MONITORING STREET NETWORK USING HIGH-RESOLUTION REMOTE SENSING DATA FOR URBAN MORPHOLOGY STUDY. CASE STUDY: THE HISTORIC CITY OF MELAKA

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ABSTRACT: This paper is based on the study of morphological changes in Melaka, Malaysia. In order to identify the morphology of this city, the street network is one of the elements that can help to determine the evolutionary of urban form and structure. The primary objective of this paper is to examine the movement and direction of the street pattern in which influenced the morphology of the city from the year 1993 to 2016. Also, the character of the Historic City of Melaka is strengthened by the unique townscape qualities of the streets and the buildings that shaped the quality of space created by these streets. Thus, three series of satellite images on the year 1993, 2005 and 2015 from SPOT satellite have been used in detecting the development of street network pattern aided by remote sensing and GIS software. This paper will concentrate on extracting the street in 20 years, and a comparison of the street pattern will be taken into consideration to examine the direction of the expansion of Melaka city. The finding shows that the streets expansion growth fast as the more settlement were built along this process. The street expansion was merely influenced by the location of the Melaka which near to Malacca Straits and as a port for trade sector, thus, the movement of streets expanding inwards to the inner city and along the shoreline. In conclusion, street network considers as one of the principle tools in the urbanisation process that provides understanding on how the cities are shaped and develop to have dynamic cities.

1.   INTRODUCTION

Monitoring the changes in urban area or can be called as urban morphology has become a very interesting topic to be tackled by a researcher in order to analyse how the city exists. With the advancement of technology, urban morphology can be traced more easily with the technology of remote sensing. Urban morphology is an important aspect of the planning system which contributes to the existence of the city, history of the city, how the city is developed, planning system of the City and so forth which contribute to the sustainable of the city. There are many aspects in analysing the

morphology of the city such as buildings, land use, urban design, street network, urban landscape, or others.

In this paper, we will analyse the street network of Melaka city as part of the criteria in the evolutionary process of development. Thus, to examine the pattern and development of the street network, road extraction method will be used to extract the road pixels in the satellite images. Road extraction approach becomes one of the significant areas to explore and heated among the researchers. There are some ways regarding strategies, type and resolution, processing and so forth to extract road from high-resolution images. For this study, IMAGINE Objective tools will be used to classify and extract features in order to provide accurate geospatial content.

2. STREET NETWORK AS AN EVOLUTIONARY ELEMENTS IN URBAN MORPHOLOGY

Street network analysis can help to identify the transformation of the urban form development and the evolutionary of urban form and structure which can determine the morphology of the city. (Cheng, 2011). Urban morphology occurred based on certain characteristic such as the configuration of urban fabrics, natural and man-made structures, street network/layout, architectural complexity, open space and other physical element (Moudon, 1997; Li and Yeh, 2004; Sharifah et al., 2013, Sun, 2013; Paul, 2008). Therefore, the street network can represent as an indicator to control the development activity and provide opportunities and constraints for city-building processes, such as land subdivision, infrastructure development, or building construction.

According to Cubukcu (2015), street pattern considers as spatial outcomes for human correlation and thus it have potential as an indicator of culture. The design of street network will reflect the culture of the city and possess certain criteria that would resemble the cultural background (Asami, Kubat, & Istek, 2001). Instead of that, the street network provides ease of movement, accessibility, reachable and safety within the area. In urban planning and development, street or road is one of the most significant criteria in forming a city. Moreover, it creates a better connection between the existing settlement and the new development area.

Besides, the morphology of cities should be understood not only in economic, historical, and physical terms, but also in cultural heritage terms. Therefore, we suggest that the preservation, redevelopment, urban policy, and future expansion of cities should incorporate analyses of the towns' historical and contemporary morphological development. Streets are one of the essential elements in the urban form that lead to the urban history and morphology studies which give impact in many aspects such as social and economic life (Shpuza, 2014). The study of streets can provide the information on the urban growth of the city and enlighten the evolution of the urban form in the particular area.

Indeed, streets have greater structural necessary which has a tendency to attract people to have more experience and making them more prone to imageability. Moreover, streets can provide unique features to the user due to the pattern of the streets such as narrowness and width of the street, and the activity along the streets (Omer et.al., 2010; Lynch, 1960). Therefore, streets network not only pointed on the traffic load only, but it has significant value to the society which can perform livable street as public spaces and provide safety to the user as well.

3. STUDY AREA

Figure 1
The study area, Melaka.

This study was conducted in Bandar Melaka, Melaka, Malaysia. Melaka is situated in the southern region of the Malay Peninsula, next to the Straits of Malacca This historic city centre has been listed as a UNESCO World Heritage Site since 7 July 2008.

The character of the Historic City of Melaka is strengthened by the unique townscape qualities of the streets and the buildings that shaped the quality of space created by these streets. Different with other towns, Melaka townscape is quite distinctive in character because of its sense of enclosure and mixture of houses, shops, and places of worship.

4.   MATERIALS AND METHOD

4.1 Data

Three different SPOT satellites images (nominally 1993, 2005 and 2015) are used to analyse the morphology of street network in the study area.

Table 1
Materials used in this study

Data types	Year	Spatial Resolution	Provider
SPOT-2 XS	1993	20m	Malaysian Remote
SPOT 5	2005	5m	Sensing Agency
Spot 6	2015	1m	(MRSA)

4.2 Methods

All the digital form of data is readily used in data processing in Digital Image Processing. ERDAS IMAGINE 2014 are the main software that used to analyse the morphology of street network by extracting the road. The formation of street network or road in the study area will be monitor based on the year 1993, 2005 and 2015. Hence, the expansion of road network will determine the development of study area within 20 years.

The method consists of a sequence of operators and processes. This method successfully enables to use to extract any information such as residential rooftops, commercial and industrial buildings, road, tree crowns and so forth. Thus, for this study, road extraction using IMAGINE Objective will be excellent helpful to separates the roads from the background. Below are steps to extract road by using IMAGINE Objective (figure 2).
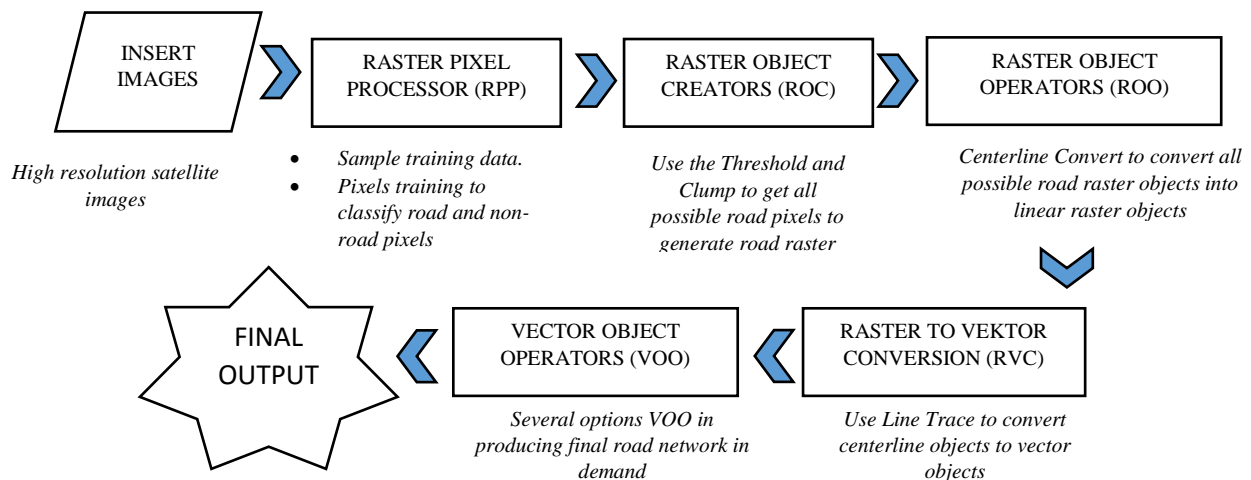

| INSERT IMAGES | | RASTER PIXEL PROCESSOR (RPP) | | RASTER OBJECT CREATORS (ROC) | | RASTER OBJECT OPERATORS (ROO) |

High resolution satellite images

- *Sample training data.*
- *Pixels training to classify road and non-road pixels*

Use the Threshold and Clump to get all possible road pixels to generate road raster

Centerline Convert to convert all possible road raster objects into linear raster objects

| FINAL OUTPUT | | VECTOR OBJECT OPERATORS (VOO) | | RASTER TO VEKTOR CONVERSION (RVC) |

Several options VOO in producing final road network in demand

Use Line Trace to convert centerline objects to vector objects

Figure 2
Road extraction flowchart

5.   RESULT & DISCUSSIONS

5.1   Road Extraction

The satellite images will be trained to classify the pixels and objects or both in order to segregate pixels between road and non-road pixels. This training road pixel is necessary to classify the pixels and turn non-related pixels to the background which it will help to see clearly the road pixel (figure 3). This step will generate and indicating the probability of being a road pixel.
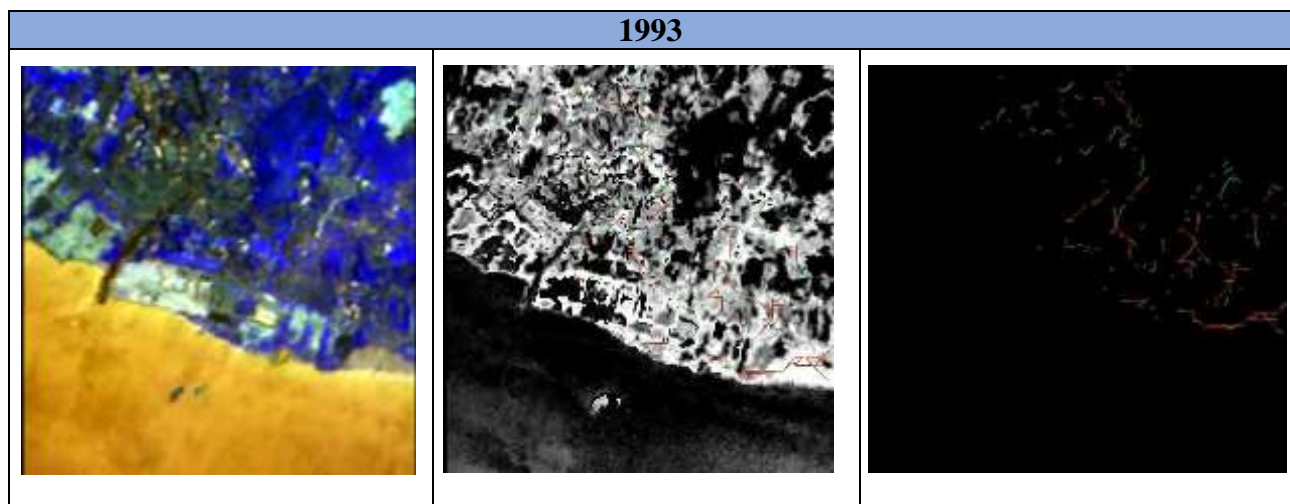
Figure 3
Before and after training and classify the pixels of road and non-road pixels during raster pixel processor stage. The non-pixels road will turn out to be background in the sampling images.

From the classification result, Raster Object Creators (ROC) process node will generate all possible road pixels to road raster objects with the use of Threshold and clump operator. Then, further reduction in the number of non-road rasters must be applied in Raster Object Operator (ROO). Several options on the operator can be used such as size filter which will remove tiny objects and for road extraction, convert centerline operator will convert all possible road raster objects into linear raster objects, which all have single pixel width.

Line trace operator will convert centerline objects to vector objects in Raster to Vector Conversion (RVC) process node. Finally, Vector Object Operators (VOO) can be used to finalising the road network demand based on the series of operators that need to use such as Line Link, Smooth, Line Snap and Ribbon Remove. The series of VOOs can be adjusted by changing the parameters or rearrange the process nodes. Below is the result of road extraction for the satellite images that have been processed.

Table 2
Road extraction results in the year 1993, 2005, and 2015

Spot-2 XS Acquisition Date: 17 February 1993 Band: 1,2,3 20 meter	RPP process node with Threshold and clump operator. VOO is used to finalize the road extraction.	VOO process node: Line Snap and Smooth
2005		
Spot-5 Acquisition Date: 20 January 2005 Band:4,3,2 5 meter	RPP process node with Threshold and clump operator. VOO is used to finalize the road extraction.	VOO process node: Line Snap and Smooth
2015		
Spot-6 Acquisition Date: 3 December 2015 Band:4,3,2 1 meter	RPP process node with Threshold and clump operator. VOO is used to finalize the road extraction.	VOO process node: Line Snap is a clean-up operator to the linear vector layer to connect lines that should be connected with L-extension and T-junction.

(Source: Malaysian Remote Sensing Agency (MRSA), 2016)

5.2   *The morphology of street/road network*

Based on the result, the road or street network showed some changes between the year 1993, 2005 and 2015. The complexity of road network develops from the inner of the city to the coastal area. In the year 1993, the development of the city is not crowded as the year 2005 which the new development was trigger over the Malacca strait. The opening of Pulau Selat as new development contribute a new road network that connects between Bandar Hilir to Pulau Selat. Thus, new commercial were build and generate social activity within this street.

The expansion of street network towards the strait Malacca become wider year by year due to the development of this city. The street during the year 1993 to 2005 was tremendously developed as the transportation facilities become improve and the needs of people to use the street to transport from one location to other location. During that time, the introduction of vehicular transportation become overwhelmed and occur high demand on the transportation needs.

Because of the needs of transportation in high demand, thus, the opening of new roads are needed. This necessity is important in the process of city's development to cater the needs and population of the people. It is important to the urban planning process in making the city more systematic and well organized to transport people from one particular destination to others. Most of the road within this city is one way route which to control the traffic congestion, especially during peak hour.

The development of the streets occur at the center of the city and urban commercial streets are more livable due to much social activity and public spaces offer to the people. As a Heritage City that recognized by UNESCO, this vibrant city attracts most of local and tourist to come and visit this city, thus it does affect the liveliness of the streets. The city center, Bandar Hilir have variety numbers of heritage buildings and no new development are allowed in this area due to the dense and saturated area. Thus, beautification of this area is needed to make sure the place were user friendly and make the spaces more livable.

CONCLUSION

In this paper, the street network is an important aspect in determining the evolutionary process of the city. From the existing of this city, the development of street network become more important not only to cater the transportation itself but to make the city more livable with attractive street design and the enhancement of street network system. The evolutionary of the street network during British administration until now make Melaka city street system improve but at the same time, control development is taken care to avoid any harm to the heritage value. With the advancement of remote sensing technology, street network analysis can be done with the method of road extraction. While doing this research, there is some area that can be improved such as the resolution of images which are suitable to conduct the extraction features such as a road. High-resolution satellite images are a must to extract features such as road, building, roof and henceforth. Indeed, this method can analyse high-resolution imagery but still maintain large scale mapping and geospatial database.

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