ROAD NETWORK ANALYSIS OF PULAU PINANG USING GIS

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CIVIL ENGINEERING
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By

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Dissertation submitted in partial fulfilment of
the requirements for the
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(Civil Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

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(A.P. Dr. Abdul Nasir bin Matori)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified soirces or persons.

HAZMAN BIN SOHARI

ABSTRACT

This project is to study the transportation network and searching on the relationship between data analysis and decision making tools. The formation of the nation's transportation system has been evolutionary. The system now in place is the product of many individual decisions to build or improve its various parts. Therefore, GIS can be used as an effective tool for road information system, which will help the planners and administrators to identify the problems associated with road development activities, location and provision of appropriate facilities, monitoring and maintenance management of the assets. For this, the study on network analysis of Pulau Pinang streets will be done. Observation and collecting data will be involved during this research. The expected findings will be the numerous function in using data and information regarding to the road network analysis.

ACKNOWLEDGMENT

First and foremost, I give thanks and praise to God for His guidance and blessings throughout the entire course of my training.

I wish to express my gratitude to A.P. Dr. Abdul Nasir bin Matori, for his guidance and support throughout completing my Final Year Project in the Civil Engineering Department of Universiti Teknologi Petronas. His knowledge is vital for the projects and activities that I have involved.

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Finally, I would like to thank my family. They have been a wonderful source of encouragement and joy to me and also not to forget the fellow students who's their help was a tremendous gift to me. May God bless all of us and only HE, the Almighty could repay all my debts to them.

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INTRODUCTION

1.1 Background of Study

Mobility is the backbone of the activity system of the human race. Adequate mobility tends to broaden the perspective of an individual in particular and society in general. Road transportation network has been essential infrastructure facilities, which need to be developed and maintained to accommodate a growing population and economy.

Malaysia is consists of two geographical regions divided by the South China Sea which is Peninsular Malaysia and East Malaysia (Sabah and Sarawak). With 329,758 km2 of total land area, Malaysia has a population of 26 million. The country's population growth is forecast at 2.14% per annum for the period 2001-2020.

The major mode of transportation in Malaysia is predominantly by road which is influenced by its geographical aspects. The annual number of passengers transported by private cars and buses in 2003 is 1,836 million and 850 million persons, respectively. The share of road transport of passengers comprises 64.8% by private car and 30.0% by bus, as compared to 4.7% by rail transport and 0.5% by air transport. The road transport also moved 303 million tonnes of goods or an overwhelming 96.4% of total freight in 2003[10].

PASSENGER		
Transportation type	'000 persons	Percentage
Private car	1,836,338	64.8%
Bus	850,000	30.0%
Rail	133,43	4.7%
Air	12,830	0.5%

Table 1: share of transport - passenger

Among the factors believed to justify a transportation project are improvements in traffic flow and safety, savings in energy consumption and travel time, economic growth, and increased accessibility. Some transportation projects, however, may be selected for other reasons-for example, to stimulate employment in a particular region, to compete with other cities or states for prestige, to attract industry, to respond to pressure from apolitical constituency, or to gain personal benefit from a particular route location or construction project. In some instances, transportation projects are not selected for construction because of opposition from those who would be adversely affected. For example, a new highway may require the taking of residential property, or the construction of an airport may introduce undesirable noise due to low-flying planes. Whatever the reason for selecting or rejecting a transportation project, a specific process led to the conclusion to build or not to build.

Figure 1: roads which formed the network across the country.

Item		QUANTITIES		Ave. Annual Growth Rate (% pa)
		1991	2004	
1	Total Vehicle Trips (Million Trips)	7.08	20.51	8.5
2	Total Commodity (Million Ton)	1.77	5.05	8.4
3	Total veh-km (million veh-km)	122.35	425.24	10.1
4	Total Passengers-km (million pass-km)	242.35	571.63	6.8
5	Total ton-km (million-km)	67.72	231.84	9.9

Table 2: Estimated Daily Total Road Traffic Demand in Peninsular Malaysia

The process for planning transportation system is a rational one that intends to furnish unbiased information about the effects that the proposed transportation project will have on the community and on its expected users.

Information system today plays vital role in planning and development of areas. The invention of high-tech in the field of telecommunications, remote sensing and computers would lend a valuable support to spatial planning process. The most advanced computer based information technology tool for spatial planning is the Geographic Information System, which would become indispensable in planning and management of database. GIS can be used as an effective tool for road information system, which will help the planners and administrators to identify the problems associated with road development activities, location and provision of appropriate facilities, monitoring and maintenance management of the assets.

A geographic information system (GIS) is a computer system that uses location information which is including the detail of address, postal code, census block, latitude and longitude coordinates. With the various functions of GIS, user is allowed to see patterns, relationships, and trends. A GIS can also map information stored in spreadsheets as well As databases. Hence, GIS gives you an entirely new, dynamic perspective on your information and helps you make better decisions.

During the project, it is decided of using ArcView as an initial tool. ArcView provides an intuitive, interactive, easy-to-use, stand-alone interface for calculating travel routes, finding the closest facility, reporting the results as directions and finding service areas.

It enables you to solve a variety of problems based on;

- Geographic networks (i.e., streets, highways, rivers, pipelines, utility lines)
- Finds the most efficient travel route across town
- Generate travel directions
- Finds the closest emergency vehicle or service facility to an incident
- Defining service areas or sales territories based on travel time

1.2 Problem Statement

Worldwide, the transportation problems faced by various nations have increased manifold, necessitating search for methods or alternatives that ensure efficient, feasible and faster means of transport. Various situations, particularly emergency situations demand a method that can ensure speedy transportation.

Because of that, it is crucial to analyze the transportation network in order to generate direction and find the shortest route from one location to another, for an example. However, it doesn't stop there. Network analysis gives the user's ability to solve more problems regarding transportation network system.

1.3 Objectives

The objectives of the study are:

- To find the best route: find out which route one has to take if intends to travel all the places of interest with shortest path and best possible order.

- To locate the closest facility: find out which route one has to take if intends to go from current place to any other closest facility of choice, through entire road network.

1.4 Scope of Study

The whole project would start with the knowledge gathering and theoretical studies of GIS. Taking the data from the potential field would be the first step in this project, followed by the extracting of the data itself. Then, a methodology will be developed according to the step-by-step procedures from identifying, extracting, and analyzing the data.

In this study, two categories of network analysis problems will be solved using mostly ArcView Network Analyst extension module. It is decided to analyze the road network of Pulau Pinang, Malaysia.

Figure 2: area of study.

CHAPTER 2

LITERATURE REVIEW

The heart of GIS is the analytical capabilities of the system. What distinguish the GIS system from other information system are its spatial analysis functions. Although the data input is, in general, the most time consuming part, it is for data analysis that GIS is used. The analysis functions use the spatial and non-spatial attributes in the database to answer questions about the real world. Geographic analysis facilitates the study of real-world processes by developing and applying models. Such models illuminate the underlying trends in geographic data and thus make new information available. Results of geographic analysis can be communicated with the help of maps or both [9].

The organization of database into map layers is not simply for reasons of organizational clarity, rather it is to provide rapid access to data elements required for geographic analysis. The objective of geographic analysis is to transform data into useful information to satisfy the requirements or objectives of decision-makers at all levels in terms of detail. An important use of the analysis is the possibility of predicting events in another location or at another point in time.

Before commencing geographic analysis, one needs to assess the problem and establish an objective. The analysis requires step-by-step procedures to arrive at the conclusions [9].

The range of geographical analysis procedures can be subdivided into the following categories.

- Database Query.
- Overlay.
- Network analysis.
- Statistical and Tabular Analysis.

There are two applicable types of modelling which are simulation and predictive models. Simulation modelling involves using the GIS to simulate a complex phenomenon in nature which generally requires a high degree of technical expertise and can vary in the degree to which it is linked to the GIS. However, once the GIS and the model are linked, they can be used to evaluate different features of the data, whether it is spatial or non-spatial. The predictive modelling, on the other hand, is a more powerful modelling tool where an expert acquires data and uses it to build a statistical model and then tested by regression analysis. Once the model has been tested on known data, it is applied to new data in order to predict results. This type of modelling has been used to predict processes like flooding, groundwater contamination, and soil loss. Similarly it is used to carry out the land use – transportation (road density) interaction study which is the subject of this paper [7]. The ability to link GIS to these models has greatly increased the usefulness of GIS as a scientific tool.

With respect to the land use – transportation (road density) interaction modelling, which is the subject of this paper, the predictive modelling is applied. The proposed model uses an open-source urban simulation application where as many as eighteen independent variables involving two major towns are tested to determine the most significant parameters that contribute to the urban road density.

In assisting the modelling process, a GIS is used to establish the geospatial database which includes data of various forms and from various sources. The model is regressed by least square fitting method and calibrated to study the level of acceptability. With the future land use plan the model is then used to predict the road density level and again GIS is applied to import the forecasted data and graphically display the distribution. The results demonstrate that only five variables show the significant effects on the road density with each town has its own combination of these parameters [7].

The modelling requires certain parameters of a base year data. Some data are of spatial nature while the other are purely numbers representing a certain quantity. The spatial datasets may be extracted from many sources such as maps, aerial photographs and satellite images.

In preparing datasets, a geospatial database representing mainly the land use data of the two study towns is established. A number of analytical functions including map overlay, distance measurement and attribute data manipulation is applied to extract the required information. The GIS's cartographic tool is later used (after the model is established) to demonstrate the actual, predicted and forecasted road density levels of each town.

A geospatial database is a database that contains objects with locational information. Maps are an example of a medium that stores geospatial objects such as land uses (residential areas, roads, etc). With the advent of information technology tools such as those available in GIS, this geospatial information can be stored in a digital database, which can then be easily and quickly retrieved and analyzed for certain purposes.

CHAPTER 3
METHODOLOGY

For successfully completing a GIS project, it is crucial to follow a sequence of activities which are discussed here. Prior to this, the required data need to be identified and the sources of data require being located. It is also required to arrange a significantly elaborate working plan and proceed step by step following this work plan.

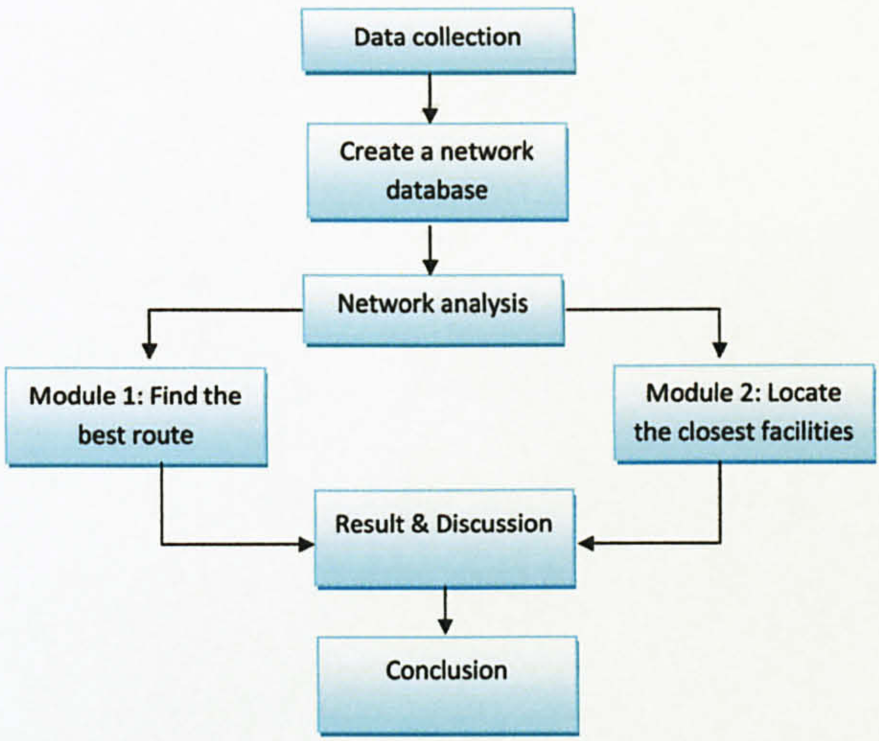

Figure 3: analysis work flow

3.1 Project Tool

In this case of study, ArcView GIS software is used. ArcView Network Analyst solves problems associated with any network. By using the software, users can;

- Access geographic network data based on ARC/INFO® coverages, ESRI shapefiles, or computer-aided design (CAD) drawings.
- Find the most direct route between two locations, or find the best way to visit several locations.

3.2 Data Collection

Data can abundantly obtain. But all data are in it very own format. Usually data is obtained as AutoCad (.dwg, .dxf) format. In order to work this thing out, the data has to be export or convert into shapefile (.shp) format file. A shapefile is a completely different creature compared to a DWG. For instance a shapefile can only contain one entity type (point, line or polygon). A shapefile only contains spatial and attribute data. It cannot contain layout information. A shapefile can not contain text features. A shapefile is made up of multiple files each with a specific purpose.

3.3 Creating a Network Database

Networks used by ArcView GIS Network Analyst are stored as network datasets. A network dataset is created from the feature source or sources that participate in the network. It incorporates an advanced connectivity model that can represent complex scenarios, such as multimodal transportation networks. It also possesses a rich network attribute model that helps model impedances, restrictions, and hierarchy for the network. The network dataset is built from simple features (lines and points) and turns. The following (figure 4) is an example of a transportation network in downtown Klang Valley.

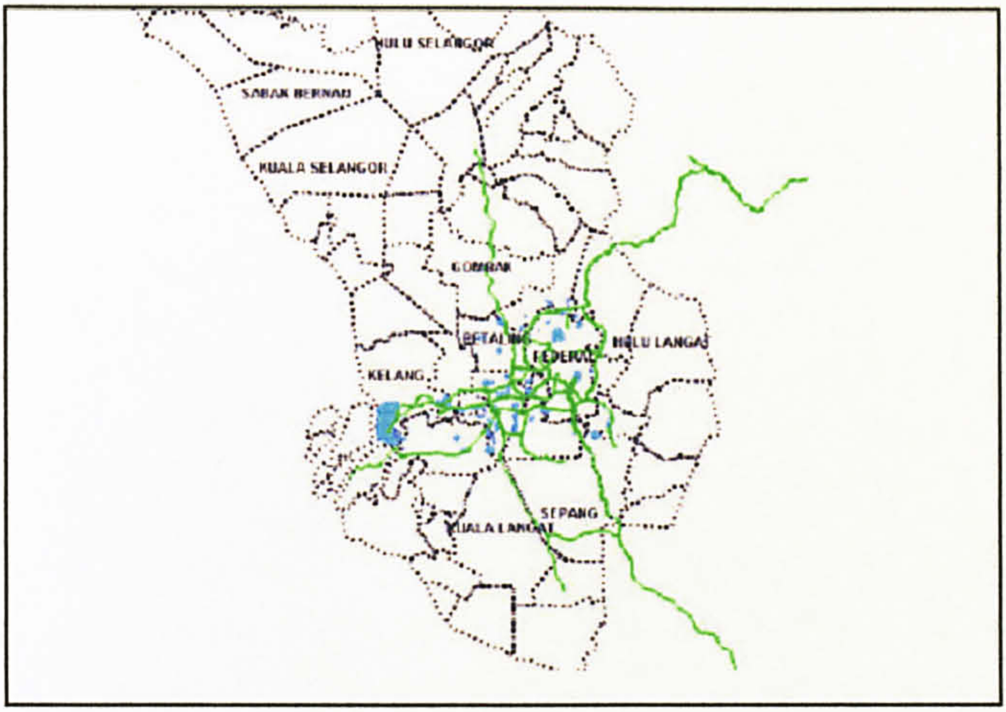

Figure 4: transportation network in Klang Valley

In ArcView GIS, a network was created when a network analysis function was run on a line shapefile. The network dataset then stores and can be modify its properties, and create a variety of networks using network datasets.

3.4 Network Analysis

Once the network datasets are set, the network analysis can be done. In this case of project study, network analysis including;

- Find the Best Routes
  Best route for the given order of stops based on travel distance.
- Locate the Closest Facilities
  Find the closest facilities (e.g., gas station) that can respond at a given location.

3.4.1 Finding the best routes

In this project study, we will find the best route for the given order of stops based on travel cost which in this case In this case, the travel cost is length. This is the simplified work flow in finding the best route using Arcview software.

3.4.1a Finding Simple Route

Plenty of methods can be done in finding a route direction from one point to another. Here in this case, if one enter the Penang Island and intends to leave right away from the island to the bridge.

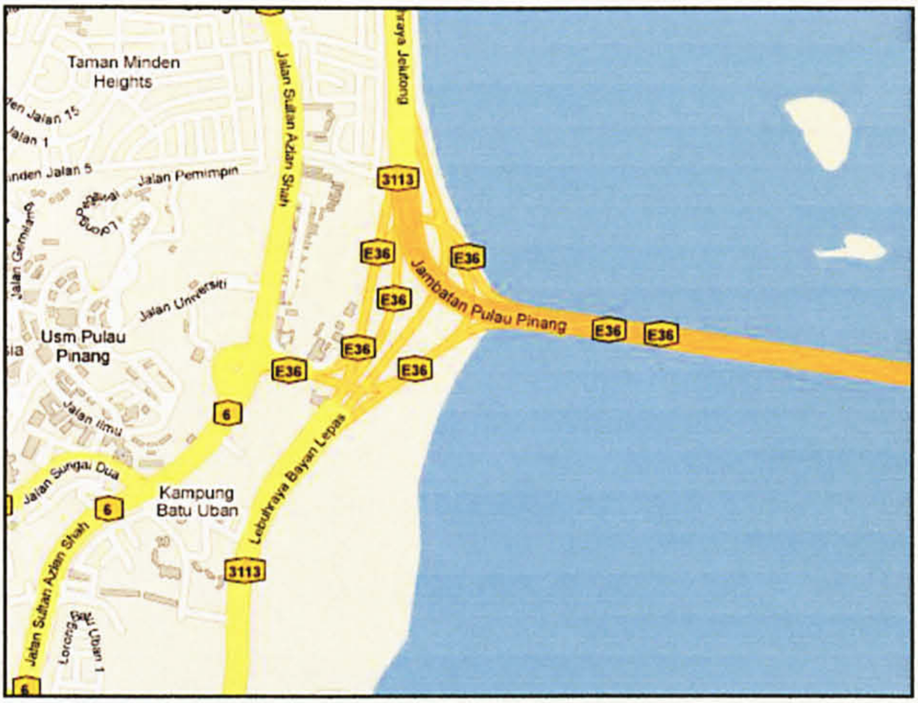

Figure 5: road network nearby the bridge

Maps were superimposed on one another for the analysis. All the routes and stops maps were superimposed on the above said maps. Using Network Analysis Extension 'Find the Best Route' option was used for this analysis.

3.4.1b Finding the Best Routes – Places of Interest

For an example, imagine a traveller intend to visit selected places of interest around Pulau Pinang. Hence, it is necessary to know the best route should be taken in best order of destinations.

Figure 6: places of interest in Pulau Pinang

A collective series of procedures has to be identified and established in order to achieve desired objectives of analysis. Therefore, the following are basic parts of network analysis procedure.

a) Creating the route analysis display

The network analyst window now contains detailed road network map and boundary region of Pulau Pinang themes.

Figure 7: layers of themes is set

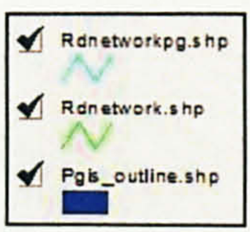

Figure 8: shapefile data input

b) Adding stop points

Adding destinations from a point file for which a layer file has been created. Now, there are 8 desired destinations are listed and are displayed as places of interest on the map.

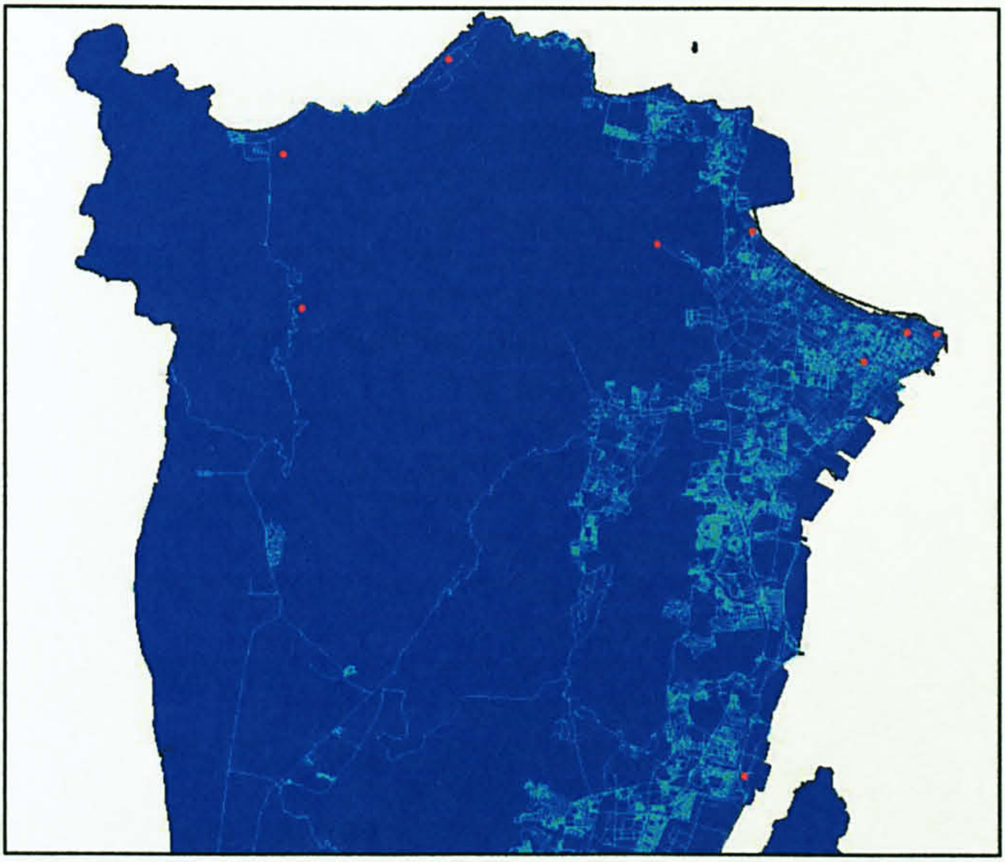

Figure 9: layer of places of interest is set

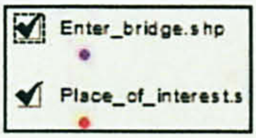

Figure 10: shapefile data input

c) Setting up the parameters for the analysis

To specify that your route will be calculated based on distance, that all locations are visited in best order that the traveller return to the origin.

d) Run the process to compute the best route

The route polyline appears in the map and in the route category. The polyline shows the best way to take from point (Bridge) and return, taking account the stops at all places. The direction is showed for more detail including the distance and distance taken.

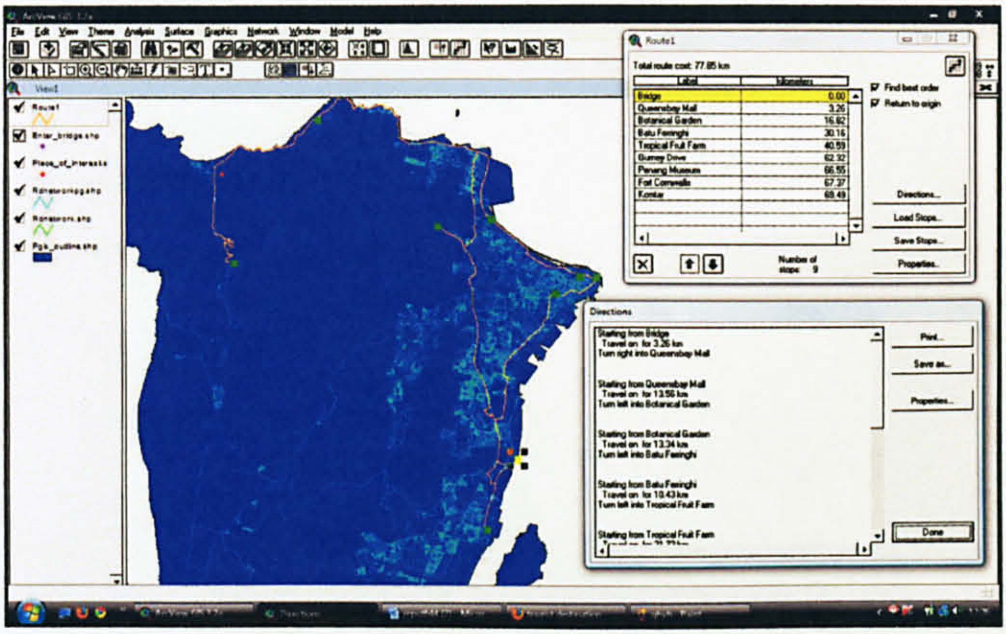

Figure 11: best route polyline and directions detail

3.4.2 Locating the closest facilities

In this case study, we will find the closest facilities which in this case, gas stations around Pulau Pinang that can respond to a certain location.

Figure 12: gas station locations in Pulau Pinang

Similarly, a series of procedures has to be identified and established in order to achieve desired objectives of analysis. There are different slight in setting up events and parameters. Therefore, the following are basic parts of network analysis procedure.

a) Creating the road network and region boundary layer

The network analyst window now contains detailed road network map and boundary region of Pulau Pinang themes.

b) Adding facilities

Add facilities (gas station) from a point file for which a layer file has been created. Now, there are 49 gas stations are listed and are displayed as facilities on the map.

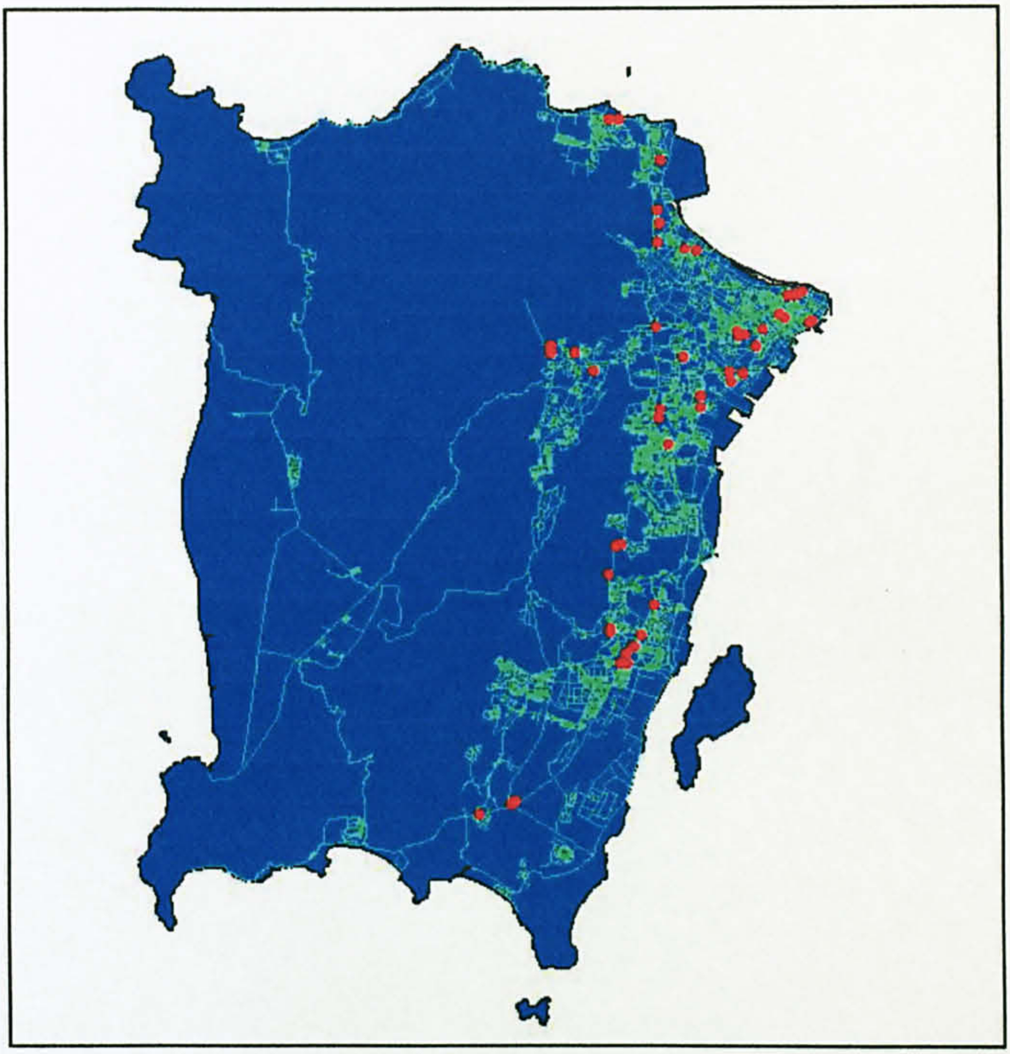

Figure 13: listed facilities – gas station

c) Setting up the events

To specify the parameters of the closest facility analysis.

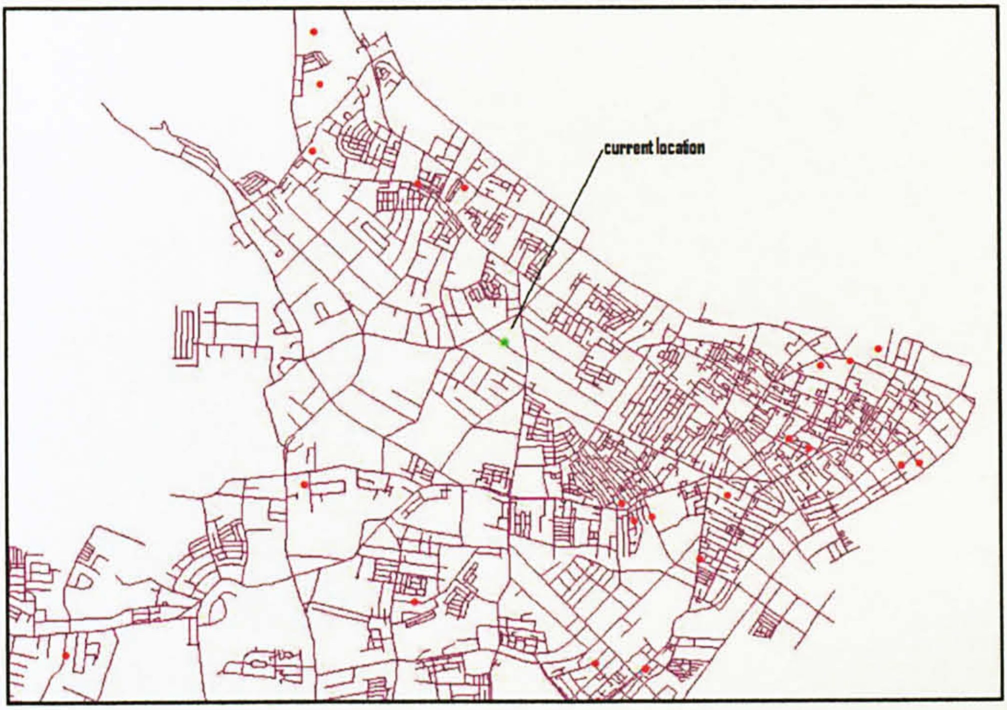

Figure 14: finder current location

d) Run the process to identify the closest facility

The routes appear in the map and in the route category.

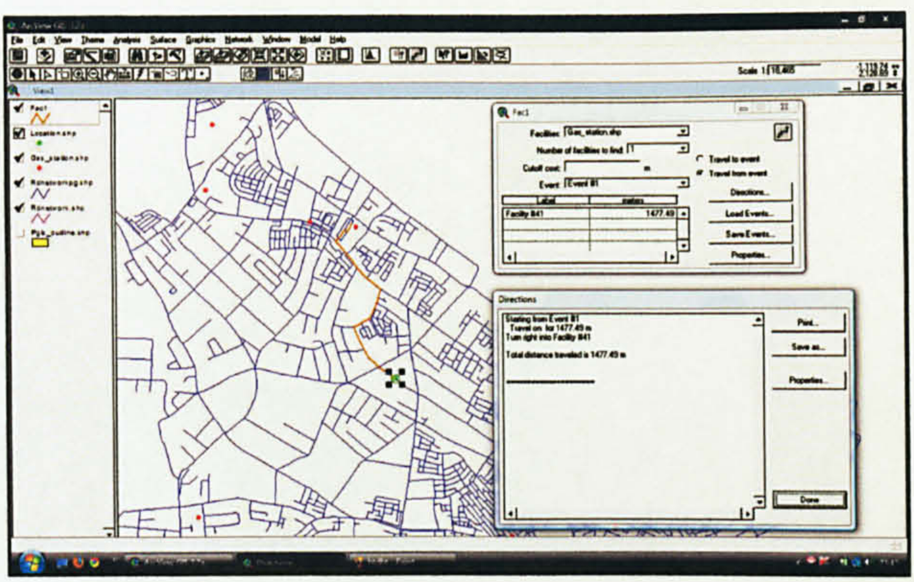

Figure 15: calculated route polyline and details

CHAPTER 4
RESULTS & DISCUSSIONS

Throughout this project study, it is shows that network analysis has numerous types of data and analysis method. But, in this case of study, as mentioned before, it is including; (1) find the best route (2) find the closest facility.

4.1 Finding the Best Route

Several of methods can be done in finding a route direction from one point to another. Here in this case, if one enter the Penang Island and intends to leave right away from the island to the bridge. Maps were superimposed on one another for the analysis. All the routes and stops maps were superimposed on the above said maps. Using Network Analysis Extension 'Find the Best Route' option was used for this analysis.

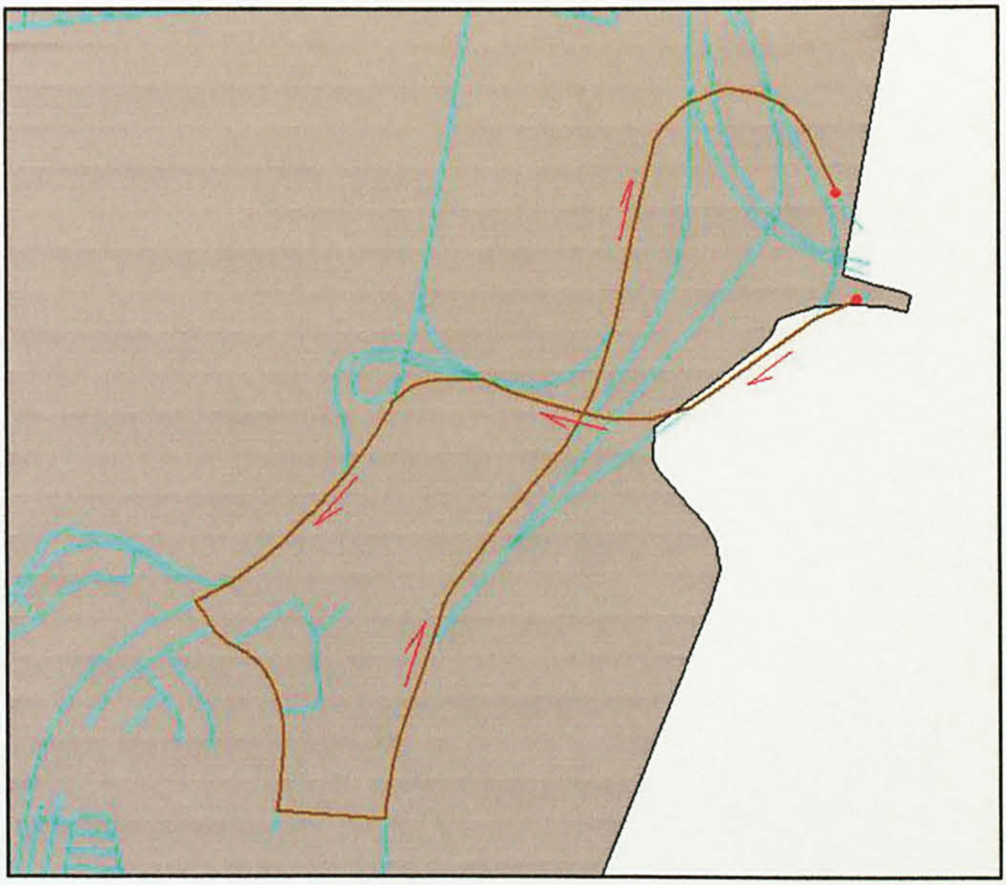

Figure 16: calculated route polyline

Total distance travelled is 3.7 km. The route was given with the exact directions which are significant to the calculated route. The directions are;

- Starting from Event #1
  Turn left onto Jalan Sultan Azlan Shah
  Travel on Jalan Sultan Azlan Shah for 1350 m

- Turn left onto Jalan Batu Uban
  Travel on Jalan Batu Uban for 400 m

- Turn left onto Jalan Batu Uban
  Travel on Jalan Batu Uban for 190 m

- Turn left onto Lebuhraya Bayan Lepas
  Travel on Lebuhraya Bayan Lepas for 1750 m

There are several important places of interest in Pulau Pinang. Since the island is located at a strategic point along the peninsular Malaysia west coast, it has been considered as the best place for tourism. There are various places of interest located on the island. These are (1) Fort Cornwallis (2) Queensbay Mall (3) Komtar (4) Penang Museum (5) Botanical Garden (6) Gurney Drive (7) Tropical Fruit Farm (8) Batu Ferringhi.

The results of the network analysis of two categories of problems mentioned under objectives of study are presented in this section. In this study, road network map and boundary map of the Pulau Pinang were used. These two maps were superimposed on one another for the analysis. All the routes and stops maps were superimposed on the above said two maps. Using Network Analysis Extension 'Find the Best Route' option was used for this analysis. Graphic picks were used on these desired locations and traced the route optimum path using the 'Find Best Order' option. In this case, the impedance factor, namely, travel cost has been considered as length as the criteria for network tracing.

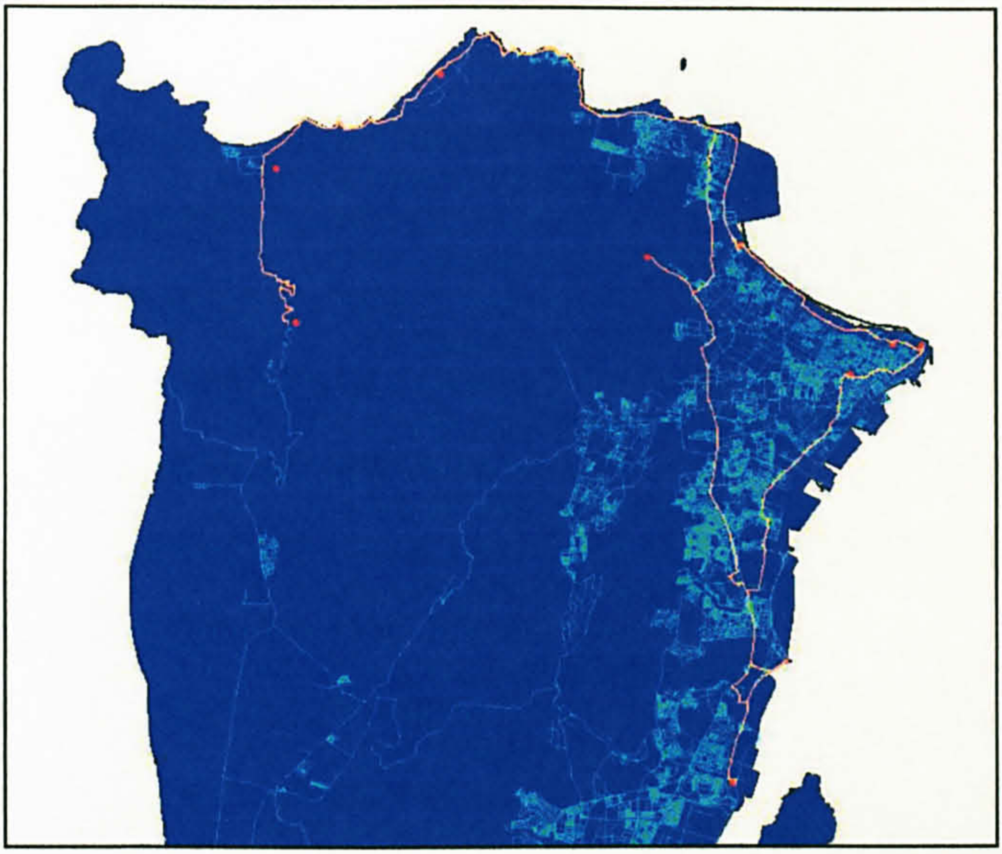

Figure 17: all destinations connected in a path

Noticed that the selected destinations were picks and set into database randomly. However, it is turns into the best order path after the analysis is done.

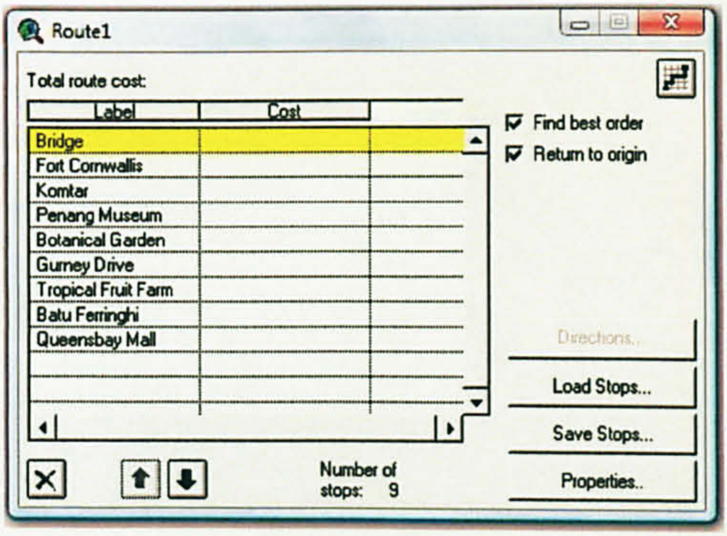

Figure 18: point location which randomly picks

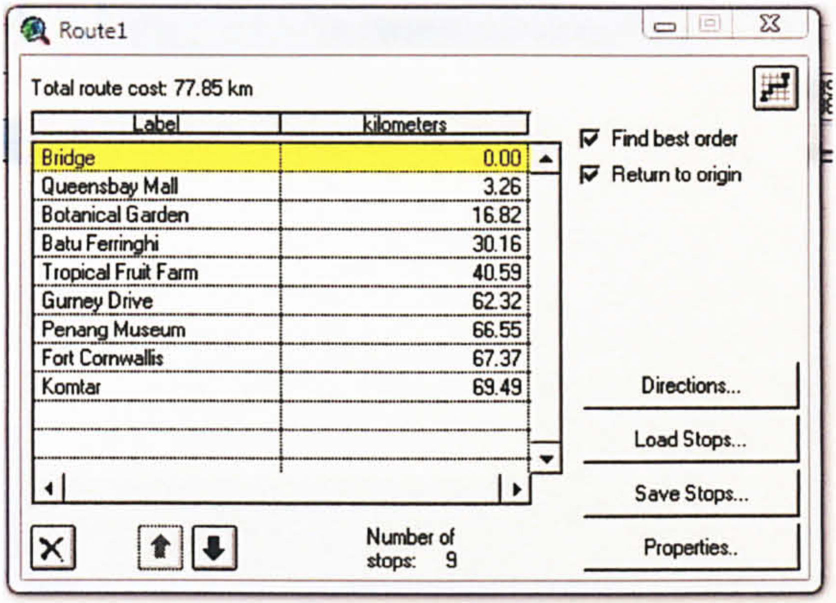

Figure 19: location is formed into best order

To find out which route one has to take if one intends to visit all the places of interest, using 'find the best route' option in the network analysis tool, the problem was solved. All the said places of interest were traced and route followed was from the point of 'Bridge' through all selected location and end at origin. It shows that the distance took is 77.85 km. In this case, the travel cost is length (see appendix for detail direction).

4.2 Locating the Closest Facilities

To find out which route one has to take if one intends to find the closest facility which in this case is gas station, the existing gas station location, detailed road network map, and boundary map of Pulau Pinang were used in this analysis. These three maps were superimposed on one another. All the 49 gas stations around Pulau Pinang were traced.

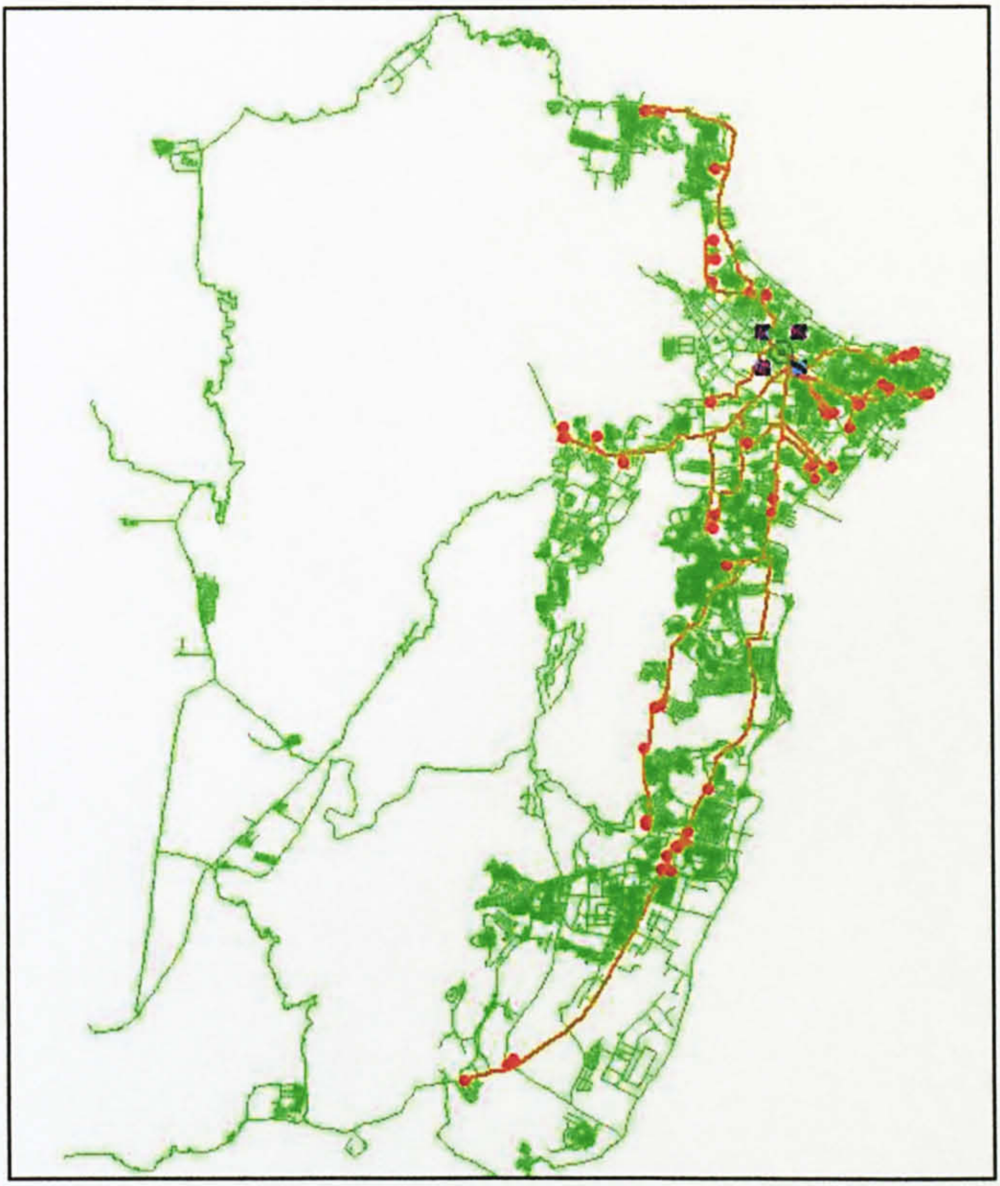

Figure 20: all responding gas station route

Using the 'Find Closest Facility' option of the network analysis. It is found that the closest gas station from the current location is 1477.49 m away.

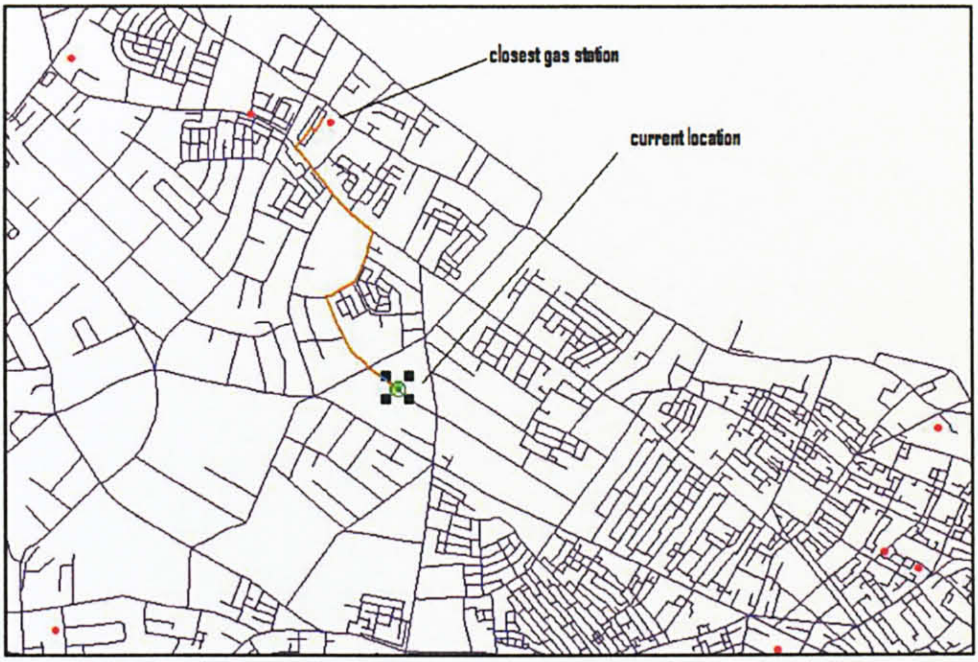

Figure 21: nearest facility (gas station) spotted

The route was given with the exact directions which are significant to the calculated route (refer appendices for detail of direction).

CHAPTER 5
ECONOMIC VALUES

5.1 Business Element

Routes and networks are the interrelated features that are used for transportation and include highways, and city streets. Intricate networks of road require analysis to improve the movement of people, goods, services and the flow of resources. To exhibit the use of network analysis, this study focused on determining the optimal route between two or more destinations based on specific travel expense. Geographical Information System (GIS) software is used to determine the quickest way or the shortest way between locations. Using ArcView with the extension of Network Analysis does analysis of such complicated networks. Hence, the tasks can be accomplished by:

- Study of the transportation sub fields by their respective implementation to the GIS
- Obtaining data of the study area
- Manipulation of data from the geographical spatial data
- Analyzing the data by using GIS software
- Querying the attributes of road network through database and graphics
- Evaluation of the study and analysis of the road network

Through all the collectives procedure done to complete the tasks, cost can be vary due to the constraints. In the other hand, the project does not have large cost attributes to numerous procedures. Well in this case, the project cost is respect to the GIS software and data availability. Hence, cost may imply on these factors.

5.2 Project Cost

GIS software has a wide range of choice which is not quite different compared to a software developer to another. There might be slight different in functions and input. But, it always has the same targets or goals in GIS analysis. Usually software costs a large amount of money and it is often applicable for the commercial use in organization. Therefore, as this project going, the cost of the software is often neglected.

Data can abundantly obtain. But all data are in it very own format. In addition, not all data obtained have specific desired requirement for specific project. On the other hand, data sometimes are not meant for free. This is usually involving detailed and confidential specific data. Hence, data often can be purchased through agencies who does provides specific data with specific requirements for the use of analysis.

CHAPTER 6
CONCLUSIONS & RECOMMENDATIONS

In this stage of project had given the exposure of understanding theory and geometry of the GIS system. The approach taken toward the project will ensure that the data is fully optimized and fully functional.

In the present study, two categories of network analysis problems were solved using mostly ArcView Network Analyst extension module. Which are; to find the best route - which route one has to take if one intends to travel all the places of interest with shortest path and best possible order. And to locate the closest facility - which route one has to take if one intends to go from current place to any other closest facility of choice, through entire road network. The methodology provides a means to incorporate existing data sources, integrate the data in a useful environment and visualize results.

In order to maintain efficiency and accuracy of the analysis results obtained, there might be a few recommendations or modification can be made. Transportation network are changing from time to time due to rapid development of particular area. An analysis is depending on the liability of the information itself in order to avoid any biases. Therefore, data collected should be the latest information to achieve high accuracy of results.

A road network analysis required attributes that are necessary to the project objectives. In this analysis, an attribute is a property of a managed object that has a value. Mandatory initial values for attributes can be specified as part of the managed object class definition. Attributes may be either mandatory or conditional. In respond, information obtained should keep enough data of attributes for a analysis. Therefore, high efficiency of analysis can be obtained as the data is well connected to one and another.

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APPENDICES

1. Detail travel route of places of interest in Penang Island
2. List of facility – Gas Station
3. Detail travel route of nearest facility – Gas Station

APPENDIX 1 - Detail travel route - places of interest in Penang Island

Starting from Bridge
Turn right onto Lebuh Raya Sungai Nibong
Travel on Lebuh Raya Sungai Nibong for 3.00 km
Turn left onto Pesiaran Bayan Indah 1
Travel on Pesiaran Bayan Indah 1 for 0.16 km
Turn right onto Pesiaran Bayan Indah
Travel on Pesiaran Bayan Indah for 0.11 km
Turn right into Queensbay Mall

Starting from Queensbay Mall
Turn left onto Pesiaran Bayan Indah
Travel on Pesiaran Bayan Indah for 0.11 km
Turn left onto Pesiaran Bayan Indah 1
Travel on Pesiaran Bayan Indah 1 for 0.16 km
Turn right onto Lebuh Raya Sungai Nibong
Travel on Lebuh Raya Sungai Nibong for 1.71 km
Turn left onto Jalan Batu Uban
Travel on Jalan Batu Uban for 0.62 km
Turn right onto Jalan Sultan Azlan Shah
Travel on Jalan Sultan Azlan Shah for 2.46 km
Turn left onto Hala Pemancar
Travel on Hala Pemancar for 0.11 km
Turn left onto Jalan Pemancar
Travel on Jalan Pemancar for 0.35 km
Turn right onto Jalan Bunga Raya
Travel on Jalan Bunga Raya for 0.41 km
Turn right onto Lebuh Bingham
Travel on Lebuh Bingham for 0.01 km
Turn left onto Jalan Selatan
Travel on Jalan Selatan for 0.18 km
Turn right onto lorong tepi
Travel on lorong tepi for 0.01 km
Turn left onto Jalan Selatan
Travel on Jalan Selatan for 0.13 km
Continue straight onto Jalan Utara
Travel on Jalan Utara for 0.14 km
Turn left onto Jalan Masjid Negeri
Travel on Jalan Masjid Negeri for 3.11 km
Continue straight onto Jalan Scotland
Travel on Jalan Scotland for 0.91 km
Turn left onto Jalan Brook
Travel on Jalan Brook for 0.78 km
Turn left onto Jalan Utama
Travel on Jalan Utama for 1.12 km
Continue straight onto Jalan Kebun Bunga
Travel on Jalan Kebun Bunga for 1.25 km
Turn left into Botanical Garden

Starting from Botanical Garden
Turn right onto Jalan Kebun Bunga
Travel on Jalan Kebun Bunga for 1.25 km
Turn left onto Jalan Gottlieb
Travel on Jalan Gottlieb for 0.62 km
Turn left onto Jalan Mount Erskine
Travel on Jalan Mount Erskine for 2.04 km
Continue straight onto Jalan Fettes
Travel on Jalan Fettes for 0.02 km
Turn right onto lorong tepi
Travel on lorong tepi for 0.04 km
Turn left onto lorong belakang
Travel on lorong belakang for 0.03 km
Turn right onto Newspring Drive
Travel on Newspring Drive for 0.07 km
Turn left onto Jalan Evergreen
Travel on Jalan Evergreen for 0.30 km
Turn right onto Orchard Avenue
Travel on Orchard Avenue for 0.05 km
Turn left onto Jalan Bintang
Travel on Jalan Bintang for 0.16 km
Turn right onto Jalan Lim Liew Saik
Travel on Jalan Lim Liew Saik for 0.08 km
Turn left onto Jalan Gajah
Travel on Jalan Gajah for 0.60 km
Turn left onto Jalan Tanjung Bungah
Travel on Jalan Tanjung Bungah for 3.10 km
Continue straight onto Jalan Batu Ferringghi
Travel on Jalan Batu Ferringghi for 4.99 km
Turn left into Batu Ferringhi

Starting from Batu Ferringhi
Turn left onto Jalan Batu Ferringghi
Travel on Jalan Batu Ferringghi for 1.24 km
Continue straight onto Jalan Telok Bahang
Travel on Jalan Telok Bahang for 3.87 km
Continue straight onto Jalan Hassan Abas
Travel on Jalan Hassan Abas for 0.00 km
Turn left onto Jalan Telok Bahang
Travel on Jalan Telok Bahang for 5.32 km
Turn left into Tropical Fruit Farm

Starting from Tropical Fruit Farm
Turn right onto Jalan Telok Bahang
Travel on Jalan Telok Bahang for 5.32 km
Turn right onto Jalan Hassan Abas
Travel on Jalan Hassan Abas for 0.00 km
Continue straight onto Jalan Telok Bahang
Travel on Jalan Telok Bahang for 3.87 km
Continue straight onto Jalan Batu Ferringghi

Travel on Jalan Batu Ferringghi for 6.23 km
Continue straight onto Jalan Tanjung Bungah
Travel on Jalan Tanjung Bungah for 3.46 km
Continue straight onto Jalan Tanjung Tokong
Travel on Jalan Tanjung Tokong for 2.57 km
Continue straight onto Jalan Kelawai
Travel on Jalan Kelawai for 0.10 km
Turn left onto Tingkat Kelawai
Travel on Tingkat Kelawai for 0.01 km
Turn left onto jalan susur
Travel on jalan susur for 0.13 km
Continue straight onto Jalan Khidmat
Travel on Jalan Khidmat for 0.03 km
Turn right into Gurney Drive

Starting from Gurney Drive
Turn right onto Jalan Khidmat
Travel on Jalan Khidmat for 0.16 km
Turn right onto Pesiaran Gurney
Travel on Pesiaran Gurney for 1.84 km
Turn left onto Jalan Sultan Ahmad Shah
Travel on Jalan Sultan Ahmad Shah for 1.75 km
Continue straight onto Lebuh Farquhar
Travel on Lebuh Farquhar for 0.47 km
Turn right into Penang Museum

Starting from Penang Museum
Turn left onto Lebuh Farquhar
Travel on Lebuh Farquhar for 0.01 km
Turn right onto Lebuh Light
Travel on Lebuh Light for 0.71 km
Turn left onto Jalan Tun Syed Sheh Barakbah
Travel on Jalan Tun Syed Sheh Barakbah for 0.10 km
Turn left into Fort Cornwallis

Starting from Fort Cornwallis
Turn right onto Jalan Tun Syed Sheh Barakbah
Travel on Jalan Tun Syed Sheh Barakbah for 0.10 km
Continue straight onto Jalan Pantai
Travel on Jalan Pantai for 0.83 km
Turn right onto Lebuh Armenian
Travel on Lebuh Armenian for 0.34 km
Turn right onto Lebuh Acheh
Travel on Lebuh Acheh for 0.04 km
Turn left onto Lebuh Carnarvon
Travel on Lebuh Carnarvon for 0.37 km
Continue straight onto Lebuh McNair
Travel on Lebuh McNair for 0.02 km
Turn right onto Jalan Gladstone

Travel on Jalan Gladstone for 0.34 km
Turn right onto Jalan Cheong Fatt Tze
Travel on Jalan Cheong Fatt Tze for 0.07 km
Turn right into Komtar

Starting from Komtar
Turn left onto Jalan Cheong Fatt Tze
Travel on Jalan Cheong Fatt Tze for 0.07 km
Turn right onto Jalan Gladstone
Travel on Jalan Gladstone for 0.09 km
Turn left onto Jalan Gurdwara
Travel on Jalan Gurdwara for 0.95 km
Turn right onto Jalan Jelutong
Travel on Jalan Jelutong for 2.77 km
Turn left onto lorong belakang
Travel on lorong belakang for 0.59 km
Continue straight onto Jalan Faraday
Travel on Jalan Faraday for 0.26 km
Turn left onto Jalan Tunku Kudin
Travel on Jalan Tunku Kudin for 0.02 km
Turn right onto Jalan Faraday
Travel on Jalan Faraday for 0.91 km
Turn right onto Jalan Akuarium
Travel on Jalan Akuarium for 0.25 km
Turn left onto Jalan Sultan Azlan Shah
Travel on Jalan Sultan Azlan Shah for 1.54 km
Continue straight onto Lebuh Raya Sungai Nibong
Travel on Lebuh Raya Sungai Nibong for 0.93 km
Turn left into Bridge

Total distance traveled is 77.85 km

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APPENDIX 2 - List of facility – Gas Station

No.	Facility	Distance
1	Gas Station #1	17062.58 m
2	Gas Station #2	16175.86 m
3	Gas Station #3	16006.05 m
4	Gas Station #4	10445.92 m
5	Gas Station #5	10525.61 m
6	Gas Station #6	9425.82 m
7	Gas Station #7	10396.92 m
8	Gas Station #8	10907.88 m
9	Gas Station #9	11196.48 m
10	Gas Station #10	11249.49 m
11	Gas Station #11	11055.00 m
12	Gas Station #12	11283.76 m
13	Gas Station #13	9016.96 m
14	Gas Station #14	8171.78 m
15	Gas Station #15	8114.66 m
16	Gas Station #16	3336.16 m
17	Gas Station #17	3490.08 m
18	Gas Station #18	2648.78 m
19	Gas Station #19	2463.74 m
20	Gas Station #20	2050.11 m
21	Gas Station #21	2387.68 m
22	Gas Station #22	1786.27 m
23	Gas Station #23	1908.60 m
24	Gas Station #24	2711.28 m
25	Gas Station #25	2883.39 m
26	Gas Station #26	3230.96 m
27	Gas Station #27	5616.16 m
28	Gas Station #28	5480.49 m
29	Gas Station #29	5096.82 m
30	Gas Station #30	4416.64 m
31	Gas Station #31	2082.77 m
32	Gas Station #32	2324.09 m
33	Gas Station #33	4075.29 m
34	Gas Station #34	4327.69 m
35	Gas Station #35	5018.23 m
36	Gas Station #36	3289.76 m
37	Gas Station #37	3029.31 m
38	Gas Station #38	2859.90 m
39	Gas Station #39	2648.11 m
40	Gas Station #40	3011.32 m
41	Gas Station #41	1477.49 m
42	Gas Station #42	1525.59 m
43	Gas Station #43	2453.84 m
44	Gas Station #44	6882.08 m
45	Gas Station #45	7074.50 m
46	Gas Station #46	4455.45 m
47	Gas Station #47	3236.49 m
48	Gas Station #48	3117.06 m
49	Gas Station #49	1610.41

APPENDIX 3 - Detail travel route of nearest facility – Gas Station

No.	Directions
1	Starting from Event #1 Turn right onto Jalan Dunn Travel on Jalan Dunn for 146.16 m
2	Continue straight onto Jalan Pierce Travel on Jalan Pierce for 334.91 m
3	Continue right onto Lengkok Burma Travel on Lengkok Burma for 348.28 m
4	Continue left onto Jalan Burma Travel on Jalan Burma for 464.83 m
5	Continue right onto Lorong Bangkok Travel on Lorong Bangkok for 97.21 m
6	Continue right onto Lorong Tepi Travel on Lorong Tepi for 21.34 m
7	Continue left onto Lorong Belakang Travel on Lorong Belakang for 64.75 m
8	Turn right into Gas Station #41
Total distance travelled is 1477.49 m	