UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF WEB-BASED GIS FOR TRAFFIC MANAGEMENT SYSTEM WITH OBSTACLE AVOIDANCE TECHNIQUE USING OPEN SOURCE SOFTWARE

NIK MOHD RAMLI BIN NIK YUSOFF

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By

NIK MOHD RAMLI BIN NIK YUSOFF

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Chairman: Associate Professor Helmi Zulhaidi Mohd Shafri, PhD
Faculty: Engineering

Distribution of road information on the internet is an enforcing factor for the authorities. This is due to the capability of the internet to disseminate information and provide geo-related information analyses with no location restrictions. Web-based GIS has been used to distribute road information and provide shortest path analysis on the internet. However, the function of the analysis on the internet is still limited. The shortest path is a well-known network analysis that exists in traffic management systems. It provides the shortest route calculation between two points for road users. However, this function could not help to avoid its users from the congested areas due to the presence of obstacles on the roads. Therefore, the main objective of this study is to improve the traffic management system by implementing the shortest path analysis with obstacle avoidance technique. This is to avoid the presence of obstacles on the roads. In order to calculate the shortest path between two nodes, Dijkstra algorithm was utilized. Obstacle avoidance technique was implemented in this algorithm to avoid the congested areas. A web-based traffic management system was developed using open source software in this study. Verification of the shortest path calculation result obtained from the traffic management system was done via comparison of the performance and result with the use of Quantum GIS (QGIS) software and Waze application. Qualitative validation was run in order to test the function of obstacle avoidance technique in 50 km, 100 km, and more than 150 km route lengths with the presence of one, two, and three obstacles respectively. The system also was tested in urban, sub-urban, and rural areas to investigate the functionality of the system. For quantitative validation, the system was validated in terms of the time travel and fuel consumption. User satisfaction test was conducted concerning website acceptability and performance testing was made during this research. The shortest path result from the traffic management system produced similar result to QGIS. The obstacle avoidance technique has worked successfully in avoiding the presence of obstacles in different lengths of roads and different numbers of obstacles in a route. User satisfaction test results showed that most of the respondents agreed that this system could help the administrators in managing road activities effectively and provide the shortest path analysis with obstacle avoidance technique for road users in avoiding congested roads.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN GIS BERASASKAN WEB UNTUK SISTEM PENGURUSAN JALAN BERSAMA TEKNIK PENGELAKAN HALANGAN MENGGUNAKAN PERISIAN BEBAS

Oleh

NIK MOHD RAMLI BIN NIK YUSOFF
September 2014

Pengerusi: Professor Madya Helmi Zulhaidi Mohd Shafri, PhD
Fakuti: Kejuruteraan

Penyebaran maklumat jalan di dalam internet merupakan faktor keperluan kepada pihak berkuasa. Ini disebabkan kebolehan internet untuk menyebarkan maklumat dan menyediakan hasil analisis berkaitan geografi tanpa sebarang sekatan lokasi. Oleh itu, GIS berasaskan web telah digunakan untuk menyebarkan maklumat jalan dan menyediakan analisis laluan terpendek dalam internet. Walau bagaimanapun, fungsi analisis dalam internet masih terhad. Laluan terpendek merupakan analisis rangkaian yang terkenal yang wujud dalam sistem pengurusan jalan. Ia menyediakan pengiraan laluan terpendek antara dua titik untuk pengguna jalanraya. Namun, fungsi ini tidak dapat membantu pengguna untuk mengelak dari kawasan-kawasan sesak disebabkan wujudnya halangan di jalanraya. Oleh sebab itu, objektif utama kajian ini adalah untuk meningkatkan sistem pengurusan jalan dengan melaksanakan analisis laluan terpendek bersama teknik pengelakan halangan. Ini adalah untuk mengelak kewujudan halangan di jalanraya. Untuk mengira laluan terpendek antara dua titik, algorithm Dijkstra telah digunakan. Teknik pengelakan halangan telah dilaksanakan dalam algorithm ini untuk mengelak kawasan yang sesak. Sistem pengurusan jalan yang berasaskan web telah di bangunkan menggunakan perisian bebas dalam kajian ini. Verifikasi pengiraan laluan terpendek yang diperolehi dari sistem pengurusan jalan telah dilakukan dengan membandingkan prestasi dan hasil dari perisian Quantum GIS (QGIS) dan aplikasi Waze. Pengesahan kualitatif telah dijalankan untuk menguji fungsi teknik pengelakan halangan masing-masing pada 50 km, 100 km, dan lebih dari 150 km panjang laluan dengan kehadiran satu, dua, dan tiga halangan. Sistem ini juga telah diuji di kawasan bandar, sub-bandar, dan luar bandar untuk menyiasat fungsi sistem tersebut. Untuk pengesahan kuantitatif, sistem telah disahkan dari segi masa perjalanan dan penggunaan bahan bakar. Ujian kepuasan pengguna telah dijalankan berkaitan dengan penerimaan laman web dan ujian prestasi telah dibuat semasa kajian dijalankan. Hasilnya, laluan terpendek dari sistem pengurusan jalan telah menghasilkan keputusan yang menyamai dengan QGIS. Teknik pengelakan halangan telah berfungsi dengan berjaya bagi mengelak kehadiran halangan dalam panjang jalan yang berbeza dan bilangan halangan yang berbeza-beza dalam satu laluan. Keputusan ujian kepuasan pengguna menunjukkan kebanyakan responden telah bersetuju bahawa sistem ini dapat membantu pentadbir dalam mengurus aktiviti-aktiviti jalan dengan berkesan dan menyediakan analisis laluan terpendek bersama teknik pengelakan halangan bagi pengguna jalanraya untuk mengelak jalan yang sesak.

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I certify that a Thesis Examination Committee has met on 26 September 2014 to conduct the final examination of Nik Mohd Ramli Bin Nik Yusoff on his thesis entitled "Development of Web-based GIS for Traffic Management System with Obstacle Avoidance Technique using Open Source Software" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Hussain Hamid, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Shattri Mansor, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Wan Azizon Wan Adnan, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Zulkiflee Abd Latif, PhD
Associate Professor
Faculty of Architecture, Planning & Surveying
Universiti Teknologi Mara
40450 Shah Alam, Selangor
(External Examiner)

ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 23 January 2015

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Helmi Zulhaidi Mohd Shafri, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Ratnasamy Muniandy, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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LIST OF ABBREVIATIONS

GIS	Geographic Information System
WebGIS	Web-based Geographic Information System
LLM	Lembaga Lebuhraya Malaysia
SQL	Structured Query Language
PHP	Hypertext Preprocessor
QGIS	Quantum Geographic Information System
HTML	Hypertext Markup Language
VMT	Vehicle Miles Travel
MIROS	Malaysian Institute of Road Safety Research
IT	Information Technology
ITS	Intelligent Transportation System
FCD	Float Car Data
RMK-10	Tenth Malaysia Plan
STA	Smart Traffic Agent
TIEP	Traffic Information Exchange Protocol
TIC	Traffic Information Centre
XML	Extensible Markup Language
DSS	Decision Support System
GPS	Global Positioning System
MOT	Ministry of Transport
ICT	Information and Communication Technologies
FHWA	Federal Highway Administration
AASHTO	American Association of State Highway Officials
DOT	Department of Transportation
GIS-T	Geographic Information System for Transportation
WWW	World Wide Web
GML	Geographic Markup Language
API	Application Programming Interface
CSCW	Computer Supported Collaborative Work
J2EE	Java Platform Enterprise Edition
JSP	JavaServer Pages
SDSS	Spatial Decision Support System
ITMS	Integrated Transportation Management System
2D	Two Dimensional
IMS	Internet Map Server
HTTP	Hypertext Transfer Protocol
OSM	Open Street Map
KM	Kilometre
UML	Unified Modelling Language
GUI	Graphic User Interface
JKR	Jabatan Kerja Raya
PLUS	North-South Expressway
3D	Three Dimensional

CHAPTER 1

INTRODUCTION

1.1 Introduction

In developing countries, the numbers of vehicles on the roads have rapidly increased from year to year. According to Santos et al. (2011), the rate of vehicle growth has exceeded significantly over the rate of population and economic growths over the last decade. Hence, this situation increases the rate of accidents (Sohadi, 2005). Therefore, in order to avoid such situation, road surfaces should be kept in safe and good condition and they should be able to function for a long period of time. Improvement in traffic management, in terms of road maintenance, road rehabilitation, and road repairing, is very important. Improper traffic management will damage the road condition and the roads would be inoperative for a long time.

The road network is a major and important transportation infrastructure. In order to maintain the road infrastructure, a comprehensive monitoring system should be developed. Geographic Information System (GIS) is a tool that has the capability to manage and maintain road data efficiently. GIS is a computer-based system that collects, stores, analyses, and distributes geographic information to the public. Although GIS has a lot of advantages, there are still some limitations in accessing information of road conditions in real-time and at different locations. Desktop GIS is a static system that cannot be accessed from different places. Besides, this system only relies on computers with GIS software installed to handle spatial data.

To overcome this problem, web-based GIS system is introduced. This system is similar to the desktop GIS, but it will work based on internet connection availability. There is no limitation to access this system. Therefore, as long as internet connection is available, this system can be accessed. Some researchers have used the WebGIS system for road transport management and maintenance in their studies (Peng & Huang, 2000; Alesheikh et al., 2002; Xiaolin, 2004; Xie, 2010; Kubota et al., 2011). From their studies, it has been proven that this method is appropriate to be implemented in traffic management and monitoring process.

The usage of web-based GIS in traffic management system can reduce the cost needed compared to previous methods using the desktop GIS system (Xie, 2010). Through the use of WebGIS, maps can be published on the internet quickly and this could enhance the dissemination of road information (Alesheikh *et al*., 2002; Xie, 2010). Even though web-based application is currently widely used, some improvements are still needed.

The shortest path analysis is widely used in the road network analysis, especially for road mapping system. This platform enables people to interact using the internet to calculate their distance from one location to another. Several algorithms have been used before to generate the shortest path analysis in internet platform. Dijkstra algorithm is a widely used algorithm in generating single-source shortest path analysis in computer network (Pettie, 2004; da Silva & de Almeida, 2007; El-Houssaini & Badri, 2012; L. Zhang & He, 2012). Dijkstra algorithm is widely used in calculating the shortest path problem that involves the number of edges and

vertices in directed graph (Pettie, 2004). A graph (G) usually consists of a set V of vertices and a set E of edges. This algorithm will calculate the distance from source (u) to target (v) which is denoted by (u, v). On the other hand, A* or A-Star algorithm is commonly used in calculating the shortest path analysis on web with weighted directed graph (Chabini & Lan, 2002; Goldberg & Harrelson, 2005; Fu *et al*., 2006). A-Star uses estimates on distances to the destination to guide vertex selection in a search from the source (Goldberg & Harrelson, 2005). Furthermore, Goldberg and Harrelson (2005) have studied the relationship between A-Star and Dijkstra algorithm. From their study, they found that A-Star algorithm is equivalent to the Dijkstra algorithm on a graph with non-negative edge length and therefore, finds the optimal path.

The shortest path problems have been extensively studied, but it still has disadvantages on travel distances and mitigates traffic congestions on the web server. This research proposes obstacle avoidance technique in the shortest path analysis in order to avoid congested roads.

1.2 Problem Statement

The shortest path problem concentrates on finding a path with minimum distance, time, or cost from the source node to the destination node (Gao, 2011). Finding the shortest route between two nodes is a popular application in road network analysis. According to Singh and Singh (2012), the development of algorithm is a major issue in generating the shortest route that requires less travel distance and able to avoid traffic congestion due to the increasing number of vehicles on the road.

In current technology, the function of web search is ubiquitous in our daily lives. Important information is embedded in web server so that it can be retrieved in a short period of time, especially for road conditions and traffic information which are very essential to be accessed in real-time. However, the computation of the shortest route depends on the proxy server and selection of the algorithm (Thomsen *et al*., 2012).

Shortest path problems have been intensively studied in broad applications and various science and engineering disciplines. Finding the shortest connection in transportation networks is a familiar problem to anybody who ever travelled. However, only a few researchers were focused on efficient speed-up time independent route planning in road network (Delling & Wagner, 2009).

Due to the inefficiency of the current system in selecting the algorithm, it increases road congestions and at the same time, contributes to road accidents. According to Noland and Quddus (2005), increase of traffic congestion will increase the potential of collision because of the stressful environment and the drivers are rushing to reach their destinations.

Road events such as accidents, road closure, and road maintenance locations can be represented as obstacles on the road. Zlatanova *et al*. (2013) has stated that even though many routing algorithms have been developed, there are a few efforts which have been devoted to the efficient routes in avoiding obstacles. Obstacle avoidance technique has been applied in disaster management to find the optimal route to aid

rescue workers and citizens in determining the shortest route to certain locations (Nedkov & Zlatanova, 2011; Zlatanova *et al*., 2013). However, the capability of obstacle avoidance technique still not yet studies in traffic management system.

Dijkstra algorithm is a very popular technique used and it is mostly used in network analysis for finding the shortest route (Thomsen et al., 2012; L. Zhang & He, 2012). This algorithm can be classified as classical algorithm (Gao, 2011) and the network is required to determine the arc lengths. However, because of failure, maintenance, or other reason, the arc lengths are nondeterministic in many situations. As a result, it is improper to employ Dijkstra algorithm in certain situations. Therefore, the capabilities of this algorithm need further study in order to improve the travel time between two nodes, provide shortest distance, and able to avoid obstacles that usually contribute traffic congestions.

1.3 Justification

Through the conduct of this research, a traffic management system based on web-based GIS is produced to provide an alternative route to avoid traffic congestions. Other than that, this system can reduce the rate of road accidents that usually occur in congested areas.

The time travel should be consider during travelling. The route that can provide the shortest distance must be chosen. Sometimes, the shortest route cannot be indicated as the fastest route due to the existence of obstacle on the road. The fastest route can be defined as the route that can provide less travel time compared to other routes. It means that, users can reach their destination earlier rather than using the other routes and at the same time they can save their fuel consumption during travelling.

In Malaysia, traffic congestions always occur in the main roads especially during peak hours; early morning (7am – 9am) and evening (5pm – 8pm). This situation arises because the road users are rushing to arrive at their offices in the morning and back to their homes in the evening. This situation becomes severe when any construction for maintaining the road or accident takes place.

The government agency that is responsible in maintaining and controlling the activities on highways and federal roads is the Lembaga Lebuhraya Malaysia (LLM). This agency provides a web-based mapping system that shows the map of peninsular of Malaysia with the current road condition. This system is developed using Web-based GIS software. However, the loading time is very slow and makes it unable for one to calculate the shortest distance. Furthermore, the current service cannot provide alternative route to avoid obstacles on the road.

Therefore, this research is designed to assist two different parties, which are the road authorities and the road users. With the use of this system, it can help the authorities such as LLM to improve development and control road maintenance activities. Other than that, this system can be utilized by users to improve their travel activities. By using this system, users can improve their time travel from one location to another location. At the same time, it reduces the fuel consumption during travelling. Thus, the less the time taken during travelling, the less fuel is consumed.

1.4 Objectives

The main objective of this study is to develop a web-based GIS for traffic management system. The specific objectives of this study are:

1) To determine the significant parameters and attributes required for web-based GIS application for traffic management system

2) To develop an online traffic management system using open source GIS software

3) To implement the shortest path analysis with obstacle avoidance technique on the internet platform

1.5 Scope of Research

Geographic Information System (GIS) is widely used currently because it has the capability to collect, store, analyse, and present beneficial information from different sources of data. In traffic management aspect, GIS application can be adopted to present map and important information for road users, such as road traffic conditions and the location of road constructions. In fact, road network analysis can be developed to calculate the shortest route between two nodes, as well as provide alternative route to avoid traffic congestion locations.

There are two types of GIS software in reality, which are the commercial and the open source software. However, this research is only confined to the usage of open source software. As the cost of commercial software is high, there is a need to use open source software in developing the web-based GIS system. The open source GIS software that is involved in this research is PostgreSQL with PostGIS extension for database platform, apache server with PHP language for server site platform, and HTML for client site scripting language. Quantum GIS (QGIS) is used to do some validation for time travel and distance between the two selected nodes.

The data are confined based on crowd sourced information about the road network from the OpenStreetMap data. The combination of crowd sourcing and web mapping technologies have produced OpenStreetMap (Nedkov & Zlatanova, 2012).

1.6 Outline of Thesis

This thesis is organized into five chapters. Chapter 1 introduces the subject of the research, problem statement, research justification, and the main and specific objectives to achieve.

Chapter 2 consists of literature review that presents some background of the traffic management system worldwide, issues in this area, the development of GIS in traffic management service, and the usage of open source in web-based GIS system.

Chapter 3 presents the methodology of research and development of web-based GIS for traffic management system. The development of database is also presented in this chapter. Besides, all the data and algorithm, including the shortest path analysis applied for the network analysis, are stated in this chapter. The concepts of Dijkstra algorithm and obstacle avoidance technique are presented in this chapter too.

Chapter 4 shows the interface of system, base maps with maintenance locations, and the shortest path analysis in the system. Obstacle avoidance technique is tested with different situations. The results of the analysis are discussed in detail here.

Chapter 5 is the conclusion part of this research which discusses the overview of the system that has been developed. In this chapter, recommendations for further research are suggested.

REFERENCES

Abdul Rahman, A., & Ujang, M. U. (2007). *Implementing Dijkstra shortest route for 3D indoor navigation system*. Proceedings of the International Map Asia 2007, KL Convention Center, Kuala Lumpur, Aug 14-16, 2007.

Agosto, E., Ardissone, P., & Rinaudo, F. (2007). GIS And Web-GIS, Commercial and Open Source Platforms: General Rules for Cultural Heritage Documentation. *International Archives of The Photogrammetry, Remote Sensing and Spatial Information Sciences, 36*, 625-630.

Alesheikh, A., Helali, H., & Behroz, H. (2002). *Web GIS: technologies and its applications.* Proceedings of the Symposium on Geospatial Theory, Processing and Applications. Ottawa, July 09-12, 2002.

Ananraya, K., & Ammarapala, V. (2010). *The development of highways assets management system.* Proceedings of the 7th International Conference on Service Systems and Service Management (ICSSSM). Tokyo, June 28-30, 2010. IEEE Xplore Press. pp: 1-6.

Anderson, G., & Moreno-Sanchez, R. (2003). Building Web-Based Spatial Information Solutions around Open Specifications and Open Source Software. *Transactions in GIS, 7*(4), 447-466.

Barbier, G., Zafarani, R., Gao, H., Fung, G., & Liu, H. (2012). Maximizing benefits from crowdsourced data. *Computational and Mathematical Organization Theory, 18*(3), 257-279.

Bry, F., Lorenz, B., Ohlbach, H. J., & Rosner, M. (2005). A geospatial world model for the semantic web *Principles and Practice of Semantic Web Reasoning* (pp. 145-159): Springer.

Chabini, I., & Lan, S. (2002). Adaptations of the A* algorithm for the computation of fastest paths in deterministic discrete-time dynamic networks. *Intelligent Transportation System, 3*(1), 60-74.

Chao, W., A, Q. M., & G, I. S. (2009). Impact of traffic congestion on road accidents: A spatial analysis of the M25 motorway in England. *Accident Analysis & Prevention, 41*(4), 798-808.

Cherkassky, B., Goldberg, A., & Radzik, T. (1996). Shortest paths algorithms: Theory and experimental evaluation. *Mathematical Programming, 73*(2), 129-174.

Cottrell, W. D., Bryan, S., Chilukuri, B. R., Kalyani, V., Stevanovic, A., & Wu, J. (2009). Transportation Infrastructure Maintenance Management: Case Study of a Small Urban City. *Journal of Infrastructure Systems, 15*(2), 120-132.

da Silva, G., & de Almeida, P. E. M. (2007). *On the shortest path problem: a new approach with fuzzy inference systems and conventional Geographic*

Information Systems. Proceedings of the 7th International Conference on Intelligent Systems Design and Applications (ISDA), 2007. Rio de Janeiro, Oct. 20-24, 2007. IEEE Xplore Press.

Delling, D., & Wagner, D. (2009). Time-dependent route planning. *Robust and Online Large-Scale Optimization* (pp. 207-230): Springer.

Deng, J., & Mo, Y. (2009). *Intelligent decision support system for road network planning.* Proceedings of the International Colloquium on Computing, Communication, Control, and Management (CCCM) 2009. Sanya, Aug. 08-09, 2009. IEEE Xplore Press. pp: 139-142.

Derekenaris, G., Garofalakis, J., Makris, C., Prentzas, J., Sioutas, S., & Tsakalidis, A. (2001). Integrating GIS, GPS and GSM technologies for the effective management of ambulances. *Computers, Environment and Urban Systems, 25*(3), 267-278.

Dornan, D. L. (2002). Asset management: remedy for addressing the fiscal challenges facing highway infrastructure. *International Journal of Transport Management, 1*(1), 41-54.

Duan, Z., Liu, L., & Sun, W. (2009). *Traffic Congestion Analysis of Shanghai Road Network Based on Floating Car Data.* Proceedings of the International Conference on Transportation Engineering 2009. pp: 2731-2736.

Durango-Cohen, P. L., & Sarutipand, P. (2009). Maintenance optimization for transportation systems with demand responsiveness. *Transportation Research Part C: Emerging Technologies, 17*(4), 337-348.

Eklund, P. W., Kirkby, S., & Pollitt, S. (1996). *A dynamic multi-source Dijkstra's algorithm for vehicle routing.* Proceedings of the Conference Intelligent Information Systems, 1996. Australian and New Zealand. Nov. 18-20, 1996. Adelaide, SA. IEEE Xplore Press.

El-Houssaini, S., & Badri, A. (2012). *A web-based spatial decision support system for effective monitoring and routing problem.* Proceedings of the International Conference on Multimedia Computing and Systems (ICMCS). Tangier, May 10-12, 2012. IEEE Xplore Press. pp: 669-674.

Fallah-Fini, S., Triantis, K., de la Garza, J. M., & Seaver, W. L. (2012). Measuring the efficiency of highway maintenance contracting strategies: A bootstrapped non-parametric meta-frontier approach. *European Journal of Operational Research, 219*(1), 134-145.

Farahani, R., Rezapour, S., & Kardar, L. (2011). *Logistics operations and management*. USA, Access Online via Elsevier. ISBN: 0123852021.

Feng, X., & Quanwen, L. (2010). *Development of Highway Management System Based WebGIS.* Proceedings of the WASE International Conference on Information Engineering (ICIE) 2010. Beidaihe, Hebei. Aug. 14-15, 2010.

IEEE Xplore Press. pp: 136-138.

Findley, D. J., Cunningham, C. M., & Hummer, J. E. (2011). Comparison of mobile and manual data collection for roadway components. *Transportation Research Part C: Emerging Technologies, 19*(3), 521-540.

Firdhous, M., Basnayake, D., Kodithuwakku, K., Hatthalla, N., Charlin, N., & Bandara, P. (2010). Route Advising in a Dynamic Environment–A High-Tech Approach *Innovations in Computing Sciences and Software Engineering* (pp. 249-254): Springer.

Frez, J., Baloian, N., & Zurita, G. (2014). SmartCity: Public Transportation Network Planning Based on Cloud Services, Crowd Sourcing and Spatial Decision Support Theory. In R. Hervás, S. Lee, C. Nugent & J. Bravo (Eds.), *Ubiquitous Computing and Ambient Intelligence. Personalisation and User Adapted Services, 8867*, 365-371: Springer International Publishing.

Fu, L., Sun, D., & Rilett, L. R. (2006). Heuristic shortest path algorithms for transportation applications: state of the art. *Computers & Operations Research, 33*(11), 3324-3343.

Gao, Y. (2011). Shortest path problem with uncertain arc lengths. *Computers & Mathematics with Applications, 62*(6), 2591-2600.

García, K., Mendoza, S., Decouchant, D., Rodríguez, J., & Pérez, T. (2013). Determining and locating the closest available resources to mobile collaborators. *Expert Systems with Applications, 40*(7), 2511-2529.

Ghazali, M., & Ezanee, F. (2009). *Operational Risks For Highway Projects In Malaysia*. Proceedings of the Conference on World Academy of Science, Engineering and Technology 53. Malaysia. May 2009.

Goetz, M., & Zipf, A. (2013). Indoor Route Planning with Volunteered Geographic Information on a (Mobile) Web-Based Platform. In J. M. Krisp (Ed.), *Progress in Location-Based Services* (pp. 211-231): Springer Berlin Heidelberg.

Goldberg, A. V., & Harrelson, C. (2005). *Computing the shortest path: A search meets graph theory.* Paper presented at the Proceedings of the sixteenth annual ACM-SIAM symposium on Discrete algorithms. USA. pp: 156-165.

Goldberg, A. V., & Radzik, T. (1993). A heuristic improvement of the Bellman-Ford algorithm. *Applied Mathematics Letters, 6*(3), 3-6.

Hall, G. B., Chipeniuk, R., Feick, R. D., Leahy, M. G., & Deparday, V. (2010). Community-based production of geographic information using open source software and Web 2.0. *International Journal of Geographical Information Science, 24*(5), 761-781.

Harral, C. G., & Faiz, A. (1988). *Road deterioration in developing countries: Causes*

and remedies: World Bank Washington, DC.

He, J., Zeng, Z., & Li, Z. (2010). Benefit evaluation framework of intelligent transportation systems. *Journal of Transportation Systems Engineering and Information Technology, 10*(1), 81-87.

Hougardy, S. (2010). The Floyd–Warshall algorithm on graphs with negative cycles. *Information Processing Letters, 110*(8), 279-281.

Hugentobler, M. (2008). Quantum GIS *Encyclopedia of GIS* (pp. 935-939): Springer.

Ikeda, T., & Imai, H. (1994). *Fast A3 Algorithms for Multiple Sequence Alignment.* Proceedings of the genome informatics workshop.

Jenelius, E., Petersen, T., & Mattsson, L.-G. (2006). Importance and exposure in road network vulnerability analysis. *Transportation Research Part A: Policy and Practice, 40*(7), 537-560.

Jifeng, W., Huapu, L., & Hu, P. (2008). System dynamics model of urban transportation system and its application. *Journal of Transportation Systems Engineering and Information Technology, 8*(3), 83-89.

Jonathan, L. G. (2010). ICT and road transportation safety in the United States: a case of "American exceptionalism". *IATSS research, 34*(1), 1-8.

Kubota, S., & Mikami, I. (2011). Data model-centered four-dimensional information management system for road maintenance. *Journal of Computing in Civil Engineering*, 27(5), 497-510.

Kubota, S., Sugawara, T., Kosawada, T., & Abe, A. (2011, 24-26 June 2011). *Web GIS-bsed information portal system for road maintenance.* Proceedings of the 19th International Conference on Geoinformatics. Shanghai, June 24-26, 2011. IEEE Xplore Press. pp: 1-5.

LaValle, S. M. (2006). *Planning algorithms*. United States of America: Cambridge university press.

Lee, W.-H., Tseng, S.-S., & Shieh, W.-Y. (2010). Collaborative real-time traffic information generation and sharing framework for the intelligent transportation system. *Information Sciences, 180*(1), 62-70.

Lu, X., & Camitz, M. (2011). Finding the shortest paths by node combination. *Applied Mathematics and Computation, 217*(13), 6401-6408.

Ma, X.-y. (2008). Transportation Development Strategic Plan about 2010 Guangzhou Asian Games. *Journal of Transportation Systems Engineering and Information Technology, 8*(4), 16-22.

Ministry of Transport Malaysia (MOT), (2014). Available at http://www.mot.gov.my/en/Pages/Default.aspx. (Accessed on January 16, 2014).

Mizutani, F., & Uranishi, S. (2006). *Privatization of the Japan Highway Public Corporation: Policy Assessment.* Proceeding of the 46th Congress for the European Regional Science Association. Japan.

Moreno-Sanchez, R., Anderson, G., Cruz, J., & Hayden, M. (2007). The potential for the use of Open Source Software and Open Specifications in creating Web-based cross-border health spatial information systems. *International Journal of Geographical Information Science, 21*(10), 1135-1163.

Nedkov, S., & Zlatanova, S. (2011). *Enabling obstacle avoidance for Google maps' navigation service.* Proceedings of the 7th International Conference on Geoinformation for Disaster Management. Turkey. May 03-08, 2011.

Nedkov, S., & Zlatanova, S. (2012). *Google maps for crowdsourced emergency routing.* Proceedings of the XXII Congress of the International Society for Photogrammetry and Remote Sensing. Melbourne, Australia. 25 Aug.-1 Sept. 2012.

Noland, R. B., & Quddus, M. A. (2005). Congestion and safety: A spatial analysis of London. *Transportation Research Part A: Policy and Practice, 39*(7–9), 737-754.

O'Flaherty, C. A. (2002). *Highways: The location, design, construction and maintenance of road pavements.* Burlington, MA: Access Online via Elsevier.

Peng. (2005). A proposed framework for feature-level geospatial data sharing: a case study for transportation network data. *International Journal of Geographical Information Science, 19*(4), 459-481.

Peng, & Huang, R. (2000). Design and development of interactive trip planning for web-based transit information systems. *Transportation Research Part C: Emerging Technologies, 8*(1–6), 409-425.

Perez, A. S. (2012). *OpenLayers Cookbook*. Birmingham, UK: Packt Publishing.

Pettie, S. (2004). A new approach to all-pairs shortest paths on real-weighted graphs. *Theoretical Computer Science, 312*(1), 47-74.

Qingyun, W. (2007). Progress of transportation development in China. *Journal of Transportation Systems Engineering and Information Technology, 7*(1), 1-12.

Rao, M., Fan, G., Thomas, J., Cherian, G., Chudiwale, V., & Awawdeh, M. (2007). A web-based GIS Decision Support System for managing and planning USDA's Conservation Reserve Program (CRP). *Environmental Modelling & Software, 22*(9), 1270-1280.

Ray, J. J. (2007). A web-based spatial decision support system optimizes routes for oversize/overweight vehicles in Delaware. *Decision Support Systems, 43*(4), 1171-1185.

Rouse, P., & Chiu, T. (2009). Towards optimal life cycle management in a road maintenance setting using DEA. *European Journal of Operational Research, 196*(2), 672-681.

Samanta, S., Jha, M., & Oluokun, C. (2005). *Travel time calculation with GIS in rail station location optimization.* Proceeding sof the 25th ESRI International User Conference. San Diego, CA. July 25-29, 2005.

Santos, L., Coutinho-Rodrigues, J., & Antunes, C. H. (2011). A web spatial decision support system for vehicle routing using Google Maps. *Decision Support Systems, 51*(1), 1-9.

Sekimoto, Y., Watanabe, A., Nakamura, T., Kanasugi, H., & Usui, T. (2012). Combination of spatio-temporal correction methods using traffic survey data for reconstruction of people flow. *Pervasive and Mobile Computing*, 9(5), 629-642.

Shaw, S.-L. (2010). Geographic information systems for transportation: from a static past to a dynamic future. *Annals of GIS, 16*(3), 129-140.

Shoaib, Y., & Das, O. (2011). Web application performance modeling using layered queueing networks. *Electronic Notes in Theoretical Computer Science, 275*, 123-142.

Shrestha, P. P., & Pradhananga, N. (2009). *GIS-Based Road Maintenance Management.* Proceedings of the International Workshop on Computing in Civil Engineering 2009. Austin, Texas. June 24-27, 2009. Paper presented at the Computing in Civil Engineering (2009). pp. 472-484.

Singh, A. K., & Singh, P. (2012). An approach for web based GIS Route finder system. *International Journal of Advance Research in Computer Science and SOftware Engineering, 2*(5), 184-189.

Singh, V., & Kumar, P. (2010). Web-Based Advanced Traveler Information System for Developing Countries. *Journal of Transportation Engineering, 136*(9), 836-845.

Sobek, A. D., & Miller, H. J. (2006). U-Access: a web-based system for routing pedestrians of differing abilities. *Journal of Geographical Systems, 8*(3), 269-287.

Sohadi, R. U. R. (2005). Updates of road safety status in Malaysia. *IATSS research, 29*(1), 78-80.

Spinellis, D., & Giannikas, V. (2012). Organizational adoption of open source software. *Journal of Systems and Software, 85*(3), 666-682.

Steiniger, S., & Bocher, E. (2009). An overview on current free and open source desktop GIS developments. *International Journal of Geographical Information Science, 23*(10), 1345-1370.

Steiniger, S., & Hunter, A. J. (2012). The 2012 free and open source GIS software map–A guide to facilitate research, development, and adoption. *Computers, Environment and Urban Systems*, 39, 136-150.

Steiniger, S., & Weibel, R. (2009). GIS software–a description in 1000 words. *Encyclopeadia of Geography*. University of Calgary.

Tang, K. X., & Waters, N. M. (2005). The internet, GIS and public participation in transportation planning. *Progress in Planning, 64*(1), 7-62.

Thomsen, J. R., Yiu, M. L., & Jensen, C. S. (2012). *Effective caching of shortest paths for location-based services.* Proceedings of the International Conference on Management Data 2012. USA.

Van Exel, M., Dias, E., & Fruijtier, S. (2010). *The impact of crowdsourcing on spatial data quality indicators.* Proceedings of the 6th GISceince International Conference on geographic information science. Zurich, Switzerland. Sept. 14-17, 2010.

Wang, Z., & Zlatanova, S. (2013). Taxonomy of navigation for first responders *Progress in Location-Based Services* (pp. 297-315): Springer.

Wattanavarangkul, N., & Wakahara, T. (2013). Indoor Navigation System for Wheelchair Using Smartphones *Information Technology Convergence* (pp. 233-241): Springer.

Wu, Q., Tang, J., & Sun, Q. (2011). *Research on highway network planning method based on four factors.* Proceedings of the 11th International Conference of Chinese Transportation Professional (ICCTP) 2011. Nanjing, China. Aug. 14-17, 2011.

Xiaoge, T. (2009). *Application of GIS to Freeway Management System.* Paper presented at the Asphalt Material Characterization, Accelerated Testing, and Construction Management. Proceedings of the GeoHunan International Conference. Changsha, Hunan, China. August 3-6, 2009.

Xiaolin, L. (2004). *A new approach for Web-GIS based collaborative transportation planning system design.* Proceedings of the 8th International Conference on Computer Supported Cooperative Work in Design, 2004. May 26-28, 2004, 2, 637-642.

Xiaolin, L. (2006). GIS-T web services: A new design model for developing GIS customized ITS application systems *Computational Science and Its Applications-ICCSA 2006* (pp. 875-884): Springer.

Xie, F. (2010). Design and Implementation of Highway Management System Based WebGIS. *Journal of Networks, 5*(12), 1389-1392.

Yan, X., & Crookes, R. J. (2010). Energy demand and emissions from road transportation vehicles in China. *Progress in Energy and Combustion*

Science, 36(6), 651-676.

Zhan, F. B. (1997). Three fastest shortest path algorithms on real road networks: Data structures and procedures. *Journal of geographic information and decision analysis, 1*(1), 69-82.

Zhang, L., & He, X. (2012). Route Search Base on pgRouting *Software Engineering and Knowledge Engineering: Theory and Practice* (pp. 1003-1007): Springer.

Zhang, T., Wei, R., Gao, L., Gu, J., Tang, H., Zhou, R., & Li, W. (2011). *Regulating the Road Transport of Dangerous Goods: A Framework for a Dynamic Monitoring System.* Proceedings of the 11th International Conference on Chinese Transportation Professionals (ICCTP). Nanjing, China. Aug. 14-17, 2011.

Zlatanova, S., Peters, R., Dilo, A., & Scholten, H. (2013). *Intelligent Systems for Crisis Management*. Lecture Notes in Geoinformation and Cartography. Verlag, Berlin Heidelberg. Springer.