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SHARING OF GIS SPATIAL DATA IN TRANSPORTATION ENGINEERING

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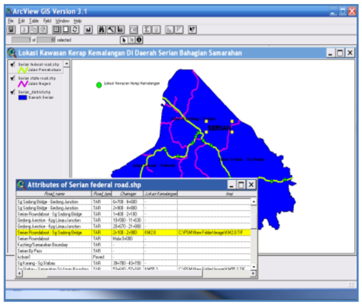
Graphical abstract



Abstract

Geographic Information System (GIS) is classified as an information technology to solve various spatial problems in civil engineering. GIS provides spatial information to the system and therefore, complex spatial analysis of problem could be carried out. The objective of this paper is to promote the use of GIS as a tool for civil engineering problem solving. This paper describes the work undertaken to demonstrate the potential use of GIS in civil engineering via a prototype project. The presentation of this article is mainly focused on the applications of GIS in transportation engineering including transportation, highway and traffic. Moreover, this study could also contribute relevant and benefit guidance to the public and private sectors with techniques in determining potential activity using the GIS software. The utilisation of GIS can prepare and contributes towards a profitable cost and effective service. The end product should be an effective information system and a final potential GIS map. With GIS support, it could assist user to make a more effective and efficient decision on any difficulties that will arise. Compared to the conventional methods, the system provides a proper and an effective, update and accessible result of spatial analysis.

Keywords: GIS, civil engineering, transportation engineering, spatial data, attribute data

1.0 INTRODUCTION

Geographic Information System (GIS) was a computer-based system that usually has been applied to manage on both spatial data and database or also known as attribute data. In addition to that particular speciality, GIS also had the ability to collect, store, process, analyse and visualize any geographic information [1]. Because of these reasons, the management of transportation was deployed into application of GIS to enhance the performance of the data handling [2]. From general observation that has been done before, a lack of performance and out-dated methods were identified in this field of study. As for information in manual management, data like maps were still stored in analog format and records were stored in hardcopy; scattered and difficult to access. Hence, a computer-based management was apparently needed to solve this sort of problems.

As an action to the road accident in transportation engineering, an effective way in controlling or even stopped the phenomenon from getting worst must be done. This can be achieved through a superb and overwhelmed management system that can handle this type of problem. Apparently, GIS was the best solution that had the ability to ease road accident investigations and making predictions for any decision to be made. This study will look into the efficiency of using GIS in transportation engineering as well as to improve the conventional methods.

The objective of this paper is to promote the use of GIS as a tool for civil engineering problem solving. This paper describes the work undertaken to demonstrate the potential use of GIS in civil engineering via a prototype project. The presentation of this article is mainly focused on the applications of GIS in transportation engineeringincluding transportation, highway and traffic.

2.0 MATERIALS

In transportation engineering studies, data were divided into two different categories that has it own identity. Spatial data represents the position on earth such as road maps. The other one was attribute data that shows record or attribute data such as road names or road classes. By using ArcInfo, those data can be stored together and are related to each other. In ArcInfo, data were not only stored, but also can be edited, processed, analysed and retrieved.

2.1 Advantages Of Using GIS

One of the advantages in using GIS as a management system was its ability to store maps and data files in one database, coverage by coverage. In addition, the coverages can also be overlayed into one map that obviously can't be done by conventional maps. The other advantages were its capability to work with complex problems that can be seen through the process of data retrieval, topography modeling, logical relationships and data visualisation. But the most important part was the ability to produce spatial data and attribute data simultaneously.

2.2 Spatial Data

Basically, spatial data was a space-geographical related data that also can be called as space data or geographic data. It can be stored as vector or raster form. Raster data were stored in bit-map format that shows the true image of data by cells or pixels. For vector data, they were stored in X-axis and Y-axis coordinate format that depends on the position of the data or the beginning and the end of any shape of images. Z-axis indicates the height of the object from datum. Raster data can be presented in line shape, ordinary or complex objects that represent the area or the networking of selected region [3].

The visualisation methods that has been produced by spatial data were to define the objects in such way that is:

i. The position of the object on earth surface (spatial components).
ii. Attribute objects that was not related to its position (non-spatial components).
iii. The relationships between the objects.
iv. The real time of those related components.

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2.3 Attribute Data/Non-Spatial Data

Attribute data can also be recognised as conventional or classic data model. Generally, attribute data were the collection of information that showed residence density, regional area, land use activities, name of a place and other valuable information. It usually been visualised in attribute's table format. There were four different ways in modeling the data that is table model, hierarchical data model, link data model and relationship data model.

2.4 GIS Components

The fundamentals of GIS were divided into four components that is the hardware, software, institution and data itself [4].

i. Hardware

Hardware has the ability to work with GIS software. Hardware including digitiser, scanner and plotter used to generate and produce the information needed by users.

ii. Software

GIS software was used to develop a system in order to generate the final product from the analysis that has been done by the users. There were two different types of software that is custom made software and generic software. Custom made software was made by the software's developer to meet the requirements needed by the users. Generic software was used for general purposes that can be found as more popular to be used by individuals or small company because it was less expensive and easy to work with.

iii. Data

Actually, the data takes the highest cost and being the most valuable component from the others. Usually, it takes almost the entire development cost of a project. Despite its expensive cost, it is also very valuable and had a long period of life.

iv. Institution

The last component was referred to the institution itself whether it was individual or organisation that designed and developed the data using GIS. In order to create a good data management system, the users must have the creativity and good skills on using GIS. This can be achieved through attending GIS courses or self-learning.

3.0 METHOD

The utilisation of GIS is still lacking in engineering works especially in transportation engineering. The method of decision making on the analysis are still being conducted using the conventional method. This is due to the fact that most data on transportation is still kept in a form that could not be linked with geographical data. Apart from that, ordinary users could not comprehend data on transportation except for the parties involved in managing the incidents.

The Purpose of this research is to monitor the potential areas for transportation using the GIS tools. There are many factors that should be considered in determining the areas that are prone to transportation, such as traffic and highway factors. This study is carried out to explore the ability of GIS in comparison to the conventional method. The phases involved in this study is as follows and shown diagrammatically in Figure 1.

1. Data collection
2. Data transfer and processing
3. Developing database
4. Spatial analysis
5. Interpretation of result and user interface development
6. Visualisation

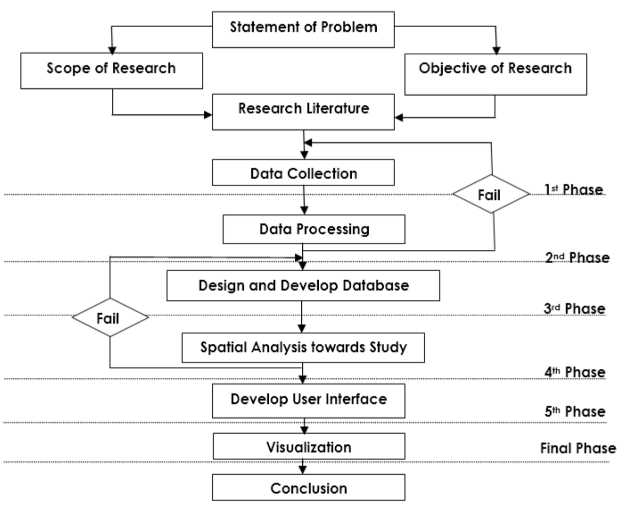


Figure 1GIS application flow chart

4.0 TRANSPORTATION ENGINEERING GIS CASE STUDIES

4.1 Case Study 1: Identify Accident Locationsin Serian Samarahan Sarawak

This study aims to identify and provide information on the accident prone areas and to develop accident prone areas database system using GIS. The main objectives of this study are to identify and provide information on the accident prone areas, and develop accident prone areas database system using GIS. The scope of the study involving basic analysis of accident data by using GIS application to determine the accident prone areas in Serian District, Samarahan Division Sarawak. Liang *et al.* summarized that GIS offer an advanced engine to drive, both area-wide and location-oriented investigation [5]. A GIS based application was chosen as the best alternative to improve the accuracy and timeliness in priorities accident location. The initial advantages are its user friendly software interface, ability to locate locations quickly and accurately on a map, database setup is inexpensive and ability to find out the accident prone area quickly. The user can retrieve accident information through the node analysis or the distribution plot which able to visualize road accident on the selected location with maps, photos, and simultaneously, further information such as site information and accident data will be display statistic graphically [5]. Currently, accident reports are prepared in textual format. This situation makes it difficult to give enough information to road users on the accident locations. Therefore, in this study, the author have developed a database system using GIS by transforming these textual data to tabular form and then this tabular data were georeferenced onto the highways and visualized in the form of map. Data gathered through interview and site inspection. Secondary data, as shown in Table 1 mainly provided by Serian Traffic Head Office and Department of Survey and Mapping of Malaysia, which was analyst, defined, summarized and organized for future retrieval. Both spatial and attributes data were collected for the development of the study. The spatial data obtained is in shapefile format and the accident data for the years 2006 to 2010 for Serian District has been taken from the relevant authorities to locate the accident prone areas. The road and accident particulars like type of road, road geometry, lighting factor, accident locations, persons injured or death are included in the GIS database. Once the development stage is completed and successful with database systems successfully developed, the data can be shown in digital using ArcView software and system inquiries have been formed to facilitate users to search for any information contained in the system. The information would be useful in adopting improvement measures to reduce accident in future.

Table 1 Attributes of accident database

Type of data	Attributes
Accident	ID Date Type of accident Type of users Factor Location Photo
Road Network	Name Width Road type ID

4.1.1 Result

The results of the GIS and the development of database applications have been developed. The results can be used in planning and management purposes to examine the appropriateness and effectiveness of the GIS. The database model was constructed showing the actual position of accident prone locations especially on the study area which is the federal road in Serian District Samarahan Division Sarawak.

Generally there are two types of major achievements in the development of the application of this GIS. One of them is a graphical search of the information related to the study area. Information can be obtained by activating the *Theme* and click on the *Identify* button (Figure 2). Apart from the table spaces in the study area, other information such as details in the form of graphic art and design report can be obtained via the *Hotlink* function (Figure 3).

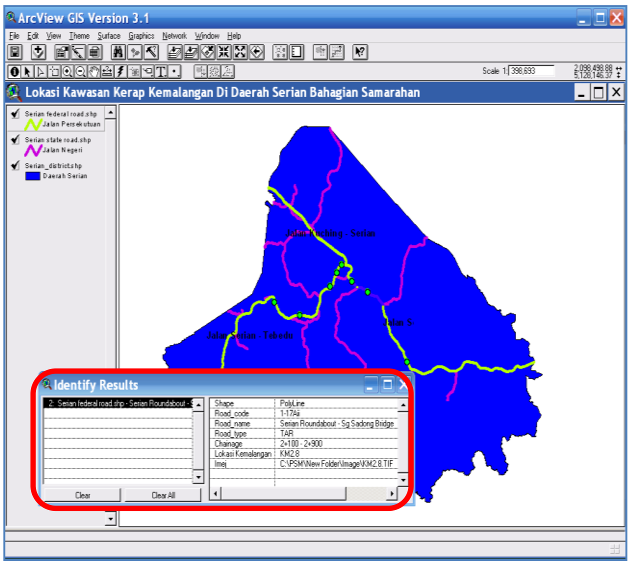


Figure 2 Search of graphic

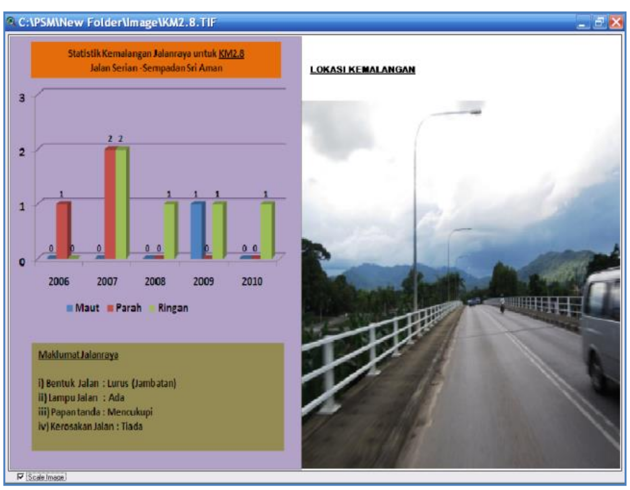


Figure 3 Hotlink preview

The second achievement is to search the database of object location of case study (Figure 4).It enables users to determine the position or the exact location of the object chosen for this study provided information and reference name is known.

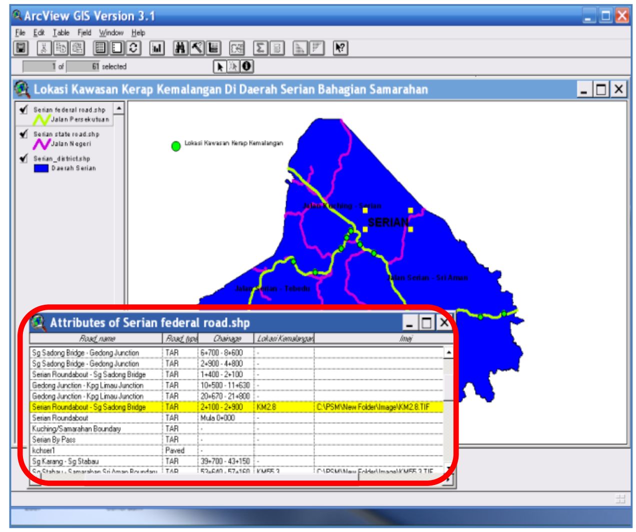


Figure 4 Search the database

Arc*View* capabilities in carrying out further analysis of the results to show the effectiveness of the GIS there. The goal is to help in civil engineering work management, planning, statistics and the purpose of analysis should be conducted. Function is used as a search *query*, the search for information in the database based on certain criteria [6].

Based on the data, the accident could be predicted by analyzing the current trend of the accident. Statistical analysis proved that the average number of accident is eight. The accidents will not more than ten cases in a month (Figure 5).

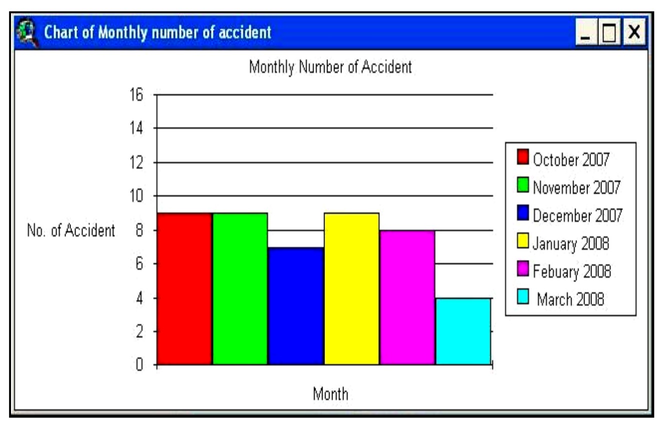


Figure 5 Accident statistic from October 2007 until March 2008

GIS may assist in decision making by suggesting road maintenance for high frequency of accident rate in certain road section. Public Work Department (PWD) may take the advantages to improve data management system in their organization with graphical database to promote high standard of work accuracy and quality. Factor divided into six categories based on cases occurred in research period. Figure 6 shows users careless is the main factor followed by collision by another which occur almost every month. Road defect also present and graphically informed that maintenance needed in that particular road section.

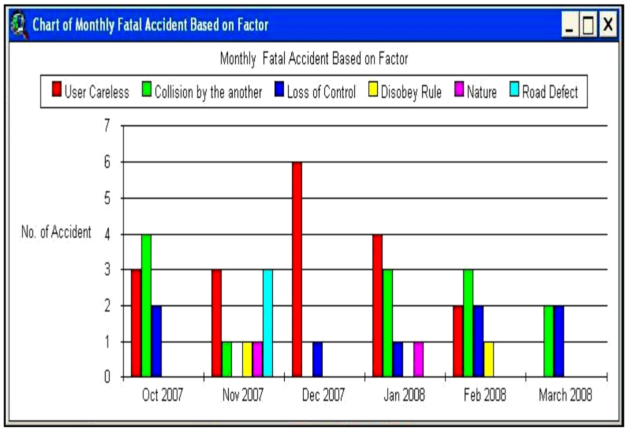


Figure 6 Monthly fatal accident based on factor

There were six types of users involved in fatal accident as shown in Figure 7. Motorcyclist is the most involved in accident which governed 52 per cent of the total accident cases. This may due to road facilities such as motorcycle lane. In the other hand, van only involved once in six months.

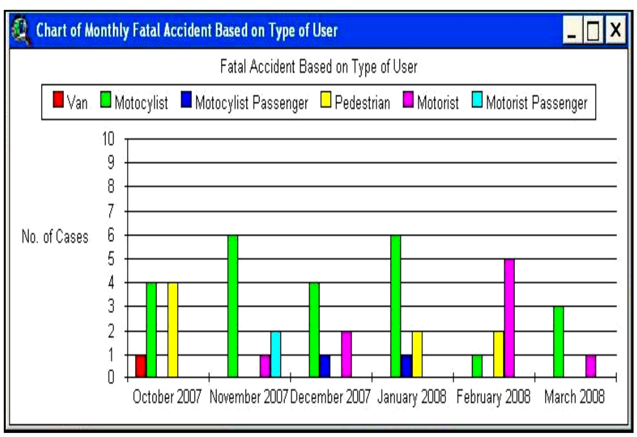


Figure 7 Monthly fatal accident based on type of user

4.1.2 Suggestions

From results of the study, it can be concluded that the objectives of the study has been achieved whereby the development of accident prone areas in district of Serian Samarahan Sarawak database using GIS has successfully been developed in order to provide enough information to the users to identify those locations. The use of GIS enables relevant accident data to be quickly processed and displayed on a map. GIS has also been used as a tool to identify hazardous locations along any other roads in Sarawak depending on the historical road accident data. These in turn will help to improve the safety of road by advanced planning and maintenance of the so-called accident-prone areas. The real ability of ArcView software as one of GIS tools was proven reliable in managing the data without requiring complicated matter in using and applying it.

Since this study focused on data modeling to provide required information only, the data modeling should include the analysis process through computer programming. Therefore in order to achieve optimum ability and effectiveness of GIS the analysis should be carried out together with its quality improvement of which can be done by providing Query operation during the data collection stage. Wider range of designing data base by using other softwares such as Microsoft Access, Microsoft Excel, FoxPro, and dBase can also be applied. Database which was designed systematically will increase the ability of GIS. Furthermore, data sources also one of the important aspects in the development of GIS model. Therefore updated and latest information should be taken into account in order to give proper outputs without any doubts. The collected data has to be precise and update. It was suggested that the data to be collected has to be based on the need of the study. As such, multiple data entries can be avoided and at the same time saving time and cost.

4.2 Case Study 2: Road Maintenance Management System

Road maintenance means to protect and to repair the construction elements of the road in order to sustain its condition. An effective Road Maintenance Management System (RMMS) is needed in order to organize the large database including the information of inventory and condition of the road [7]. Therefore, GIS which is able to integrate the spatial and attribute data can provide a systematic database management system for the road maintenance [8]. In this study, the ArcCatalog and ArcMap 10 software are used and the study area is Federal Road FT001 from Section 1 to Section 21 (from Skudai to Johor Bahru town). The matters to be sustained are divided into two main groups including the physical entities of the road and the pavement condition [9]. The study was focused on particular road information including signboard, kilometre post, bridge, and culvert for road furniture data while IRI value, rutting and texture depth for road pavement condition data. Table 2shows the spatial and attribute data obtained for this project. All the spatial data in Shapefile format were obtained from Road Facility Maintenance Branch, PWD Malaysia. While for the signboard, handheld GPS Leica GS20 was used to get the spatial location of signboard along the road. For attribute data, the pavement condition data including IRI, rutting and texture depth was provided by Road Facility Maintenance Branch as well. Raster images or photos were added to the signboard layer and also to show the road defect condition of each distance. It was done by adding photos as attachment to each feature. Other than this, the raster image also can be added directly as a field in attribute table.

Table 2 Spatial and attribute data

	Data Type	Data Format	Data Source
Spatial Data	Johor district border	Shapefile	PWD
	Cadastral lot	Shapefile	PWD
	Federal road center line (FT001)	Shapefile	PWD
	Kilometre post	Shapefile	PWD
	Bridge and culvert	Shapefile	PWD
	Signboard	Excel	GPS survey
Attribute Data	IRI	Excel	PWD
	Rutting	Excel	PWD
	Texture depth	Excel	PWD

4.2.1 Result

The result of the database can be viewed in ArcMap. The pavement data was analyzed to assess the condition of the federal road. At the end of this study, a database integrating the spatial location of the road elements and the attribute data as description was produced. Government and private sector can save cost and time in sustaining the road condition. With a good road condition, the hazardous factors due to the road condition can be minimized and a safer journey is provided to the road users. Other than this, the fully implementation of GIS at PWD is believed can help in planning and scheduling the road maintenance schedule, wisely allocating the budget and also reduction in time, cost and human resource.

As a result of inputting spatial and attribute data, the road map with details in tabular data and image visualization is presented. Figure 8 to Figure 10 shows the results of the overall road map, road furniture and road pavement condition together with the raster image which will pop up in a click and display the real condition.

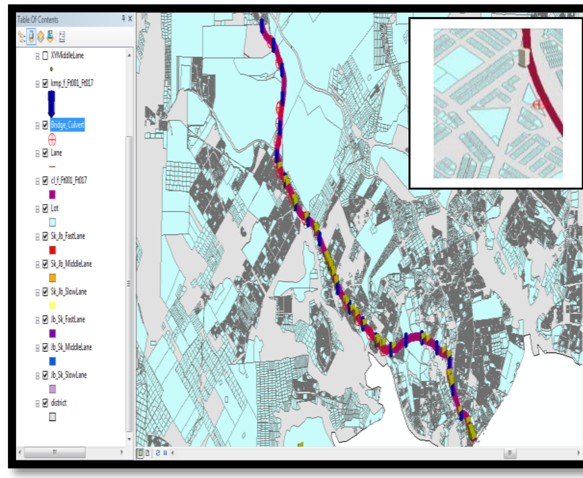


Figure 8 Displaying overall map

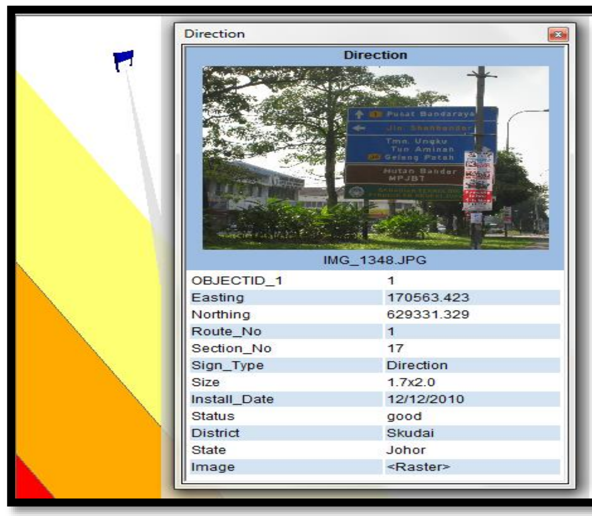


Figure 9 Signboard with attribute table and image displayed

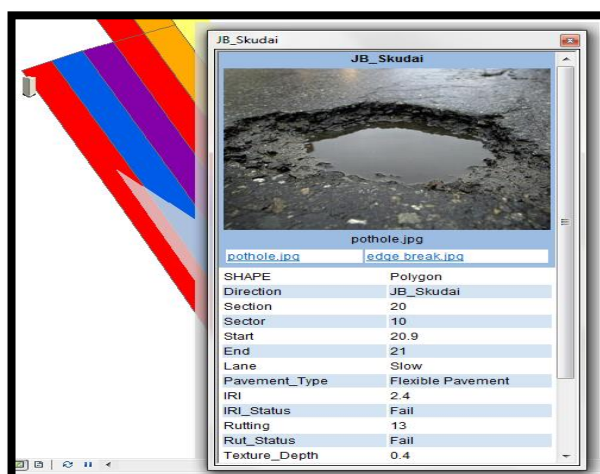


Figure 10 Road pavement condition on each part of road

For road maintenance activity, the schedule needs to be planned earlier where the status of the road needs to be known. For example, if the value of the IRI doesn't pass the required criteria, then that particular part of the road need to be maintained. By refering to the PWD criteria, the requirement for IRI to pass is less than 2.0 mm. Using the Select by Attribute function, the command "***IRI > 2.0***" is applied and all the road sectors which fail in IRI criteria will be highlighted in the attribute table, and also in the map with the colour visualization. Figure 11 to Figure 13 show the steps and result using this function.

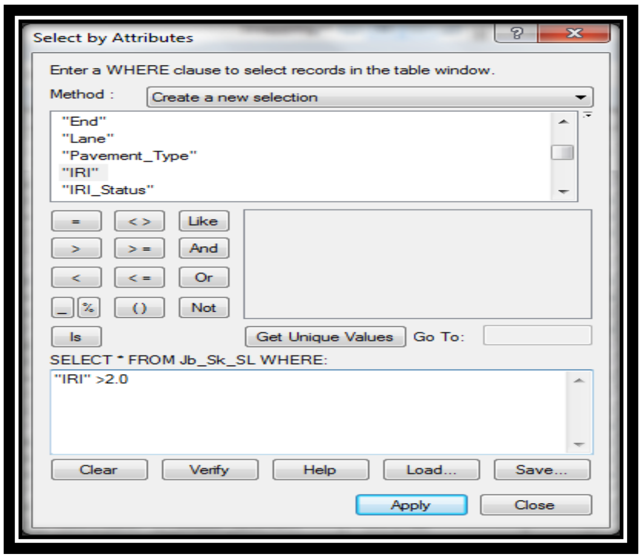


Figure 11 Displaying road condition using *Select by Attributes* function

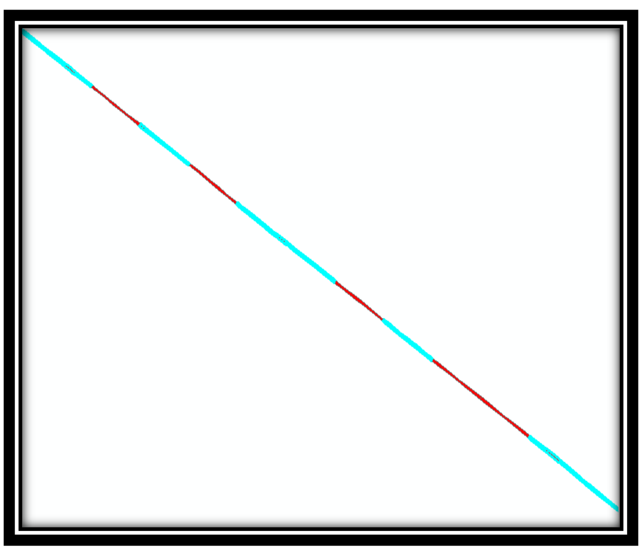
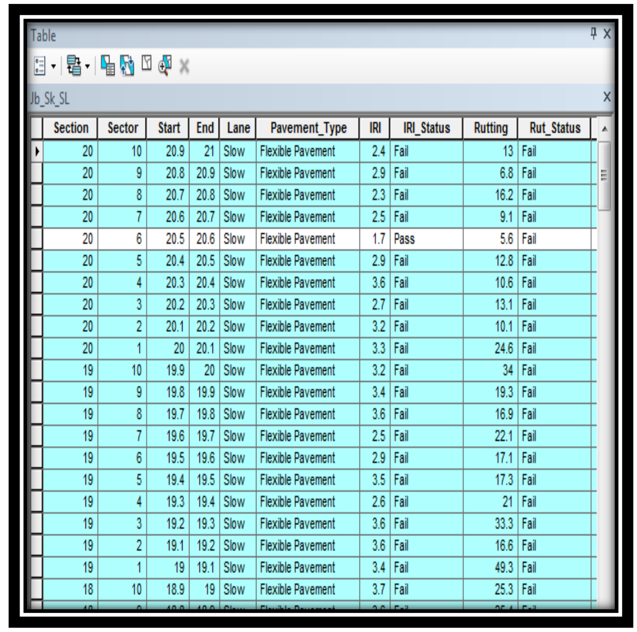


Figure 12 Road sectors which fulfilled the condition were being highlighted in green colour



Table

Jb_Sk_SL

Section	Sector	Start	End	Lane	Pavement_Type	IRI	IRI_Status	Rutting	Rut_Status
20	10	20.9	21	Slow	Flexible Pavement	2.4	Fail	13	Fail
20	9	20.8	20.9	Slow	Flexible Pavement	2.9	Fail	6.8	Fail
20	8	20.7	20.8	Slow	Flexible Pavement	2.3	Fail	16.2	Fail
20	7	20.6	20.7	Slow	Flexible Pavement	2.5	Fail	9.1	Fail
20	6	20.5	20.6	Slow	Flexible Pavement	1.7	Pass	5.6	Fail
20	5	20.4	20.5	Slow	Flexible Pavement	2.9	Fail	12.8	Fail
20	4	20.3	20.4	Slow	Flexible Pavement	3.6	Fail	10.6	Fail
20	3	20.2	20.3	Slow	Flexible Pavement	2.7	Fail	13.1	Fail
20	2	20.1	20.2	Slow	Flexible Pavement	3.2	Fail	10.1	Fail
20	1	20	20.1	Slow	Flexible Pavement	3.3	Fail	24.6	Fail
19	10	19.9	20	Slow	Flexible Pavement	3.2	Fail	34	Fail
19	9	19.8	19.9	Slow	Flexible Pavement	3.4	Fail	19.3	Fail
19	8	19.7	19.8	Slow	Flexible Pavement	3.6	Fail	16.9	Fail
19	7	19.6	19.7	Slow	Flexible Pavement	2.5	Fail	22.1	Fail
19	6	19.5	19.6	Slow	Flexible Pavement	2.9	Fail	17.1	Fail
19	5	19.4	19.5	Slow	Flexible Pavement	3.5	Fail	17.3	Fail
19	4	19.3	19.4	Slow	Flexible Pavement	2.6	Fail	21	Fail
19	3	19.2	19.3	Slow	Flexible Pavement	3.6	Fail	33.3	Fail
19	2	19.1	19.2	Slow	Flexible Pavement	3.6	Fail	16.6	Fail
19	1	19	19.1	Slow	Flexible Pavement	3.4	Fail	49.3	Fail
18	10	18.9	19	Slow	Flexible Pavement	3.7	Fail	25.3	Fail

Figure 13 The road sectors in the attribute table were highlighted

4.2.2 Suggestions

This study had shown how GIS can be implemented in RMMS by creating and managing a road database. Due to the availability of data from JKR, the researcher was focusing on managing particular road furniture data including signboard, bridge, culvert, kilometre post and pavement condition data including IRI, rutting, texture depth. Through the use of ArcCatalog and ArcMap software, an organized RMMS database was formed which enhances the data storing, editing and visualizing. GIS should be fully implemented in PWD to store and manage all the road data from related department in order to improve the road maintenance management system in Malaysia. An integrated database can save a lot of time, cost and human resource in dealing with bulky road information. A good RMMS is to focus on maintaining the good condition of road once it was constructed. It is not the matter of how fast and how good the road can be repaired.

A good RMMS can help PWD in preparing and allocating the budget cost of road maintenance and also the distribution the maintenance work and budget to the private company. The system can integrate all databases from different company to make the job more efficient.

For future development, this study can be integrated with mathematical formulas and programming to enhance this RMMS in calculating the IRI value automatically. Besides, the integration of flood management or stormwater management can also help in planning the new transportation routes. By knowing the related environmental factors, the design of road furniture and pavement can be improved in order to last for longer. In addition, future researcher may produce 3-dimensional view for the road condition to show the structure of the road even clearer.

4.3 Case Study 3: Road Network Analysis

Routes and networks are the interconnected features that are used for transportation including highways, railways, city streets, rivers, transportation routes (transit, school buses), and utility systems. Networks are an important part of our everyday lives and analysis of these networks improves the movement of people, goods, services and the flow of resources [10]. Route planning is one of the most popular applications within transportation, for obvious reasons. Consequently, any business deploying vehicles is interested in determining which route is the best to follow as means to save time and essentially gain the best cost/benefit ratio. This can be used to distribute goods and delivering materials such as newspapers, respond to emergency calls, or to plan your personal travel [11]. This study focuses on the GIS in the field of transportation to determine the optimal route between two destinations including the complicated road networks based on a specific travel expenses such as travel time and travel distance. The GIS data was obtained by digitizing an aerial photograph. The basic data was collected in the form of AutoCAD drawing format. This data includes the map of the study area which contains the details of the road network, surrounding area and destinations of the roads. The network of road contains all the roads which are analyzed in final analysis of this study. Furthermore, some other data from roads was also collected by measuring and observing the network which contain the following:

- i. directional resistance i.e. whether the road is one way or both way,
- ii. traffic resistance on the road,
- iii. speed limits i.e. total speed is allowed to drive,
- iv. travel time i.e. total time it will take to drive on that segment of road,
- v. length of road segment i.e. total distance of that road segment,
- vi. difference in reduced level of road and
- vii. other resistances in each segment.

Other data include some other features related to intersections that are,

- i. type of intersection i.e. T-intersection or 4-leg intersection etc.
- ii. signalized or unsignalized,
- iii. turning restrictions i.e. restricted right or left turn,
- iv. cul-de-sac etc.

Later it was converted to spatial data format by cleaning and building the topology in AutoCAD Map. Finally it was transferred to GIS software as a vector attribute data. The travel expenses were observed by traveling on the roads so that all factors such as traffic delays, speed variation affected by elevation etc could be considered. The database contains the fields for which the data was collected. The database was developed by putting all the information collected about the roads and the intersections. This database shows the real time attributes to analyze the network of roads. After completing the data tables of all attributes, prototype analysis was started in ArcView Network Analyst on the whole study area to locate some best routes [12]. Certain locations will be selected to find the optimal routes from origin of travel to the destination. From these certain optimal routes, fastest route or shortest route might be selected.

4.3.1 Result

The database for the road network of study area was developed for its attributes. From the database, user is able to make the query to get the information about the roads. This query can be made by selecting desired road from the map or by entering text in the query builder. This database demonstrates the system to determine optimal route by reading cost attributes from database (Figure 14 and 15). From the analysis of road network, the result came up with determination of an optimal route representing total cost of route in terms of distance and in terms of time (Figure 16 and 17). The results also show the analysis of route while visiting several locations to determine total route cost. The results of optimal route are shown in graphical format as well as in text format (Figure 18). The graphical format shows the highlighted route on the map and the text format shows the directions of travel for that route.

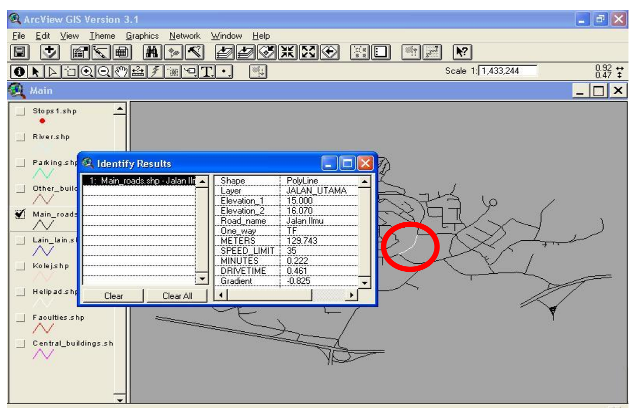


Figure 14 Displaying the information of the selected road segment

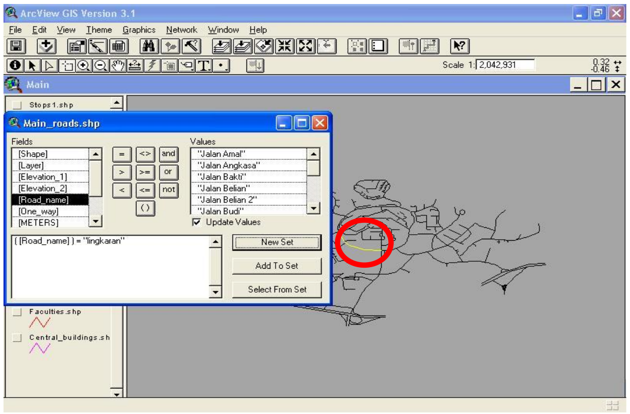


Figure 15 Query for the road named '*Lingkaran*'

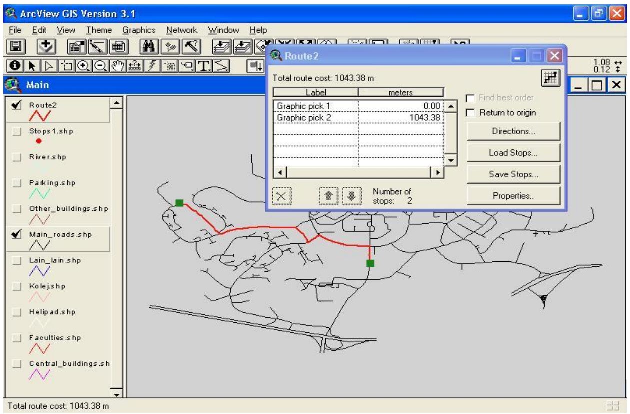


Figure 16 Suggested route between origin and destination and total cost in meters

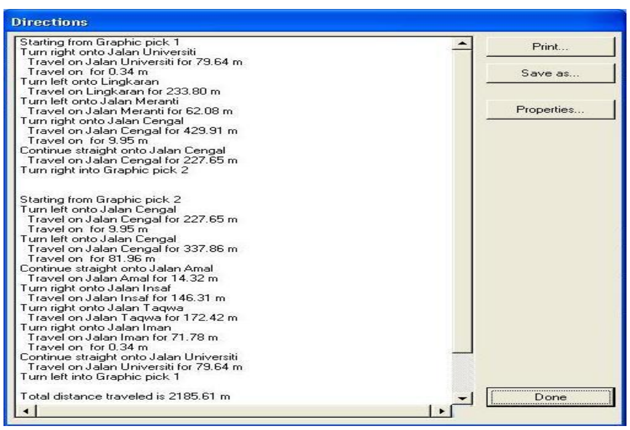


Figure 17 The directions starting from origin to destination point giving the distance in meters

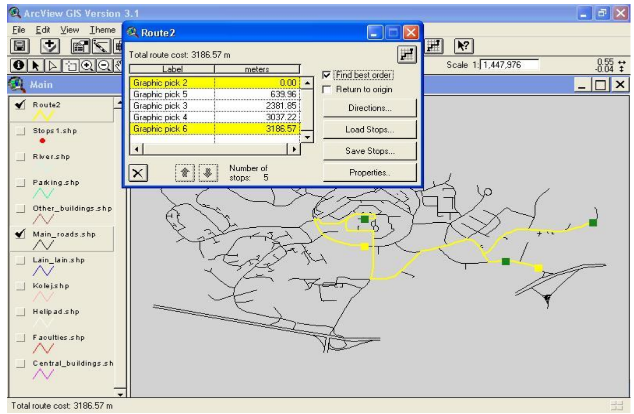


Figure 18 Multiple points visited by using *find best order* option to find the best route

4.3.2 Suggestions

Network analysis can be used to find not only the shortest or fastest routes but also modeling hydrologic flow, traffic flow, service areas, directions and the closest facilities. In the field of civil engineering, roads are not the only network that can benefit from GIS analysis but also pipe lines, sewer lines and rivers can be analyzed [13]. In the above study, queries were the output by developing the database of all attributes about the road characteristics. The query was made to get the information about the features by using this system. The route was analyzed by setting the origin and destination points to determine the cost of travel. And by finding the best order while visiting various locations around the network, cost of route was reduced by using the system. This type of system can be helpful to analyze the large area networks to find optimal routes and to inquire the information about network features. In the large area networks with major highways, it is important to remember that the shortest route is not always the fastest route since travel times are generally faster on major highways compared to streets. The network analysis for road network became very easy by implementation of GIS softwares. By using GIS, complicated network of roads can be visualized and worked out in a very precise manner.

5.0 CONCLUSION

Sharing of GIS spatial data in transportation engineering is the bridge that links fundamental data model to GIS technology, with the result that application are enhances and research finding are broadened and deepened. The nature of any natural or economic activity with a spatial dimension cannot be properly understood without reference to its spatial qualities. The maintenance and transformation of spatial data concerns the ability to input, manipulate, and transform data once it has been created. The use of GIS spatial modelling tools in several traditional resource activities has helped to quantify processes and define models for deriving analysis products. GIS usage is able to provide and contribute to cost-benefit effectively. Benefits or future contributions seen in this study are road safety analysis, traffic analysis at road junction and the prediction of suitable development based on traffic database.

References

[1] Association for Geographic Information (AGI). 1994. *Geographic Information and Geographic Information System Standards.* CCTA The Government Centre For Information, United Kingdom.

[2] Seyed Mahdi Sajjadi, Assoc. Prof. Dr. Mohd. Zulkifli Mohd. Yunus, Assoc. Prof. Dr. Othman Che Puan and Taha Mehmannavaz. 2014. The Effects of Safety Optimization on Highway Alignment: A Review. *International Journal of Engineering and Innovative Technology (IJEIT).* 4(1): 240-246. July 2014. ISSN 2277-3754.

[3] Environmental Systems Research Institute. 1996. *Using ArcView GIS.* Redlands, USA.

[4] Goodchild, M. F., and Kemp, K. K. 1990. *Introduction to GIS: Core Curriculum:* Berkeley, California: National Center for Geographic Information And Analysis.

[5] Liang, L. Y, Ma'some, D. M. and Hua L. T. 2005. Traffic Accident Application Using Geographic Information System. *Journal of the Eastern Asia Society for Transportation Studies.* 6: 3574-3589.

[6] Miller, H. J. and Shaw, S. L. 2001. Geographic Information Systems For Transpotation. Principles and Applications. *New York: Oxford University Press, Inc.* 360-379.

[7] Nurul Wahida Binti Mohamed. 2010. *Road Maintenance Management System: A Case Study at Public Work Department.* Thesis (M. Ed.), Universiti Teknologi Malaysia.

[8] Mohd Zulkifli B. Mohd Yunus and Hamidah Bt. Hassan. 2010. Managing Road Maintenance using Geographic Information System Application. *Journal of Geographic Information System.* 2: 215 – 219.

[9] Seyed Mahdi Sajjadi, Assoc. Prof. Dr. Mohd. Zulkifli Mohd. Yunus, Asooc. Prof. Dr. Othman Che Puan, Taha Mehmannavaz and Iman Faridmehr. 2014. Analyzing Accidents Caused by Overturn of Vehicles (Case Study of Iran-Zanjan Province in 2010. *Research Journal of Applied Sciences, Engineering and Technology.* 7(12): 2509-2515. *March. ISSN 2040-7459*.

[10] Lo, C. P. and Young, A. K. W. 2002. Concepts and Techniques of Geographic Information Systems. *New Jersey: Prentice-Hall, Inc.: 212-216.*

[11] *Hanson*, S. 1995. *The Geography of Urban Transportation.* The Guilford Press, New York.

[12] Zhao, F. 1997. Transportation Applications of Temporal GIS, *ESRI User Conference:* 1-3.

[13] Good Child, M. 1999. GIS and Transportation: Status And Challenges. Paper Presented at *International GIS-T/ITS workshop,* Chinese University of Hong Kong, Shatin, Hong Kong.