast to the conventional way of measuring affordability, Kutty (2005) and Stone (2006) recognise that housing affordability should address the issue of large families with more needs versus the one- or two-person households. Their approach, which is known as 'shelter poverty' measure or residual income, considers the adequacy of household income to cover both housing costs and non-housing costs.

However, the residual income approach shares some shortcomings of the ratio measure, such as inability to cover the housing condition and impacts of location (Mulliner et al. 2012). Bogdon and Can (1997) question whether the condition, location and neighbourhood characteristics of the housing are as important as housing price and standards. Recently, literature has offered contradictory findings about affordability and satisfaction in different places and times. For instance, Mulliner et al. (2012) argued that environmental and social sustainability must also be taken into consideration for measuring the affordability in the UK. They identified 13 social sustainability indicators, such as availability of affordable home ownership products, safety (crime level), quality of housing, and access to public services and facilities. In addition, they identified four environmental sustainability indicators namely, energy efficiency of housing, availability of waste management facilities, and presence of environmental problems. Other studies suggested more planning, management, and regulatory factors such as, density and mixed-use development, growth management initiatives, regulatory tax, local land use controls, and building regulations (Nelson et al., 2002; Aurand, 2010; Cervero and Duncan 2002b; Cheung et al. 2009; Glaeser and Gyourko 2001; Quigley et al. 2004).

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In Malaysian context, studies on housing quality and affordability have indicated the importance of neighbourhood facilities, environment, housing costs and types, and length of residency (Salleh 2008; Tan 2012; Salfarina et al. 2011; Mohit et al. 2010). Salfarina et al. (2011) proposed to include the quality of life and satisfaction on housing and neighbourhood conditions in measuring affordability of housing in Malaysia. Similar to the argument of Bogdon and Can (1997), Salfarina et al. (2011) agreed that besides house price, the Malaysian urban residents are also concerned about location, neighbourhood, and distance from work place. In addition, the period of housing ownership which influences the socio-cultural interactions as well as access to religious facilities are considered by Malaysian households. However, these factors have yet to be included in measuring the affordability of housing in neighbourhood level in the Malaysian context.

The Malaysian government has been committed to provide adequate, affordable and quality housing for all Malaysia, particularly the low income group as addressed by the Seventh (1996-2000), Eight (2001-2005), Ninth (2006-2010), and Tenth (2011-2012) Malaysia plans (Government of Malaysia, 1996, 2001, 2006, 2010). As a strategy for transportation planning, the Ninth Malaysia Plan suggested that the commuter, LRT and monorail systems be improved by taking into account the growth of new residential areas, new commercial centres and complexes, new public infrastructure such as schools and also population growth and density around transportation networks (Government of Malaysia 2006). Nevertheless, these systems need to be integrated comprehensively with a wider network in order to become more effective. The Tenth Malaysia Plan 2011-2015 initiated the Urban Public Transport as one of six National Key Result Areas (NKRA) which to considerably increase public transport ridership in three urban areas: Greater KL, Pulau Pinang and Johor Bahru. This plan promotes mixed-use developments, which calls for building high-density mixed-use developments, which must be integrated with a well-functioning public transport system. However, no attempt was made to quantify the association between TOD and affordable housing in implementing the government initiatives.

The findings from literature indicate that most factors related to affordable housing and TOD are similar and interchangeable. Both of them seek to provide a reliable quality of life for households. However, affordable housing and TOD as smart growth components are likely to be in controversy (Cervero 2007). Hence, a supportive policy should foster the affordable housing implementation in well-serviced locations of the city. Real affordable housing index should serve as a decision support tool to help the government and other advocates to formulate accurate policies.

METHOD AND MODEL

Since this study is considering both affordable housing and TOD as the components of smart growth, it would be relevant if the meaning of affordability is redefined using new components such as neighbourhood characteristics, accessibility, and socio-economic factors. The Centre for Neighbourhood Technology (CNT) has introduced a new affordability index, called "H + T Affordability Index", by adopting housing and transportation costs (Haas et al. 2008). The index is tested on several US metropolitan areas. To date, there is no report on the application of this index on international level. Nevertheless, in order to adopt the H + T affordable index on other cities than US, it is necessary to consider the local characteristics and requirements. This section presents the new conceptualisation of H + T affordable index based on Malaysian context.

The neighbourhood characteristics determine housing type, affluency of households and the amount of money spent on transportation, thus the characteristics outline the transportation demand (Dissanayake et al. 2012). The neighbourhood characteristics can be divided into two: physical, and accessibility. The former characteristics are density, walkability, and availability and quality of transit service. The later characteristics include access to facilities like shopping, health centre, school, and entertainment or access to job. Neighbourhoods with all these characteristics are considered as "location efficient" (Soo et al. 2008), where the household cost is lower than the others. These costs should be considered in the housing affordability standards which can be used in allocating low-income housing incentives and schemes. Figure 1, indicates the conceptualization of affordability index based on housing and transportation costs in Malaysian context. Providing both housing and transportation facilities allow low-income households to get access to better quality of life. This combination also provides a substantial incentive to the private sector to invest in transit-oriented locations, and supports the public sector in making investments that reduce household transportation costs. The affordability of a home, therefore, can be calculated based on the market value and the transportation costs acquired in each location. It is possible also to perform the measurement in both regional and local levels. In both levels, the decision makers can investigate the different needs of communities and the distribution of services, thus enhancing affordability.

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Affordability Index Model

There are three general factors in calculating affordability index (*AI*), namely housing cost (H_c), transportation cost (T_c) and neighbourhood income (N_I). The housing cost includes current housing sales price and rents, while transportation cost is measured based on the sum of auto ownership, auto use, and public transit costs as three separate components. The neighbourhood income is the average income of households in the neighbourhood.

$$AI=(H_C+T_C)/N_I \qquad \text{(Eq.1)}$$

The three components of transportation cost are the dependent variables which are affected by nine independent variables, seven which are built environment variables, and two are household variables. Table 1 includes all the dependent variables and Table 2 summarizes the independent variables. These variables represent the neighbourhood and socio-economic characteristics that affect the household transportation costs. The resolution of the model is based on the census data tract, although the best resolution would be at the scale of enumeration block that represents the neighbourhood characteristics.

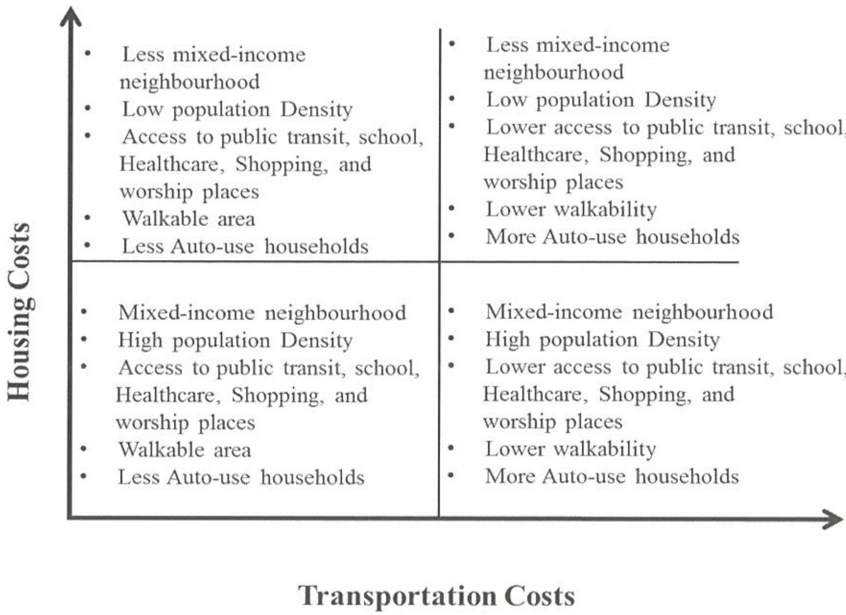

Figure 1: Conceptual framework for Affordability Index

Table 1: Dependent Variables in the Transportation Cost Model

Dependent Variables	Source	Purpose
Auto ownership (vehicles per household)	Calculated based on independent household and local environment variables	To determine the number of auto-ownership by each household and ownership costs
Auto use (annual miles driven per household)	Calculated based on household travel survey and vehicle miles travelled fitted to the independent variables	To determine the mileage a household drives each vehicle and usage costs
Transit rides per day	Calculated based on independent household and local environment variables	To determine the number of transit riders per day per household

Table 2: Independent Variables in Transport Cost Model.

Independent Variables	Purpose
Household per residential area unit (e.g. Acre, Hectare)	Measures the density, which influences auto ownership and use
Household per total area unit (e.g. Acre, Hectare)	Measures the density, which influences auto ownership and use
Average block size in area unit (e.g. Acre, Hectare)	Contributes to the walkability of area, which influences on three dependent variables
Transit Connectivity Index	Availability and extent of transit, which influence transit use
Distance to job centre	Access to job influences auto-ownership and auto-use
Job density and access	Number of jobs per square area unit (e.g. Mile, Km) Influences three dependent variables
Access to facilities	Existence of nearby services influences three dependent variables
Household income	Influences auto-ownership and use
Household size	Influences auto-ownership and use

A spatial interaction model determines proximity to the employment centres (Birkin et al. 1996). It considers the number of and distance to all available jobs related to the neighbourhood. The flow of people is calculated by two main hypotheses: 1. Flows between residential areas and job centres will be proportional to the attractiveness of the job centre rather than all other

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competing destinations. 2. Flows between residential areas and job centres will be proportional to the relative accessibility of that centre rather than other competing centres (Equation Eq. 2).

$$F_{ij}=A_i \times O_i \times W_j \times f(d_{ij}) \quad \text{(Eq. 2)}$$

Where, F_{ij} is the job accessibility, O_i is the total number of potential job seekers in the neighbourhood (representing the demand factor), W_j is a measure of the attractiveness of centre j, d_{ij} is the distance from the centre of the neighbourhood i to the job centre j, and A_i is a balancing factor wich takes account of the competition and ensures that all demand is allocated to job centres in the region. It is written as:

$$A_i=1/\sum_j W_j \times f(d_{ij}) \quad \text{(Eq. 3)}$$

In order to estimate the three dependent variables of transportation cost, namely, auto ownership, auto use, and transit use, different methods and data sources should be used. The auto ownership in each neighbourhood is determined based on the vehicles per household, and the costs are based on Malaysian standards and available data on depreciation, finance charges, insurance, and license, registration and taxes. Similarly, auto use should consider the local costs such as fuel price, maintenance, and repairs.

The transit use costs also are very dependent on data availability. There are several sources to estimate the transit use costs such as the report on total revenue of transit agencies, and reports on total passenger trips (Ministry of Transportation, 2010).

The general model of transportation cost is presented in Equation Eq.4. Auto ownership (Au_o), auto use (Au_u), and public transport (Pub_t) are functions of the local environment (V_{le}) characteristics, and household income and size (V_{Hh}).

$$T_{tc}=[C_{Au_o} * F_{Au_o}(V)]+[C_{Au_u} * F_{Au_u}(V)]+[C_{Pub_t} * F_{Pub_t}(V)] \quad \text{(Eq.4)}$$

And

$$V=V_{le}, V_{Hh} \quad \text{(Eq. 5)}$$

In Equation Eq.4, T_{tc} is the total transportation cost, andC_{Au_o}, C_{Au_u} ,and C_{Pub_t} are cost factors of auto ownership, auto use, and public transit use respectively. Similarly,F_{Au_o}, F_{Au_u}, and F_{Pub_t} are functions of the independent variables for auto ownership, auto use, and public transit uses respectively. In order to construct the regression equations, each variable should be tested separately for two reasons. First, it determines the distribution of the sample, and second it shows the strength of relationship to the variable.

CASE STUDY AND SAMPLE SELECTION

Kuala Lumpur is selected for the case study which is the only urban area that receives the transit service by both bus and light rail transit (LRT). The affordability of housing also is under quest in this city due to the concentration of services (Tan 2012). The 2010 Malaysian household consumption reported that families spent about a quarter of their income on food, followed by housing at nearly 20%. The expenditure on transportation constitutes the third item at 13.4% (Bank Negara 2010). According to the Department of statistics Malaysia (2011), generally, the average monthly household expenditure increased by 88.6% from RM1,161 in 1993/94 to RM 2,190 in 2009/10. A substantial increase was reported for housing, water, electricity, gas and other fuels (102.0%), as well as transport (94.6%) (Figure 2). It is assumed, however, that the figure is different in Kuala Lumpur as the housing price and transportation cost is higher than other parts of the country.

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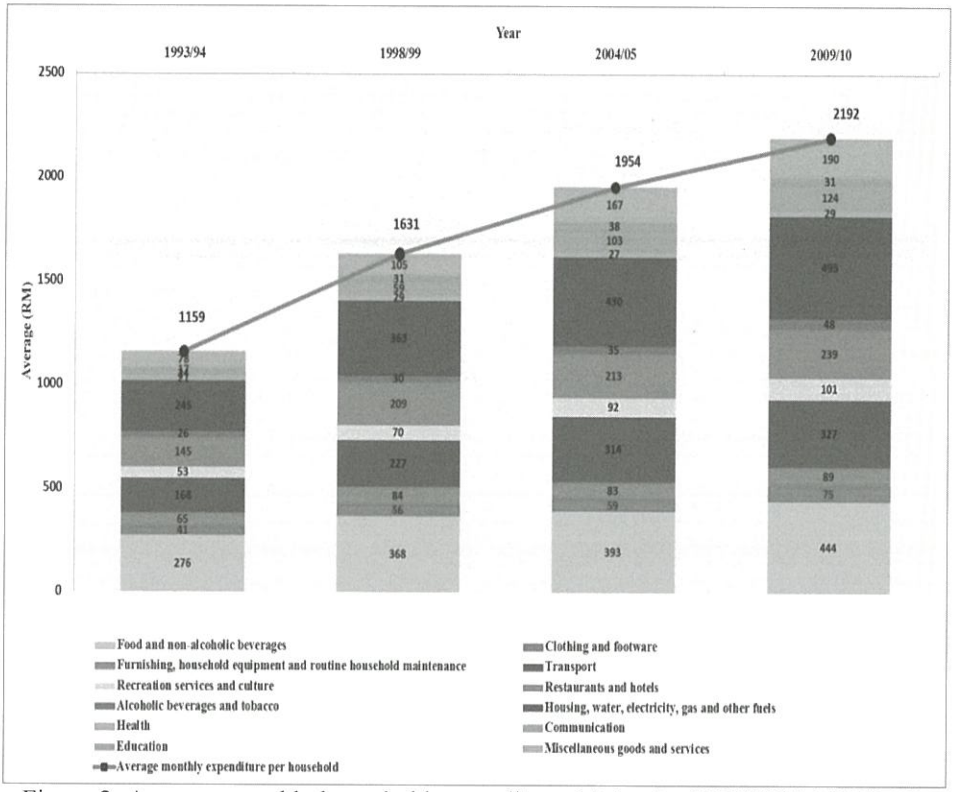

Figure 2: Average monthly household expenditure, Malaysia, 1993/1994-2009/2010.
Sources: Adopted from Department of Statistics Malaysia (2011).

A low-cost house in Kuala Lumpur is generally priced at RM 42,000 which is considerably higher than other low-cost houses in other parts of Peninsular Malaysia, which is from RM 25,000 to RM 32,000. Thus, a household with a monthly income of less than RM 2,500 in Kuala Lumpur will have difficulties to spend only 20% for housing. The transportation cost, however, maybe less than other parts of the country in case the public transport is available for such households.

The traditional measure of affordability, however, ignores transportation costs which incur relatively high proportion of income. Combining housing and transportation costs offers an expanded view of affordability. In order to test this claim, three different neighbourhoods (Tamans) in Kuala Lumpur are selected. These are Taman Melati, Taman Setiawangsa, and Taman Teratai Mewah (Figure 3).

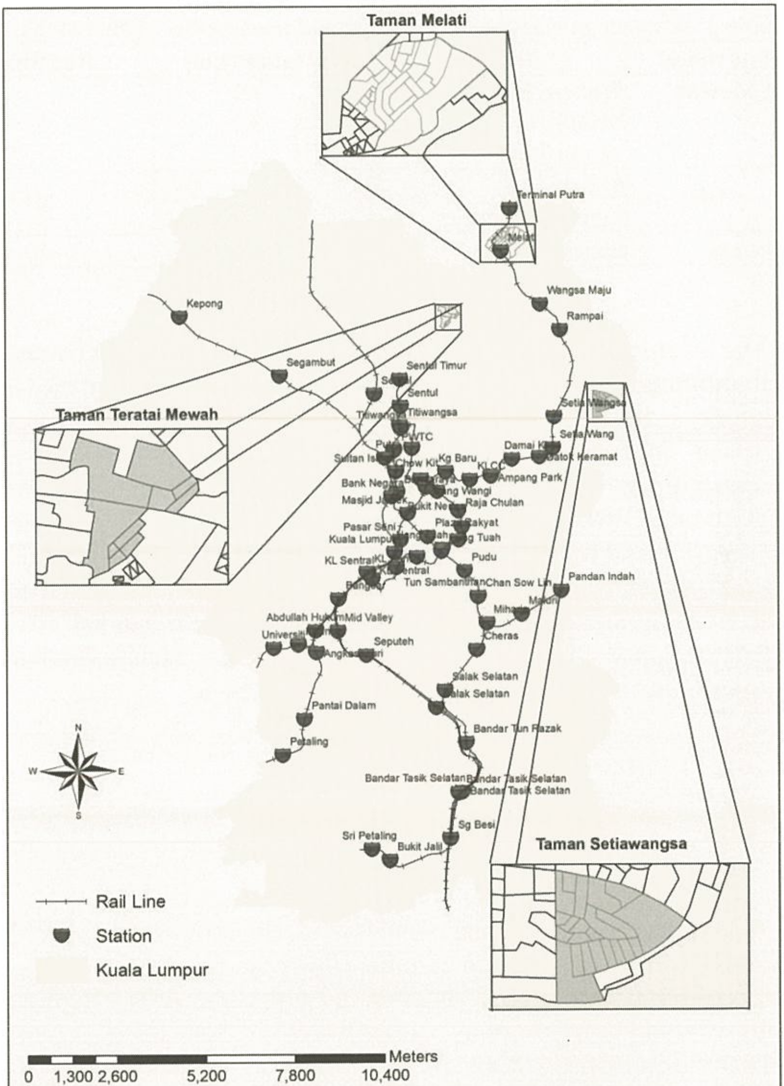

Figure 3: Location of Taman Teratai Mewah, Taman Melati, and Taman Setiawangsa in Kuala Lumpur.

Taman Melati and Setiawangsa are located in close proximity to two of Kelana Jaya LRT stations. The third Taman is relatively far from the nearest LRT station at 3.7 Km. Table 3 indicates the distance of each neighbourhood from the nearest LRT station. The density of bus stops in Taman Teratai Mewah is lower than two other neighbourhoods.

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Table 3: Distance to Nearest LRT Station and the Number of Bus Stops.

Neigbourhood	Station	Distance (km)	Bus Stops
Teratai Mewah	Wangsa Maju Melati Sentul Timur	3.7 3.7 4.4	2
Melati	Melati Terminal Putra	1.4 1.2	4
Setiawangsa	Setiawangsa	1.8	8

The affordability of residential buildings in the three neighbourhoods is measured and mapped based on the income and rental price. The measurement of affordability is based on the classic definition that considers the percentage of income spend on housing and maintenance (Figure 4). The percentage of housing expenditure in Taman Melati is between 18% and 24%, while the percentage in other two neighbourhoods is between 20% and 24%. It means that the housing price and rental in Taman Melati are slightly more affordable than the other two, which is most likely due to existing public housing schemes such as "Public Housing Sri Tioman I" and "Public Housing Sri Tioman II". Despite the existence of medium-high cost housing in Taman Melati (Melati Utama Condominium), the housing expenditure remains at 18%.

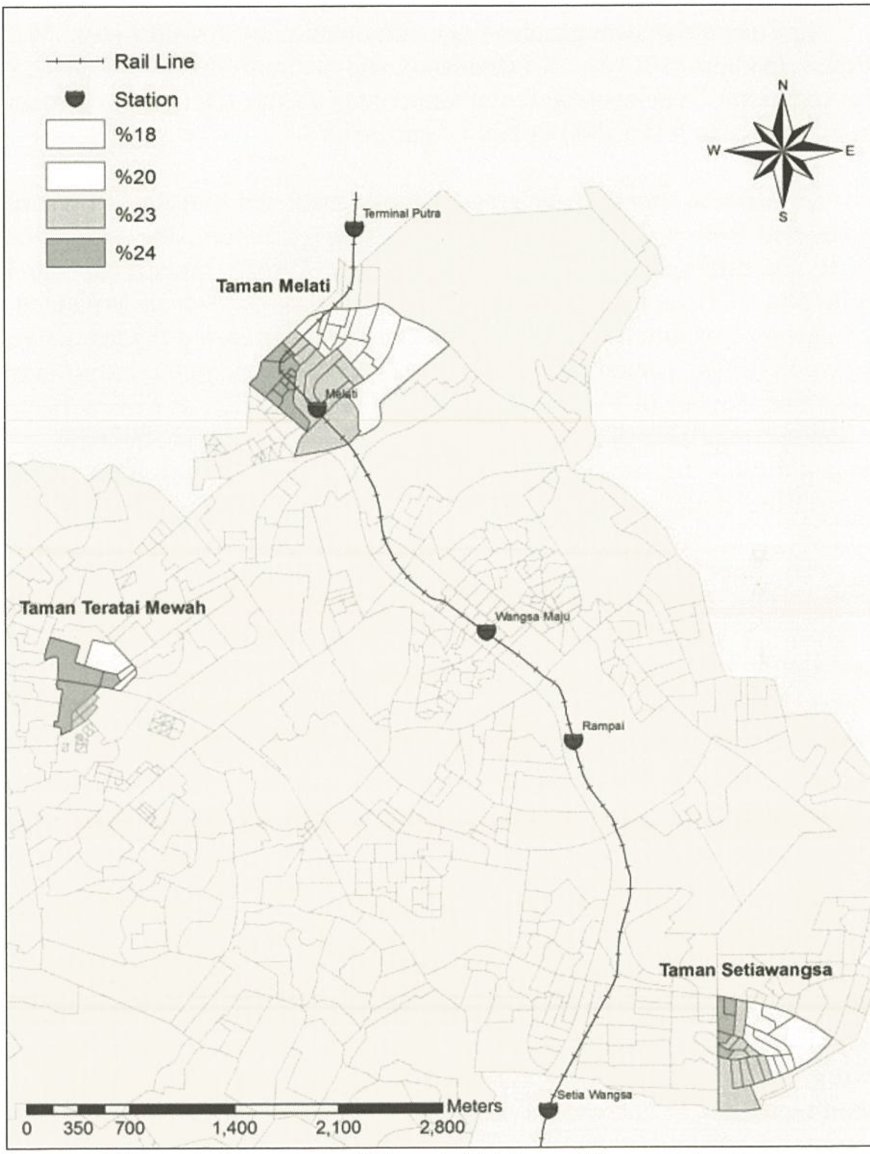

Figure 4: Percentage of Households' Expenditure on Housing

In Taman Teratai Mewah, the majority of residential buildings are medium-cost houses and the lowest rental value is RM 600. However, there are residents earning RM 2,800 a month, which are categorized as low-income, living in these houses. They would have to spend up to 24% of their income for housing.

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In Taman Setiawangsa there is a combination of low-cost (e.g., Menara Sri Pulai), medium-cost (e.g., Sri Cendana), and medium-high cost housing (e.g, Putra Apartment). The average rental value ranged from RM 300 in Menara Sri Pulai in Menara to RM 1, 000 in Putra Apartment.

In order to measure the transportation cost, the independent variables are extracted from several databases. As mentioned before, the transportation services are different for each neighbourhood. Taman Melati has the best combination of transit rail and bus routes and stations, which explained the development of medium-high cost residential buildings during the last six years. In contrast, Taman Teratai Mewah is receiving the lowest public transportation service. The number of bus stops in this neighbourhood is as low as two; one near to residential area and the second one closed to the local shopping centre. Table 3 indicates that the nearest train station to Taman Teratai Mewah, which is twice farther than the other two neighbourhoods.

The number of bus routes and stops are higher in Taman Setiawangsa than the other two neighbourhoods. However, there is a poor connection between train station and bus services in this neighbourhood. Thus, the transportation cost for households is affected as they have to change the transport two times to reach the train station. The straight distance of Setiawangsa LRT station to the study area is about 1.6 km. It is expected that access to the LRT station has to be supported by bus services. Conversely, the nearest bus stops to this station are about 400 meters, which adds to frustration in changing several modes of transport and consequently, a decline in ridership.

MODEL IMPLEMENTATION AND RESULTS

Table 4 shows the independent variables for each of the three neighbourhoods. The household costs are measured separately based on the tenure status, allowing the affordability index to be measured for both owner and tenant resident types.

As can be seen in Table 4, despite the lower annual median household income in Taman Teratai Mewah, the average vehicle per household as well as the percentage of workers using private cars for the daily commute are higher. This is confirmed by the transit connectivity index, which is low in Teratai Mewah compared to the other two neighbourhoods.

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Table 4: Background information on three neighbourhoods of Melati, Setiawangsa, and Teratai Mewah

Independent variable	Indicator	Taman Melati	Taman Setiawangsa	Taman Teratai Mewah
Demographics	Number of household	3,279	2,166	1,196
	Avg. household size	4.2	4.1	3.5
Income Factors	Annual median household income (RM)	33,000	45,500	28,500
	Annual median household income range (RM)	18,000-39,000	18,000-90,000	18,000- 39,000
Density Measures	Walkability	1.18	2.00	5.2
	Avg. households / residential acre	30.3	49.98	23.05
	Jobs / sq. mi.	21	65	5
Access to transit and jobs	Percent commuting by transit	10%	10%	7%
	Transit Connectivity Index	High	Medium	Low
Housing and transportation cost indicators	Avg. monthly mortgage payment (RM)	707	778	647
	Avg. monthly rental payment (RM)	590	710	500

To calculate the total transportation costs, values for the unit of each component are determined. Ultimately, the aggregation of values concluded the specific transportation cost of each neighbourhood.

Auto Ownership Costs

There are several variables in auto ownership that can be assumed as fixed values in calculating the total cost. These are depreciation, finance charges, insurance, license, registration and taxes. Generally, the most used cars for low and medium-income households in Malaysia are the local productions. In order to cover almost all engine classes, four years old Proton Persona with engine capacity of 1600cc is considered. The total ownership cost is estimated at RM14,000 based on usage miles per annum. Table 5 shows the percentage of each variable in estimating the car ownership cost.

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Table 5: Auto Ownership Cost Calculation.

	Total cost per mile	Depreciation per mile	Finance charges	Insurance per mile	Registration, licenses, tax per mile	Ownership cost per mile
Percent	100.00	35.00	27.00	15.00	3.00	20.00
Value(RM)	0.96	0.34	0.26	0.14	0.029	0.77
Total (RM)	13,520	4,732	3,650	2,028	405	10,816

Auto Use Costs

Three variables are identified for auto use costs in this study, namely, fuel, maintenance, and repairs. These variables are largely different depending on type, age and level of usage. For simplicity, Proton Persona is again used to calculate the auto use cost. The maintenance and repairs per mile are taken as 5% and 2% of the total price, which are equivalent to RM0.07 and RM0.03 per mile respectively.

The fuel cost is calculated based on the 2010 price of regular petrol, which is RM 1.9 per litre. Thus, the fuel cost per mile is RM0.26, assuming the fuel consumption is 8.5 litre for 62.137 miles (equivalent to 100 kilometres). The total auto use cost, which is equal to RM 0.35 per mile (0.06 + 0.03 + 0.26), is then applied to the modelled results of average vehicle miles travelled (VMT) by each household. The VMT for each neighbourhood is calculated based on trip generated by each household, data of which is obtained from the Kuala Lumpur City Hall.

Transit Use Costs

According to the Transport Statistics report (Ministry of Transportation 2010), the number of passenger trips in Malaysia has risen from 52.5 million in 2001 to 58 million passengers in 2010. Although, the highest number of passengers was recorded at 60.2 million in 2006, the 2010 figure is still remarkable. This statistic forms the basis for transit use cost in the current research.

The average fare for Kelana Jaya Line is RM1.6, which is calculated based on the minimum RM0.7 per station and the maximum RM2.5 for full length of trip in 2010 (RapidKL, 2011). The breakdown of total transportation cost in each neighbourhood is indicated in Table 6.

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Table 6: Breakdown of Total Transportation Cost in Each Neighbourhood

	Taman Melati	Taman Setiawangsa	Taman Teratai Mewah
Auto ownership cost (RM)	12,979	14,061	17,306
Auto use cost (RM)	445	570	579
Transit cost (RM)	2,203	1,421	469
Transportation cost (RM)	13,424	16,051	18,353

It can be seen that in Taman Melati, which has relatively efficient transport coverage, the transportation costs are far less than the other two neighbourhoods. This implies that the lack of public transport in Taman Teratai Mewah does contribute to higher transportation cost. Basically, auto ownership contributes to the higher transportation cost. The study shows that if the total transportation cost as a percentage of household income is deducted from household expenditure, the affordability index is different.

The results of combined housing and transportation costs, as shown by Table 7, indicate that Taman Setiawangsa offers more affordable opportunity than the other two neighbourhoods. Taman Melati is the second affordable area for low- and medium-income residents. Ultimately, Taman Teratai Mewah is not affordable, with risk of spending up to 90% of household income on housing and transportation.

Table 7: Housing and Transportation Costs in the Three Neighbourhoods

	Taman Melati	Taman Setiawangsa	Taman Teratai Mewah
Median income (RM)	33,000	45,500	28,500
Annual transportation costs (RM)	13,424	16,051	18,353
Transportation costs as percentage of income	40%	35%	64%
Average housing cost as percentage of income	21.2%	22%	22.4%
Housing and transportation cost for owners	66%	56%	91%
Housing and transportation cost for renters	61%	54%	85%

It was expected that Taman Melati is more affordable than Taman Setiawangsa, however, since the median annual income in this neighbourhood is lower than the other two, affordability index is lower as well. Despite lower

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median household income in Taman Teratai Mewah, the affordability is low due to poor public transport coverage. The results of this study show that housing provisions without considering the transportation costs is not representing true affordability of a neighbourhood.

DISCUSSION AND POLICY IMPLICATION

The purpose of this study is to provide guiding principles for development of affordable housing with respect to TOD and affordability concepts. The conceptual framework, considers the socio-economic, population density, accessibility, neighbourhood physical characteristics, and auto-use criteria in order to examine the housing and transportation costs. Overall, our findings are consistent with previous research in showing that considering transportation costs incurred by the location and characteristics of neighbourhood is necessary in measuring affordability of a neighbourhood (Holtzclaw et al. 2002; Hess and Almeida 2007; Haas et al. 2008). In addition, unlike the previous studies on measuring the affordability and satisfaction of housing in Malaysian context (Salfarina et al. 2011; Salleh 2008; Mohit et al. 2010), we examined the association of neighbourhood's physical characteristics (e.g Average block size, walkability, etc.) with housing and transportation costs that indicates the extent in which a neighbourhood satisfies the requirements of all income-groups.

Specifically, two dependent variables of auto ownership and auto use were significant predictors of transportation costs, whereby, access to jobs and public facilities as independent variables contributed more than the others. Consistent with the research on "location efficient neighbourhood" (Holtzclaw et al. 2002) and sustainable housing affordability (Mulliner et al. 2012), our findings suggest that when neighbourhoods are located close to job centres and other urban facilities, residents are most likely to use public transport. This is more apparent when there is a high or medium level of interconnection between residential blocks and transit stations. However, no relation was found in walkability and public transport usage. A possible explanation is that the neighbourhood with high value of walkability has a low interconnectivity index. In contrast, neighbourhoods with low value of walkability have high and medium interconnectivity index. Since walkability is measured by the average block size, smaller block sizes are an indication of greater streets network, where housing and other amenities are within walking distance. However, a high value of walkability cannot indicate better public transport usage if there is a poor interconnection of residential blocks and transit stations.

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The evidence from this study suggests that despite the existence of medium- and high-medium cost housing types, neighbourhoods with good public transportation services have higher affordability index. The other major finding was that combining different modes of transport, motorised and non-motorised (i.e. walking, bus, train) contribute to higher affordability of the neighbourhood. One explanation for this is that neighbourhoods with high accessibility to different modes of transport incur considerably lower transportation costs than the others. It is interesting to note that the average household's expenditure on transport at the three neighbourhoods (40% at Melati, 35% at Setiawangsa, and 64% at Teratai Mewah) in this study is significantly higher than the 2009/2010 national average which is 14.9% (Department of Statistics Malaysia 2011). This can be explained by the higher auto ownership and use in Kuala Lumpur than the other parts of the country. Alternatively, in this study more factors are considered in calculating the transportation costs (i.e. finance charges, insurance per mile, registration, licenses, and tax per miles) that may not be used in the government's figure. This is a good reason for providing more varied modes of transport in order to reduce the household's transportation costs.

Our findings suggest that a modified affordability index is an appropriate tool for measuring affordability of a neighbourhood. For this tool the gravity model is replaced by spatial interaction model in measuring job accessibility. In this study, two concepts are added to the H + T affordability index. These are the stochastic behaviour of households in selecting the job centre, and the interaction of attractiveness and accessibility in job selection by households. This model has also considered more variables in determining the affordability of a neighbourhood. There are other variables, however, that may be important in decision making such as the number and age of children, multiple occupied homes, especially in studentified areas (Sabri et al. 2010). The spatial factors can also be considered in this model, such as safety and security, weather condition, pedestrian environment, and quality of services (Haas et al. 2008).

Such tool can be used to develop a development framework which can accommodate a rapidly urbanising city into a more sustainable urban growth. Central to an entire discipline of TOD is the concept of housing and land use governance. In a federated system of government, the land use governance can be simply conducted by all levels of government (Knaap and Hacco 2007). However, the dominant role in land use governance is played by local governments (Hawkins 2011). Kuala Lumpur, envisaged to be a world class city is expected to offer a world class living environment having among other things adequate housing and efficient transportation (Kuala Lumpur City Hall 2008).

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Although the Kuala Lumpur Master Plan promised to implement Travel Demand Management measures, particularly in increasing public transport usage, a more holistic manner of city design in accordance with TOD principles should be considered to allow affordable housing environment.

CONCLUSION

The present research adds to the growing literature on combining transport and housing costs to measure affordability. It concludes that improved affordability index, which combines housing and transportation indicators is an appropriate tool for examining affordability of Malaysian neighbourhoods. Based on the implementation of the affordable index in three neighbourhoods of Kuala Lumpur, our findings confirmed the need to address affordability by both the housing and transportation costs.

Despite the deficiencies, this study is able to highlight the impact of spatial characteristics on neighbourhood's affordability. The interactions of transportation, housing market, and socio-economic characteristics are illustrated in constructing the morphology of neighbourhood and the level of satisfactory in living area. More research should be conducted to explain other possible factors based on various neighbourhoods.

ACKNOWLEDGMENT

The authors would like to express their appreciation to the Universiti Teknologi Malaysia, Johor, Malaysia for sponsoring this research through Fundamental Research Grant Scheme (FRGS) from 2009 – 2011, vote number: 78438. Thanks are due to Mr. Ismail Mohd Yusof Deputy Director of Urban Planning Department, City Hall Kuala Lumpur for his generous assistance in providing valuable information for the study.

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PLANNING MALAYSIA
Geospatial Analysis in Urban Planning
Volume **II** (2013), Page 101 - 118

POTENTIAL URBAN DEVELOPMENT PARAMETERS THAT REDUCE ENERGY CONSUMPTION IN RESIDENTIAL AREA

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Abstract

Cities are relatively the larger energy consumers in comparison to its rural counterparts. Reducing energy consumption in cities through various controlling strategies has significant impact on the conservation of natural resources and environment. Residential density and *floor area to land ratio* has been used as key parameters in development control tools towards creating harmonious urban development. However no attempt has been made to employ them to lower residential energy consumption. This study attempts to demonstrate the possibility of using residential density and floor area to land ratio as passive parameters to reduce non-transportation energy consumption at household level. The analysis was based on questionnaire survey of non-transportation energy consumption viz. energy for lighting, thermal comfort and cooking purposes at household level in Bandung City, Indonesia. The result shows that non-transportation energy consumption perceptibly associates with the two parameters of development control with a u-shape pattern i.e. the correlation has one lowest point with higher trends at both ends. This finding is important for urban planners in formulating strategies towards lower consumption of non-transportation energy in tropical cities and consequently contributing to better-off urban environment.

Keywords: urban parameters, energy consumption, residential density, floor area to land ratio, development control

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INTRODUCTION

Energy is becoming a vital commodity due to the continuous increases of its price. While energy demand relentlessly increases, non-renewable energy reserve invariably decreases. The era of low hanging fruit for energy is now over and therefore low-cost energy is no longer available. Energy is one of the most influential commodities in the world because of the ever-increasing consumers. Cities are undeniably important energy consumers because of their large energy consumption. The level of energy consumption of cities will continuously increase as they grow and develop. The changing life style of the urban population will also lead to increased energy consumption and this has become a challenge to the urban development.

It has been reported that nearly half of world's population is living in cities and towns at the turn of the new millennium (Leitmann 1999). United Nations (2006) noted that the population in urban areas is growing annually with the rate of 2.60 percent, compared to 1.12 percent in rural areas. The increase of urban population along with the changing life style brings to a constant increase of energy consumption, and this clearly confronts sustainable development i.e. "development that meets the needs of present without compromising the ability of future generation to meet their own needs" (WCED 1987). This condition is supported by Wackernagel and Rees (1996), as they argue that the world has been exploited by most of humankind, while the ability of future generation to meet their own needs must also be fulfilled. From this point, conflicts between utilization and consumption, vis-à-vis conservation of natural resources are commenced, and it has also been enhanced with the fact that cities or any urban areas are the great consumers of any resources including energy.

The largest quantity of energy used by various transportation modes in many developing countries are non-renewable energy sources such as oil and natural gas. These types of fuels are still abundant and easily acquired, and this leads to their continued wider use. As a result, consumption of oil and natural gas are increasing over time. Likewise, the production also takes the same fashion. Similarly, energy consumption of residential buildings, in aggregate, increases over time as the number of residential buildings increases.

Energy consumption of residential buildings is governed by various factors which are essentially centred at the residential building's occupants. Inability to perfectly adapt to local condition is one of the causes of energy-inefficient building as illustrated by Tantasavasdi et al. (2001) and West (2001). Ventilation which affects thermal performance of buildings and effective

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utilization of daylighting are two other factors which also influence the consumption of energy in residential buildings. In naturally ventilated buildings, ventilation technique is one of the important elements in a building to achieve thermal comfort. Geros et al. (2005) acknowledge that thermal impact of night ventilation affect energy use to achieve thermal comfort. Tantasavasdi et al. (2001) explored the potential of using natural ventilation as passive cooling system for new houses design in Thailand. Although mostly applies for buildings in sub-tropical countries, Assimakopoulos et al. (2005) show that building orientation may affect residential energy consumption through heating and cooling loads. At city level, Ghiaus et al. (2006) confirms that urban environment influences natural ventilation. Flor and Dominguez (2004) also show that there is a clear interaction between urban context and thermal performance of buildings. Similar argument, Niachou et al. (2008) show that urban street canyon effect, created by roads and buildings, governs airflow pattern which affects urban temperature, and eventually, thermal comfort. Urban texture, which is essentially a spatial structure of an urban area formed by urban elements e.g. buildings, roads and green areas, affects energy consumption in building (Ratti et al. 2005). These arguments show that orientation and geometry of the buildings affect energy consumption in buildings. It also substantiates that development control may be employed as strategies to reduce energy consumption in residential buildings, because orientation and geometry of buildings can be regulated by development control tools.

RESIDENTIAL BUILDINGS AS ENERGY USERS IN THE STUDY AREA

Residential buildings are the largest energy users in terms of quantity of the consumption. One reason is that residential buildings are the only building that is used round-the-clock in comparison to other buildings. This feature makes residential buildings an important energy consumer where significant amount of energy can be saved through various efforts, including design and development control. Bandung City, Indonesia was selected as the study area to corroborate the viability of development control in reducing residential energy consumption. Bandung is the capital city of West Java Province of Indonesia. It is located at 107^{O} East and $6^{O}55'$ South and covers an area of 16,767 hectares. There are five urban development forms identified in the study area, namely controlled residential-cum-commercial areas, naturally grown urban *kampungs*, unplanned urban sprawl, leap-frog development, and planned satellite towns. The residential buildings located in these different urban features exhibit different

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socio-economic and environmental characteristics which may influence the energy consumptions.

Energy consumption in residential buildings depends greatly on the environment where the buildings are located. Table 1 shows the use of electricity in cities at different geographical locations.

Table 1: Electricity Uses within Residential Building

Type of Usage	Percentage of Electricity Usage		
	Bandung, Indonesia[1]	Phnom Penh, Cambodia[2]	US Households[3]
Lighting	9.50	11.80	8.80
Water heating	10.30	8.80	9.10
Space heating	0.00	0.00	10.10
Air conditioning	4.00	50.70	16.00
Fan	10.50	8.80	NA
Refrigerator	11.40	7.50	13.70
Others[4]	54.30	12.40	42.30
TOTAL	100.00	100.00	100.00

Note: [1]*Source: Field Survey (2010)*
[2]*Source: Souvanandara (2002)*
[3]*Source: Energy Information Agency (2008), http://www.eia.doe.gov*
[4]*Others include home appliances such as TV, DVD/VCD players, rice cooker, iron and water pump*

Table 1 shows that the equipment for thermal comfort e.g. air conditioner or electrical fan is much lower in Bandung (14.5%) in comparison to Phnom Penh (59.5%). The average temperature in Bandung is 26 ^{O}C compared to Phnom Penh, which is 32 ^{O}C. The temperature in Bandung is relatively low (20 ^{O}C) during night time, which is lower than thermal comfort (27 ^{O}C). With this situation, the use of electricity for water heating is higher than that of Phnom Penh. This comparison shows how urban environment influences the energy use within residential buildings. One of the possible causes is the presence of urban heat from the concrete jungle.

Cities notoriously create urban heat island effects due to some possible causes such as land surface and discharge of hot water from the use of air conditioner, and this causes unpleasant local climatic conditions and even imperils human health, especially for cities in climates with a distinctively hot season (Alexandri and Jones 2008). Higher urban air temperature, due to urban heat island effect, influences cooling load of buildings (Santamouris et al. 2007). It is also found that urban canyons affect wind speed, wind flow and thermal comfort (Alexandri and Jones 2008; Santamouris et al. 2007). If the

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phenomenon is downscaled into individual residential buildings, the distance between buildings disallow undisturbed wind flow and thereby lessen cooling loads. Therefore, residential density and plot ratio become important factors of the energy consumption, particularly for cooling purposesat household level. This study defines the residential density as the numbers of residential buildings contained within one hectare of land plot. The study also defines plot ratio as the total floor area of residential buildings within one hectare of land plot.

Studies above verify the presence of passive interaction among residential buildings, which is reflected by, among others, distance between the buildings and residential density. It also substantiates that the mixture of buildings in urban texture may create higher cooling load and ultimately higher urban energy demand. Urban texture features many forms of built and natural environment. Some studies attempt to model urban areas with respect to urban vegetation and microclimates as offered by Sashua-Bar et al. (2006), Simpson (2002), Sashua-Bar and Hoffman (2000) and Takakura et al. (2000). The above aspects influence residential energy consumption, thus to reduce the energy consumptiona passive strategy can be undertaken through development control. The study attempts to revive the latent parameters of development control, which has been in place for quite a long time towards harmonious urban development, and expands the role of passive development control to another dimension of residential energy consumption. The development control can be applied through residential density and plot ratio. The objective of this control is to passively influence the use of energy within residential buildings. The study was carried out by using questionnaire survey.

METHODOLOGY

A household-based residential energy uses were investigated to accomplish a comprehensive information on current energy consumptions in a residential building for a given urban residential density and floor area to land ratio.

Research findings will provide the correlation between energy consumption and urban parameters, particularly residential density and plot ratio. Analysis on the correlation between residential density and energy consumption at household level is expected to discover minimum energy consumption for a particular residential density and plot ratio. If these two correlations were substantiated, the residential density and plot ratios are therefore viable tool for development control towards more efficient residential energy consumptions in urban areas.

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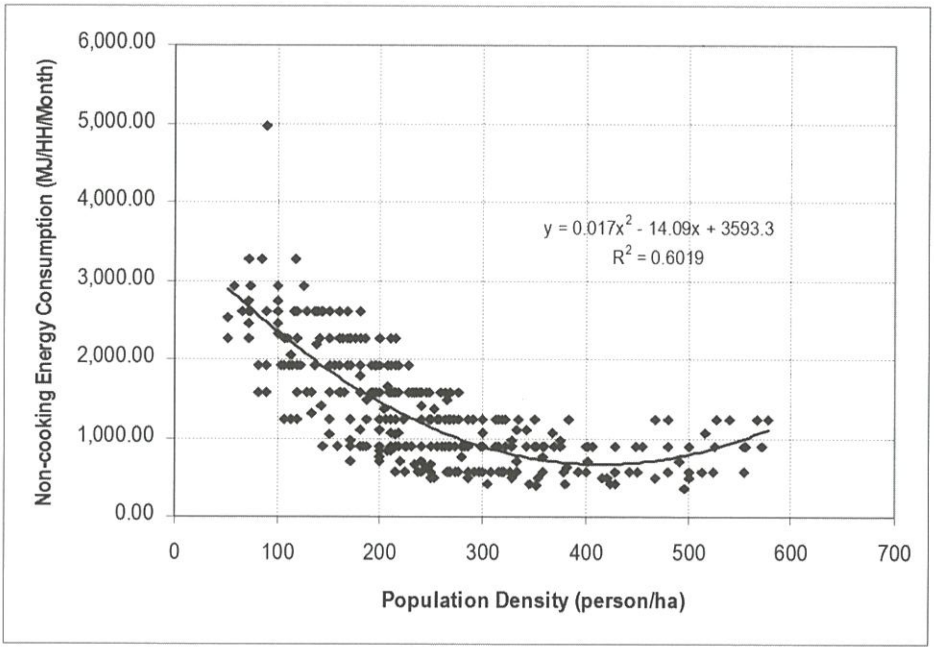

Figure 2: Correlation between Non-cooking Energy and Population Density Based on 389 Data Samples in 21 Towns

A structured questionnaire was randomly distributed to 750 respondents to gather the residential energy consumptions at household level (Figure 1). The respondents of this study were proportionally and randomly distributed over 21 out of 26 towns within Bandung City. Five (5) towns were excluded due to similar physical and social performances of the towns, for example, the similarity in number of population, size and main activities. From 750 respondents, 389 responses were received during the survey.

ENERGY CONSUMPTION AT HOUSEHOLD LEVEL IN STUDY AREA

The total energy consumption in Table 2 gives an indication of household energy consumption in residential building in 21 towns in Bandung. Energy consumption figures shown in this table could be considered as primary energy use since the information was mainly from electricity bill (in Indonesian Rupiah, IDR, and then converted to energy unit). The use of gasoline or diesel in unit of volume (litre) was computed as transport energy use for the respondents who have private vehicles. For respondents who used public transports, the transport energy use was computed from their origin-destination distance and energy consumption of their public transport modes. Cooking energy was computed from the use of LPG in the unit of weight (kg) as well as the use of electric cooking equipment.

Table 2: Energy Consumption in 21Townships of Bandung City

Town	Weighted Average Energy Consumption (MJ/HH/Month)					
	Transport Energy	Non-cooking Energy	Cooking Energy	Total	Energy Used per Capita	Non-cooking Energy per m^2 of building
Andir	5,809	1,218	557	7,584	1,828	9.42
Lengkong	6,718	1,958	725	9,401	2,107	14.89
Sukasari	6,595	1,356	671	8,622	1,826	9.32
Cicendo	4,659	1,583	653	6,895	1,400	12.61
BbkCiparay	6,056	1,545	672	8,273	1,546	11.37
Sumur Bandung	7,284	1,509	657	9,450	2,089	6.92
Ujung Berung	3,707	1,048	550	5,306	1,293	8.37
Rancasari	4,492	839	568	5,899	1,241	6.84
Kiaracondong	3,294	832	558	4,684	1,182	8.31
Regol	3,744	1,395	631	5,770	1,107	12.12
Bandung Wetan	6,102	2,012	726	8,840	1,782	14.62
Coblong	5,722	1,368	692	7,783	1,559	10.32
Bandung Kulon	5,871	1,431	703	8,005	1,414	8.48
BojongloaKaler	6,451	1,558	668	8,678	1,666	9.63
BojongloaKidul	5,216	1,554	660	7,430	1,910	10.27
CibeunyingKidul	5,409	1,377	524	7,310	1,589	9.88
Cicadas	4,151	1,111	561	5,823	1,105	10.11
Batununggal	5,686	1,298	602	7,586	1,687	8.80
Bandung Kidul	4,867	1,136	556	6,559	1,355	10.97
Margacinta	5,390	1,218	582	7,190	1,577	10.68
Astanaanyar	7,090	1,352	635	9,077	1,798	6.86
Mean	5,195	1,302	620	7,169	1,519	9.59
Standard Dev	1,128	298	63	1,373	299	2.23

Source: Questionnaire Survey, January 2010

Table 3 shows comparison of residential energy consumption in selected developing countries in Asia. It shows that India recorded the highest quantity of residential energy consumption in comparison to other countries even though its income per capita is relatively low. On the other hand, Malaysia and Thailand, who have higher income per capita than India, recorded lower residential energy consumption. Brunei and China recorded almost the same level of energy use although their incomes per capita differ widely. This international comparison is in contrary with the common belief that higher

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income will lead to higher energy consumption, since it depends on the lifestyles of respective nations, as shown by examples of some Asian countries. At national or local level where almost similar lifestyle and behaviour exist, the correlation might perhaps valid.

Table 3: Residential Energy Consumption in Some Developing Countries in Asia (2005)

Country	Residential Energy Consumption (MJ/HH/Month)[1]	Income per Capita (USD/Capita/Year)[1]	Residential Electricity Price (USD/KWh)
Brunei	3,362	16,800	0.160[2]
China	3,440	1,533	0.004[5]
India	3,680	726	0.040[3]
Indonesia	3,387	1,263	0.029[3]
Malaysia	2,428	5,159	0.080[4]
Thailand	2,560	2,749	0.070[3]

Sources:
[1]*World Research Institute, http://www.earthtrends.wri.org, and United Nations, http://unstats.un.org)*
[2]*Dep of Electricity Service Brunei Darussalam http://www.des.gov.bn/tariff.htm*
[3]*Energy Price Information, US Department of Energy, http://www.eia.doe.gov/emeu/international/ prices.html*
[4]*ASEAN Centre for Energy, http://www.aseanenergy.org/publications_statistics/electricity_database/ malaysia02.htm*
[5]*China Daily http://www.chinadaily.com.cn/english/doc/2005-02/18/content_417238.htm*

There are numerous factors that influence the energy consumption in residential buildings. However, the purpose of this study is to correlate energy consumption with urban parameters as it intends to provide valuable inputs for urban planners. The urban parameters are population density, residential density and plot ratio, by keeping other parameters *ceteris paribus*.

From 389 respondents, there were 26 (6.7%) respondents with monthly income less than 150 USD, and 190 (48.9%) respondents with monthly income from 150 to 300 USD. While 132 (33.9%) respondents with monthly income between 300 and 450 USD, 37 (9.5%) respondents with monthly income between 450 and 600 USD, and 4 (1.0%) respondents with monthly income greater than 600 USD. The income group interval of 150 USD was determined to closely represent and to obtain uniform distribution of the citizen's income in their respective income groups.

CORRELATION BETWEEN ENERGY CONSUMPTION AND URBAN PARAMETERS

To reinforce the argument, the study also analyses the correlation between transport energy, cooking energy and non-cooking energy at household level, and the urban parameters. Of these, it seems that only non-cooking energy consumption is strongly correlated with the urban parameters. Transport energy particularly concerns only with geographical location between origin and destination, although other variables may also govern. Cooking energy is apparently independent from these urban parameters, since cooking energy depends mainly on lifestyle. The rationale behind non-cooking energy correlation with urban parameters can be simply explained by contrasting two comparable houses. Take two houses A and B with similar floor area but different household size. The house with larger household size will usually have higher non-cooking energy consumption than that with smaller household size. Therefore, energy consumption per floor area at house A is greater than at house B.

Based on the above rationale, an attempt to validate the correlation between non-cooking energy consumption and urban parameters is carried out. These parameters most likely contribute to energy consumption for lighting and thermal comfort using air conditioning. Population and residential densities as well as plot ratio have no apparent contribution to cooking energies. However, to a certain extent, population density does affect transport energy consumption (see for example Barter 1999; Newman and Kenworthy 1999). Transport energy, as described earlier, is particularly affected by origin and destination as Jun and Hur (2001) established in the study of a new town near Seoul where leap-frog development is predominant. User's awareness on the efficient use of energy is necessary to be included in the analysis, because of its paramount importance in contributing to energy use. The difference in energy consumption will be significant in household with and without adequate awareness on energy saving.

Energy consumption in residential buildings is affected by a set of contributing factors such as income, floor area, thermal and visual comfort, building envelopes, and surrounding environment. Survey undertaken in the study area on energy consumption was actual use of energy at household level rather than resulting from energy auditing. It was therefore independent from the contributing factors. Considering this state, it is then valid to associate energy consumption with the parameters such as population density, residential density and plot ratio. This is the fundamental basis of the correlation between energy consumption and urban parameters.

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Three hundreds and eighty nine (389) respondents of 21 Townships were included for the purpose of analysis. From the analysis, as depicted in Figure 2, it is found that polynomial correlation with a quadratic function between non-cooking energy consumption and population density is the best fit to describe such correlation with coefficient of determination R^2=0.6019. The figure depicts u-shape pattern of the correlation. Despite inadequate data for population density larger than 600 people/ha, it appears that at a certain population density, non-cooking energy consumption reaches a lowest level. It can be calculated by taking first derivative of the equation, which is $y=0.017x^2-14.09x+3593.3$, and $dy/dx=0.034x-14.09=0$, it gives y=414 people/hectare. At two ends of this point along the equation, higher energy consumption is shown. One logical explanation on this phenomenon is that the area with denser population allows energy sharing among the citizens. Sharing on light and entertainment, for example, are the most probable causes in denser population area. In a place with sufficient lighting (luminance) for reading for one person, there is not necessary to add more luminance as the number of person increases. On the contrary, in lower density residential area, share lighting and entertainment will not be possible due to physical distance. One certainty in the study area is that most of the higher income households live in a relatively low population density area. In line with that, it is valid that the energy consumption for high income household is also high. That is why the households living in lower residential density areas consume more energy than their counterparts in higher residential density areas.

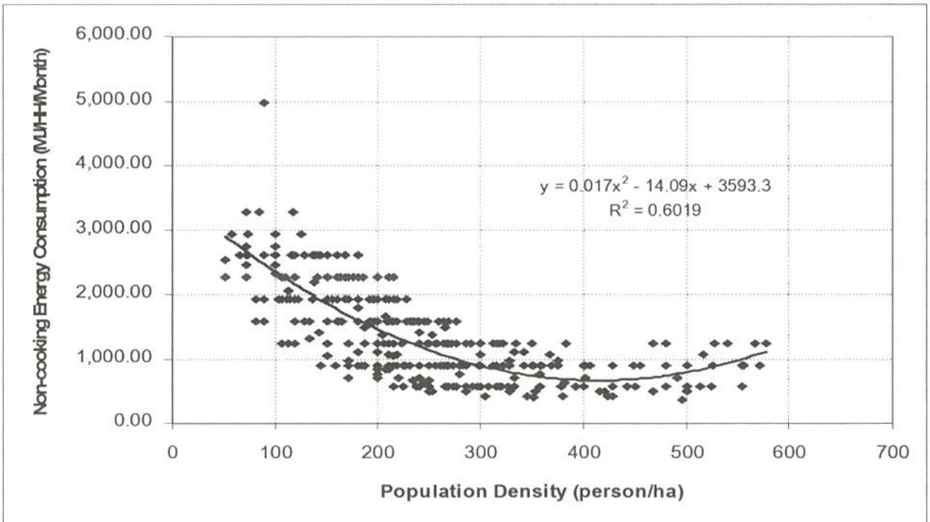

Figure 2: Correlation between Non-cooking Energy and Population Density Based on 389 Data Samples in 21 Towns

A scientific explanation of this phenomenon can be examined from two sides; thermal comfort and lighting. With respect to thermal comfort, production of heat is mathematically expressed by $Q=AU(t_r-t_o)$ (Watson and Chapman, 2002), where$A$is surface area, U is thermal transmittance, t_r is room temperature and t_o is outside temperature. Consider a closed room with occupants. This formula implies that more occupants will require more energy to achieve thermal comfort because A increases therefore Q also increases. At the same time, the needs of lighting is generally constant as number of occupants increases. The need of energy for thermal comfort increases with the existence of overcrowding, as revealed by a study undertaken by Johansson (2006), because of the impedance of air flow to achieve perfect ventilation. The impacts of urban canyon and urban texture to this particular phenomenon may also be possible as demonstrated by Ratti et al. (2005) and Niachou et al. (2008).

Figure 2 was derived from the survey of the study area. Population densities were measured at city blocks where the respondents stay. City block was selected as a basis of population density calculation. The reason was that if the calculation of population density was based on administrative unit or township, the result would not be accurate, because the residential areas are not proportionally distributed over the administrative unit or township in the study area. The township was also too large for a basis of population density calculation.

The above finding shows the importance of population density as a factor for consideration to accomplish energy efficient city. Urban planners may certainly need to consider including this variable in their city planning. However, a particular city must have an adequate data record to establish its own correlations as discussed above. With sufficient information and knowledge on this particular factor, urban planners and managers are well-informed on the precondition of city towards the achievement of energy efficient city.

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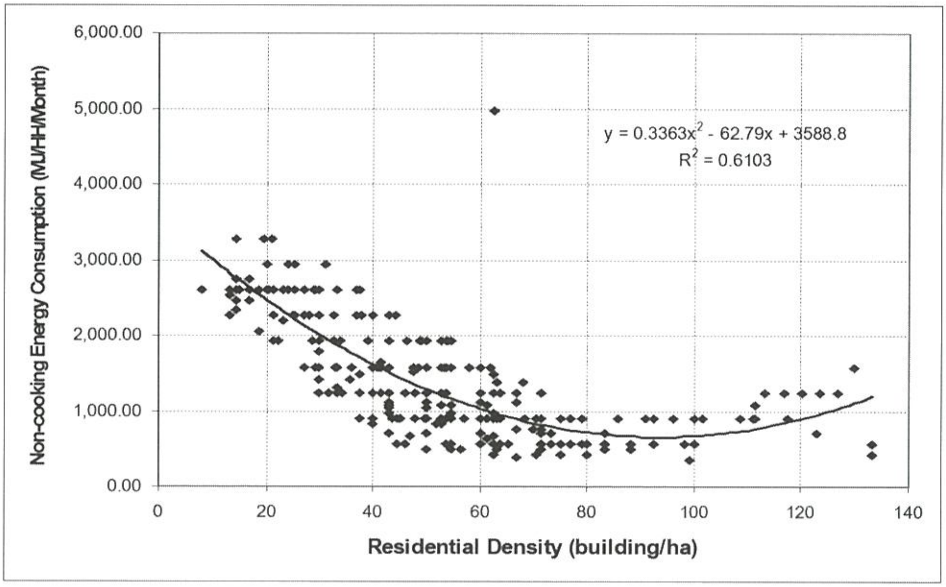

Figure 3: Correlation between Non-cooking Energy and Residential Density Based on 389 Data Samples of Energy Consumption in 21 Towns

Although population density may correlate to household size, but to consider household size in establishing a correlation between population density and energy consumption may cause a bias, if the size of household varies greatly. To avoid this bias, an attempt to correlate residential density with energy consumption is carried out, because residential density is another essential factor which may influence the urban energy use. This variable is somehow different with population density, because for the same population density, the residential density can be different. It depends also on household size. Attempt is made to correlate this variable with energy consumption. The correlation between residential density and energy consumption is shown in Figure 3.

Almost similar situation with population density exists. The best fit correlation is a quadratic equation which carries a coefficient of determination of R^2=0.6103. The exact value of residential density, where the energy consumption is the lowest, can be derived with similar process as described earlier. The equation of correlation is found to be $y = 0.3363\ x^2 - 67.29\ x + 3588.8$. Its derivative is equal to $dy/dx = 0.6726x - 67.29 = 0$. This equation leads to $x = 93$. With residential density about 93 buildings per hectare, it theoretically returns the lowest energy consumption.

A scientific explanation can be employed to describe this phenomenon. Flor and Dominguez (2004) found that there is a correlation between the surrounding environments of the urban area with the building. Again, it is possibly due to urban canyon effect, urban texture and urban heat island phenomena. This phenomenon has an impact particularly on building's thermal performance. Similar finding is also verified by Ghiaus et al. (2006). Even though the correlation is corroborated, but the use of derived value should be applied with caution.

The values should be used with careful attention to its validity. The values are derived from a study on tropical city with certain urban characteristics, and the values will only be valid with the following major conditions;

- Concentric land use in nature, with high density mixed use in the centre and low residential density in the peripheral areas
- Leap-frog development with relaxed policy on residential development
- Having potential likelihood to achieve thermal comfort by passive cooling
- Motorized travel dependent, with rudimentary services of public transport
- Having moderate level of awareness of the citizens on energy uses.

The correlation between energy consumption and residential density will perhaps be misleading if the floor area of residential buildings greatly varies. In case of samples of the buildings in the study area, there is insignificant variation of floor area of the residential buildings. To confirm the above findings, the correlation between energy consumption and plot ratio is also established as shown in Figure 4.

Plot ratio shows the ratio between total floor areas of residential building and total land areas at a given residential unit or block. From the figure, similar pattern with two previous correlations is found. Again, it shows that in a crowded area, where total area of the building's floor exceeds land area, non-cooking energy consumption increases. The equation which gives a point where energy consumption is the lowest is expressed by $y=6933.7x^2-12178x+6060.6$, taking its first derivative $dy/dx= 13867.4x-12178=0$, it gives $x=0.88$. With the value of floor area to land ratio of 0.88 and residential density of 93 buildings per hectare, it theoretically gives the ideal residential building size for this city about 94 square meter. This size disregards the urban development forms where the residential buildings are located, since the samples were taken irrespective of residential development typology. Different

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urban characteristics will lead to different results. Additional information will then be required if major characteristics of urban area is slightly different. The values cannot be used if major disparities exist. Major urban characteristics of the study area restrain potential elements toward further minimizing urban energy use.

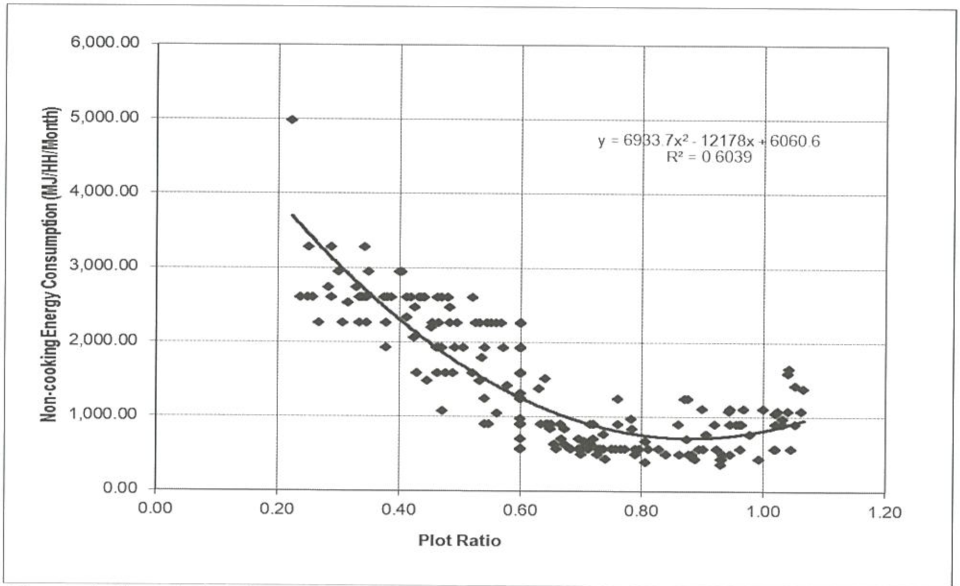

Figure 4: Correlation between Non-cooking Energy Consumption and Plot Ratio Based on 389 Data Samples in 21 Towns

The above three urban parameters namely population density, residential density and plot ratio are substantiated to have correlation with residential energy use e.g. non-cooking energy. By controlling these parameters, non-cooking energy consumption can be reduced, and therefore total urban energy consumption can be reduced as well. Urban parameters are essentially controllable and modifiable through existing urban planning instruments. The policy to control the three urban parameters can be implemented by planning tools. Population density, residential density and floor area to land ratio are potential urban development parameters those are so far dormant or neglected to be included in the strategies to control the constant increase of residential energy uses towards energy efficient city. This is basically reinventing development control which gives another insight towards different dimension other than conventional role of the development control. This ought to be reflected in the present policies on energy efficient for urban development.

POLICY IMPLICATIONS IN THE STUDY AREA

Land use and building control are two instruments which are conventionally employed by most of cities in either developed or developing countries. City authority in the study area also employs such instruments to manage urban growth. However, ineffective implementation of these planning instruments has caused the urban management of Bandung City fruitless. Urban sprawling which creates higher transport energy continues to expand. The inability of buildings particularly residential buildings to adjust to local bioclimatic condition causes higher energy consumption of residential building. These are examples of the inadequate policy and ineffective implementation of land use and building control.

The finding of this study suggests that minimum energy consumption of residential building is achieved if urban population density is around 414 people/ha, residential density is around 93 buildings/ha, and plot ratio is around 0.88. By taking these findings as the rationale of the proposed strategies, it is suggested that housing plot is orderly arranged with some amounts of free space. Twelve percent of free space is required as optimum plot ratio is 88 per cent. This finding also suggests a relatively uniform residential building size of about 94 m2. These requirements can be integrated into existing policies or new policies on land use and building control. Control on residential density and plot ratio is more pragmatic in comparison to controlling population density through building control strategies. Controlling population density seems impossible because of infringement of personal matter, for example limiting the household size.

The discussion shows that controlling residential density and plot ratio are two potential and promising strategies towards lower residential energy consumption. This is promising in a sense that it works at the root level of the issues. It works indirectly in comparison to other direct strategies such as the use of energy saver appliances, given that development control is carried out appropriately. This strategy can be synergistically carried out with other strategies towards the achievement of energy efficient city and ultimately sustainable city.

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Geospatial Analysis in Urban Planning
Volume **II** (2013), Page 119 - 136

INCORPORATING PEDESTRIAN INDEX INTO GOOGLEMAPS

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Abstract

The trend for new urbanism which encourages public transportation usage has increasingly focused on pedestrian facilities. Pedestrian facilities can be defined as facilities that continuously provide pedestrians with safe access to land uses. Unfortunately, roadway design prioritizes the needs of motorists while putting pedestrians at risk. A number of studies have developed methods to determine pedestrian Level of Service (LOS). However, none have considered the road hierarchy which has a different design standard, level of road usage, access management and scope of pedestrian needs. This paper develops a pedestrian index (P-Index) which incorporates selected indicators according to road hierarchy in evaluating pedestrian facilities. The index is an analytical tool to rate pedestrian facilities using 5 star rating formats whereby the higher the number of stars, the better quality of facilities of a particular pedestrian segment. The method focuses on four indicators namely Facility, Mobility, Safety and Accessibility. Using Taman Bukit Indah, Johor Bahru as the study area, it was revealed that the overall quality of pedestrian facilities achieved three stars, which are interpreted as walkable. The rating scores of pedestrian facility are next incorporated into Google Maps to enable the public to visualise the rating score of pedestrian facilities. The index can also serve as an evaluation tool by the authorities for auditing purposes in the provision and monitoring of pedestrian facilities.

Keywords: pedestrian index, pedestrian facilities, level of service, road hierarchy, evaluation tool, visualization

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INTRODUCTION

As population and vehicle miles traveled continue to grow, transportation planners, engineers and policy makers are looking to non-motorized transportation, often in combination with transit, to relieve some of the pressure of the traditional transportation system. Transport planners are increasingly focusing on pedestrian facilities in order to enhance public transportation usage as a measure to achieve the objectives of sustainable urban development.

The functionality of a roadway should be balanced with the needs of pedestrians. Pedestrian facilities can be defined as facilities that continuously provide pedestrians with safe access to land uses. Unfortunately, roadway design prioritizes the needs of motorists while putting pedestrians at risk. Pedestrians would be well accommodated if they received the same design considerations as motorists. To accomplish this task, roadway designers must understand how road design impact pedestrians and prioritize accessibility. Despite becoming a key policy requirement, no tool is yet available to measure the quality of pedestrian facilities in relation to different road hierarchy.

This paper presents a pedestrian index method that measures and relates pedestrian facilities to different road hierarchy. Pedestrian facilities can be defined as facilities that continuously provide pedestrians with safe access to land uses. This study focuses on four indicators to evaluate pedestrian facilities namely, facility - promote ease of usage; mobility - continuously available; safety - physically and spatially separated; and accessibility - closeness to land uses.

This paper will next review the current risk facing pedestrians, followed by the discussion on the method of assessment on the quality of pedestrian facilities. The next section shows the derivation of the pedestrian index (P-Index) and the computation of the P-index for the study area. The final section demonstrates the application of the P-index in the Google Maps.

PEDESTRIANS AT RISK

Based on statistics road accidents were the third highest cause of death among Malaysian whereby it was reported that 25 of every 100,000 Malaysian died in year 2003 alone (Royal Malaysian Police 2004). The increasing trends in car ownership further heightened the number of conflict between pedestrians and vehicles. The Malaysian Motorcycles Safety Program launched by the Malaysian Government in 1996 involving black spot treatments, overtaking lanes, motorcycle lanes, junction improvement and curve improvement have been successful in controlling the problems involving motorcyclists. However, pedestrians as road users have not been given attention although they are categorized as a vulnerable group. In Malaysia, most of the people killed by road accidents are pedestrians, cyclists and motorcyclists (Royal Malaysian Police 2008). Although the main reasons that attributed to the high numbers of pedestrians accidents is due to careless crossing (Goh et.al. 2012), the lack of good quality pedestrian facilities is an equally important factor.

Generally, pedestrian safety has not been given recognition. At present, not all roads are provided with pedestrian facilities (Public Works Department 1995). The existing pedestrian walkways are either badly built or poorly maintained. Many footpaths are obstructed by holes, garbage, tables and chairs and even vehicles. The vulnerability of pedestrians is further increased when they have to negotiate among moving traffic while crossing. Noise, fumes, obstructions and dangers from speeding vehicles also increased roads hostility, which makes it unpleasant to walk.

Table 1 shows the road fatality statistics for all categories. It can be seen from that the number of death involving pedestrian is the third highest after car passenger/drivers and motorcycle pillion/rider. If the number of road fatalities involving pedestrians is combined with bicycle pillion/riders, which in most cases share the same space, the total is higher than any other categories which are 27%.

Table 1: Road Fatality Statistics from July 2008 and 2009

Consumer Categories	2008	2009	Difference	Percentage (%)
Passenger/Driver Car	102	127	25	24.5
Motorcycle Pillion/Rider	300	374	74	24.7
Pedestrian	47	53	6	12.8
Pillion/Rider Bicycle	21	24	3	14.3
Bus Passenger/Driver	1	1	0	0
Driver/Lorry Attendant	14	16	2	14.3
Driver/Attendant Van	12	9	-3	-25
Driver/Attendant Race 4 Wheel	11	8	-3	-27.3
Others Vehicle	1	6	5	500
Total	509	618	109	21.4

Source: Royal Malaysian Police (2008-2009)

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Table 2: Pedestrian Accidents Injury Type (2005-2010)

Injury Type	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Fatal	601 (17%)	595 (21%)	636 (23%)	598 (25%)	593 (25%)	626 (29%)
Serious Injury	747	711	672	617	613	516
Light injury	2175	1493	1430	1184	1171	1019
Total	3523	2799	2738	2399	2377	2161
Total Registered Vehicles & Total Population as at 31 December 2010						
Total Registered Vehicle *	14,816,407	15,790,732	16,825,150	17,733,084	19,020,000	20,006,953
Population **	26,130,000	26,640,000	27,173,600	27,728,700	28,310,000	29,845,448
Pedestrian Deaths Rate						
Death / 10,000 vehicles	0.40	0.38	0.37	0.33	0.31	0.31
Death / 100,000 people	2.30	2.23	2.34	2.16	2.09	2.10

*Source: ** Statistical Department; *Transport Department, Ministry of Transport (MOT) & Royal Malaysian Police (2005-2010)*

Although pedestrian death rates per 10,000 vehicles and per 100,000 peoples have reduced from 0.40 in 2005 to 0.31 in 2010, the number of pedestrian fatalities has remained constantly high at an average of 608 deaths per year with the highest number of 636 in 2007. By implication, efforts to improve pedestrian safety have been minimal since there is negligible difference between the yearly death rates.

THE RELATIONSHIP OF ROAD HIERARCHY AND PEDESTRIAN FACILITIES

The road network system is based on a simple hierarchy which is a means of defining each roadway in terms of its function such that appropriate objectives for that roadway can be set, and appropriate design criteria can be implemented. Most trips originate on local roads, before going through collector roads and ultimately to arterial road, which are intended to carry a large volume of vehicle at relatively higher speeds. This system is based on the assumption that most trips occur by motor vehicle, so most of the facilities are designed primarily for motor vehicle travel (FHWA 2009). The system results in road designs that do not serve pedestrians well for several reasons as follows:

- Some collector and arterial streets are built with inadequate or no sidewalks or walkways, discouraging or limiting safe pedestrian movement along streets.

- Since arterial roads are designed to facilitate smooth and efficient motor vehicle flow, they often have multiple lanes in each direction to accommodate high motor vehicle traffic volumes. It has a direct effect on the complexity of road crossing, thus increasing risk to pedestrians.

- Wide streets encourage and allow higher vehicle speeds, which relate directly to more severe injuries to pedestrians when an accident occurs.

- Typically, wide arterial streets have intersections that are even wider due to the addition of multiple turn lanes. This requires pedestrians to cross longer distances and watch for more cars in more lanes.

- Wide intersections and those with multiple turn lanes create a long wait for pedestrians. If a crosswalk is closed, the pedestrian is left with three choices: cross illegally with no signal protection, walk a long distance around the intersection, or walk to another location to cross.

Until transport planners integrate the needs of pedestrian facilities for all types of road, the transport system will not work in totality. For example, for arterial road which accommodate high volume of vehicles running at relatively high speed, traffic signal should be provided to facilitate pedestrian crossing. On the other hand, the volume and speed of vehicles for local road is significantly low, so it is not necessary to provide zebra crossing. Therefore, it is important to consider the characteristics and requirements of different road hierarchy in designing facilities for pedestrians.

METHODS OF ASSESSMENT FOR THE QUALITY OF PEDESTRIAN FACILITIES

Evaluation of pedestrian facilities is important to determine how well a facility is fulfilling its intended objectives. However, there are various factors which need to be considered when assessing the quality of pedestrian facilities since it varies according to the needs of pedestrians.

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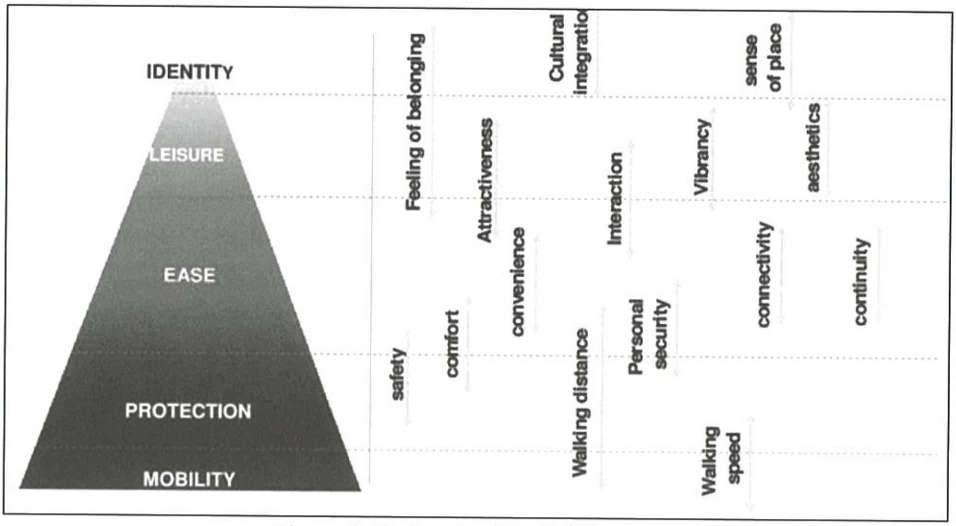

Figure 1: Pedestrian Needs Hierarchy

Source: Babiano 2003

Figure 1 shows the pedestrian needs hierarchy proposed by Babiano (2003). The diagram has been adopted based from the human needs concept by Maslow (1968) and Max-Neef (1992). The attributes indicated on the right side of the figure corresponds to the factors that would directly fulfill the particular need on the left. There are factors that could satisfy two or three needs at the same time. It is hypothesized that the basic need of pedestrians is to move. Fulfilling the needs hierarchy would provide a corresponding increase in the satisfaction level of pedestrians.

At the lowest level, pedestrians need to move from an origin to a destination point. Given that the need for movement has been satisfied, the next level of need for pedestrians is to feel protected, meaning to feel safe along walking paths. In the next level, after the need for protection is satisfied, pedestrians would want to feel at ease while walking. This refers to more secure, comfortable and convenient walking paths. On a higher level, if pedestrians would feel at ease, he would want to enjoy his walking experience. This level is dependent on various factors such as location of pedestrian facility and level of hierarchy of roads. On the highest level is the need for identity which refers to the concept of being able to identify with the surroundings.

Review of existing pedestrian facilities is important as part of an overall strategy to ensure that walking facilities provide acceptable levels of connectivity and demonstrate design consistency. Because of the various levels of needs, different methods have been applied to assess pedestrian facilities.

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The level of service (LOS) concept was first developed for vehicular capacity studies connected with street and highway design, and it was later adopted for pedestrian facilities. This section reviews selected methods to evaluate pedestrian facilities according to different variables from previous studies (Sarkar 1993; Khisty 1994; HCM 2000; Landis 2001).

Sarkar (1993) proposed a qualitative method to compute pedestrian LOS based on six factors, which are safety, security, convenience and comfort, continuity, system coherence and attractiveness. She described qualitative attributes of pedestrian environments as opposed to their quantity, thus, the measurement of each factor cannot be easily calibrated.

A methodology which results in a LOS of the facility as perceived by its users was developed by Khisty (1994). He identified six criteria namely; attractiveness, as a pleasant and interesting walking experience; comfort, which refers to adequate space to enable ones to walk at their own pace; convenience, which is good connections and services; safety, which refers to conflicts with cars and with other pedestrians; security, such as good lighting and police presence and lastly system coherence, which means clear orientation and easy navigation. Although Khisty's method provides a quantitative measure of pedestrian LOS on a point scale, the results from this scale is not easy to interpret. A fundamental question remains as whether these scaling systems really address the pedestrian facilities and do pedestrians agree with these scaling systems.

The Highway Capacity Manual (HCM 2000) defines six ranges of LOS (from A to F). However, pedestrian facilities are given equal treatment with the other motor vehicles. A mathematical model was proposed by Landis et. al (2001) based on five variables: lateral separation of pedestrians from motor vehicle traffic, presence of physical barriers and buffers, outside lane traffic volume, motor vehicle speed, and vehicle mix. The Landis's model has been developed for roadway segments only, but intersections have not been considered.

Table 3 summarizes the limitation of various models in assessing the pedestrian LOS. It can be concluded that different variables and evaluation criteria were considered, and as a consequence, there is no definite method to assess pedestrian LOS. However, none of the methods considers the need of pedestrian facilities according to road hierarchy. Thus, this research fills the gap by incorporating selected criteria of pedestrian LOS, as well as road hierarchy into the P-Index computation.

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Table 3: Limitation of Various Models in Assessing the Pedestrian LOS

MODEL	PEDESTRIAN LOS EVALUATION CRITERION / VARIABLES	LIMITATION / SHORTCOMING OF MODEL
Sarkar (1993)	Safety, Security, Convenience and Comfort, Continuity, System Coherence and Attractiveness	Qualitative attributes of pedestrian environments are described, but not quantified.
Khisty (1994)	Attractiveness, Comfort, Convenience, Safety, Security, System Coherence and Continuity	Although Khisty's method provides a quantitative measure of pedestrian LOS on a point scale, the results from this scale is not easy to interpret.
Dixon (1996)	Provision of Basic Facilities, Conflicts, Amenities, Motor Vehicles LOS, Maintenance, Travel Demand Management, Multimodal Provisions	The method is simple and easy to apply but criteria points are randomly chosen.
Highway Capacity Manual (2000)	Space available per pedestrian, Flow Rates, Speeds	HCM 2000 focuses on ease of movement which bias to motor vehicles
Landis (2001)	Lateral separation of pedestrians from motor vehicle traffic, Presence of physical barriers and buffers, Outside lane traffic volume, Motor vehicle speed and Vehicle mix	The model has been developed for roadway segments only. Intersections have not been considered.
Gallin (2001)	Design factors, Location factors and User factors	This model is based on physical description of pedestrian facility and their weightage in Pedestrian Level Of Service score. Pedestrians' perception is not included in the calculation.

STUDY AREA

This research was conducted in Taman Bukit Indah, Johor Bahru, Johor. A township located in the heart of Nusajaya, Iskandar Malaysia, Johor. The township launched in 1997, has a population of over 60,000 with over 10,000 houses. Bukit Indah is designed based on the award winning "Australian Green-Street Concept" characterized by extensively landscape environment and meticulously designed houses with wide access ways. The township recognized as one of the better design development has won an array of landscaping awards

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including the Johor State Landscape Award 2001, National Landscape Competition 2001 and Best of the Best National Landscape Award 2005.

The neighborhood was selected as the study area because it is the hub for human activity. Walking is the most convenient mode of movement due to the proximity to the different type of land uses. However, there are several hypermarkets and facilities located within the town center of Taman Bukit Indah which generate high volume of motorized traffic. Hence, there is a need to assess whether the facilities are pedestrians friendly.

The study of pedestrian facilities was conducted on various road segments covering different types of road hierarchy including the Arterial, Collector and Local roads (Table 4).

Table 4: The Detail Information of Selected Road Segments

Road Segment	Road Hierarchy (Width in feet)	Road Name	Road Length (km)
1	Arterial Road (66)	Persiaran Indah	3.16
2	Arterial Road (66)	Jalan Indah Utama	1.90
3	Collector Road (50)	Jalan Changkat Indah	1.83
4	Collector Road (50)	Jalan Indah 15/2	0.71
5	Local Road (40)	Jalan Indah 17/5	0.26
6	Local Road (40)	Jalan Indah 18/4	0.44
7	Local Road (40)	Jalan Indah 10/4	0.52
8	Local Road (40)	Jalan Indah 10/3	0.41
		Total	9.23

THE PEDESTRIAN INDEX METHOD

The P-Index utilizes the 5 star rating formats where the better quality of facilities of a particular pedestrian segment, the higher the number of stars. Mathematically, the P-index (P) is a function of three criteria - Index of Pedestrian Facilities at Arterial Road (P_{AR}); Index of Pedestrian Facilities at Collector Road (P_{CR}) and Index of Pedestrian Facilities at Local Road (P_{LR}). The functional relationship between P-index (P) and the criteria is given in Eq. (1) below:

$$P = f\left(P_{AR}, P_{CR}, P_{LR}\right) \qquad \text{(Eq. 1)}$$

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F_{CR} = facility indicator for collector road
F_{LR} = facility indicator for local road
B_i = bollard facility
R_i = ramp facility
Z_i = zebra crossing facility
TS_i = pedestrian traffic signal facility
RI_i = pedestrian refuge island facility
WS_i = pedestrian warning signage facility

B_i, RI_i, TS_i, WS_i = 2, if available on both sides
1, if available on one side
0, if not available

Z_i, R_i = 1, if available
0, if not available

Mobility (M) Indicator

The Mobility (M) indicator describes the provision of a paved, continuous pathway relative to the total length of roadways for the pedestrians. The formula for the Mobility (M) indicator is as in Equation 7 below;

$$M = \left(\frac{0.5D_C}{D}\right) \times 100 \qquad \text{(Eq.7)}$$

Where:

Dc = total length of paved pedestrian pathway, calculated on both sides of the roads (km)

D = total length of roadway, calculated one-way (km)

Safety (S) Indicator

The Safety (S) indicator describes how safe the pathway is for the pedestrians. For this purpose, a safe pathway is defined as pathways that provide both spatial and physical separations between the pedestrians and the motorized vehicles. The formula for the Safety (S) indicator is as in Equation 8 below;

$$S = \left(\frac{0.5D_{SP}}{D}\right) \times 100, \quad 0 \le D_{SP} \le D_C \qquad \text{(Eq. 8)}$$

Where:

D_{SP} = total length of spatially and physically separated paved pedestrian pathway, calculated on both sides of the roads (km)

D_C = total length of paved pedestrian pathway, calculated on both sides of the roads (km)

D = total length of roadway, calculated one-way (km)

Accessibility (A) Indicator

Finally, the Accessibility (A) indicator measures the closeness of houses to selected land uses. The formula for the Accessibility (A) indicator is as in Equation 9 below:

$$A = \frac{\sum_{j=1}^{k} L_j}{k} \times 100 \qquad \text{(Eq. 9)}$$

Where:

L_j = percent (%) of houses within walking distance to land uses j, $j = 1, 2, \ldots, k$

COMPUTATION OF P-INDEX FOR TAMAN BUKIT INDAH

The calculation of P-Index for the various road segments i.e. P_{ARi}, P_{CRi} and P_{LRi} is shown in Table 6. Meaning that all the indicators, Facility (F), Mobility (M), Safety (S) and Accessibility (A) were added and then divide by four, which means all the indicators have the same weightage. Then, the next step is to calculate the value of P_{AR}, P_{CR} and P_{LR}. The value of arterial road (P_{AR}) was obtained by dividing the total score of (P_{ARi}) with the number of each road type, *n*. The same steps go to collector road (P_{CR}) and local road (P_{LR}) as shown in the Table 7.

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Table 6: Calculation of Facility (F), Mobility (M), Safety (S) and Accessibility (A)

Road Segment	F	M	S	A	(F+M+S+A) /4	Rating
1	20.83	55.54	87.34	31.81	48.88	3 stars
2	20.83	96.05	192.11	31.81	85.20	5 stars
3	10	0	0	31.81	10.45	1 star
4	40	91.55	0	31.81	40.84	3 stars
5	0	0	0	31.81	7.95	1 star
6	0	0	0	31.81	7.95	1 star
7	0	0	0	31.81	7.95	1 star
8	0	0	0	31.81	7.95	1 star

Table 7: The Calculation of P_{AR}, PCR, PLR

Road Type	Total Score	The value of P_{AR}, P_{CR}, P_{LR}
P_{AR}	(48.88+85.20)/2	67.04
P_{CR}	(10.45+40.84)/2	25.65
P_{LR}	(7.95+7.95+7.95+7.95)/4	7.95

The next step is to calculate the coefficient b_1, b_2, b_3. The coefficients were obtained by dividing the road length (km) for each road hierarchy with the total road length (km). Table 8 shows the calculation of the coefficients (b_1, b_2, b_3).

Table 8: The coefficient b_1, b_2, b_3

Road Hierarchy	Road Length (km)	Coefficients (b_1, b_2, b_3)
Arterial Road	5.06	$b_1 = \frac{5.06}{9.23} \times 100 = 0.5482$
Collector Road	2.54	$b_2 = \frac{2.54}{9.23} \times 100 = 0.2752$
Local Road	1.63	$b_3 = \frac{1.63}{9.23} \times 100 = 0.1766$
Total	9.23	100%

From Table 8, $b_1 = 0.5482$, $b_2 = 0.2752$ and $b_3 = 0.1766$, so that the final step is to calculate P, which is the overall rate of pedestrian facilities using the improved method as shown below:

$$\begin{aligned} P &= b_1 (P_{AR}) + b_2 (P_{CR}) + b_3 (P_{LR}) \\ &= 0.548\ P_{AR} + 0.275\ P_{CR} + 0.177\ P_{LR} \\ &= 0.548\ (67.04) + 0.275\ (25.65) + 0.177\ (7.95) \\ &= 45.1993 \text{ (3 stars)} \end{aligned}$$

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According to the P-Index method, the three stars rating for pedestrian facility in Taman Bukit Indah can be interpreted as walkable (Refer to Table 9). This means in relation to the actual facilities, the new improved method is correctly and truly describe the quality of the facility because it considers the different purposes of pedestrian needs according to different road hierarchy.

Table 9: P-Index, Star Rating and Associated Colour Codes

Colour Codes	P-Index value	Star Rating	Description
	0 - 20	★	Dangerous for pedestrians
	21 - 40	★★	Unfavourable to pedestrians
	41 - 60	★★★	Walkable
	61- 80	★★★★	Supportive towards pedestrians
	81 - 100	★★★★★	Very pedestrian friendly

Source: Zaly and Nelson 2008

Finally, the results are mapped according to the star rating. Figure 2 shows the visual star rating of pedestrian facilities for the road segment in the study area which is Taman Bukit Indah. The three star ratings can be interpreted as walkable according to Table 9.

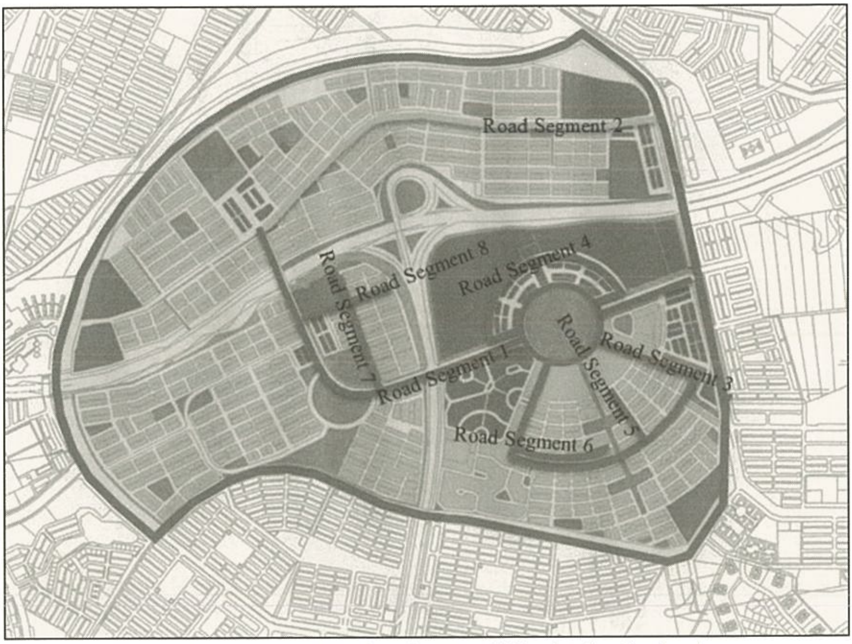

Figure 2: Ratings of Pedestrian Facilities in the Study Area

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GEOCODING RATING OF PEDESTRIAN FACILITY IN GOOGLEMAPS

P-index can be translated visually so that the value of ratings can be more meaningful. This simple concept is presented here through the use of Google Maps that would dynamically display pedestrian walkway's rating information. Using Google Maps has many advantages. It is free, highly accessible and ubiquitous. A life example of these ratings in action can be viewed online at a purpose built website www.lokasee.com./maps/pedestrian.php. A snapshot of this webpage is shown in Figure 3. On this particular webpage, visitors can view the quality of pedestrian facilities. Clicking on any of the markers will open an info box with the name of the roadway it represents and an image of the pedestrian walkway (Zaly and Nelson 2008).

Colour Codes	*P*-Index value	Rating	Qualitative Meaning
	0	-	Extremely unsafe for walking
	1 - 20	★	Hostile towards pedestrians
	21 - 40	★★	Unfavourable to pedestrians
	41 - 60	★★★	Walkable
	61 - 80	★★★★	Supportive towards pedestrians
	81 - 100	★★★★★	Very Pedestrian Friendly

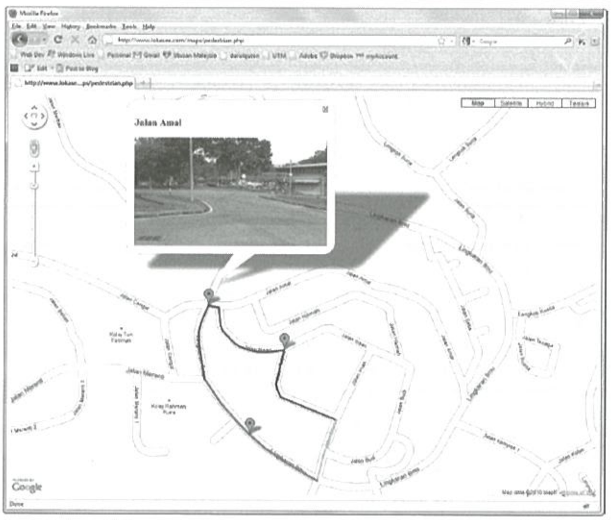

Figure 3: Colour-coded Lines Representing Different Ratings of Pedestrian Facility using Google Map

Source: Zaly and Nelson 2008

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CONCLUSION

The P-index is an analytical tool developed to increase the visibility of pedestrian needs in urban planning policy applications. It encourages urban planners, city agencies, developers and community groups to use the index and its concepts for transportation and land use planning and as an evaluation tool. It give benefits to the local authority include standard guideline to measure pedestrian facilities and as a tool for Town and Country Planning Department (JPBD) requirement as well as auditing purposes. For the developer, the benefits such as marketing tool and improve the quality of property of the area. Lastly, for the community, it will benefits them in terms of create a walkable and healthier communities.

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PLANNING MALAYSIA
Geospatial Analysis in Urban Planning
Volume **II** (2013), Page 137 - 162

SEISMIC MICROZONATION FOR BANDA ACEH CITY PLANNING

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Abstract

Of all natural disasters of the twentieth century, earthquakes caused the largest amount of losses. Although the number of earthquakes remains fairly unchanged, the loss of properties and human lives in recent periods has increased manifolds due to increasing concentration of human population and urbanisation in earthquake-prone areas. Recent improvement in documentations and computational facilities, however, allows for the preparation of seismic microzonation maps of such areas for urban planning and earthquake mitigation purposes. This paper discusses the development of seismic microzonation maps for Banda Aceh which lies close to the Sumatra Subduction Zone and the Sumatran Transform Faults, making the city extremely vulnerable to earthquake hazards. The development of the maps employs Geographic Information Systems (GIS) techniques that make use of several layers of parameters influencing earthquake hazards such as seismological data, faults, tsunami, etc. and site characteristic data such as soil type, groundwater distribution and depth, geological and geophysical data. The seismic microzonation maps incorporate various seismic hazard maps including ground shaking hazard map, liquefaction susceptibility hazard map, landslide potential hazard map, surface faulting hazard map and tsunami hazard map. The final composite map identifies zones with various degrees of hazards which will enable planners to avert hazardous locations during site selection processes, thus reducing losses.

Keywords: Earthquake, Seismic, Hazard, Mitigation, Microzonation, GIS.

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INTRODUCTION

Earthquake is one of the most devastating natural disasters which can cause severe impact on human life, loss of valuable goods and massive damage to structures such as buildings, transportation systems and communication systems. It can even lead to total devastation of cities. There are many earthquakes that are well known not just for their magnitude but also for the damage and casualties they caused. A compendium report on the significant earthquakes worldwide, from the oldest to the most recent ones, lists the tremendous loss of lives and property damage caused by earthquakes (Chen and Scawthorn 2003). The damage caused is not only dependent on the magnitude of the earthquakes and the distance from the epicentre, but also on the level of socio-economic activities in the area. Though the number of incidences of large earthquakes has remained fairly stable, the recent magnitude of losses of properties and human lives has increased tremendously due to the intensification of urbanisation and economic activities, especially in larger urban areas situated in susceptible regions. However, intense urbanisation alone is not a single most important factor since the level of earthquake preparedness can, on the other hand, lessen the impact. Developed countries that have in place more sophisticated warning-systems and stricter building codes as well as restrictive land use zoning are less susceptible and more resilient to earthquake damage compared to underdeveloped countries, given the same magnitude of earthquakes (Westen 2002; Walling and Mohanty 2009). Thus, it is therefore crucial for these underdeveloped countries to determine what kind of pre-disaster initiatives can help mitigate disaster risk, especially in urban areas.

Although the occurrence of earthquakes is inevitable, the social and economic setbacks following the occurrence can be reduced through a comprehensive assessment of the seismic hazards. Most countries that are susceptible to earthquakes have developed seismic zones which have been regarded as a basic tool for earthquake damage mitigation (Coburn and Spence 2002; Roca et al. 2006; Ansal et al. 2009); but these are deemed inadequate for planning purposes as more detailed assessments are needed. A more detailed seismic zonation or seismic microzonation maps are able to provide a more detailed assessment of potential earthquake effects which include ground shaking, liquefaction, landslide, surface faulting and tsunami susceptibilities which are more useful as guidance to urban planning and development. At the urban level, the identification of relative hazard variations due to different earthquake characteristics can be used to introduce earthquake effects as a relevant factor in land use planning and management.

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Looking back at the mega earthquake that struck Banda Aceh in northern Sumatra, Indonesia on December 26th 2004, we cannot help but think that the vulnerability of Banda Aceh to earthquake hazards underlines the value in considering risk mitigation measures for future development. Thus it is the aim of this study to develop a comprehensive seismic microzonation maps of Banda Aceh using Geographic Information Systems (GIS) coupled with the Analytical Hierarchy Process (AHP). The final composite map will provide guidance to urban planners in deciding on the potential location of future development based on hazard risks.

EARTHQUAKE HAZARD AND URBAN PLANNING

The damage incurred in an earthquake depends not only on the magnitude of the earthquake but also, to a large extent, on the medium through which the seismic waves propagate and the socio-economic development of the affected settlement (Panza et al. 2001). Hough and Bilham (2005) gave a simple relation discerning between the earthquake magnitude since 1900 and the number of deaths per earthquake but the consequences of large earthquakes depend on the proximity to urban areas, vulnerability of the dwelling inhabitants, time of the day and on the energy released (Figure 1).

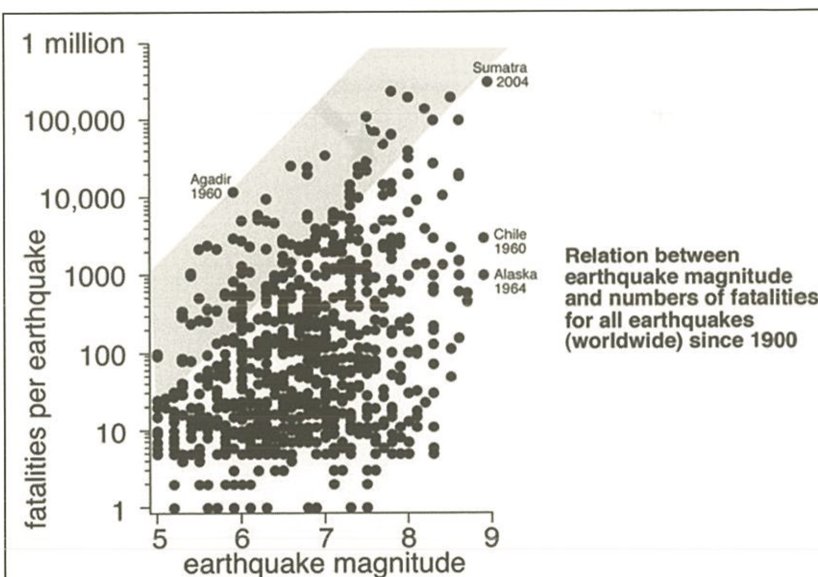

Figure 1: A Simple Relation Discerning between Earthquake Magnitude and the Number of Fatalities (grey shading)

Source: Hough and Bilham 2005

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When disasters strike cities, the effects can be worse than in other environments, and it is the poor and marginalized communities in the developing countries that face the greatest risks (e.g. Blaikie et al. 1994; IDNDR 1990). With growing urbanisation and increasing occurrences of small and large-scale disasters in urban areas, years of development effort and labour are continually being destroyed and eroded (Sanderson 2000). Maskrey (UNDP-BCPR 2004) puts it best when he stated: "The trend is for the risk to become urban". Increasing natural disasters in urban areas are continuously testing our public policies and disaster response measures beyond their capacities (Mitchell 1999).

In response to this development, it is essential to determine effective pre-disaster initiatives that can help to mitigate disaster risk. However, those involved in risk reduction and planning issues are not fully aware of the interconnection between planning and the occurrence of natural disasters (Wamsler 2004). This results in few initiatives being developed, which would integrate both fields. According to Pelling (2003), urbanisation affects disasters just as profoundly as disasters can affect urbanisation. In addition, rapid urbanisation is a factor that calls for construction of mega structures, and the main reason for human loss and property damage is lack of due considerations on the importance of adequate preparation for possible hazards. In many developed countries, however, improvements in methods for risk reduction, together with good planning, have greatly reduced the vulnerability and risk of the population (Velasquez et al. 1999). The city of Tokyo, for example, promotes 'disaster-proof urban planning' and prescribes regulations on the implementation of 'area vulnerability assessments' (Velasquez et al. 1999). An example from the developing world is Cuba, where national land-use planning and management are integrated into risk reduction considerations (UN-ISDR 2002).

Planning process rarely includes measures needed in reducing hazards, and consequently, natural disasters would result in severe economic and human suffering. Right from inception, planners and decision makers should evaluate natural hazards as they do in preparing investment projects and promote ways of avoiding or mitigating damage caused by natural catastrophic events. Adequate planning can minimize damage from natural catastrophic events. Integrating natural hazards management into development planning can pick up the planning process in the area and thus reduce the impact of natural hazards (OAS/DRDE 1991).

Site selection is the most important stage in planning a settlement or constructing a building in an earthquake-prone area. Evaluation of the degree

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of earthquake hazard should always be part and parcel of the general site evaluation and of the design requirement of any structure to be erected on such sites. A perfect site is almost none existence, thus the likely risk of earthquake hazards on a site and the costs of designing to minimize adverse effects from it should be considered. Unsafe sites should be avoided, because the mitigation costs are likely to be exorbitant.

Mapping of earthquake hazards at the regional or urban level makes it feasible in the selection of relatively less affected sites for the distribution of suitable land uses. Patterns of urban development can be oriented toward these relatively less affected regions to reduce likely earthquake damages. For this, seismic microzonation is a fundamental tool for structural designers and builders as it enables them to expect predicaments related to amplification of ground shaking, liquefaction and landslide susceptibilities (Ansal et al. 2009). The design loading and other inputs for the structural design of buildings should be provided as part of the information derived from the site assessment. Mostly this process is very much facilitated through the use of zoning map and other additional procedures addressed by pre-determined code of practice. In a situation where such code is not available, a more meticulous analysis is needed (Coburn and Spence 2002).

Seismic waves generated at the earthquake source propagate through different geological formations until they reach the surface at a specific site. The travel paths of these seismic waves in the uppermost geological layers strongly affect their characteristics, producing different effects on the earthquake motion at the ground surface (Figure 2). In general, thicker layer of soft, unconsolidated deposits tend to amplify selectively different wave frequencies. On the other hand, the local topography can also modify the characteristics of the incoming waves, leading to the so called topographic effects. Soil and topographic effects are considered under the general denomination of local site effects. Beyond these effects and under certain circumstances, induced effects may occur for large amplitude incoming waves, among which are slope instabilities (landslides) in mountainous area and liquefaction in recently deposited sands and silts area (Figure 2).

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Figure 2: Ground shaking effects in Banda Aceh earthquake, 2004

Figure 3: Tsunami effects in Banda Aceh earthquake, 2004

Source: Boen 2005

Within a more generalized scope, active faulting should also be considered. In addition, permanent differential displacements and near fault effects are other important issues to be recognized. Earthquake induced tsunami is also considered in the coastal area, especially the site near to the fault rupture in sea bed (Figure 3). In many past and recent earthquakes, it has been observed that the local site conditions, i.e. soil and topographic effects, as well as induced effects, have a great influence on the damage distribution. It is therefore, very important to take into account and predict these possible local site effects when assessing the earthquake hazard at regional and local scale.

Seismic Microzonation

Seismic microzonation can be defined as the subdivision of a region that has relatively similar exposure to various earthquake-related activities or the identification of individual areas with varying potentials for earthquake effects. The underlying concept arises from the fact that the effects of surface geology on seismic motion could be considerably large. Several studies on devastating

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earthquakes have demonstrated a large concentration of damage in specific areas due to site-dependent factors related to surface geologic conditions and local soils altering seismic motions (Nath et al. 2008).

Various approaches are currently being applied for microzonation studies. Experimental techniques, together with theoretical approaches involving ground motion modelling under different hypotheses have been used to classify urban areas into zones with different earthquake response characteristics. Microzonation is normally classified into three levels (TC4-ISSMGE 1999):

a) First grade (Level 1) map prepared with a scale of 1:1,000,000 – 1:50,000 showing the seismic hazards assessed based on the historical earthquakes and existing information of geological and geo-morphological maps.
b) Second grade (Level II) map prepared with a scale of 1:100,000-1:10,000 showing the seismic hazards assessed based on the micro-tremor and simplified geotechnical studies.
c) Third grade (Level III) map prepared with a scale of 1:25,000-1:5,000 showing seismic hazards assessed based on the complete geotechnical investigations and ground response analysis.

The three levels are calibrated with respect to their specific use and relevant objectives. For vast area land planning the first level is sufficient, while level 2 or level 3 are usually needed for accurate urban and emergency planning and for structural design (Dolce 2002). The key issue affecting the applicability and the feasibility of any microzonation study is the usability and reliability of the parameters selected for microzonation. The locations of concern, for which the preparation of seismic microzonation is most needed, is the urban or upcoming urban area that falls under the high seismic hazard zone; and locations with moderate (or low) hazard but with potential amplification due the local geological conditions. The pattern of damage due to an earthquake depends largely on the local site condition and the social infrastructures of the region, the most important condition being the intensity of ground shaking at the time of the earthquakes. Contrasting seismic response has been observed even within a short distance over small changes in the geology of the site. Moreover, designing and constructing structures on all sites to withstand conceivable future earthquake is economically not viable. As such, in terms of land-use management or city/urban and regional planning, seismic microzonation map can be regarded as an appropriate tool to minimize the impact of earthquakes.

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THE STUDY AREA

The study area covers about 1160 km^2.It includes the city of Banda Aceh (Banda Aceh Municipality) which is an area of 60 km^2 and 1100 km^2 or half of the area of Great Aceh Regency (Figure 4). Banda Aceh is the provincial capital and the largest city in the province of Aceh, located on the northern most tip of Sumatra Island, Indonesia. It is the most populous city in the region with the highest concentration of human activities and manmade structures, particularly along the eastern coastlines of the city. It serves as the principal administrative, commercial, educational and cultural centre of Aceh Province. Banda Aceh is located on latitude between 95° 16' 15" - 95° 22' 15" East and longitude between 05° 16' 15" - 05° 36' 16" North.

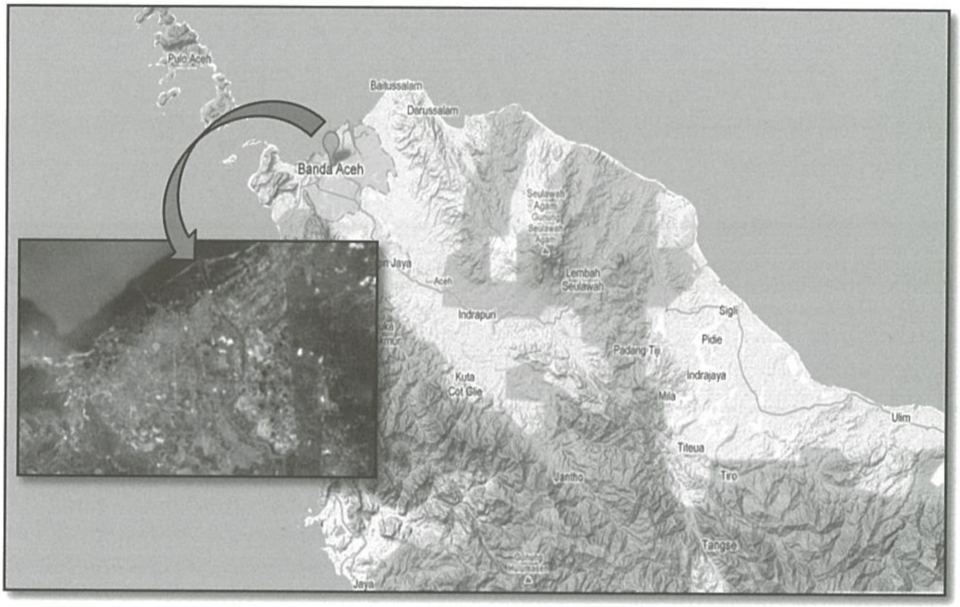

Figure 4: Location of the study area

Source: http://maps.google.com.my/- Accessed April 2013

Topographical and Geological Settings

Banda Aceh is located on the deltaic plain of Aceh River (Krueng Aceh). The city stands astride the broad valley of Aceh River which flows between the low Tertiary and Quaternary volcanic hills to the east and Cretaceous limestone hills to the west (Figure 5). The valley itself is filled with relatively recent alluvial and marine sediments to depths in excess of 179 metres (Culshaw et al. 1979). These were deposited in a graven structure formed between the main Sumatran

Fault System. The valley is relatively low lying ground with little relief in the lower part of the valley, and relatively higher relief in the upper part of the valley, much of the land is at less than 5 metres above sea level. The deltaic plain emerged mainly as a wide tidal area spreading over 1 – 2 kilometres to the coast with elevation 0 – 3 metres above the sea level. However, terraced areas on the eastern and western margins rise to over 30 metres. The deltaic lowland and beach ridges are occupied by houses while the Banda Aceh urban area is located on the deltaic plain in the central part of the coastal plain (Umitsu et al. 2006).

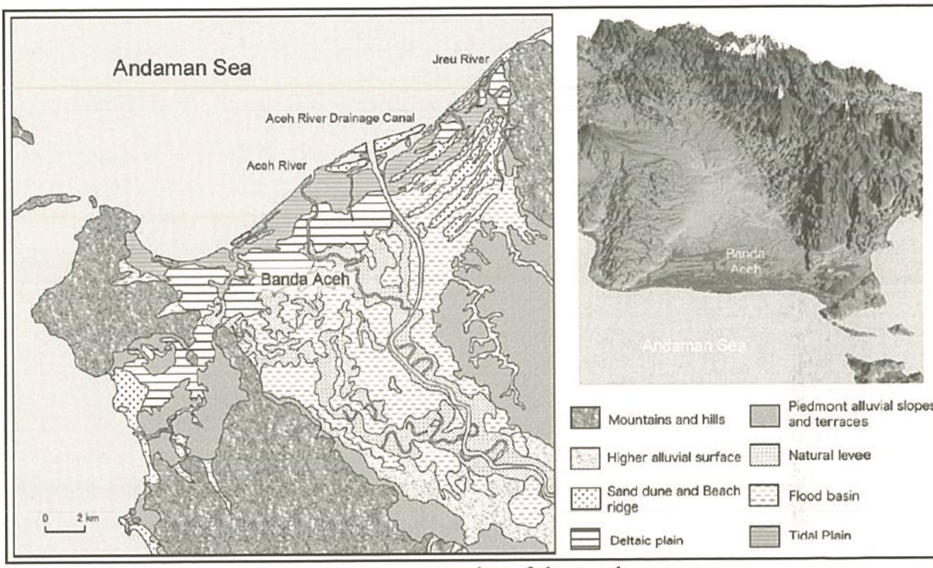

Figure 5: Topography of the study area

Source: Umitsu et al. 2006

The oldest rocks in the Banda Aceh area are limestone, slates and phyllites outcrops on the west side of the Aceh River valley. These are of Cretaceous age and form generally steep mountains at the northern end of the Barisan mountains range that runs the length of Sumatra Island. The limestone is fairly massive but moderately weathered. The east side of the valley is flanked by extensive deposits of andesitic tufts and subsidiary flows, some probably water lain (Culshaw et al. 1979). These deposits and their parent volcano, Seulawah Agam, lie on the line of the eastern Sumatran Fault, a splay off the main fault system.

The valley can be divided into three areas on the basis of the location and distribution of the deposits: the lower part (the coastal area), the middle part (along Aceh River) and the upper part (higher alluvial surface and terraces). The

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most northerly area (coastal area) consists of five to six kilometres wide coastal strip, with a series of ancient sandbars, running sub-parallel to the coast. These consist mainly of brown to grey, moderately weathered, fine to medium grained, sometimes silty sands. Weathering extends to a depth of about 2 metres. The lithological composition of these sandbars is very similar to that of the modern beach sands on the coast and to sand deposits in the channel of the Krueng Aceh.

Seismicity of the Region

Indonesia has been well known as one of the most seismically active countries in the world. This is due to its location as it is surrounded by four major active tectonic plates of the earth: Euro-Asian (Eurasian), Indian-Australian, Pacific and Philippine plates. The location of Banda Aceh near to one of the most seismically active plate, the subduction zone of India-Australian Plate (Sumatran Subduction Zone) (Zachariasen et al. 1999), and very close to the segments of Sumatran Transform Fault (Aceh and Seulimeum segment), makes it vulnerable to earthquake hazards. The study of probabilistic seismic and tsunami hazard analysis of Banda Aceh by Sengara et al. (2008), based on instrumental and historical data and potential magnitude estimated from geometry and slip rate of the plates or faults, assigned the Moment Magnitude (Mw) of earthquake in subduction zone that could trigger tsunami at Mw 9.3 in 520 years return period, Mw 8.5 in 250 years return period, Mw 8.0 in 120 years return period and 7.5 in 50 years return period.

The Sumatra subduction zone is a very active feature that has ruptured 237 times with magnitude greater than or equal to Mw 5 within the past 36 years (Petersen et al. 2004). Four past major earthquakes that were recorded were two in the 1800s i.e. Mw of 8.75 in 1833 and Mw of 8.4 in 1861; and another two in recent years i.e. Mw of 9.3 Aceh earthquake in Dec 2004 and Mw of 8.7 Nias earthquake in March 2005. The locations of these four earthquakes including the rupture zones are shown in Figure 6. The low-lying city of Banda Aceh was one of the worst affected regions and experienced massive casualties and destruction of properties, as it was close (ca. 150 km) to the source of the earthquake. The tsunami flow extended inland towards the central and western parts of the Banda Aceh plains for approximately 4 km and about 3 km towards the eastern part (Figure 7). The tsunami reached a height of 9 meters on the ground near the port of Banda Aceh and about 6-8 meters in the eastern part of the plain. The loss of human life recorded was the highest at about two-thirds of the total of 300,000 casualties (Meilianda et al. 2010).

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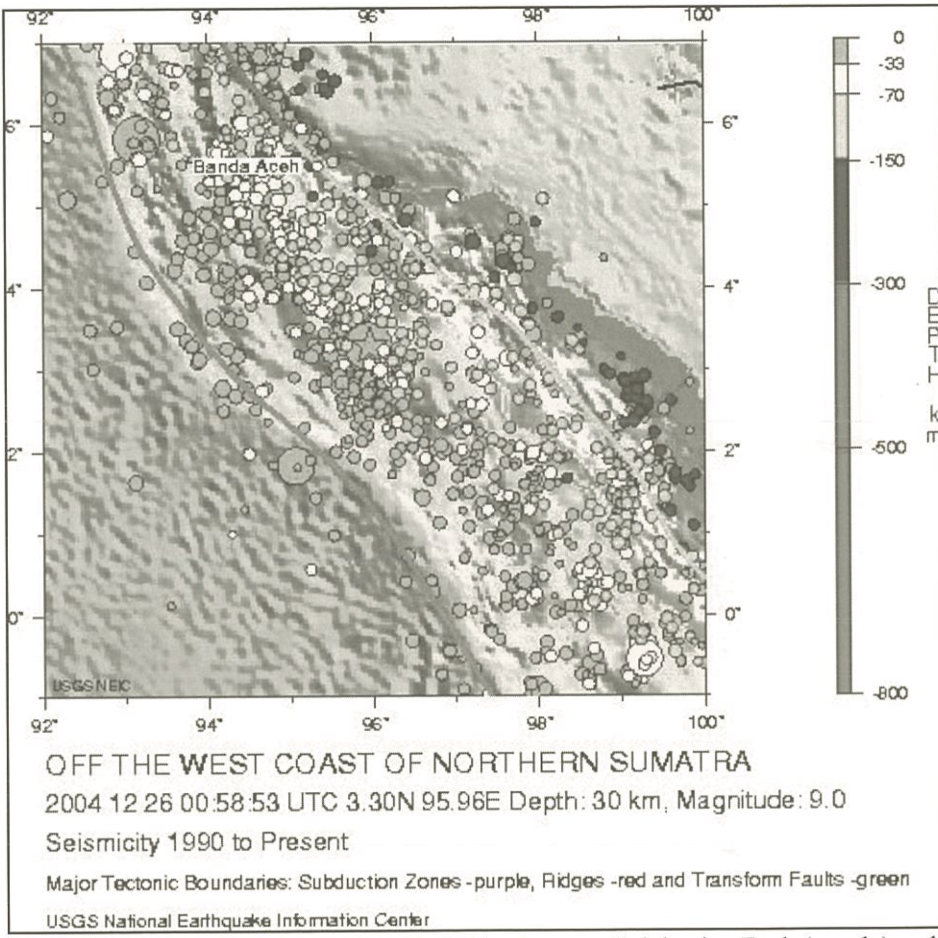

Figure 6: Seismicity of the region affected by Sumatra Subduction Fault (purple) and Sumatran Transform Fault (green)

Source: http://neic.usgs.gov/neis/eq_depot/2004/eq_041226/ neic_slav_h.html. Accessed July 2010

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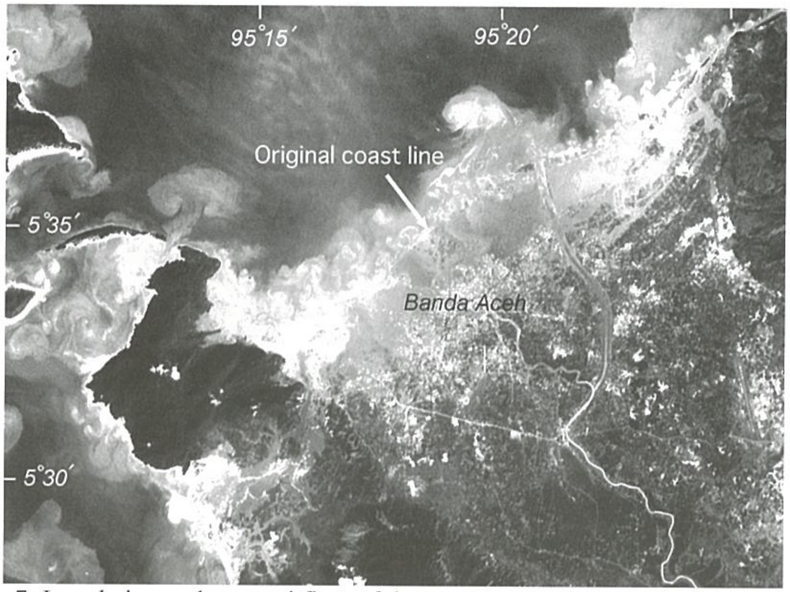

Figure 7: Inundation and tsunami flow of the Banda Ache Plain shown in the SPOT2 image. The image was taken about 4 hours after the earthquake.
Source: Includes material from CNES2005, Distribution Spot Image S.A., France, all rights reserved). (Umitsu et al. 2007)

A probabilistic seismic hazard analysis of the Sumatran subduction zone carried out by Sun and Pan (1995) indicated that the recurrence interval of an earthquake with Mw 8.5 or larger that can generate a tsunami would be about 340 years, which corresponded to a 14% probability of incidence within 50 years. Because of the large population that inhabits this region, it is prudent to suggest for seismic hazard analyses be conducted to assist in the development planning for the area.

IMPLEMENTATION OF GIS FOR SEISMIC MICROZONATION

The application of technology required to control the effects of natural hazards comprises three significant elements; prediction, monitoring and safeguarding (Alexander 1995; Turk et al. 2011). In recent years, different technologies have been developed showing possibilities for a wide range of disaster management and hazard mitigation (Yilmaz 2009). This paper focuses on the application of GIS on developing seismic microzonation for site selection for the purpose of urban planning and management. Microzonation studies is tedious to perform by means of classical methods as it involves voluminous data; the reason why a GIS is needed in order to do it accurately and quickly (Kolat et al. 2006; Kienzle et al. 2006; Nath 2005; Papadimitriu et al. 2008; Turk 2009). GIS has

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emerged to be a powerful computer-based technique that integrates spatial analysis, database management, and geographical visualization capabilities. This technology has been widely used in producing increasing numbers of seismic zone maps for the prediction of earthquake-induced hazards (Kolat et al. 2006; Sun et al. 2008; Grasso and Maugeri 2009). Guidelines for seismic microzoning developed in countries such as France (AFPS 1995), Japan (TC4-ISSMGE 1999) and the Republic of Turkey (DRM/GDDA 2004) show how GIS has been employed to establish GIS database as well as generating seismic microzonation maps. The microzonation maps consist of surface faulting map, ground shaking map, liquefaction susceptibility map, landslide and rock fall hazard map, and earthquake-related flooding hazard map. In Turkey, a seismic microzonation level 3 map, is obtained by investigating a point in a grid format of the study area and imported into GIS software, using geo-statistical interpolation technique (DRM/GDDA 2004). In India, in the absence of guidelines, researchers make assessment based on the theory of seismic microzonation, data availability and relevant objectives of the map.

Another method adopted to produce a seismic microzonation map is by using the technique of weighted overlay. This method assigns weightage to parameters such as seismic data (shear wave velocity, predominant period/frequency, peak ground acceleration/velocity) and site characteristics data (bedrock, soil layer (stratification) and type (classification), groundwater depth and topography). This method is usually used for urban and regional planning (OAS/DRDE 1991) and broadly used in India (Mohanty et al. 2007; Nath et al. 2008; Anbazhagan et al. 2008; Walling and Mohanty 2009). To conclude, many approaches have been employed in producing seismic microzonation maps subject to needs and available guidelines.

DATA AND METHODOLOGY

For the study on Banda Aceh, the seismic microzonation map which has been developed on a scale of 1:225,000 using ArcGIS ver. 9.3 can be classified as seismic microzonation level 1 (TC4-ISSMGE 1999) which is suitable for vast area planning (Dolce 2002). The seismic microzonation map is based on the analysis of historical seismological records and existing geological, geotechnical and geo-morphological data. The main data for the map was obtained from the Aceh Province's Energy and Mineral Resources Department and the Development Planning Agency. They carried out seismological, geological and geotechnical studies for the region and these complemented by seismic data from the U.S. Geological Surveys. The data was categorized into two main themes; seismological data, which include peak ground acceleration

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(PGA), faults, and tsunami inundation maps; and the site characteristics data, which include geology (soil and rock formation), lithology (soil type and classification), hydrology (groundwater quantity and distribution) and topography (contour map). The expected PGA value in the region varies from 0.05 g to 0.15 g. The highest value is on the alluvial sediments especially on the coastal region in the northern part of the area which is mainly thick clay deposits. The PGA values decrease towards the eastern part which is andesitic deposits, the western part which is limestone deposits, and the southern part which is relatively shallow bedrock. The fault map identifies two segments of the Sumatran transform faults (Aceh and Seulimum segments) located very closed to the city which implies hard shaking and surface faulting potential along the faults. The tsunami inundation map was made based on the historic tsunami occurrence and have been studied previously (JICA 2005; Borrero 2005; Umitsu et al. 2007; Takahashi et al. 2008; Lavigne et al. 2009).

The seismic microzonation map is developed by first identifying the hazards caused affected by an earthquake in the area which area ground shaking, liquefaction, landslide, surface faulting and tsunamis. The parameters or criteria and sub criteria for each type and sub criteria for each type of hazard are consequently determined. The parameters and their values can be seen in Figure 8. Ground shaking hazard map, liquefaction hazard map and landslide hazard map are created by using weighted overlays of parameters that influence the level of hazards. This process employed Saaty's (1980) Analytical Hierarchal Process (AHP). The AHP uses hierarchical structures to represent a problem, and there after develops priorities for the alternatives based on the consensus judgment. The technique utilizes organized priority in terms of weights assigned to each criteria or themes, which could be easily incorporated to the thematic layers on a GIS platform. The weighting activities in multi-criteria decision-making are effectively dealt with hierarchical structuring and pair-wise comparisons wherein the judgment between two particular elements is formulated rather than prioritize an entire list of elements. The process involves construction of a matrix of pair-wise comparisons between the factors of adopted parameters depicting relative importance based on the assigned weightage.

The highest weight is given to the PGA (0.4) as it is directly related to the ground motion and contributes more to the seismic hazard, followed by soil class (0.3), geology (0.2) and groundwater (0.1) (Nath 2004). Rank value is then determined for each sub-criterion. For example in soil-class, unconsolidated soil (soft soil) has worse impact than dense soil or rock. The weight and rank value are used as input in weighted overlay analysis (Malczewski 1999) to generate the ground shaking hazard map. The surface faulting hazard map is created by

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calculating the distance from the faults and reclassifying the distance into different hazard levels while the tsunami hazard map is generated by reclassifying the historic tsunami inundation map.

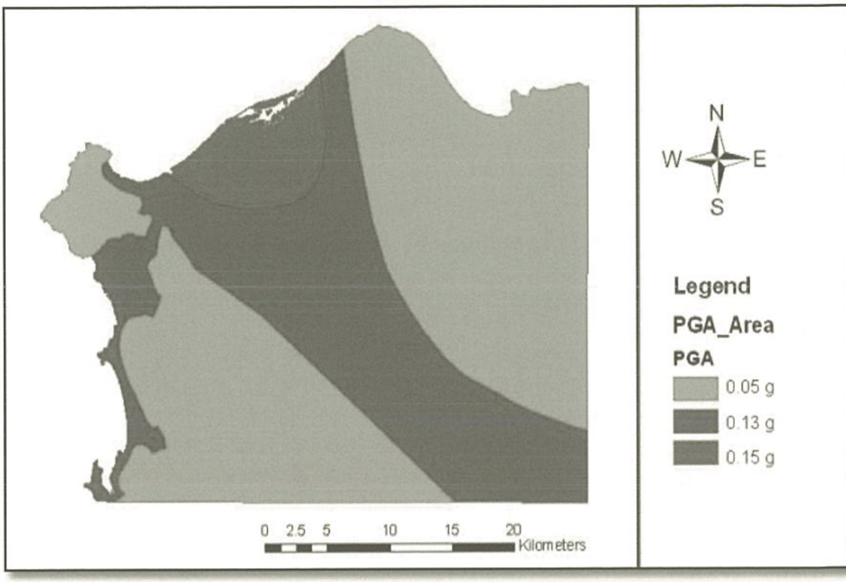

Figure 8: Peak Ground Acceleration (PGA) Data Layer

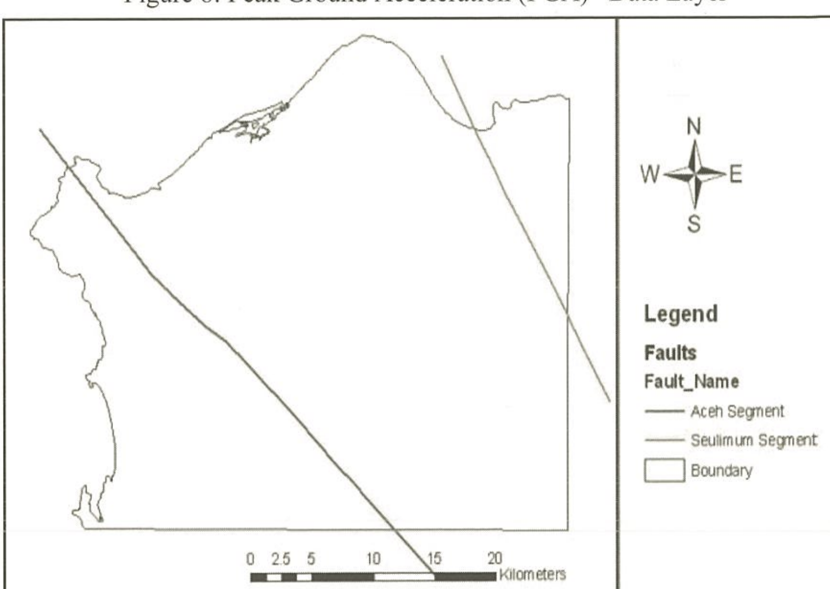

Figure 9: Fault Data Layer

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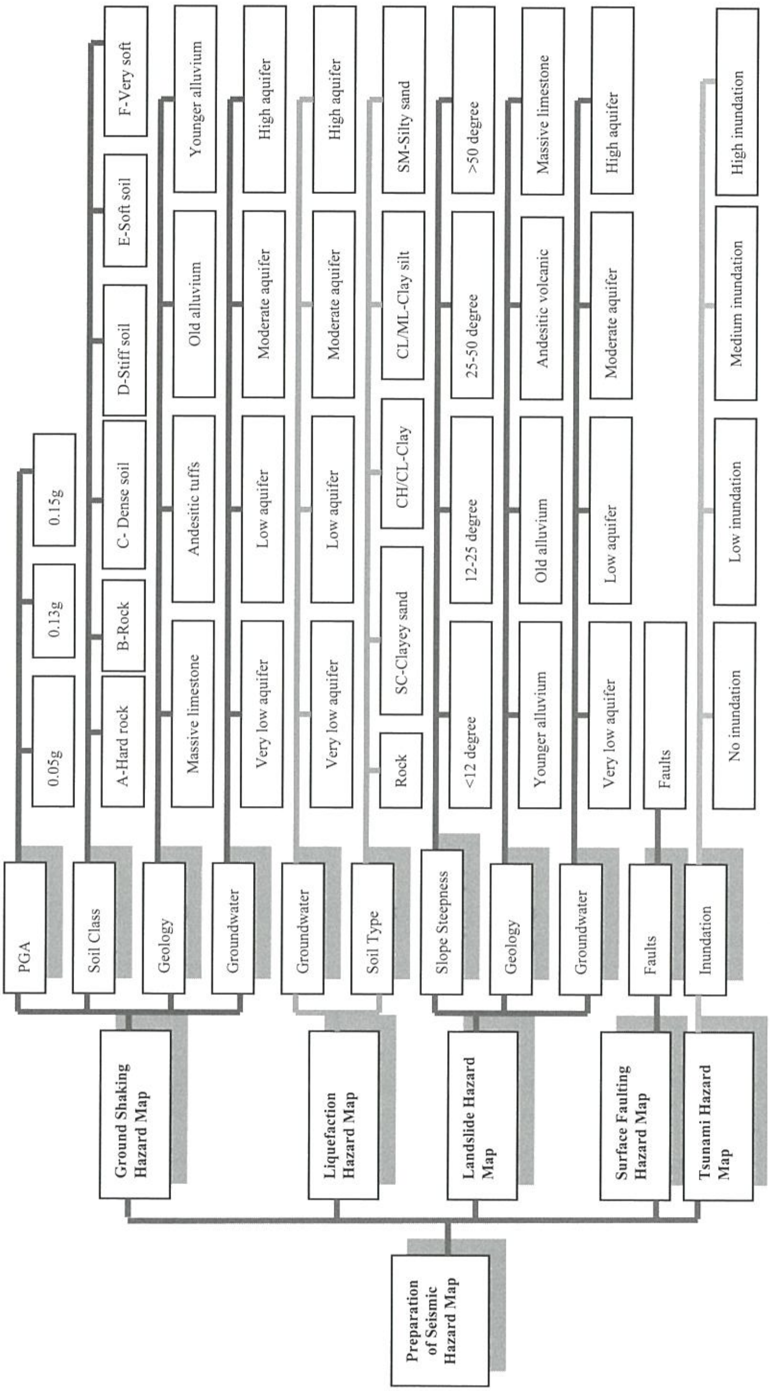

Figure 10: Seismic Hazard and its Parameters

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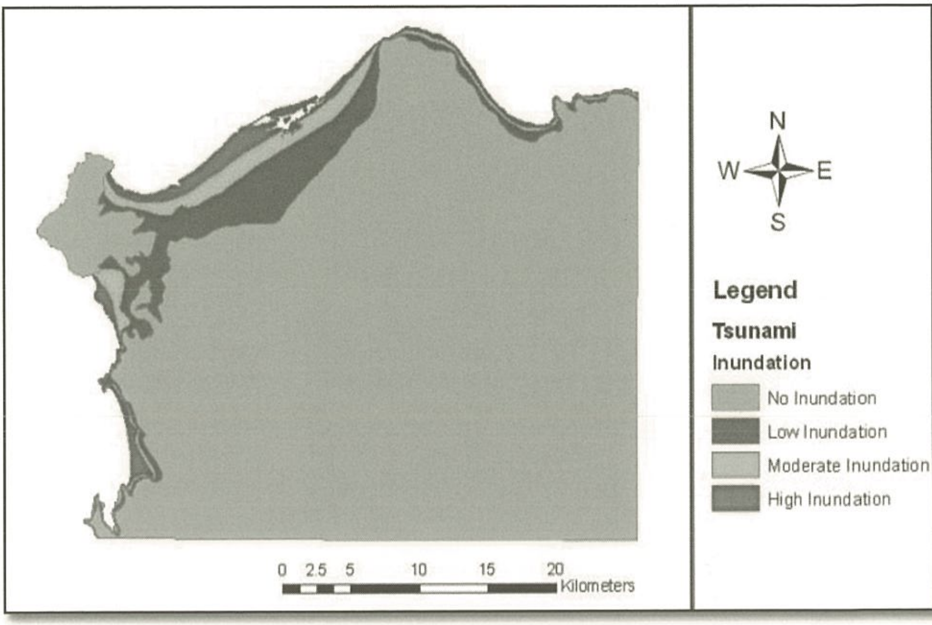

Figure 11: Tsunami Data Layer

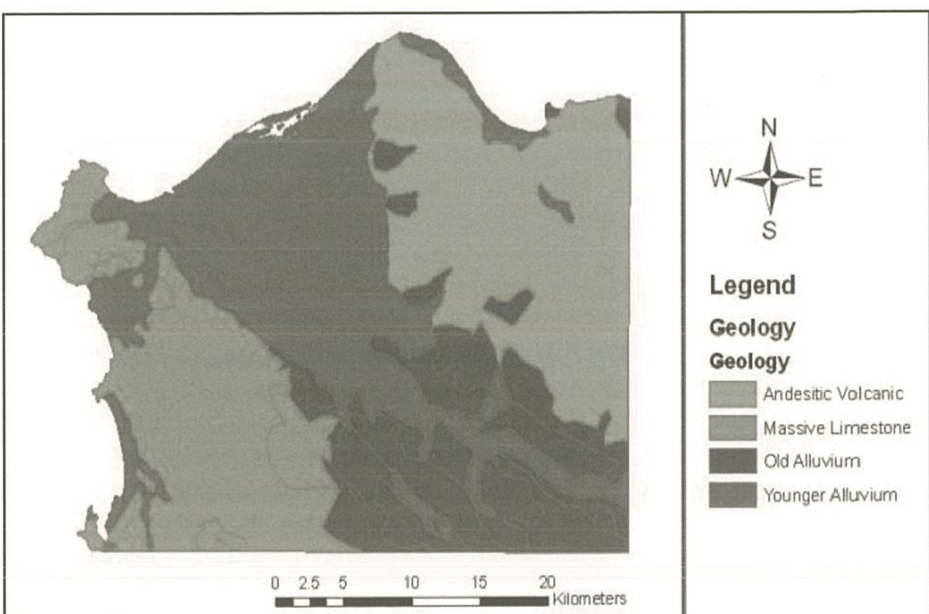

Figure 12: Geology Data Layer

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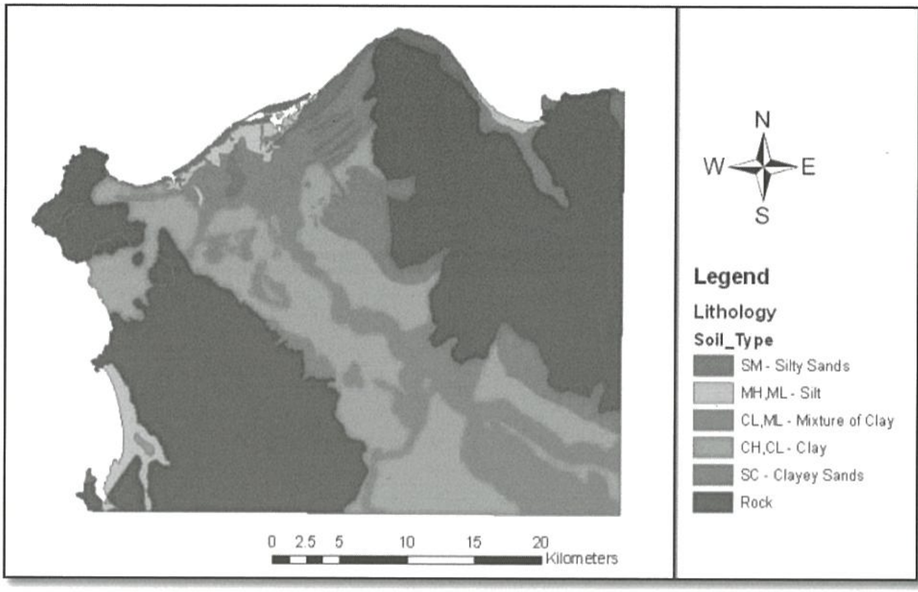

Figure 13: Soil Type Data Layer

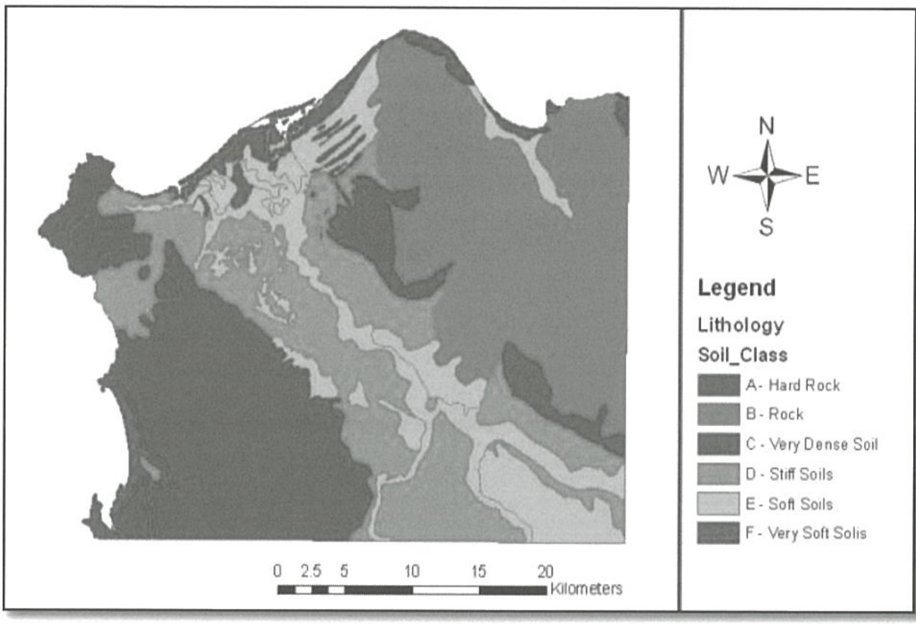

Figure 14: Soil Class Data Layer

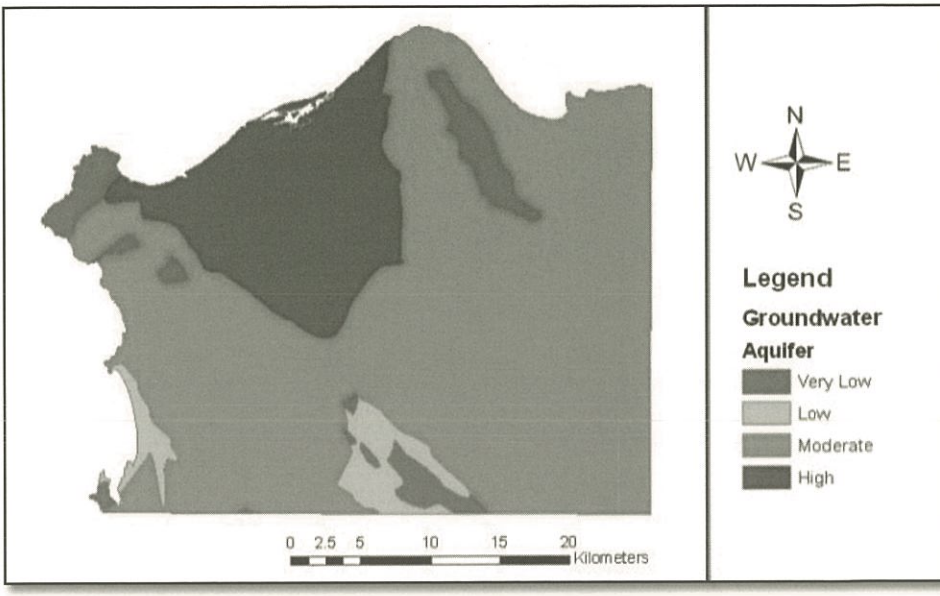

Figure 15: Groundwater data layer

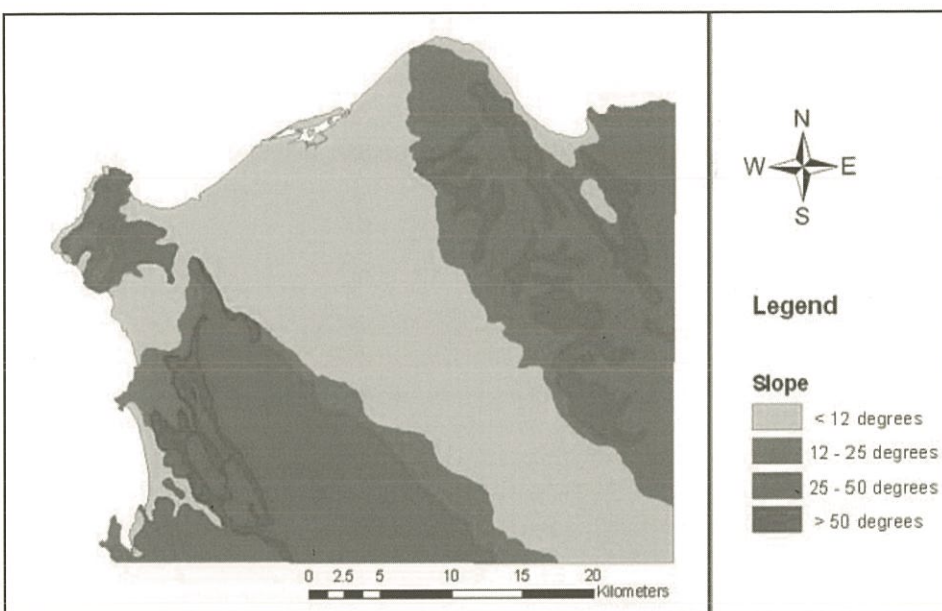

Figure 16: Slope data layer after digitized

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Table 1: Hazard Areas Generated by Various Hazards Maps

	High Hazard Area		Medium Hazard		Low Hazard	
	Hectares	%	Hectares	%	Hectares	%
Ground shaking map	6,055.58	5	30,455.52	25.76	81,737.47	69.12
Liquefaction map	2,451.82	2	8,567.05	7.25	81,737.47	90.68
Landslide hazard map	4,142.73	3.5	24,644.01	20.84	89,461.83	75.66
Surface faulting	20,710.09	17.5	-	-	97,538.48	82.50
Tsunami inundation	6,534.69	5.53	8,002.41	6.77	103,711.47	87.71

Table 1 shows the total areas in term of hazard level generated by various thematic maps. In general, relatively large proportion of areas, i.e. approximately 70% and more are classified as low hazard zone. The area around the city centre, which is located on recent alluvial plain and amounts to about 5% of the whole area, has been identified as a high hazard zone and will be most affected by ground shaking. While the valley along the river, which is on predominantly old alluvial plain is categorised as medium hazard zone and the hilly and mountain area, suggesting a dense soil or rock, is categorised as a low hazard zone. The liquefaction map on the other hand shows only 2% high hazard zone, which is the beach area that is located on silty sand with high groundwater depth; while the areas located on silt, mixture of silt and clay with high groundwater depth are categorised as medium hazard zone, and areas located on clay, clayey sand and rock as low hazard zone. The high hazard zone in terms of landslides effect is an area that lies on massive limestone with slope >50 degrees; while the medium hazard zone is also located on massive limestone and andesitic tuffs but with slope of between 25-50 degrees, and the low hazard zone is located on an older and recent alluvial plain. The surface faulting susceptibility map is created by buffering and classifying the area into two hazard zones categories); low hazard (areas >2000 meters from faults), and high hazard (areas <2000 meters around the faults). The map shows 17.5% of the area as high hazard and the other 82.5% as low hazard. The tsunami hazard map is developed based on the tsunami that occurred on 26th December 2004. The tsunami hazard map was classified into three zones: low, medium, and high hazard zones. The resulting map shows 5.53% of the area as high hazard zone or areas having tsunami inundation of more than 3 meters thus experiencing total building damage, 6.77% as medium hazard zone or areas inundated in 0 – 2 meters and having slight buildings damage while the remaining area is identified as low hazard area. The high hazard zone is located within 0 – 2.5 km inland from the coastline; while medium hazard zone is located within 1 – 5 km.

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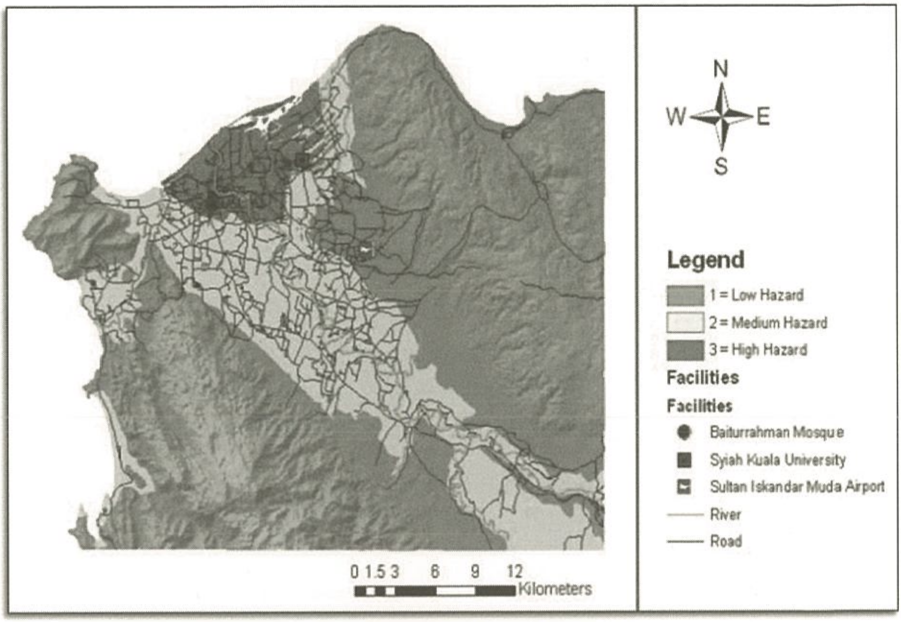

Figure 17: Ground Shaking Hazard Map

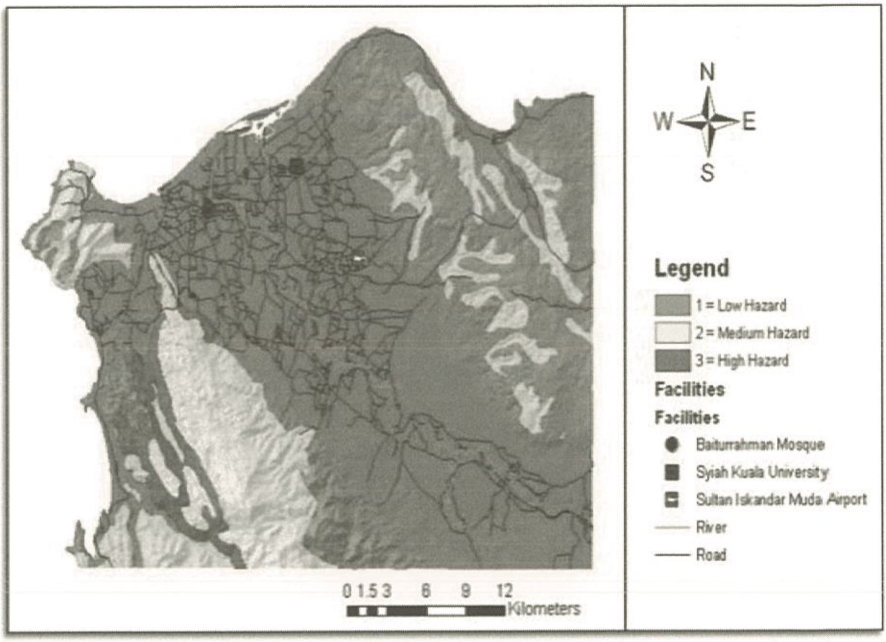

Figure 18: Landslide Hazard Map

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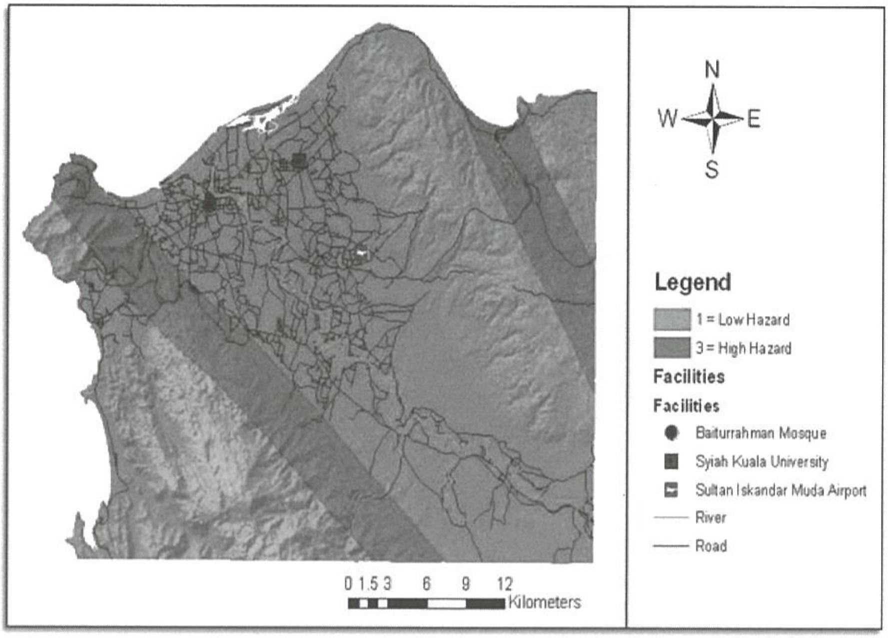

Figure 19: Surface Fault Hazard Map

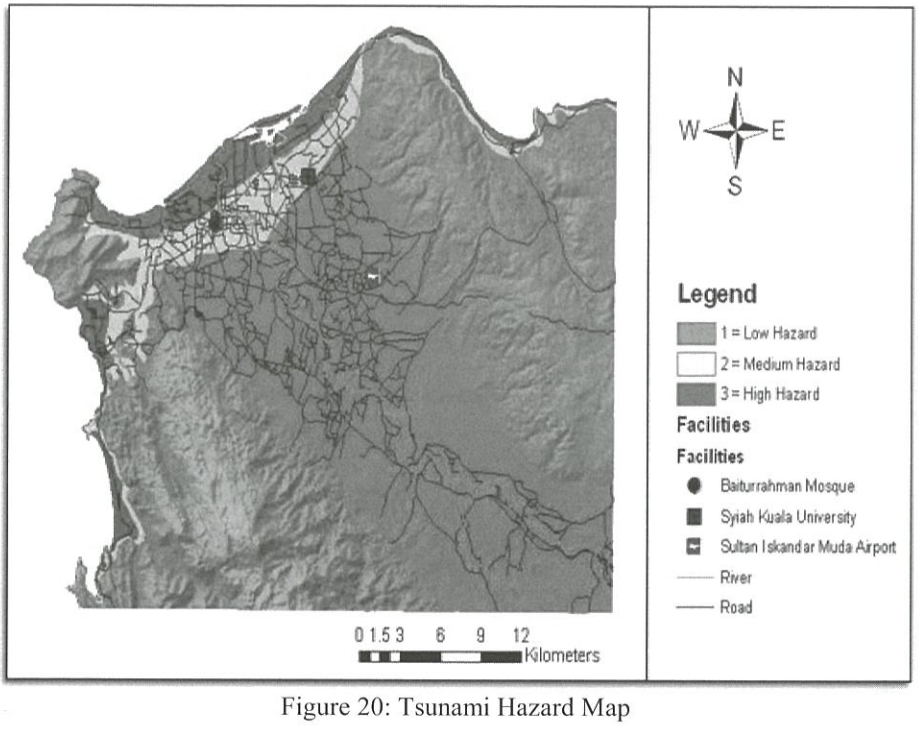

Figure 20: Tsunami Hazard Map

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The final seismic microzonation map is the composite of all the thematic maps i.e. ground shaking hazard map (Figure 17), liquefaction hazard map, landslide hazard map (Figure 18), surface faulting hazard map (Figure 19), and tsunami hazard map (Figure 20). The final map (Figure 21) identifies areas with varying hazards levels essential for land use management and city planning in order to mitigate the impact of the earthquakes. The final map shows 28.67% or 33,897.00 hectares of Banda Aceh as high hazard zone, 38.00% or 44,935.29 hectares as medium hazard and 33.33% or 39,416.28 hectares are identified as low hazard. The knowledge about possible disasters and the varying levels of hazards that might be affecting a region is invaluable for urban planners in directing future urban development to relatively safer areas thus avoiding insurmountable damages and casualties.

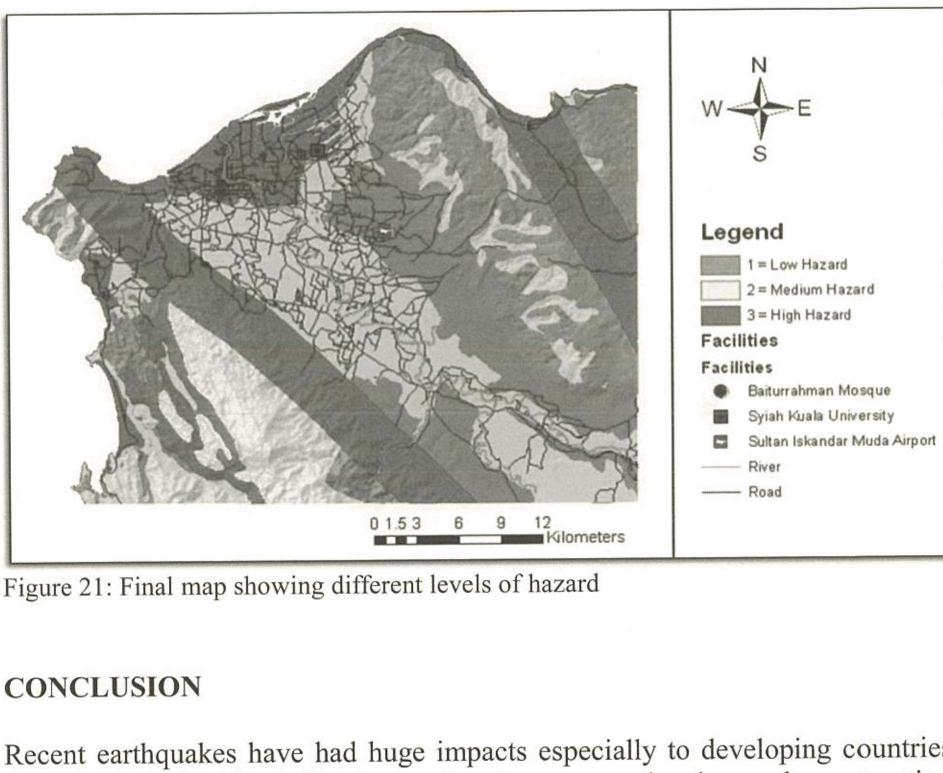

Figure 21: Final map showing different levels of hazard

CONCLUSION

Recent earthquakes have had huge impacts especially to developing countries and most of the blame has been placed on poor planning and construction practices. In disaster susceptible regions the ability to identify and avoid highly hazardous areas is pertinent to minimize casualties and damages. By using GIS, it is possible to produce a seismic microzonation map that analyses seismic risks (hazards) and thus provides assistance to urban planning. In the case study for

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Banda Aceh, a first level seismic microzonation map has been developed based on weighted parameters of seismological, geology and topographical features.

With the microzonation map it is hoped that future development will be able to avoid highly hazardous areas of related hazards and facilitating safer building codes and urban planning practices. It is a tool city planners and policy makers can use to assist in their planning decision or in taking precautionary measures prior to the construction of structures.

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PLANNING MALAYSIA
Geospatial Analysis in Urban Planning
Volume **II** (2013), Page 163 - 190

THE RELIABILITY TEST OF VISUAL LANDSCAPE FEATURES MEASUREMENT IN HIGHLANDS TOURISM PLANNING

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Abstract

Utilizing accessible data in objective measurement of visual landscape can assist planners and landscape architects to assess and understand the landscape in a technical sense. This approach requires minimal digital physical data provided by various agencies. As with this approach, the study tests the validity of objective measurement in visual landscape using the photography method for perceptual testing in 48 test scenes. The correlations between these assessments are carried out; the result of which demonstrated that the measurement used in the study for visual landscape assessment is statistically acceptable for application with significant correlation ($p<0.01$) and moderate association (0.446). In the local context this study found that village is more preferable than other built up areas. The agriculture views which are dominated in the scene are preferable than the agriculture that present in the middle ground view only. It is also found the quality of the agriculture view is influenced by the condition and manageable view, whereas the combination of forest and agriculture at the foreground and middle ground is less attractive. The study has provided more reliable objective measurement of visual landscape for highlands tourism planning.

Keywords: visual landscape assessment, visual structure analysis, urban planning, GIS application, highlands, tourism, and expert based assessment

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INTRODUCTION

Visual landscape can be assessed through expert based or perception based assessment. The quality depends on the physical landscape features or the perceptual /experiential processes that particularly based on the knowledge in the human viewer.

This approach is favoured to the local government particularly in Britain, Australia and few in United. The approach is easy to practice, consume less time and inexpensive to conduct (Lothian 2000; Daniel 2001). But, in recent years, expert based assessment has been criticized for being in adequately reliable (Daniel 2001; Lothian 2000; Daniel and Vining 1983). Unlike perception based approach, typically, the assessment is conducted based on the individual's experience, not group's experience. Hence, the reliability of individual judgement of the expert becomes important (Palmer and Hoffman 2001). Furthermore, the judgements between different experts may be varying according to different person mind and feeling (Arriazza et al. 2004). In short, the approach was questioned for its reliability particularly on subjectivity. While studies on visual landscape assessment are common, few have been carried out using scientific method and criteria of objectivity and reliability. This paper attempt to scientifically test reliability of the developed objective measurement criteria in expert based approach.

On the other hand, the design criteria of objective measurement for this assessment are fundamentally developed based on the "human aesthetic value" which means as a representative of human perception on landscape. These basic human perceptions and values offer valuable hints as to how to proceed in turning the assessment criteria into more objective measurement with scientific views and landscape in general. As they may acquaint us with, in effect the features are meaningful to the ordinary eyes. To the extent, the measurement in assessment criteria will provides more meaningful input in explaining why certain landscapes have been treasured in a technical sense. Principal and objective values in the expert based assessment derive subjective perception of what is beautiful. Conceivably, beauty is too profound to be fully understood by the scientific methods. However, it is possible to determine the physical landscape of visual and spatial characteristics as landscape constitute a particular form of beauty by its properties (Higuchi 1984).

The aim of the study is to prove the reliability of the expert based assessment on visual landscape. The assessment processes involved; a) Acquisition of accessible physical data from various agencies; b) Database development of visual structure and landscape features analyses for objective

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measurement of visual quality assessment; c) Viewpoint selection and feature landscape analyses (e.g. preparation for application in measurement criteria of physical visual landscape assessment); d) Photography methods for the perceptual testing of the visual landscape quality in the case study of Cameron highlands on the same 48 test scenes.

Highlands's tourism and planning

The resort areas, particularly in tropical Asia are located in the imposing mountain ranges and cooler latitudes, which have the high potential of outstanding sceneries with wild terrain in the hills and splendid Asian landscape (Robert 1979; Barbara 1998). These resort areas are renown not only for its beauty and distinctive character (Barbara 1998) but for its interesting history. The highlands tourism resort so called "hill station" particularly in tropical Asian countries was originated from the British colonial (Robert 1979; William 2006; Barbara 1998). These areas were built for health, relaxation and sanitary (Barbara 1998). The great hill station resort became one of the popular tourism places, which still existed in Pakistan, India, Sri Lanka, Burma, Malaysia, Indonesia, Vietnam and Philippines. These hill stations situated in the high plateau were built by someone who knew and appreciate the scenic beauty of the area where its character reflects their homeland landscape sphere. As stated by the Robert (1979), the hill station was built by a colonist who had explored into the highlands during official expeditions or informal hunting trips.

By the end of Second World War, the hill station went into decline (Barbara 1998). During the postcolonial period, the hill stations have still been regarded as favourite places for retreat for elite group as well as European and Dutch tourist (e.g. Weng 2006; Barbara 1998). At present, the highlands became more of Asian than Western history (Barbara 1998). The old hotels and villas are conserved for the tourism attraction. The natural landscape of hillside gradually converted into agriculture, and urban land uses to cater for the local communities and tourist need. Hill's station is losing its beauty, overgrown and overpopulated but still its unique character as hill station is remained (Barbara 1998).

Hill Station in Malaysia

As for Malaysia (in Peninsular Malaysia), the highlands tourism, particularly hill stations are located at Titiwangsa. These areas are the headwater catchment for main rivers and host diverse group of flora and fauna (Kumaran &Ainuddin 2006). The highlands tourism was existed since British colonialism in Malaya (Mapjabil et al. 2007). In the end of 19th century, hill stations in Malaysia

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namely Cameron highlands, Fraser Hills, and Penang Hills were built by British colonist. In the British era, the hills were built as a resort filled with botanical gardens and plantations. The development of these areas proved that planning system for the highlands was started since 1900s. As for example Cameron Highlands was planned and ruled by the British District Officer where the area is under jurisdiction and provision of Sanitarily Board Enactment. In 1926, construction of roads and zoning system namely agriculture reserve, town centre zone, residential area, services centre, National Park, administrative area and recreation area were introduced by Development Committee.

These areas have been slowly losing its beauty and image as proved by Aziz & Zainol (2009) that highlands tourism destination had low perception toward its image. As scenic scenery is one of the important factors to attract tourist (Aziz & Zainol 2009), visual landscape assessment in managing its beauty is significant in the tourism area (Zube et al. 1975). As for Malaysia, the challenges for the management of these areas are influenced by its character (remote and isolated area) (Aziz & Zainol 2009). These remote areas are very sensitive environmentally that need special development attention. The steepness of the terrain, the uniqueness of its micro climate, and the sensitivity of rare wildlife causes the areas are sensitive to change (Weng 2006). Without careful planning and management on the highlands area, the scenic landscape which is valuable for the tourism wills also loss its aesthetic value (Weng 2006).

STUDY AREA

The study area also known as Cameron Highlands (CH) is located in the state of Pahang West Malaysia and is the smallest district in the state (Figure 1). It is 100 to 2031 meters above sea level and forms part of Titiwangsa Mountain Range. CH is well known for its diverse scenic landscape and one of the oldest and largest hill resorts in Malaysia (Mariapan et al. 2008). It has a complex terrain and mountainous landscape.

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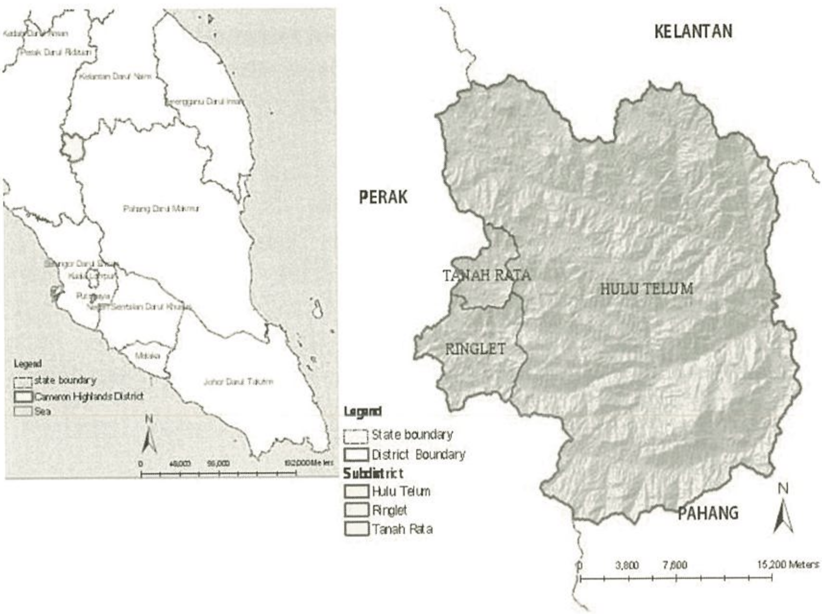

Figure 1: Study Area

To the North of CH is the State of Kelantan and to the southeast, the State of Perak. CH covers an area of 72,218 hectares representing 2% of Pahang State. It is accessible from the North-South Highway and Federal Highway II through Tapah ,Simpang Pulai road to Lojing and the Lembah Bertam to Kuala Lipis.

SITE SELECTION

There are several reasons to choose Cameron Highlands as a study site. One of them is that the district renowned for its natural setting and spectacular views. The Highlands tourism area, like other countries in the world, has a prominent fascinating panoramic view with outstanding land surface shapes. Alike to CH, the main distinguished factor for its scenic beauty is the spectacular topographical profiles and cooling climate in the tropical country. The uniqueness of CH is also because of its history portrayed by the unique cultural landscape. This beauty of CH indeed was discovered and recorded since 1885 by the British surveyor in the colonial period. William Cameron and his companion, Kulup Riau in his mapping expedition of Titiwangsa Range described CH as "a vortex of mountains" with beautiful wide area of gentle

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slopes and plateau land of an elevation 4,400ft to 5,500ft. In Malaysia, the area is popularly known as the "green bowl" and cool hill station of a small slice of England deep in the jungle. Its beautiful landscape, fertile mountain slopes for planting and cool climates makes the area a unique tourism spot in Malaysia.

However, over the past two decades the rate of development has been uncontrolled. Buang (2001) affirmed that the CH is 'slowly dying and imperceptibly through the years'. While it has benefited the local economy, poor planning and enforcement have led to repulsive environmental degradation (Vijendra 2006).The environmental degradation has influenced the landscape and visual quality of the study area whereas the visual landscape or scenic quality is encountered as a major component, particularly in the tourism or recreational area (Zube et al. 1982; Brown & Daniel 1984).

The result has a strong correlation to the poor planning and lack of serious consideration on landscape and visual quality assessment in the strategic planning and decision making. This problem is a response to the lack of expertise and the tedious work with high cost to undertake. The urban and landscape planning management of the Cameron Highland District Municipal (CHDM) jurisdiction region is under a Department of Development and Landscape Planning. The department has no more than one expert personnel; planner officer and assistant planner to take control of the entire planning and landscape management in the district. The officer is responsible for planning control and landscape planning of the area and act as a development advisor to the developer and to the top management; decision maker.

The main existing consideration and reference for development advice used statutory and non-statutory plans/documents. The statutory plan is a gazetted local plan under a provision of Town and Country Planning Act, 1976 (A172 amendment 2001). The provision under the Act A721 stated the consideration of landscape in the planning control. The consideration that has been taken in the local plan described the need of Environmental Impact Assessment (EIA) report in the sensitive area and the prohibition of tree cutting. The detail assessment on the landscape is included in the non-statutory plan. The non-statutory documents are including guidelines on highland development and Landscape Master Plan for the CH district. The guidelines, consideration and the assessment are available, yet no detail deliberations that emphasize the potentiality of the area for scenic qualities.

The traditional visual landscape quality assessment needs a comprehensive set process with tedious works. Excessive workloads, high cost and impracticable evaluation for the planner to comprehend and interpret the result for the management and decision making process are not a wise approach to be practiced. The assessment needs to be practical, simple to understand by the planner and be able to be translated into management and development control. Since the consideration is already existed, the study area shows a great need for proper planning, opportunity and room for improvement.

The main core activities of CH are forestry, agriculture and tourism. These economic activities only generate small annual revenue for the municipality. It is common practice in Malaysia that the major of Local Authority's (LA) revenue comes from development and commercial building taxes. With small revenue and small number of expertise to manage the jurisdiction area has made the assessment unfeasible. Therefore, the landscape qualities keep on degrading and land use keeps changing. There is an urgent need for an action. Waiting for a right time with a perfect and tedious work requirement is simply not a better solution.

The scenic beauty consideration is needed as CH district's landscape is experiencing huge change in the land use (Mariapan et al. 2008; Kumaran & Ainuddin 2004). The key to this problem is to utilize the existing resources. With this regard, the physical landscape study in the visual assessment will improve through more comprehensive area selection and desk study using available data provided by local government.

DATA ACQUISITION AND DATABASE DEVELOPMENT

Data Acquisition

The primary data consists of site survey and field work in the case study area. For the research, the data collection involves:

a) Interview officers from relevant agencies on the geospatial data development, availability and accessibility;
b) Field work study using photography method to collect the landscape scene in the chosen point along the existing road. The points were depicted from the road map with geo reference based acquired from the Pahang State Public Department and;
c) The respondent assessment on the photo landscape scene using assessment sheet on scoring scales.

The main secondary data acquired from the various agencies. The easily accessible data that can be utilized in the assessment area is mainly from the site

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planning data from the Town and Country Planning Department and supported by other technical departments. The relevant easily accessible data for landscape assessment of the case study (Cameron Highlands) are land use map; road map; historical data point; mountain data point; landform types and slope analysis data; river map; tourism attraction points map, and town centre point map, all with common scale of1:6336 and topographical data map with scale of 1:50,000.

Other data including written report and plan have been collected from planning and various technical departments in the different levels (Federal, State and Local) such as Malaysia Plans, National Physical Plan 2002, Pahang State Structure Plan, Cameron Highlands District Local Plan 2005-2015, Technical Report of Cameron Highlands Local Plan 2005-2015 and Technical Report of Cameron Highlands Landscape Master Plan 2007. The details report for the case study is significantly used to support objective visual landscape assessment in the research.

The database for visual landscape assessment was designed and developed to support visual structure and landscape features analyses in objective measurement. In the study, there are two types of data namely topographic data and landscape features data within the database. It is developed based on the conceptualized GIS to application of visual landscape for case study area. The gathered data is stored in its primary form, where analysis can be readily prepared for more quantitative and rational based on its need.

METHOD

Viewpoints Selection in GIS Application

The selected observation point and input surface (e.g., DEM; TIN data) are used as a baseline in measuring visual landscape quality. The viewpoints were selected along the landscape corridor (existing main road). The selection was done using the digital road lines map and attraction points. The selected viewpoints deployed in between 1 km in distance. The further selection of 48 test scenes was made based on the viewpoints and direction views. These views were then applied on the ground using photography method.

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Fieldwork-photography Method

The photography method used for the validity test in perceptual test as the method valid and acceptable in landscape assessment from established literature (e.g., Torres et al. 2007; Hull & Stewart 1992). The photographs are taken with a height of 1.5m in the selected view point along the existing road. The determination of the point is based on the objective assessment score result that includes from high to low visual quality. The photograph by slide method of analysis was employed in the 48 scenes. Slides were presented to the small group of respondents who have no background in the related landscape and design knowledge. The respondents participate voluntarily in the assessment. Instructions were given to the respondents (N=44) that referred to the individual perception on the scenes with a judgement on the attractiveness and uniqueness. The respondents were given a brief orientation to the region. No discussion or explanation of important landscape features influences the assessment was presented. The respondents were required to rate scenic beauty of the selected landscape scenes on 5-point scales to facilitate respondents in giving a definite judgement on rating. The adopted Likert scale applied in the research was outlined as 1 is not attractive; 2 is less attractive; 3 is medium attractive; 4 is attractive and; 5 is very attractive. The 10 point scales applied in the physical landscape features for expert assessment is unsuitable to be adopted in this preference study as it creates indistinguishable rating judgement to the respondents. The photo scene slides shows were presented one at a time for approximately 10 to 15 seconds per slide.

Physical Landscape Features Assessment

Visual structure of landscape analysis in measuring the visual landscape involves distance zones, *Viewshed* analysis, visibility, angle of elevation, and angle of depression. As for the distance zones, the study accepted view is divided into three distances namely foreground (short distance view), middle ground (middle distance view) and background (long distance view) (e.g., Zube et al. 1984; Litton 1972; Craik 1972; Appleton 1975; Higuchi 1984). For the case study, the tropical rain forest tree top height is considered as dominant and common tree. An intermediate zone (*canopy*) of continuous foliage is 9 to 18 meters (30 to 60ft) (Federal Department of Forestry 2008; Kumaran & Ainuddin 2004). As for the GIS application, the distance analysis is conducted using the proximity analysis (multiple ring buffers). The three distance zones are set using buffer distance value determined from the viewpoint as input features. The *Viewshed* analysis in the study determines which space is visible to an observation point. The first step for the calculation of visibility analysis is

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through the use of the 3D analysts for *Viewshed* analysis tools. The selected observation viewpoints and input surface (TIN data) are used as a base line for this analysis with an appropriate output raster based 10m- square to 30m-square for local context. Meanwhile, the derivation of the angle of elevation, angle of depression is based on the GIS application.

The result of the *Viewshed* analysis using GIS 3D analyst is in raster format. Then, the data was converted into vector format data. This data was overlaid with a GIS proximity analysis result to understand the distance dimension in visual landscape. Afterwards, line of sight analysis will be used for calculation of angle of elevation and angle of depression.

The angle of elevation for visual landscape analysis is applied to understand the aesthetic value of mountainous landscapes (Figure 2). The appreciation this landscape is based on the decisive degrees of angle of elevation. Himeno et al. (1999) affirmed the effect of distance from the observer to the landscape elements can create massive, inviting or feeble impression. Higuchi (1984) introduced the range of angle of elevation is suitable for mountainous landscape viewing that give positive impact to visual quality.

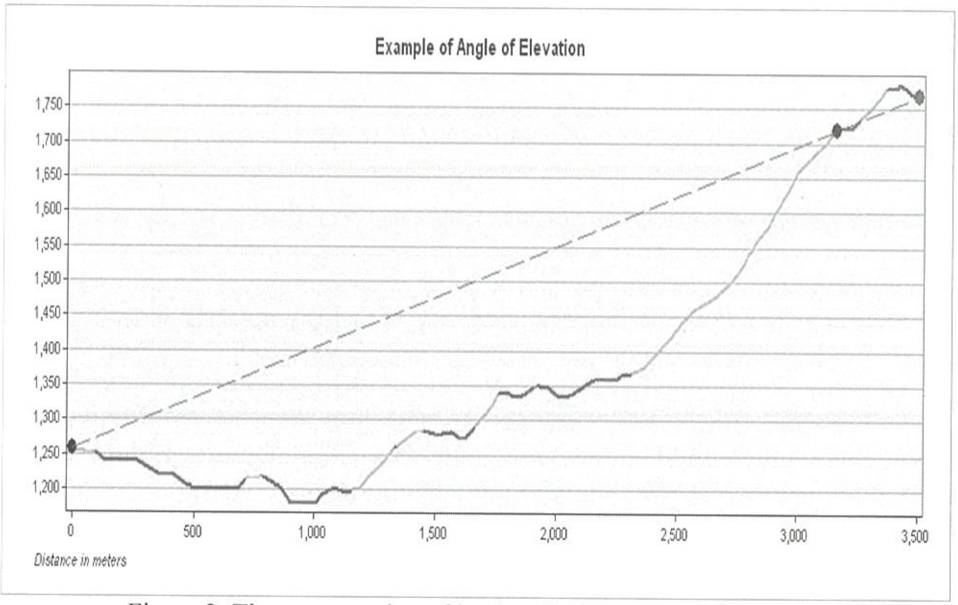

Figure 2: The cross-section of land surface for angle of elevation

Meanwhile, as for this study, the angle of depression is appropriately applied for water elements (lake or dam) and deep valley near to the observer (Figure 3). The limit of angle of depression is when the point of incidence approaches the eye with 30 degrees (Higuchi 1984). The important use of angle of depression is to determine the distance feeling and openness. The appropriate use of this analysis is identified through the landscape types (i.e., mountainous landscapes and waters capes) and its concavity. The observer height set in this study is 1.5 meters. The baseline data for the line of sight analysis is 30m TIN data (naked earth) without considering small features that may impede views.

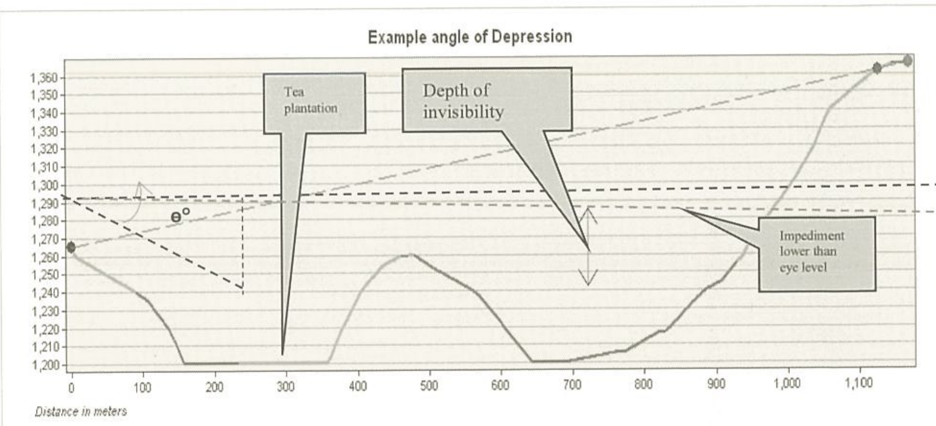

Figure 3: The cross-section of land surface for angle of depression

The analysis and measurement method in the study with regard to expert based approach and input from established perception based approach is on the landscape elements in the visual assessment. Few modifications are made to suit different available data and characteristic of the study area. The fundamental used in the study involves a combination of visual structure of landscape and the visibility of landscape features in the scène.

The criteria are derived from the consideration of landscapes (vegetation), presence or absence of water, topography and the sign of a human being. Principle of physical landscape structure was used in the study to develop more explicit and objective measurement criteria. The criteria were divided into seven elements with 4 given rating categories namely high, medium high, medium and low. The calculation of rating has taken consideration on the direction view and visibility in the viewpoints. The foundation elements used in the evaluation is almost the same as to the photograph assessment. The Likert's scale is used to give the rating score to each of the landscape elements in the measurement criteria table. The scale is given from 1 to 10 divided by four

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categories. Six elements except scarcity are summed and calculated to get an average score. The scarcity value is suggested to be isolated from the calculation and used for record and reference only.

Justification on Topography and Landform

Lothian (2001) has classified the landform types in the study area by the scene in the photograph. As for this study, the digital data of the landform types (vector format data) and TINs data model (from digital contour lines data) are used to derive landform classification analysis as well as the landscape compositional types (concavity). The topography character is identified through elevation profile, DEM data and line sight analysis. The elevation in the study area is from 0 m to 2100 meters. From the case study, there are six types of landform exist in the study area namely valley, ridges, saddles, mountain, hill and summit. Through the line sight analysis, the shape of the landform can be identified including u shape, concave, convex and variety through their prominently visible shapes. The rating criteria are classified throughout topography profile wherein it is becoming more interesting as it gets steeper or more massive, or more severely or universally sculptured. Other important criteria in topography are mountainous background with consideration on the angle of elevation.

Justification on Vegetation

Vegetation is classified as described in the land use data types. The man made elements is categorized as urban uses. The primary consideration in rating criteria for vegetation is natural settings, tea plantation area as well as other agriculture or the combination of them that create variety of form, pattern and textures. The existence of vegetation/land use diversity also has a close relationship distance views which gives a significant quality as well as landform, topography profile (angle of elevation and depression).

Water Element

The selected river line's data in the analysis is based on the main river lines. The presence of lake/water body in the land use data set is also being taken into consideration in the assessment. The judgement of the water's presence includes the degree of water dominates the scene. It is identified through the shape (winding or straight line) (Appleton 1975), distance perception views (Appleton 1975) and the sum of appearance (Herzog 2003; Appleton 1975).

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The angle of depression gives a visual relationship between the surfaces of the water body. The relationship is strong when the angle is 10 degrees or more and loses its clarity when it reaches 2 degrees (Higuchi 1984). However, an angle of depression in 30 degrees makes the surface appears to be near and give a sense of unease for fear of falling (Higuchi 1984).

Positive Element

The positive element is recognized by land use description and reference to the local plan report. The rating consideration is on the importance's level and distance views. The consideration will indicate to which positive elements dominate the scene or not.

Consideration of uniqueness based on the presence of positive element, distance zones and landscape environment settings. The assessment on scarcity is to give a written justification of the scenic features that is rare or unique in the study area. The rating is classified by the degree of rarity and the opportunity for viewing in the study area.

The important value of landscape elements for cultural and historical features is solely depending on the local character of the area. These elements can be identified through the input from relevant reports and plans. Noteworthy scenic scenery that has been stressed out in the Cameron Highlands District Local Plan and the Technical Report of the Landscape master plan 2007 case studies of Cameron's highlands is identified as below:

a) forest landscape has a high value in the region as most of the area gazetted for the reserved forest and has a historical value;
b) Agriculture land in the study area has special influence to the scenery, particularly in the valley area;
c) The most famous and outstanding view is tea plantation area in this region characterized by the upper ranges and valley area;
d) The notable special character of social value in the aboriginal settlement in which has a close relationship with the nature; other historical and cultural buildings that are significant to the case study area as stated in the Local Plan.
e) The aesthetical value of aboriginal settlements and tea plantation area in the visual quality for tourism also has been stated by Clifton (2006) and Fui et al. (2006).

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Negative Element

The rating for the negative elements takes consideration on the distance perception views and the degree of the element dominates the scene. The element is identified by using land use data set and description of land use types. The element that gives visual shocking and intrusion to the scene such as dumping area, substation is categorized as a negative element.

EXAMPLE OF TECHNICAL SENSE UNDERSTANDING

The analysis is able to identify the potential of horizontal plane view from visual corridor such lake and flat plain. From the analysis, 1 point was plotted near to the Habu Lake. This point was at the Lake House.

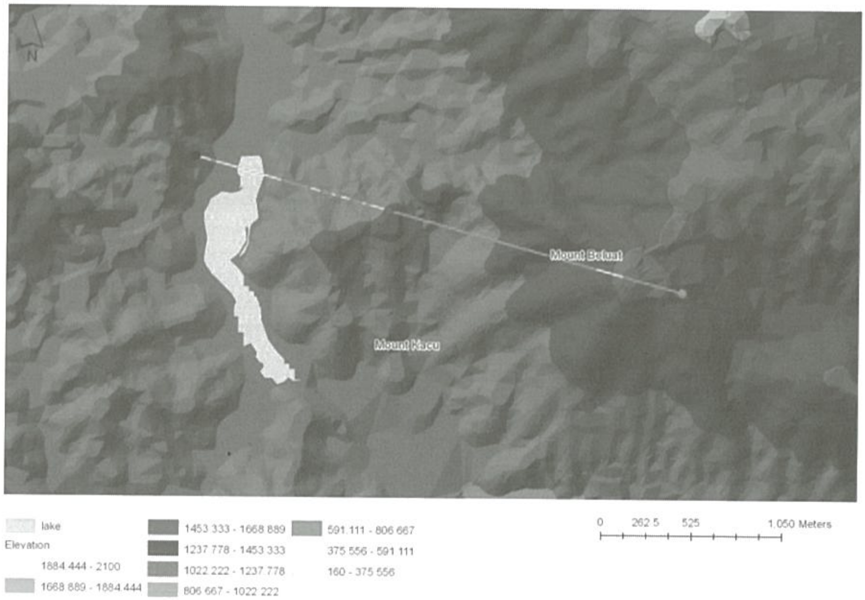

Figure 4(a): Line of sight analysis from Lake House to Lake Habu using ArcMap

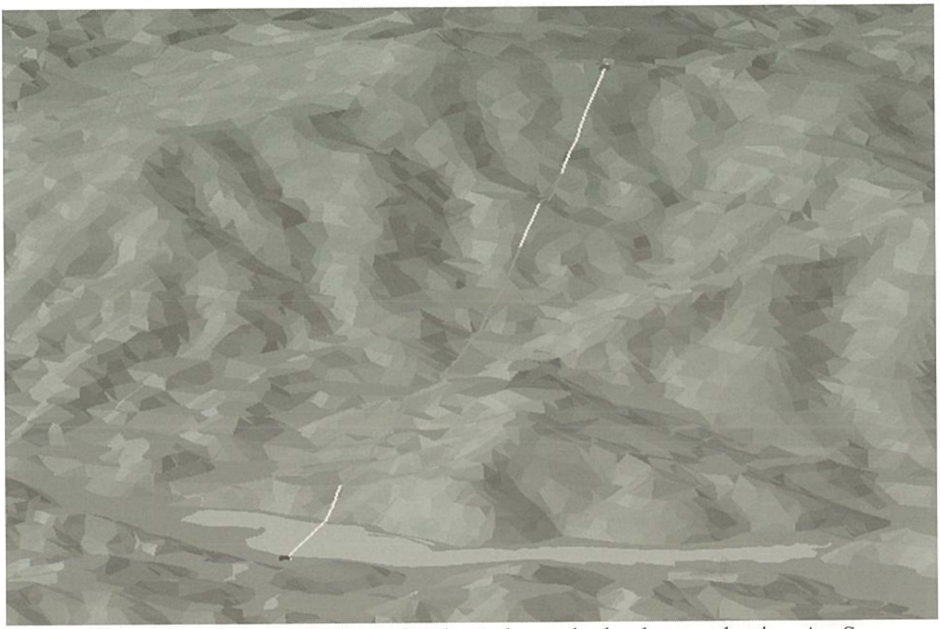

Figure 4(b): 3-dimensional view of Habu Lake to the background using ArcScene.

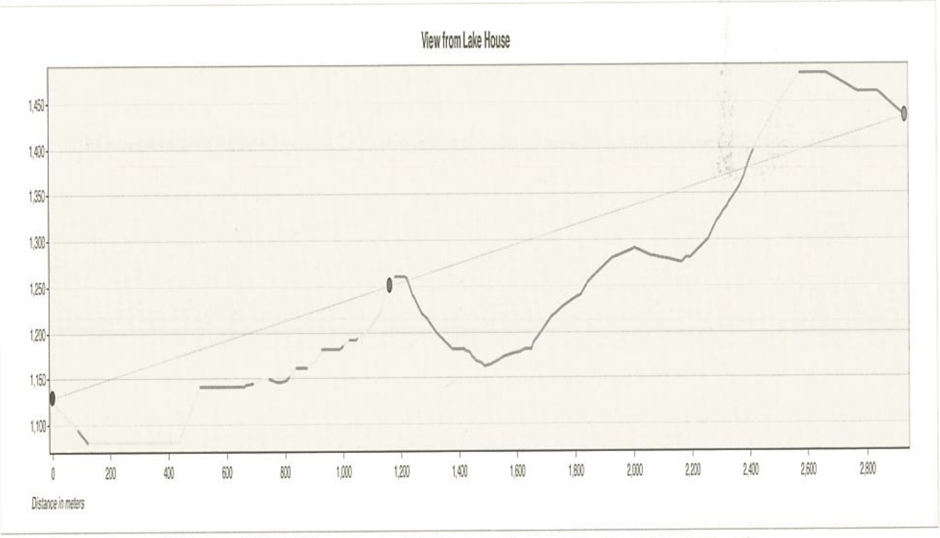

Figure 4(c): Topographical profiles of Lake House's view

We select one of the points situated at Lake House which confronting Lake Habu Lake. As refer to the Figure 4(a) to 4(c), the analysis shows the angle of depression of the point is about 21 degrees with 200 meters distance from the lake. The result demonstrates Lake House present a wide angle of

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incidence enough to the viewer. The large angle of depression with the eye level being raised to 30 meters height will give a feeling of openness to the viewer. The background view of the lake is mountainous landscape with angle elevation of 6.5 degrees which is pleasing for viewing (Higuchi 1984). It is showed the existing Tudor style resort of Lake House was built properly by someone who understood how impressive the lake and overlapping forested mountain view of Mount Kacu would look on the hill station with large angle of incidence.

The analysis of the horizontal surface explicitly showed the useful information that can be documented for the purpose of field works and planning. The detail analysis of physical features using the accessible data not only can be documented but also capable in explaining the characteristic of landscape structure.

VALIDITY TEST: PERCEPTUAL TESTING

The study describes the distribution and correlation between the preference study analysis and the physical features based assessment. The calculation for correlation makes uses the Pearson's correlation coefficient. 48 scene slides were used in the study. The same evaluation based on the expert measurement criteria in the assessment is applied using the scenes of the preference study obtained from the viewpoints and direction of view. The goal was to test the validity of the propose assessment. It was determined if the landscape features' assessment, could produce the similar result to the public preference for visual landscape quality assessment in the case study of Cameron Highlands.

The 48 direction views were subjected to an expert assessment using objective measurement criteria supported by physical landscape feature analysis. The Likert scale was applied in the assessment to assign the rating value from 1 to 10. Meanwhile, for the perceptual testing, the same scenes were presented to the group of students from Universiti Teknologi Malaysia. A by-slide method (Brown & Daniel 1984; Clay & Smidt 2004) was employed in the testing. The given scale is from 1 to 5, with the lowest value (1) indicates not attractive to the highest value (5) indicates the most attractive. The range of rating scale for perceptual testing is smaller than physical assessment scale. The reason is to ensure the observer have easy and explicit judgement on the rating scores. The examples of highest rate visual landscape are shown in Figure 5, while the lowest rates are shown in Figure 6.

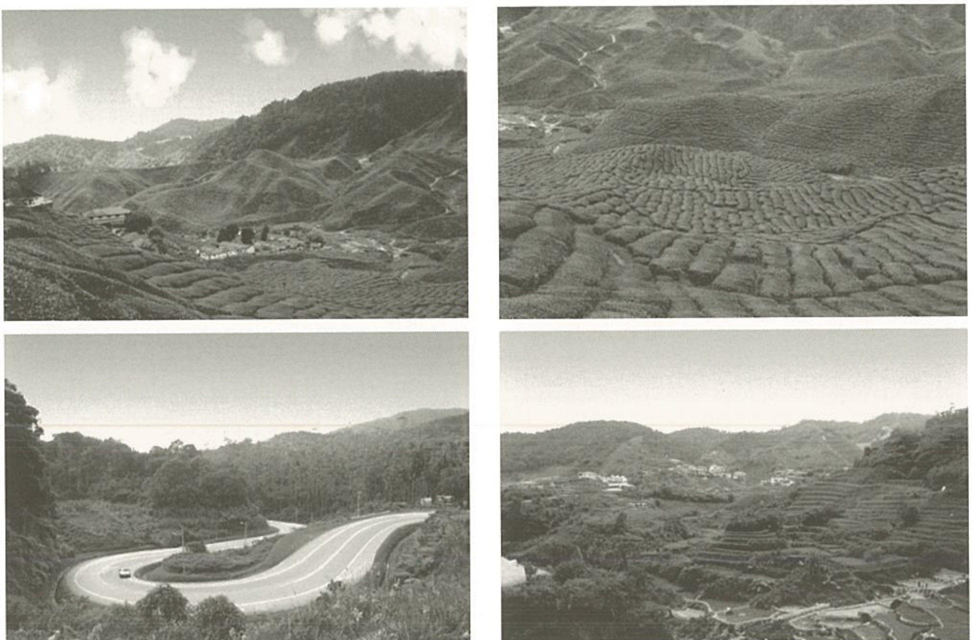

Figure 5: Examples of the Highest Rated Slide of Visual Landscape Quality

The successive interval method is applied in the analysis. It is used to obtain interval measures from ordered category data (Bliskche et al. 1975). The calculation involves the computation of frequency, proportions, cumulative proportions, conversion, standard normal deviates (z scores), density function of probability, scale value and interval data value. The calculation is computed using excel software. The tabular data is keyed in into SPSS statistical software that includes mean score and standard deviation. The percentage of distribution of preference score will address key indicators for the improvement of the measurement criteria development developed for the visual landscape assessment.

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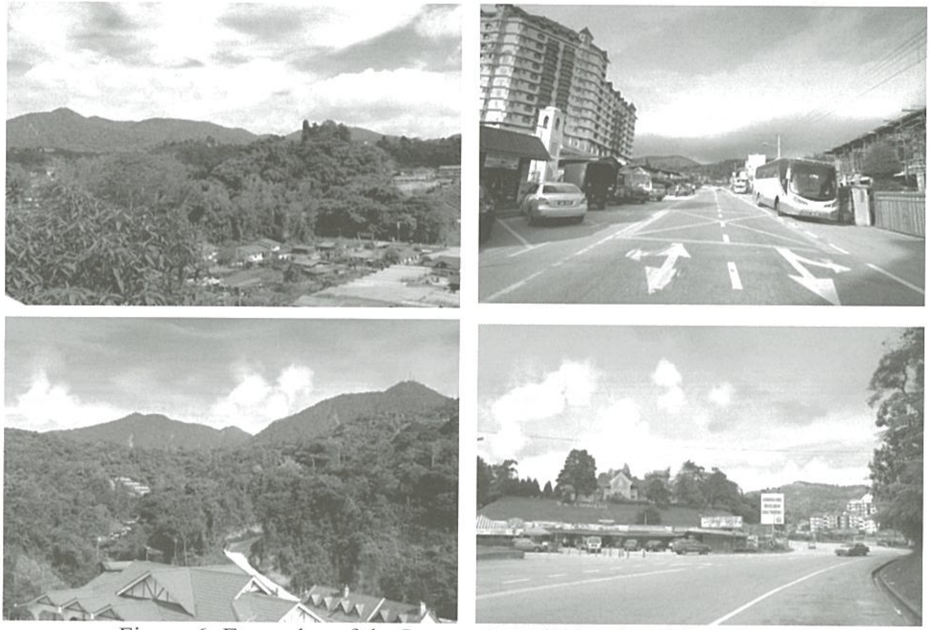

Figure 6: Examples of the Lowest Rated Visual Landscape Quality

The association of objective measurement criteria score's result and preference study (photography method) is analysed to verify the relative consistency of value to the same scenes. The correlation's analysis is prepared in the SPSS statistical package to prove the reliability of the physical assessment through association correlation and Pearson significant result. The comparison analysis will demonstrate an association of given criteria to surrogate the photography methods to record the preliminary assessment data before field work study.

RESULTS AND DISCUSSIONS

Correlations

The relationship of the physical assessment and perceptual response to the scene was conducted. The study describes the correlation between the preference study analysis and the physical assessment score. The calculation of correlation used the Pearson correlation coefficient.

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Table 1: Correlations of Perceptual test and Physical Based Assessment

Landscape features	Pearson Correlations	Sig
Preference & Physical	.443**	.000
Rating & Uniqueness	.610**	.000

An examination of correlations between the physical assessment and perceptual test of scenic beauty shows a moderate association between rating and physical features. The correlations proved to be significant (p=.000 with significant at 0.01 levels) as shown in Table 1. This showed that the physical assessment in this study is sufficiently acceptable to give planners or landscape architects reasoned and objective judgements to visual landscape quality. It is identified also that the attractiveness has a strong association with uniqueness of the scene. This suggests that as the score of attractiveness is increases, correspondingly people will give a high score to uniqueness of the scene.

Table 2: Correlations of Physical features

Landscape features	Pearson Correlations	Sig
Topography	.527**	.000
Landform	.572**	.000
Vegetation	.297*	.020
Positive element	.733*	.027
Water element	.919	.159

*. Correlation is significant at the 0.05 level
**.Correlation is significant at the 0.01 level

Further examination was conducted using correlation analysis between perceptual response to the scenes and landscape features/attributes rating score from the physical assessment.

The result of correlations and associated *P*- values are presented in Table 2. The strongest association is the water element (0.919) follows by positive element (0.733), landform (0.572), and topography (0.527). The lowest associations are vegetation (0.297). However, it is significantly correlated with $P=0.02$ at 0.05 level of confident. It is also found that all the features have significant correlation except for water element and positive element.

Perceptual Tests

The study also demonstrates a limitation through the perceptual testing of same scenes. Even though the measurement approach proved to be reliable, yet some issues should be addressed. Firstly, the physical assessment could not show the detailed present of the visual quality conditions of the area. Secondly, the

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judgement on the vegetation cover should be done thoroughly as the correlation between these features is weak (0.27). The respondents showed a different pattern of attractiveness of scenes by various vegetation covers. The natural setting proved to be a favourable scene to the respondents. However, the combination of forest and agriculture in the scene was seen as less attractive in comparison to the agriculture scene only. Additionally, the village setting received a higher score as compared to the residential area follows by the urban land uses.

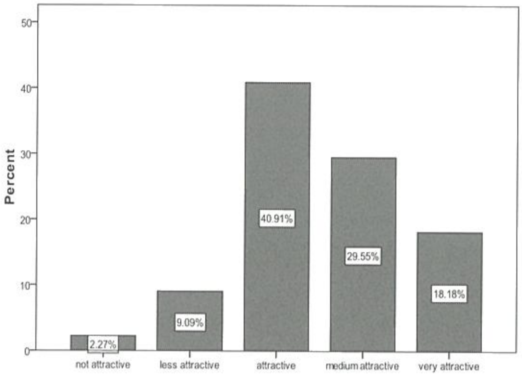

Figure 7: The Distribution of Perception Analysis and Test Scene at Lake House, Cameron Highlands (Mean 3.52)

Figure 7 shows that the score mostly falls in rating value 3- attractive scene (40.9%). Meanwhile, about 29% of respondents agreed the scene is medium attractive follows by very attractive (18.2%). From the distribution analysis, it is also found that respondents feel the scene is not attractive (2.3%) and less attractive (9.1%). However, based on the physical assessment, the scores lie on the highest quality rank (7.8). This suggests the dominance of water presence in the scene is strongly giving positive influences to the scenic beauty value. Nevertheless, people tend to reduce its value, control by the condition and quality of water (colour).The water perception value is strongly depending on the current quality condition of the water.

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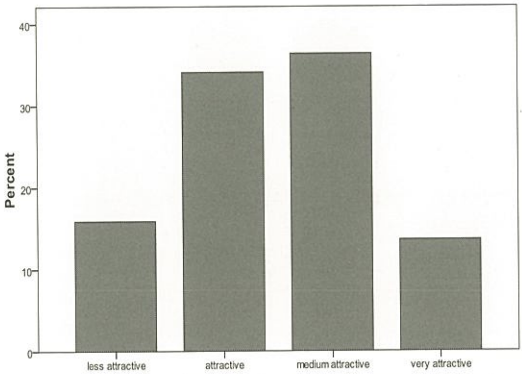

Figure 8: Distribution of Perceptual Test and Scene at Point 20 (Mean=3.48)

Figure 8 shows the scene with the presence of the water elements. The element majorly presents in the foreground with moderate dominancy in the scene. The water condition (colour) is average. From the distribution graph of perception analysis, most of the respondent agreed that the score is *4*-medium attractive (36.4%). This follows by attractive rating (34.1%), less attractive (15.9%) and very attractive (13.6%). The analysis also approved that water condition influences the score rating. The average water condition in the scene may influences the score lies to medium attractive score rather than attractive. However, the analysis shows the large number of less attractive (15.9%) as compared to the scene at Lake House. This suggests that the dominance of water presence as described in the measurement criteria of physical assessment tends to affect the score value. The physical evaluation indicates the scene has a moderate score in topography (6), landform (6) and vegetation types (6.7). These feature considerations affect scene's score value.

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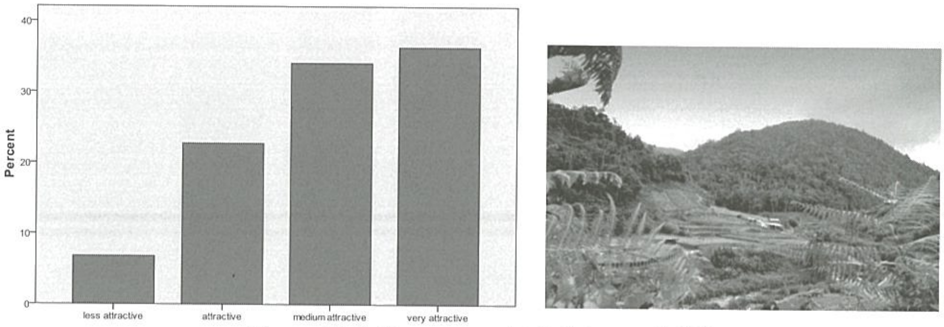

Figure 9(a): Scene at point 9 (Mean = 2.95)

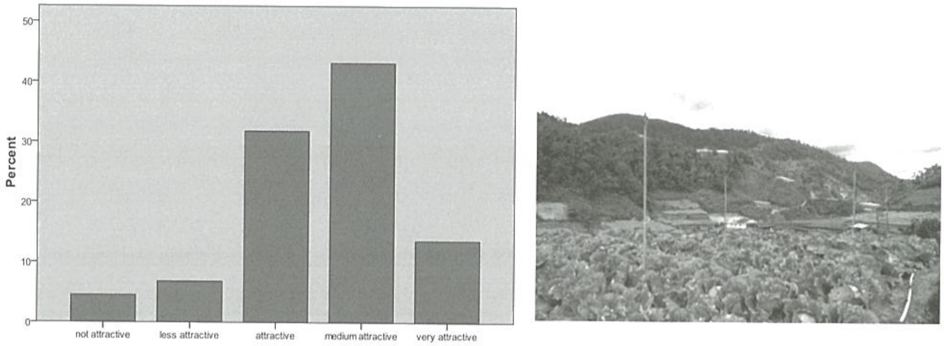

Figure 9(b): Scene at point 28 (Mean= 4.00)

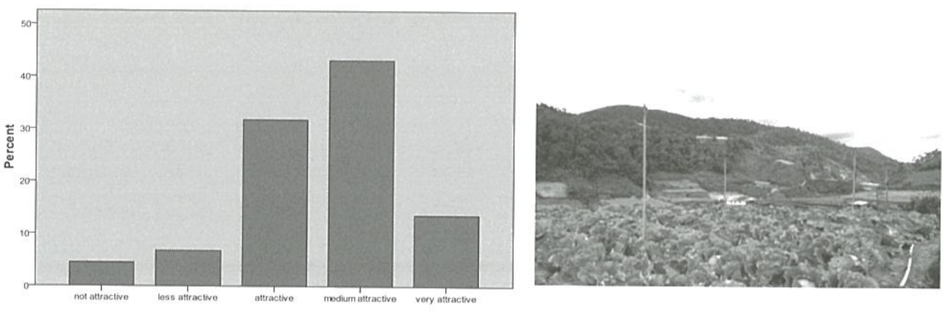

Figure 9(c): Scene at point 18 (Mean 3.55)

As for vegetation, we generate the distribution graph of responses to the scene. The three scenes show the presence of agriculture land use (vegetables farm) in the fore ground and middle ground. As for the analysis, it is found that the presences of agriculture land use may increase the rating score of the scenes. As for both scenes have a high score with a scene at point 28 (mean= 4.00) and scene at point 18 (mean is equal to 3.55), refer to Figure 9. However, as we can see the combination of secondary forest and agriculture for the scene at point 9 (mean=2.99) affects the feeling of less or not attractive with responses score of less attractive (29.55) and not attractive (6.8%). The vegetable's farm is not dominant in the scene and present in the middle ground. This suggests that dominancy of the agriculture, in the distance, zones affect the responses score.

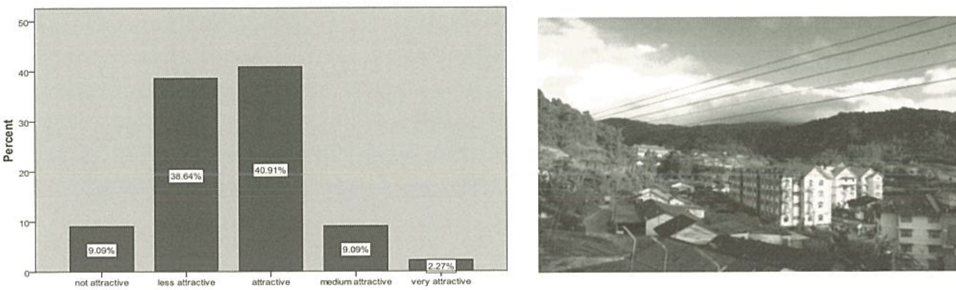

Figure 10(a): Scene at point 56 (Mean 3.55)

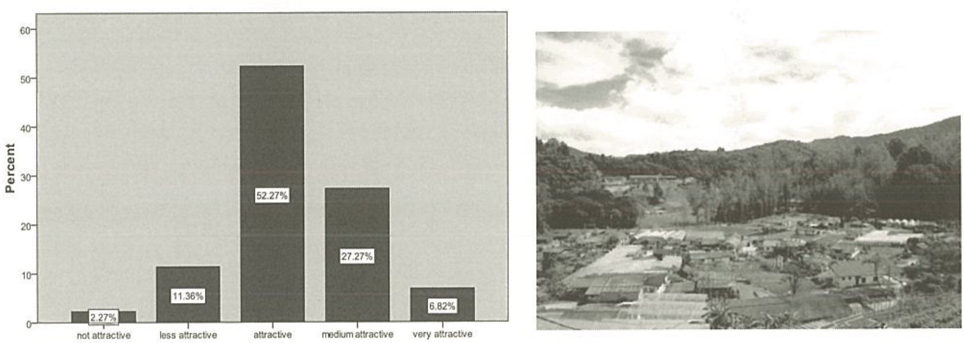

Figure 10(b): Scene at point 43 (Mean 2.57)

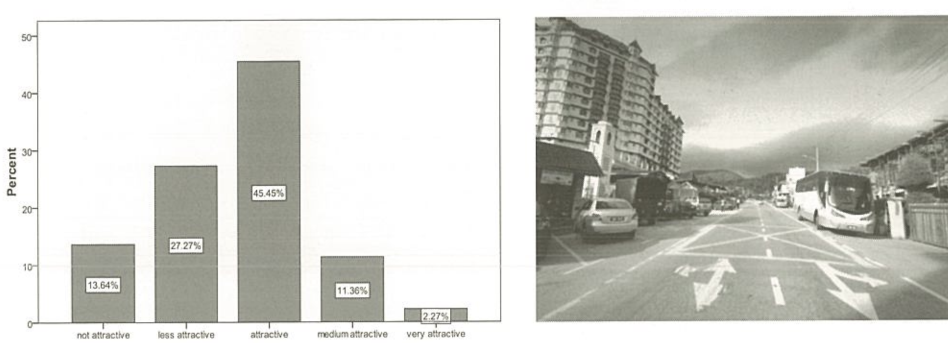

Figure 10(c): Scene at point 38 (Mean 2.61)

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Further analysis for other land use types can be seen in the Figure 10. The three scenes demonstrate visual landscape of the built up area with a scene a (village), scene b (residential area) and scene c (commercial and business area). As we can see all the scenes present dominance built up area. It is present at the foreground and middle ground views. The scene test (a) shows the highest mean score (3.55) as compared to the scene b (2.57) and scene c (2.61). Most of the respondents agreed that all scenes are attractive with the highest percentage of the scene a (52.27%). It follows by scene c (45.46%) and scene b (40.91%). It is found that respondents tend to give high score to village scenery with the moderate attractive (27.27%) and very attractive (6.82%) than both scenes. The scene b and c demonstrate a similar result where the large percentage of people feel this scenery is less or not attractive. However, the scene c shows an intense impression on the scene with the higher percentage on attractive (45.46%) and not attractive (13.64%) than the scene. This suggests the commercial/business area scene is the most unfavourable than residential area view.

CONCLUSION

In this paper, we have proposed and developed objective measurement criteria of visual landscape features using accessible physical data. The consideration of landscape features in the visual landscape assessment includes topography, landform, water element, and vegetation, as well as positive and negative elements. These can be done through the combination of visual structure of landscape analysis using minimal physical data in GIS application. Validation test for the objective measurement shows that it is acceptable for application ($p<0.01$ and moderate association 0.443) in supporting expert based assessment on visual landscape. Moreover, the study demonstrates the uniqueness of the area has a moderate correlation with the attractiveness score. This is contradicting with the assumption made for the physical assessment as the uniqueness may be found in the low visual quality. The reason is the uniqueness also can be seen in the scarcity factors where the more rarity the element is the more potential of being unique the area will be.

Correlations of the landscape features and preference scores suggest that the objective measurement criteria have its own limitation. The measurement is hardly to identify the present condition of the visual quality. The visual quality condition provides significant impact to landscape value to certain landscape features. The analysis shows water follows by vegetation are significantly influenced by the condition of its quality. However, the study shows the presence of water still provides a positive impact and high scores to the visual landscape value. Further analysis and discussion on the vegetation in

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the study suggests that more detail consideration should be taken for vegetation criteria. Village is more preferable than other built up areas follows by residential area and urban uses. The agriculture views which dominant in the scene is preferable than the agriculture that present in the middle ground view only. It is also found the quality of the agriculture view is influenced by the condition and manageable view, whereas the combination of forest and agriculture at the foreground and middle ground is less attractive (lower value).

The study provides more reliable objective measurement of visual landscape for highlands tourism planning. The method is used to reduce the cost of implementation and provides more details documentation in technical sense to support visual landscape assessment. This will also assist planners for preparing fieldworks in supporting the expert based assessment as well as planning and decision making.

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