An effective road management system using web-based GIS software

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Abstract. Recently, there is a rapid development of road transportation network. This situation arises due to the number of vehicle on the road that keeps increasing year by year. Thus, this will increase the possibility of dangerous situations to the road users if roads are not being maintained appropriately. Therefore, in order to keep the road in safe condition, the road management activity should be improved. A complete system for road management has been applied in the developed countries for the past decades. However, the usage of application programming interface (API) from GIS software has limitation to make modification in terms of interactivity of the system. Open source software was proposed as a way to assist in reducing the development cost of developing road monitoring system. In this paper, open source software was proposed as a way to assist in reducing the development cost in developing road management system. OpenLayers framework was used as map rendering platform. The system can be used by administrator of road network to update the road information. At the same time, it can be used by the road user as well to view the information regarding road-related incidents.

1. Introduction
Recently, there has been a rapid development of road transportation network throughout the world due to increased human population and economic activities. The increase of vehicle on the road has demanded the commitment to improve the current road transportation systems. Current road transportation system helps the authority in managing road infrastructure effectively. It can support in terms of monitoring the road infrastructures extensively. However, to keep the road infrastructure in safe condition, a comprehensive monitoring and managing system should be developed. By providing a comprehensive road management system, the occurrence of road accidents also can be minimized [1]. Several countries have developed road management system for past decades for their countries. However, the existing system still can be improved for future work and wider scope [2].

In previous studies, road management system has proved to be able to manage the road network system properly. [3] implemented internet-based system for highway pavement management system by integrating spatial and attribute database in the system. Meanwhile, [2] has proposed road maintenance information portal system to facilitate the sharing and retrieving of information among project participants. These examples use web-based GIS concept in order to construct the systems.
However, the usage of application programming interface (API) from GIS software has limitation to make modification in terms of interactivity of the system [4].

The usage of commercial software required the product license and need to be renewed every year. Consequently, the developer needs to spend some amount of money to maintain the software. In this paper, open source software was proposed as a way to assist in reducing the development cost in developing road management system. This paper proposed the development of road management system based on WebGIS.

Geographic information system (GIS) is a powerful tool and has capability to handle and process spatial data in a large volume. GIS is defined as a system that able to input, store, retrieve, update, display, and comprehensively analyses spatial data based on computer hardware and software [5]. It is also known as desktop GIS. GIS becomes a widespread technique that can create maps, integrate information, visualize and solve problems, and develop valuable solutions [6]. Applying GIS for road management system have been used before in developed countries [7]. It is an effective system to monitor all the activities that occur on the roads and store the records for future development. Furthermore, this system can be as decision support system (DSS) for road development and construction in the future. To make this system easy to access, it is developed as internet platform.

Web based GIS or WebGIS is an Internet-based platform that provides client-side applications using WWW protocols running on the worldwide web which can embed geographic information data as well as non-geographic data [3, 8]. It is a new type of GIS which is accompanied by the rapid development of Internet [9]. WebGIS comprises various advantages compared to desktop GIS [8].

Therefore, the objective of this study is to propose an effective road management system to improve the current system. Open source web-based GIS software is used in developing the system in order to minimise the maintenance cost. By implementing this system, it provides a comprehensive system that can monitor and manage road conditions which is also able to be accessed by users through the internet.

2. Workflow of methodology

The flowchart of this study was designed to guide the authors to achieve the objective. In achieving the objectives, six methodological steps were designed and shown in figure 1. Requirement analysis is a process that usually taken to identify problems exists in the study area. This step involves various procedures and materials. The preliminary study was conducted to identify the latest and previous systems that able to support spatial data for road management system. Interview session also was conducted with government agency in Malaysia such as Lembaga Lebuhraya Malaysia (LLM) and experts in road management system. Thus, the lacking of the current systems was identified.

From preliminary studies, the information gained was utilized to develop a comprehensive web-based GIS system that able to overcome the lacking in the current systems. The standard procedure in system development was applied in this study which started with system design, software and hardware survey, database design, and programming code. Then, the system was tested to identify the reliability and robustness in serving the functions for administrators and distributing information to users.

Hardware and software selection are vital components of GIS field. High performance of hardware is needed to support the speed of data and processing for a web. The next component that essential in web development is database platform. Database platform is used to store all information in one location for manipulating, processing, and lastly presenting to users through the web browser. In database design, it showed the overall database structure include the elements of the database. The elements of the database consist of entities, attributes, and the relationship between entities and attributes. System development is a phase to make configuration of software, data entry, and data editing of the attributes in the web-based GIS system. After the system has finished being developed, it needs to be tested or validated in term of the quality and competency in providing the function to users.
2.1. System design architecture

Web has capability to input, process, and lastly visualize the results on screen using internet platform. System design is the main procedure in web development. It shows the overall components in the system. Development of the web has three vital components to make it run efficiently. The architecture of system design is shown in figure 2.
2.2. **Client tier architecture**

Client-tier consists of web browser to display information to users. This tier also called interface to receive user request for processing. Various web browsers can support the client tier such as Internet Explorer, Mozilla Firefox, Google Chrome and others. Web browser allows users to input their request. In this study, the interface was developed using hypertext markup language (HTML) as the main programming scripting of the interface. The contents of the web page were written in the form HTML element before publishing on the web browser. At the same time, JavaScript language was embedded in the HTML scripts to generate interactive and dynamic visualization.

Client tier is the main page of the system that deals with the users. The graphic user interface (GUI) receives user requests through the web browser. Then, the requests will be transferred to the database tier for processing. The data needed will be retrieved from the central database in the database tier. Subsequently, the result will be transferred again through web tier and visualize on the client tier for user.

2.3. **Middle tier architecture**

Middle tier is the most important tier of the whole system. The function in this tier is to control the whole process of the system. After client tier received requests from user, the results will be sent back to user via middleware. It serves as the intermediate medium between client tier and database tier for webGIS system. The connection required HTTP and SQL that can translate between them.

OpenLayers framework was attached in this tier for map visualization. OpenLayers is a powerful and flexible that functions for displaying maps in web browser using JavaScript library. It is foundation of all webs mapping framework such as Google Maps, OpenStreetMap, Google Satellite, Yahoo Maps, and Bing Maps [10]. This research used three web mapping applications which included Google Maps, Google Satellite, and OpenStreetMap to look in variety of interface display as shown in figure 3.

![Figure 3. OpenLayers framework for web mapping rendering.](image)

2.4. **Database tier architecture**

Database tier or server tier is a tier that store and retrieve information in this system. It is the database management system (DBMS) for this web. PostgreSQL/PostGIS database was placed in the database tier to manage and provide data when processing were run. Hypertext preprocessor (PHP) as server-
side scripting language was used in the database tier to communicate with the client-tier. PHP code was embedded in HTML code. When clients invoke the HTML page, the Web server executes the scripts, which in turn access the data from PostgreSQL/PostGIS database. The Web server then organizes the data into HTML page and sends it back to the browser. Thus, users can view road information and shortest path route that retrieved from database on the web page.

2.5. Open source software and usage
The development of open source software for GIS usage has been implemented in the last 10 years [4]. Open source software is free license software that has capability like the license software in running and modifying program for any purpose [11]. Nowadays, it becomes popular and reliable to current system. For GIS usage, the software must have capability for creating, managing, analyzing, and visualizing geographic data [4]. To minimize the cost, this study utilized open source software for web development and attached with free database system software as well. Hence, this study can be categorized as low cost project and can be implemented in real situation to replace the current system.

One of the important components in web development is web server. This component serves and enables the information from database to be accessed using world wide web (WWW) protocol. Apache web server also known as apache HTTP server is the well-known open source web server platform. Apache is a high performance web server with full features functionalities. For database platform, this study applied the concept of integration of PostgreSQL and PostGIS as the database management system which transfers data through internet protocol. This database was used because it was most advance open source database that available today [12].

2.6. Development of web-based GIS
This system was developed on a workstation with window 7 operating system. The hardware specification of the server was a 2.4GHz Intel® core™ i5 processor with random access memory (RAM) of 4GB. The server runs WampServer to retrieve data from postgresQL database using the PHP language. The database used was PostgreSQL 9.1 with PostGIS 1.5 spatial extension to support geographic data.

Three web mapping systems were rendered in OpenLayers framework which was OpenStreetMap, Google Satellite Maps, and Google Maps. By developing this system, it can be used for administrative usage to input all information of roadwork activities that occur on the road. Moreover, it can be a control station to monitor the construction works on the road. Symbol icon will appear on the map included with progress status of the roadwork. At the same time, it can be used by the road user as well to view the information regarding road activities happen on the road.

GIS consists of five elements and two of the elements are hardware and software. Selection of software should be done in proper way because some software has different advantages and disadvantages. The selected software must be evaluated in term of functionality so that it not affects the system when it is running. In order to make this system cost-effectively, free software was used. PHP 5.4 was used as server-side scripting language and PostgreSQL 9.2 as the database platform. JavaScript programming language was used to write coding for client-site to produce interactive and user-friendly web page. Then, web browser such as Mozilla or Internet Explorer will function as user input and displays the output after processing.

3. Results and discussions
The GUI was developed to integrate all functions proposed in the developed web-GIS with roads data. The interface was developed using HTML and combined with JavaScript code to make it more dynamic. In the main interface, there are five tabs on the header of the interface. All the available functions are shown on the interface for user consideration. Figure 4 shows the main interface for web-GIS for road management system.
The five menus that were created on the main interface were Home, Admin, User, Partners, and Contact Us. Each menu has specific function to serve users when interact with the system. Home menu provides homepage of the web-GIS interface. When users click on this tab, it will return users to the homepage. The second menu is Admin. This menu was designed special for administrative usage. To keep the data precisely, only registered users can edit and update information in the database. This is because some current systems allow public users to input the information freely. This situation can reduce the authorization of data in the database. Therefore, to make sure all the inserted data free from offense, admin function was enabled in this system.

The next menu is User menu. In this menu, it consist the main content of web-based GIS system that shows the base map using OpenLayers framework. Three base maps were rendered in the framework. Users can choose which base map they prefer by selecting on the right menu. This function was created in this system due to enhance the visualization of base map. The second function of User menu is generating shortest path analysis. Users need to input their origin and destination nodes in the provided columns. If they need the specific time for travelling, they can insert the date and time in the provided columns. The reason this system chooses to use node value as the input unit instead of street name because it can detect the exact location of the source and target on the map. Thus, it increased the accuracy of the system. But sometimes it difficult for users to get the correct location based on the node value.
Partner is the fourth menu that exists in the interface of the system. However, this tab is not like other tabs. This tab used dropdown menu that listed the potential partners from government and private departments that related to road management in Malaysia such as Lembaga Lebuhraya Malaysia (LLM), Jabatan Kerja Raya (JKR), and PLUS. This menu was created in this system to integrate some information within different departments. The last menu of this system is Contact Us. The purpose of this menu is to provide the information about the person who users can contact regarding to this webGIS system.

4. Conclusion
In this paper, a comprehensive system development for road management system was developed by using open source software. The free software was used because it becoming popular in nowadays. WebGIS become the core part of the system since it can support road data which consist of spatial and non-spatial data. Development of this system involves two parts which are system design and system development. This system will give benefits to road administrator to gather information in a single database and can work as decision support system for road maintenance. At the same time, it can provide visualization for public users to plan their journey. By accessing this system, the administrator from authority departments can update information in the database easily. Only registered users are allowed to update the information in the database in order to maintain the authenticity of information. However, the road users can visualize the base maps in the interface. They can interact with the system by flying through, pan, slide, and viewing road condition with roads information on screen. Shortest path analysis also was provided in the system to enhance the capability of the system. The future work and improvement of road management system, we suggest that the data are collected from related agencies to insert in the database. The database will become more updated and the quality of data is certified. Other features such as photos and videos can be uploaded in the database to improve map visualizations.

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