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A STUDY ON URBAN MORPHOLOGY USING GIS & REMOTE SENSING TECHNIQUE

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ABSTRACT

Urban morphology is the study of the form of human settlements and the process of their formation and transformation. It is an approach in designing urban form that considers both physical and spatial components of the urban structure. Penang was awarded as Heritage City by UNSECO in July 2008. Penang is well known for its heritage character especially in the city of Georgetown with more than 200 years of urban history. Therefore, the study has conducted in Georgetown, Penang in order to identify the evolution of urban morphology and the expansion of development in terms of land use activity. This paper attempts to review a literature that is related to urban morphology in the context of using GIS and remote sensing techniques. These techniques are most widely used and the development in both technology applications has led to significant improvement in capability for decision making process. Therefore, it will help to investigate the past and present patterns and trends of urban growth in Georgetown, Penang. Thus, this finding would contribute to understand the interrelation between urban morphology study and the applications of GIS and remote sensing and its influence on creating sustainable and resilience of metropolitan area, city, town or even village.

Keywords: Urban morphology, GIS, Remote sensing, urban planning, Penang

INTRODUCTION

Urban morphology is the study of the form of human settlements and the process of their formation and transformation. The study seeks to understand the spatial structure and character of a metropolitan area, city, town or village by examining the patterns of its component parts and the process of its development. Moreover, the urban morphology occurred based on certain characteristic such as the configuration of urban fabrics, natural and man-made structures, street layout, architectural complexity, urban materials and human activities as well (Sharifah et. all., 2013).

Besides that, urban morphology analysis can helps to identify the transformation of urban form development and the evolutionary of urban form and structure (Cheng, 2011).The urban morphology analysis can be performed by using geographic information system (GIS) and remote sensing technique. These techniques can reveal the relationships of pattern, trend, form and structure of urban settlements. It will help to investigate the past and present patterns and trends of urban growth.

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PROBLEM STATEMENT

According to Whitehand (2004), the relationship between urban morphology and planning is poorly developed. Thus, the significance of urban morphological study has yet to be realized amongst urbanists. However, urban morphology study provides important knowledge to the planner in order to develop any area in city or even for fringe belt. Lack of interest and awareness in history among the planner and others prevents to develop the settlements into a systematic urban dynamic. Hence, the responsibility for the built environment is not taken seriously towards realization of sustainable urban development.

The morphology analysis can be done by using Geographic Information System (GIS) and remote sensing that provide the advance techniques and methods for studying urban land development and assist urban planning. According to Narimah (2006), over the past forty years GIS have been used in many planning applications ranging from daily administrative operations to strategic planning functions. This technology has various analytical functions that can use in dealing with spatial problems such as urban planning and management issues. It is useful in assisting planners, decision makers and the community to efficiently respond to challenges, plan successful future and improve service delivery.

Although GIS has become a common planning tool in many western developed nations, its application in many developing nations is still limited. This is because, data has to be updated, come from reliable source and available at suitable scale. Thus, data and its availability in digital format are very important in evaluating urban land use problem (Green and King, 2003). Thus, in this research there are some problems and issue, which are:

1. The transformation of urban form and spatial structure affecting urban morphology includes environment and climatic impact, land use activities, urban patterns, street layout and open space.
2. Lack of awareness using GIS and remote sensing technique as tools to analyze urban morphology that can provide comprehensive information on the transition of patterns and trends and the expansion of urban growth.
3. Rapid urbanization of urban morphology can affect the future of urban forms and trends.
4. Uncontrolled transformation provides unsustainable development for city.

AIMS AND OBJECTIVES

The aim for this research is to identify the evolution of urban morphology from past until present within specific periods. The analysis of urban morphology can be identifying by using GIS and remote sensing application. There are four objectives have been formulated in order to achieve the goal.

1. To analyze urban morphology of Georgetown in terms of urban patterns, street layout and open space.
2. To encourage the use of GIS and remote sensing technique as tool in order to determine the development of land use.

3. To examine the impacts of urban morphology on the development that occurs in the Georgetown.
4. To recommend the physical guidelines for the development of city to the local authority and stakeholders.

STUDY AREA

The study has conducted in Georgetown, Penang. The historic of Georgetown is located in the state of Penang. The state of Penang comprises of Penang Island and George Town is the heart of the metropolitan area which is the second largest urban conurbation in Malaysia. The city of Georgetown was established in 1786 by the British and it is the first British port town along the Straits of Malacca.

The city has more than 200 years of urban history. Therefore, the urban morphology of Georgetown will be analyzed to understand the trends and patterns of urban form and the expansion of urban growth. The increasing intervention from high rise construction and new developments within the historic urban fabric give some transformation and evolution in urban morphology of the city (Shuhana et. al., 2012)



Figure 1: Key plan (left) and location plan (right) of Georgetown City in Pulau Pinang.
Source: Malaysia States Map (2014) and Draft Special Area Plan Georgetown (2011)

URBAN MORPHOLOGY, GIS AND REMOTE SENSING

1.1 Definition of Urban Morphology

According to Bentley and Butina (1990), urban morphology is an approach to studying and designing urban form that considers physical and spatial components of the urban structure. The example of the components are plots, blocks, streets, buildings and open space which all of these are consider as part of history process of development.

Bentley and Butina point of view on urban morphology is similarly to the Gillen (2006). He describes urban morphology as the form and structure of urban settlement and it processes give impact on the spatial characteristics. Both researchers explain that the

changes of any area will cause an impact towards the urban development either in economic, environment or social aspects.

Special attention is given to how the physical form of a city changes over time and to how different cities compare to each other. Urban morphology can be an important part of urban design in creating urban form and can be considered as the structure of urban form. Therefore, we need the urban history and urban form back into urban design in order to achieve high quality and vibrant place. the history of a place taught to understand the needs of the area and how to overcome any problem that arise previously in forming sustainable urban development in future.

1.2 Definition of GIS

Geographical Information System or GIS derived from two distinct disciplines, namely geography and information system. According to Bhatta (2008), geography is the science that involves a combination of physical and cultural disciplines, which are used to describe, explain and help us to understand our environment and the relationship with it. It also can be define as a science of space and place that brings earth's physical and human that integrated the study of people, places and environment.

Meanwhile, information system often refers to a system containing electronic records that involves of source documents, records on electronic media and output records along the related documentation. It also defined as interactive combination of people, computer software and hardware, communication devices and procedure designed to provide a continuous flow of information to the people who need information to make decisions or perform analysis.

In short, a geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information (Esri, 1990). GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. GIS are used as an important aid for spatial decision making. Recent developments in GIS have led to significant improvements in its capability for decision making processes in land allocation and environmental management (Jiang & Eastman, 2000).

1.3 Definition of Remote Sensing

Remote sensing also known as earth observation which means observing the earth with sensors from high above its surface. A lot of definition that can define remote sensing. One of the definitions is stated by Bhatta (2008) as below:

"Remote sensing is a technology for sampling radiation and force field to acquire and interpret geospatial data to develop information about features, objects, and classes on the earth's land surface, oceans and atmosphere and where applicable on the exterior of other bodies in the solar system, or that matter, many of celestial bodies such as stars and galaxies."

According to Bagan (2012) as cited by Weng (2012), remote sensing can provide high spatial resolution and high temporal frequency that covers broad areas with spatially consistent image information. Therefore, remote sensing is an important tool for providing information on urban land-cover characteristics and their changes over time at various spatial and temporal scales.

Thus, the urban analysis needs to exploit the capabilities of remote sensing system in order to gain wider information in specific aspect of analysis. Remote sensing application would narrow the gap of any problems regarding any field such as physical, economic, social planning and forecasting future models of city.

URBAN MORPHOLOGY

2.1 Urban Morphology of Georgetown

Georgetown was built on swampy land on the northeastern tip of the island. The 1798 Popham's map shows the position of the early settlements in Georgetown where the administrative buildings scattered to the west of Fort Cornwallis and the centre to its south. The town centre, were surrounded by Light, Beach, Chulia and Pitt streets and it continues as main commercial district within Georgetown. Then, the town expands inwards and the series of reclamation with the extending towards Weld Quay as the new waterfront as well as the construction of piers and jetties.

Hence, the development of KOMTAR, Ferry terminal and Penang Bridge shown that Penang faced rapidly development country. Due to the topography features such as hills and the Straits of Malacca, it shows the significance identity of Georgetown. Nowadays, Penang faced rapid urbanization whereas more skyscrapers and modern building were built. For example, KOMTAR with 232 meters tall as symbol of a modern industrialized Penang.

Below is the urban morphology of Georgetown city from 1798 to 2010 (figure 2). The town expands inwards and the Georgetown city was recognized by UNESCO as World Heritage Site. This area was divided by two zones which are Core Zone and Buffer Zone.









Figure 2: Urban Morphology in Georgetown.

Source: Draft Special Area Plan (2011)

The development of Georgetown acquired Landsat satellite and the view of Georgetown taken from 30m distance by using Landsat MSS, TM, ETM+, 7 and 8 OLI. These images help to interpret land-use and land-cover changes for the study area from 6 separate dates (nominally 1972, 1979, 1995, 2000, 2009, and 2014). Landsat scenes are processed for standard terrain corrections by the U.S. Geological Survey. From these images, we can see the development and the expansion urban growth of Georgetown within 43 years.

Table 1: The Landsat images of Georgetown development for 43 years (1972-2014).

1972 MSS 1-3	1979 MSS1-3
	
1995 Landsat TM	2000 Landsat ETM+
	
2009 Landsat 7	2014 Landsat 8 OLI
	

Source: U.S. Geological Survey (USGS) (2014)

2.2 Component of Urban Morphology

The evolution of urban morphology can be defined by three components which are urban pattern, street layout and open space/landscape. These components can justify the

transformation of urban form that occurs from past years to the present years in Georgetown.

2.2.1 Urban Pattern

Due to the rapid development of the trade sector within the Southeast Asian region, much emphasis was placed on the structure of ports cities. Therefore, the British applied the gridiron township layout. The implementation of a gridiron concept within British colonized township was heavily influenced streets/ roads that forms straight lines, which enabled rectangular land areas to be carved out of these port cities.

According to Hassan (2009), the urban pattern in the inner city of Georgetown is the uniqueness of the formation that called 'divide and rule' concept which adopted by the British authority. Under the 'divide and rule' concept, these immigrants were located to settlement areas based on their ethnic background under one leader known as 'kapitan' (captain). The boulevards, streets and roads were used as the boundary for these divisions.

The transport network in this inner city was influenced by the 'divide and rule' concept. Unlike formation of well-planned gridiron pattern in other British colonial cities such as in North America, Canada and Australia, the formation of the urban pattern in George Town has an irregular gridiron pattern. This type of urban pattern is typical under 'divide and rule' concept and this had indirectly influenced the setting and planning of the present street access and transport networks.

2.2.2 Street Layout

According to Shuhana (2011), the streets and its streetscape elements are important in defining the character of urban areas. The qualities of urban space convey a significant impact to the townscape and influencing the identity of the place. Historically, there are eight zones during colonial era of development planning (Hassan, 2009):

1. British Administration and Settlements
2. Indian Hindu Settlement
3. Fort and Financial Area
4. Indian Muslim Settlement
5. Malay Settlement
6. Chinese Settlement(East)
7. Chinese Settlement (North)
8. Commercial Area and Market Place

The uniqueness of Georgetown due to the historic architecture building and these rows of building enclosed the areas and create the urban spaces which divided into few significant streets and the names of the streets names referring to the history of the area. Each of the streets portrays the existence of community with different historical background such as Acheh Street, Farquhar Street, Armenian Street and Pitt Street (Jalan Masjid Kapitan Keling) for Muslim/Indian Muslim Community, Bishop Street, and more.

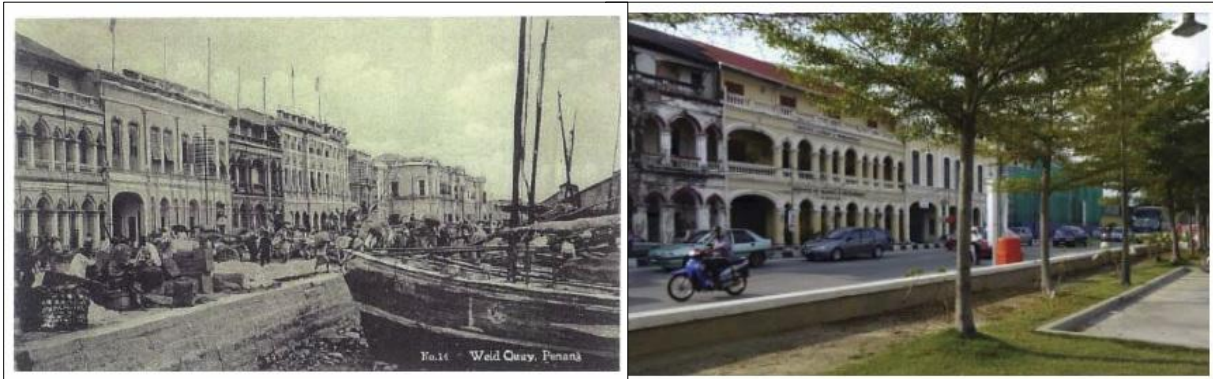


Figure 3: The transformation of Pengkalán Weld from South view.
Source: Draft Special Area Plan Georgetown (2011)

2.2.3 Open Space/Landscape

The most significant open space in Georgetown is Esplanade which is the historical colonial open spaces in Georgetown. The esplanade is associated with the Fort Cornwallis and adjacent to the colonial government buildings. Burke and Ewan (1999) stated that open space contributes the quality of life to the people. The activities occur at Padang Kota and Esplanade significantly contribute to the visual and sensory experience of George Town's townscape.



Figure 4: Open Space in Georgetown
Source: Draft Special Area Plan Georgetown (2011)

URBAN MORPHOLOGY STUDY FROM DIFFERENT ASPECT

The study of urban morphology attract the attention most of the researchers in analyzing the urban morphology in various of aspect. The urban morphology analysis is widely study in the whole world to produce different research objective in different field. Therefore, understanding urban morphology is important in creating urban settlement in sustainable manner. Moreover, urban morphology also can help to identify how the process of development taking involves in the study area. Despite of this, it also clarifies the physical condition in present time. Some of the components that can take as consideration to determine the evolution of urban morphology such as buildings, street layout, land use activities, urban materials, architectural complexity, urban landscape and natural and man-made surfaces. Below is the list of research related to the urban morphology study in different perspective of aspect.

Table 2: Study by different researcher on urban morphology

NO.	AUTHOR/YEAR	TITLE	CONTENT	DATA/METHOD
1	Bagan, H. & Yamagata, Y (2012)	Landsat analysis of urban growth: How Tokyo became the world's largest megacity during the last 40 years	<ol style="list-style-type: none"> 1. To investigate spatial and temporal land-cover changes in the Tokyo. 2. To investigate the past and present patterns and trends of urban growth from 1972-2011 	Data: Landsat MSS, TM, and ETM+ images Method: <ol style="list-style-type: none"> 1. Subspace methods and classification 2. Grid cell process
2	Ng, E.et. al.(2011)	Improving the wind environment in high-density cities by understanding urban morphology and surface roughness: A study in Hong Kong	<ol style="list-style-type: none"> 1. The understanding of urban surface roughness based on the urban structure to establish the relationship between urban morphology and urban air ventilation environment. 2. To analyze the interaction between the urban area and the atmosphere has made an important contribution to the understanding of urban air ventilation of the city. 	Data: MM5/CALMET model simulated wind data Method: <ol style="list-style-type: none"> 1. Davenport roughness classification, 2. morphometric methods 3. micrometeorologic al methods
3	Kuffer, M. & Barros, J. (2011)	Urban Morphology of Unplanned Settlements: The Use of Spatial Metrics in VHR Remotely Sensed Images	<ol style="list-style-type: none"> 1. To analyze spatial characteristics of unplanned settlements in terms of morphology aspect which are size, density and layout pattern. 	Data: spatial metrics in combination with remote sensing Method: Image segmentation

4	Peeters, A. & Etzion, Y. (2012)	Automated recognition of urban objects for morphological urban analysis	1. focuses on the extraction of morphological attributes essential for analyzing the relation between climatic conditions and urban form.	Data: GIS Method: Object shadow technique
5	Whitehand, J.W.R et. al. (2011)	Urban morphology and conservation in China	1. Discussed in relation to the problems faced by urban conservation in China, where the pressures for change to, and the removal of, the traditional urban fabric are greater than practically anywhere else in the world. 2. In relation to China, aspects of Urban morphological thinking concerning conservation that have been developed largely in the West.	Data: Site Observation
6	Sharifah et. al. (2013)	The Influence of Urban Landscape Morphology on the Temperature Distribution of Hot-Humid Urban Centre	1. To provide understanding on the influence of urban landscape morphology and its impact to the climatic variance in hot-humid city. 2. To investigates the variability of outdoor air temperature produced on the different urban landscape morphology in Putrajaya	Data: Site Observation Method: stratified random sampling technique
7	M. Boukhabla et. al. (2013)	The effect of urban morphology on urban heat island in the city of Biskra in Algeria	1. To assess the impact of urban morphology upon the air temperature variation of urban condition in hot and dry climate of Biskra city in the	Data: Field measurement Method: Temperature measurements

south east of Algeria				
9	Allan, P. et al. (2013)	The Influence of Urban Morphology on the Resilience of Cities Following an Earthquake	1. Conceptual theory of resilience in urbanism and to enhance the resilience of a city through the design of its urban morphology. 2.	Method: Case study of one Pacific Rim city, Concepcio´n, Chile, after the 2010 earthquake.
10	Cheng, J. (2011)	Exploring urban morphology using multi-temporal urban growth data: a case study of Wuhan, China	1. To demonstrates an innovative application of a machine learning method-Maxent for analyzing the urban morphology of a fast growing city -Wuhan, China.	Data: Multi-temporal data, remote sensing image Method: Maxent method
11	Gillen, M. (2006)	The challenge of attaining a sustainable urban morphology for South East Queensland	1. How to accommodate future population and development growth in a sustainable manner. 2. To investigate current spatial policy conception is robust enough to alter the realities of contemporary urbanism in one of Australia's largest metropolitan regions.	Content analysis
12	Kalyani, P. & Govindarajulu, P. (2013)	A multi-scale Urban Analysis Using Remote Sensing and GIS	1. To provide a holistic perspective on the urban characteristics, an interdisciplinary research approach is used which are GIS and remote sensing. 2. Focused on the multi-scale approach with remote sensing, to support urban management with area-wide and up-to-date datasets in Hyderabad.	Data: GIS, Remote sensing Method: Oriented Classification

THE SIGNIFICANCE OF GIS AND REMOTE SENSING ON URBAN MORPHOLOGY STUDY

Morphological analysis makes it possible to summarize the changes and trends of urban spatial structure and urban form. It analyze a city's evolution from its formative years to current transformations which identifying and dissecting its various components As a result, urban morphology analysis requires multi-temporal data sets covering the whole urban area across a long period. Stimulated by rapid advances in geospatial technologies,

high-resolution remotely sensed imagery has become widely available and at low cost. These have made monitoring urban growth possible and the availability of multiple temporal data sets much improved recently.

Multi-temporal analysis is a kind of spatial analysis and model using multi-temporal data sets. For example, Liu and Zhou (2005) reported a land use change trajectory analysis method based on multi-temporal imagery and further applied this method for the prediction of urban growth into the future (Cheng, 2011).

In additional, the integration of GIS and remote sensing has justifiably received widespread and extensive attention in the recent literature. Most of the journalist has devoted at least one issue to this subject and this trend likely increase over the next few years. According to Wilkinson (1996), the interface between GIS and remote sensing can be envisaged in one of three different ways as below:

- a. Remote sensing can be used as a tool to gather data sets for use in GIS
- b. GIS data sets can be used as ancillary information with which to improve the products derived from remote sensing and;
- c. Remote sensing data and GIS data can be used together for modeling and analysis.

Urban analysis needs to exploit the capabilities of technology such as remote sensing systems of their spatial coverage and detail. The urban analysis aims at a holistic understanding of the dynamics of urban growth process. Therefore, the use of remote sensing technology can be referring in the city of Hyderabad in India where the images of Hyderabad of the years 1997 and 2007 for the detection of recent changes of the urban extension. The contribution of remote sensing to the planning of sustainable urban development is two-fold. First, a spatial overview on the extension of the city and its structure change over time is presented. Second is a highly detailed analysis of the urban structure (Kalyani & Govindarajulu, 2013).

In addition, GIS has become a useful planning tool in urban land use planning in Malaysia. This technology has various analytical functions that can be used in dealing with spatial problems such as urban planning and management issues. It is useful in assisting planners, decision makers and the community to efficiently respond to challenges, plan successful future and improve service delivery (Narimah, 2006).

Hence, GIS and remote sensing application is use to investigate the transition from past and present patterns and trends of urban growth. The integration both techniques are widely used technologies applications and it will provide tremendous result of the study area. The development of both applications gives power in decision-making process in handling land and environment management. GIS and remote sensing applications are able to analyze in terms of physical planning, economic planning, social planning and forecast models of sustainable urban system.

CONCLUSION

In conclusion, urban morphology study is important as a fundamental key in urban system. This study will identify the process of development that occurs in the metropolitan area, city, town or village. From this perspective, it will give basic understanding how the settlements faced the evolution of development in terms of urban forms and urban spatial structure.

Moreover, traditional urban theories investigate how cities develop and grow through systematic interactions of infrastructures, people and economic activities. With given advances in technology, and the sheer scale and pace of contemporary urban growth, the most rapid changes in urban form, pattern and structure, are taking place where historical roots are weakest as in the recent suburbs of long established Western cities, or in the new cities of developing countries. That is how the significance of urban morphology in replaces or improves the weakest area to become more urban dynamic area.

This study will give most of party such as planner, architect, and local authority to give more attention in developing the settlements by using this morphology analysis as a guideline to create sustainable urban system. The advancement of technology such as GIS and remote sensing application will give comprehensive information on urban morphology and in addition, it have capability in helping any party in decision-making process such as planning, policy making, and legislate law.

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