# ROAD TRAFFIC ROUTING FOR MOBILE APPLICATION

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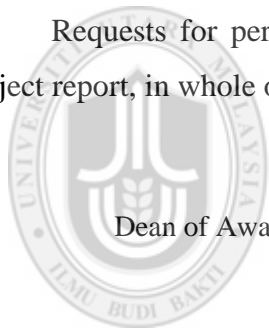
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Abstract

In urban traffic area such as Klang Valley, many studies are conducted in order to produce a good planning of routing direction from one place to another place by taking into account of reducing the distances and lowering the time travel required to complete the journey as much as possible. The least travel time path, the least travel expense path and the least synthesis expense are considered as well as the shortest travel distance in vehicle navigation system, those different significance path are generally called optimal paths (Pan, Zhang & Wang, 2009). Besides, research interests are growing on how efficiently traffic can be directed in a non-congested manner towards their destinations (Humaun Kabir, Nasre Alam & Kyung Sup, 2013).

Therefore, the main idea of this study is to design, develop and test Road Traffic Routing application which is an extension to a prototype system called Traffic Status system. The Traffic Status system is an android based application that collects input of traffic flow information from fixed detection sensors installed at each node in the roadways. By using the sensors that located along the road, the vehicles' average speed will be collected for formulating a node's travel time and the Road Traffic Routing application then will use the node's travel time for planning and suggesting a routing direction for optimal paths.

Acknowledgement

In the name of Allah S.W.T the almighty and the most merciful, praise to Allah S.W.T, for His consent that I have successfully completed this study as a requirement to complete my MSc of Information Technology (Hons.). First and foremost I would like to thank to my Supervisors Mr. Ahmad Hanis Mohd Shabli and Dr. Ahmad Suki Che Mohamed Arif, for their valuable encouragement, ideas, comments, and guidance in my work. Special thanks to all my lecturers for their co-operation in giving ideas and opinions for me when needed. Warmest thanks to my wife, Puan Noor Azlina for her morale support, blasting ideas and always with me through ups and downs, our children Iman, Anas, Adam and Nuha for their patient and cooperation during the completion of my project and my family who always supports and encourages me during my difficult times and for their endless prayers. Not forgotten to my friends who keep-on giving me comments and ideas every time I needed it. I hope that with the experiences that I have gained during this study session will help me to become a successful person in the future, InsyaAllah.

Sincere Grateful

Zulkefli Abu Bakar
June 2015

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CHAPTER ONE
INTRODUCTION

1.1 Introduction

Nowadays, Klang Valley roads are increasingly becoming congested and effort for expanding existing roads and developing new roads are limited. This problem is exacerbated by the increasing number of cars on the road and the road itself could not supply the demand of the vehicles. Beside, constructing roads to meet the demand is not so easy especially in Kuala Lumpur (Morikawa et al, 2001). This is proved by the study that carried by Dissanayake and Morikawa (2002) where both in developed and developing countries, traffic congestion is a major problem in many urban regions. Shokri, Chu, Mokhtarian, Rahmat & Ismail (2009) also shared due to dramatic increase in the number of vehicles, traffic congestion has become an increasingly serious problem in large cities around the world. Much effort has been made in transportation engineering to control and management of the travel time especially in the peak-period (Hau, 2005).

Therefore, the goal of this study is to design, develop and test Road Traffic Routing application that used the vehicles' average speed to formulate a node's travel time for planning and suggesting a routing direction for optimal paths.

1.2 Problem Statement

This paper focuses on problem faced by car drivers that using the roads in Klang Valley area, to find the most precise and suitable roads with least travel time

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and avoid congested road which it is not an easy task, especially for those who want to drive to their destination without knowing what lies ahead.

Unfortunately, an aggregated travel time will increase if they have to go through the congested area. In addition, the need for effective solutions to ease traffic congestion especially for finding a smart vehicles navigation system (VNS) for planning and suggesting a routing direction with optimal paths which can minimize the aggregated travel time of the journey is really crucial and important.

1.3 Research Objectives

The goal of this research is to propose an alternative solution in order to assist Klang Valley car drivers upon choosing and make decision for their routing journey with mini-mum and optimum aggregated travel time. This alternative solution would apply the usage of heuristics algorithm through one of the routing direction algorithms (A*) which is using the node's travel time as a parameter input. In order to achieve the goal, the following objectives should be satisfied:

i.   To formulate the node's travel time formula based on vehicles' average speed that passing through.

ii.   To design and develop the Road Traffic Routing application by applying heuristics algorithm (A*) and using formula in (i).

ii.   To test the Road Traffic Routing application on Traffic Status system to produce optimum routing direction using the data (estimate and actual node's

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travel time) captured at each node located between origin (start) and destination (end) points.

1.4 Research Questions

The suggestion of using the estimate and actual node's travel times for nodes located between origin (start) and destination (end) points for producing the optimum routing direction is one of the alternatives that essentially needed in order to encounter all mentioned problems. With this in mind, this study aims to answer the following questions:

i.   Is it possible to formulate the node's travel times according to the vehicles' average speed that passing through?

ii. How does the heuristic algorithm (A*) and the node's travel time formula can be accommodated into the Road Traffic Routing application?

ii. How does the Road Traffic Routing application plans the optimum routing direction that can be used to avoid car drivers to go through the congested area which can affect the aggregated travel time?

1.5 Research Scope and Limitations

The scope of the study concerns the car drivers that are using Klang Valley roads. The reason why the Klang Valley roads were selected is that the fixed detection sensors are currently only installed at nodes located along Midle Ring

Road 2 (MRR2) and Federal Highway roads and it is already operate. Beside, using simulated sensors that placed virtually in the Traffic Status system which is randomly operate through the set of input are considered for resulting an expected output. The simulated sensors are located along Duke Highway and Jalan Kuching Highway.

The algorithm that will be applied on this proposed solution in order to produce the optimum routing direction through the nodes is the heuristic algorithm (A*). As for collecting the input data of the estimate and actual node's travel times that representing an estimation cost and cost so far (h'(n) and g(n)), is through the centralized server that connected to fixed detection sensors at each node via the internet connection.

This proposed solution is an extension module of the prototype system called Traffic Status system that runs on android operating system (OS) which can easily operating at any android mobile devices.

1.6 Significant of the Study

The significant of the research for this study is that it could prove by using the average vehicles' speed that captured by the fixed detection sensors located at each node along the roads which can assist the car drivers via mobile devices to identify the optimal paths they could take to reach their destination at optimum aggregated travel time as well as plan for avoiding the congested roads. Shokri, Chu, Mokhtarian, Rahmat & Ismail (2009) also conclude that using the accurate travel

time as an input of traffic flow information, it will notify the driver about the status of the road and help them to avoid from driving through the road that currently are congested. With this, it will cause of the reduction of the traffic congestion and minimize the travelling cost (less usage of fuel).

1.7 Expected Output

Therefore, as an expected output, the Traffic Status system through the road traffic routing application could offer a solution to encounter the problem by collecting for each node the vehicles' average speed and distance to another node, formulating the estimate and actual node's travel time and producing the optimum routing direction in real-time based on stated origin (start) and destination (end) points.

1.8 Summary

This chapter described about the introduction of the research that focused on the congestion problem that faced by the car drivers in Klang Valley and effort for finding the optimum routing direction that can help them to avoid from driving through the road that currently are congested. This chapter also described the problem statement, research questions, research objectives and project scope of the research. The system prototype is a mobile application that can be installed easily for Android devices. Lastly, this chapter discussed about the research significance where it is hoped that the system prototype can bring benefits to car drivers in Klang Valley for planning and suggesting a routing direction with optimal paths.

CHAPTER TWO
LITERATURE REVIEW

This chapter presents the literature review that is discussing about the published research information in a particular subject within a specific time. This literature review will be used as a foundation and support for a new insight of this research contribution. This literature review also will test the research question against what already is known in these research subjects. These research subjects are routing algorithm and travel time.

2.1 Routing Algorithm

The route computation module is one of the most important functional blocks in a dynamic route guidance system. Although various algorithms exist for finding the shortest path, their performance tends to deteriorate as the network size increases (Jagadeesh & Srikanthan, 2002). Jagadeesh and Srikanthan added from the empirical results indicate that the computation time becomes unacceptable as the network size become large even though those algorithms can guarantee their algorithm can compute the result. They stated the most popular algorithm is the Dijkstra's algorithm that has a runtime complexity of $O(n2)$, where n is the number of node in the network.

However, Jagadeesh & Srikanthan (2009) also concluded that the A* algorithm, which is widely used in vehicle navigation, is an improved version of the

Dijkstra's algorithm. It makes use of an appropriate heuristic function to search the most promising nodes first thereby reducing the computation time. Besides, Jacob et al (1998) suggested an improvement to the A* algorithm, wherein the heuristic function, which is an estimate of the remaining cost to the destination, is multiplied by an appropriate factor to make the algorithm runs faster at the cost of accuracy.

In addition, H.Halaoui (2009) aslo described that A* is an Artificial Intelligent graph algorithm was proposed by Pearl whereby the main goal of this algorithm is to find a cheapest cost graph path between two nodes using a heuristic function.

According to Zhao and Weymouth (1991), their heuristics search (or modified A*) algorithm expands fewer nodes than popular Dijkstra's which they stated the most promising route could define as the route which takes the least travel time by having a proper heuristic-evaluation function.

Therefore, by adapting this heuristic algorithm A* into Road Traffic Routing application can conclude that f'(n) is the evaluation function for node n, is the sum of the actual travel time g(n) and the estimated travel time h'(n), [f'(n) = g(n) + h'(n)] which this function enables the algorithm to search for more promising route first. The estimated travel time h'(n) is computed by dividing the estimated distance by the average speed.

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2.2 Travel Time

Travel time is very important in various fields of traffic system such as traffic management systems, advanced traveler information system, vehicle management system and etcetera. Therefore, accuracy in travel time data is very crucial for it will determine the traffic flow, traffic congestion and travelling cost. In fact, the travel time data is the essence for the system to operate.

Nowadays, the travel time will fluctuate depending on many factors. Shokri, Chu, Mokhtarian, Rahmat & Ismail (2009) documented there are two factors, 1) traffic factors such as routing path selected , traffic volume, occupancy of road and traffic facilities (e.g., signals), 2) non traffic factors including complexity of road network, traffic event, weather, road construction, speed limit and etcetera.

Previous studies, many intelligent transportation systems and transportation agencies use the traffic data from dual-loop detectors which are capable of archiving with traffic count (the number of vehicles that pass over the detector in that period of time), velocity, and occupancy (the fraction of time that vehicles are detected) and readily available in many locales of freeways and urban roadways (Lin and Zito, 2005). Nowadays, traffic data collecting techniques have made great progress and evolved to real-time collecting in order to improve traffic management efficiency. According to Lin and Zito (2005), process of collecting the traffic information and measuring the travel time can be done through three difference approaches that are site based, vehicle based and sensor based.

For this project, sensor based approach will be used as collecting the traffic information through the fixed detection sensors are installed at nodes along the road of MRR2 and Federal Highway. The calculation of the travel time will be based on the collected data in real time events such as detours, traffic congestion, accident, weather, road construction and etcetera.

2.3 Summary

This chapter described about the literature review of existing research that could be used as the guideline and direction of this research. The things that has been discussed are routing algorithm mostly been used for getting an optimum path and how to derive the input of vehicle speed for getting a travel time.
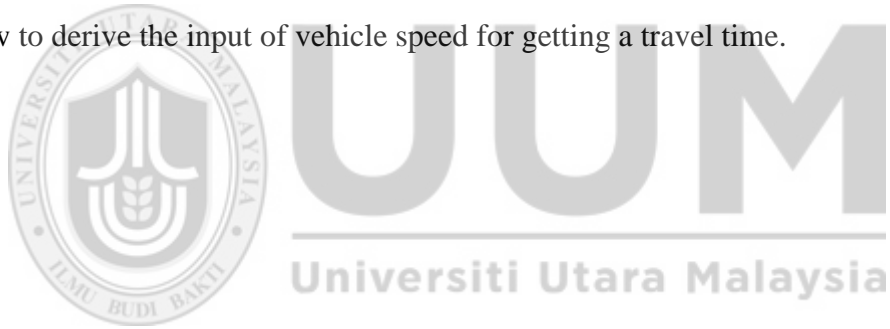
CHAPTER THREE
RESEARCH METHODOLOGY

Research methodology is a systematic way to solve a problem. Methodology is the procedures by which researchers go about their work of describing, explaining and predicting phenomena. It is also defined as the study of method by which knowledge is gained. Research methodology also aim to give the work plan of the research. There are various approaches of the methodology for system development. The approach that been used in this research is the Rapid Application Development (RAD) Prototyping.

3.1 Prototyping

Prototyping is the process of building a working replica of a system by performing analysis, design and implementation phase concurrently & repeatedly until the system is completed. It perform analysis, design and implementation phases concurrently and repeatedly until the system is completed. According to Otto and Wood (2001), the advantage of prototyping are better understanding of customers need, exploring interface issues and reducing costly iterations in the design phase.
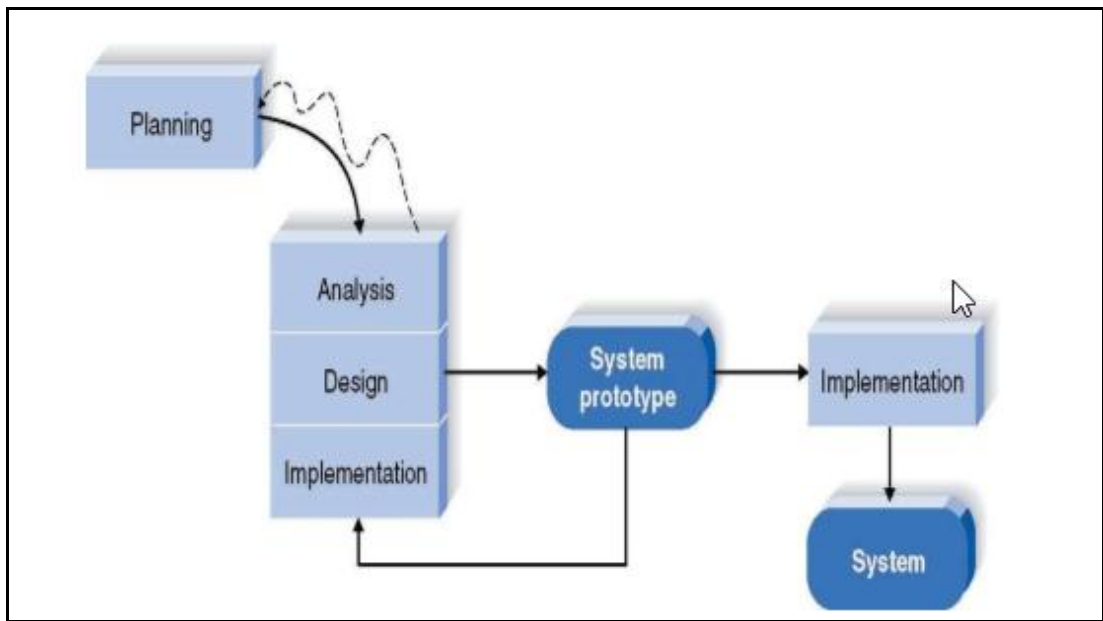
Figure 3.1: UCMS Prototyping Methodology

3.2 Planning

During the planning phase, literature review and requirement gathering was done. The activity covered during the literature review is understand the A* algorithm and formu-late the estimate h'(n) and actual g(n) variables based on node's travel time for producing the optimum routing direction in real-time based on stated origin (start) and destination (end) points. The node's travel time is calculated based on average vehicles speed that passing through the node against the distance of the node to other connected nodes.

3.3 Analysis, Design and Implementation

The information gathered from the planning phase is analyzed. Based on the information gathered, the users, behaviors, states and functions of the system is defined. The output from the analysis is the requirement model for the road traffic routing module.

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The design will be based from the Unified Modelling Language (UML) diagram that consists of use case diagram, sequence diagram, class diagram and state chart diagram. The use case diagram will be used to describe the basic functions and activities that will be performed by the users of the system. The sequence diagram will be used to illustrate the objects that participate in a use case and the messages pass between them over time for one use case. The class diagram will be used to show the classes and relationship among classes that remain constant in the system over time. Lastly, the state chart that will be used to shows the different states that a single object passes through during its life in response to events, along with its responses and actions.

For implementation, the prototype will be developed using Eclipse SDK for the interface and the functions involved such as getting the nearest node for originating and destination point, formulating and calculating an estimate and an actual node's travel time, producing the list of visited nodes using the A* algorithm based on originating and destination points and constructing routes direction between the nodes are using the ASP.NET c# language. The data transmitted between these two entities (interface and functions) are using web services XML structured data files. MySQL DB is used for the database which to store the information of the nodes (sensors) such as current average speed for vehicles that passing through, distance between the nodes and direction of the nodes. For the server, the cPanel server will be used so that it can be accessed online during the development and validation.

3.3.1 Requirement Model

Requirement model discusses about the requirement analysis and design. It will describe more about the process of requirement gathering that contribute to design the requirement model of UML Diagram that consist of use case diagram, sequence diagram, class diagram, state diagram and activity diagram.

3.3.1.1 Use Case Diagram
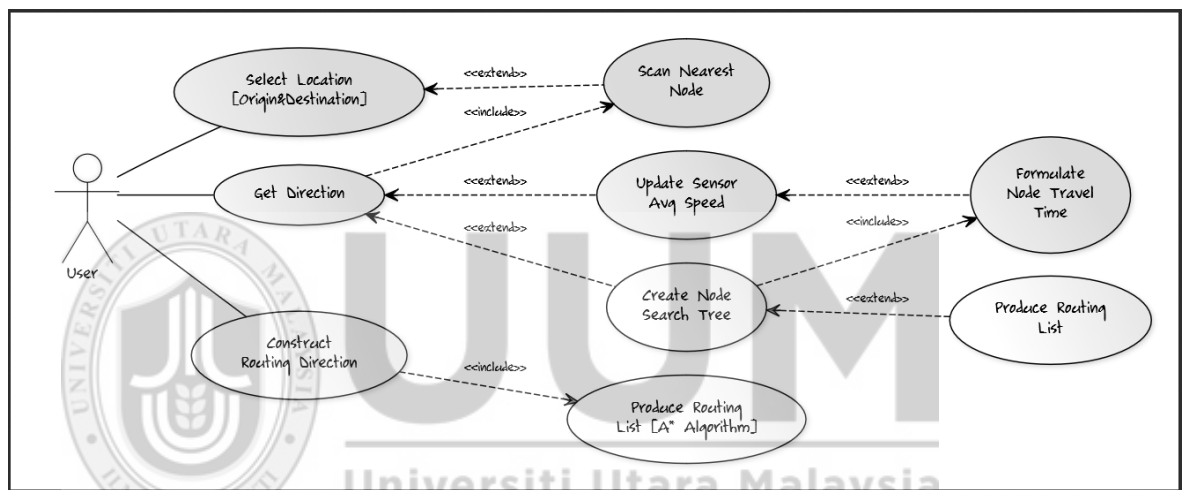
Figure 3.2: Use Case Diagram

Figure 3.2 above shows the use case diagram of the requirement model. As illustrated by the figure, there are three (3) use cases that can be done by the user. The use cases are Select Location [Origin & Destination], Get Direction and Construct Routing Direction. For Select Location use case, the activities involved are getting the address, latitude and longitude of originating and destination points from the GoogleMapV2 web services. The information retrieved at this use case will be used by Scan Nearest Node use case's activities. For Get Direction use case, the activity that need to be completed earlier is scan and get the possible nearest node

which involve in Scan Nearest Node use case. Then, Update Sensor Avg Speed and Formulate Node Travel time use cases will come after that. After the node travel time has been formulated, Create Node Search Tree use case will be called and later Produce Routing List use case which involved activity of getting the optimum routing direction using A* algorithm will be executed. Lastly for Construct Routing Direction use case, is having an activity of drawing the routing direction line for visualizing it to the user.

3.3.1.2 Class Diagram
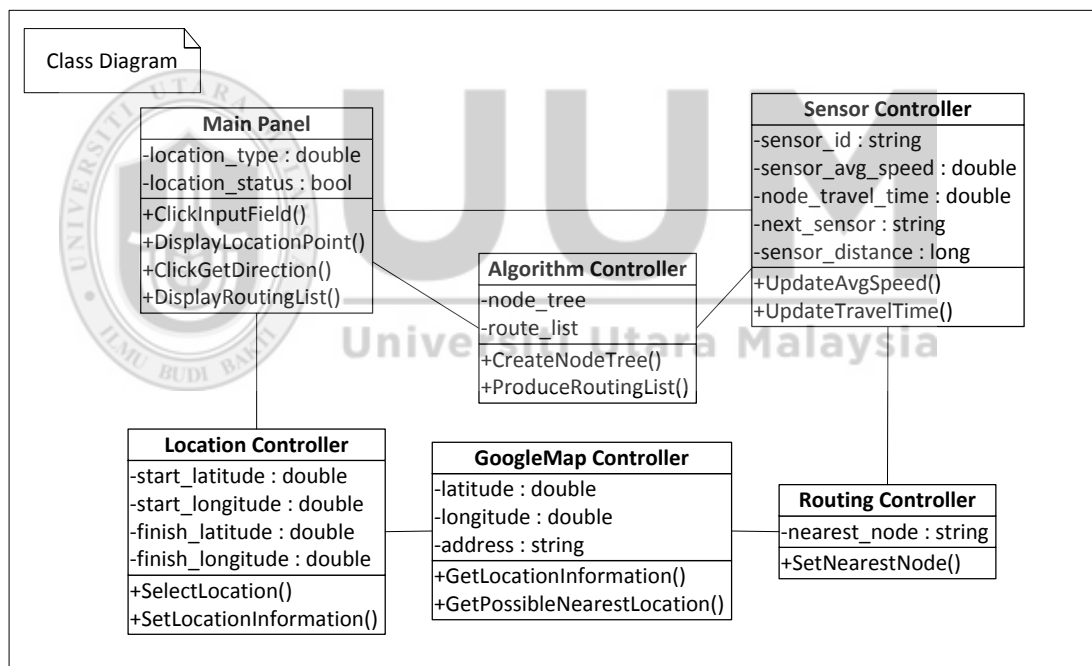
Figure 3.3: Class Diagram

Figure 3.4 shows the class diagram which consist of Main Panel, Location Controller, GoogleMap Controller, Sensor Controller, Routing Controller and Algorithm Controller classes. In the Main Panel class, there are variables of

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location_type and location_status. The location_type is used by function ClickInputField() for determining what type of location that user want to select on map whether origin or destination. For location_status variable is to determine whether the selected origin or distination location is valid and accessible by invoking the functions of SelectLocation() and GetLocationInformation() in Location Controller and GoogleMap Controller classes.

Next, the ClickGetDirection() function gets invoked by the user when the location_status is true. The function is doing the sequences processes of updating the sensor's average speed, updating node's travel time, scanning nearest node of origin and destination, creating node tree and producing routing list by invoking the functions of UpdateAvgSpeed(), UpdateTravelTime(), GetNearestLocation(), CreateNodeTree() and ProductRoutingList() that are belong to Sensor Controller, GoogleMap Controller and Algortihm Controller classes.

Lastly, the DisplayRoutingList() function gets invoked by the user is to draw the routing direction line for visualizing it on the screen. The function is in the Main Panel class.

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3.3.1.3 Sequence Diagram
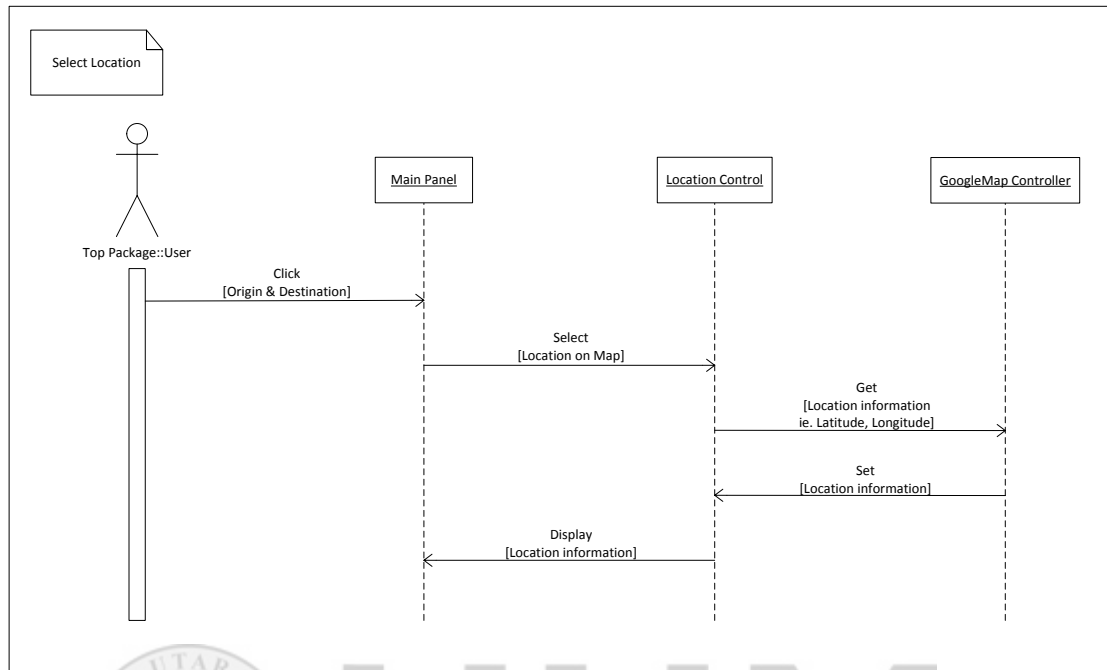
Figure 3.4: Select Location Sequence Diagram

The above figure is the sequence diagram for Select Location. It starts when the user clicks at the Origin or Destination field on the application. Then, the application will prompt a menu to the user to select the location on map or get a current location based on GPS service provider. Next, the application will send a request to GoogleMapV2 web services through XML structured data file for getting the location information such as location address, latitude and longitude. Next, the information will be displayed on the application.
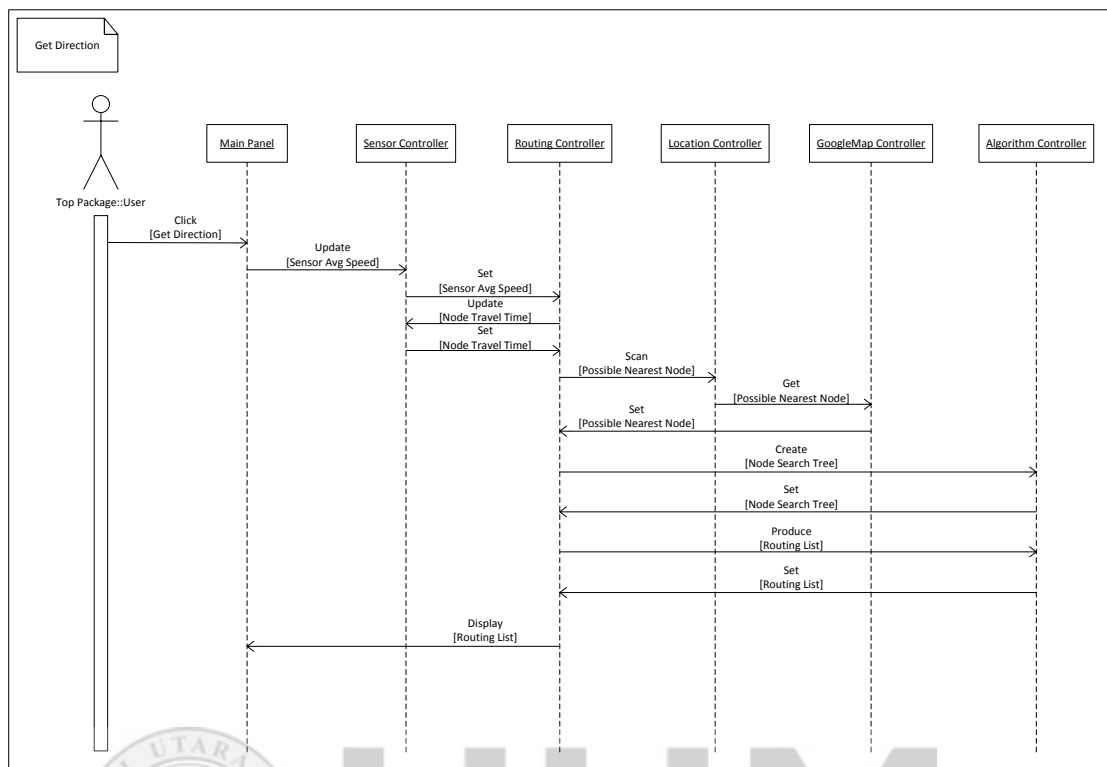
Figure 3.5: Get Direction Sequence Diagram

Figure 3.5 above is the sequence diagram for Get Direction where the user starts the activity by clicking at the Get Direction button on the application. The moment the button is clicked, the application will process activities of updating sensors average speed based on vehicles that passing through and node's travel time calculated based on the distance between the nodes. Then, the application will scan and get all possible nearest nodes of the originating and destination points. Once all the information is gathered, the application will create Node Search Tree and produce the routing list based on heuristics A* algorithm. Next, the information of routing list will be displayed on the application.
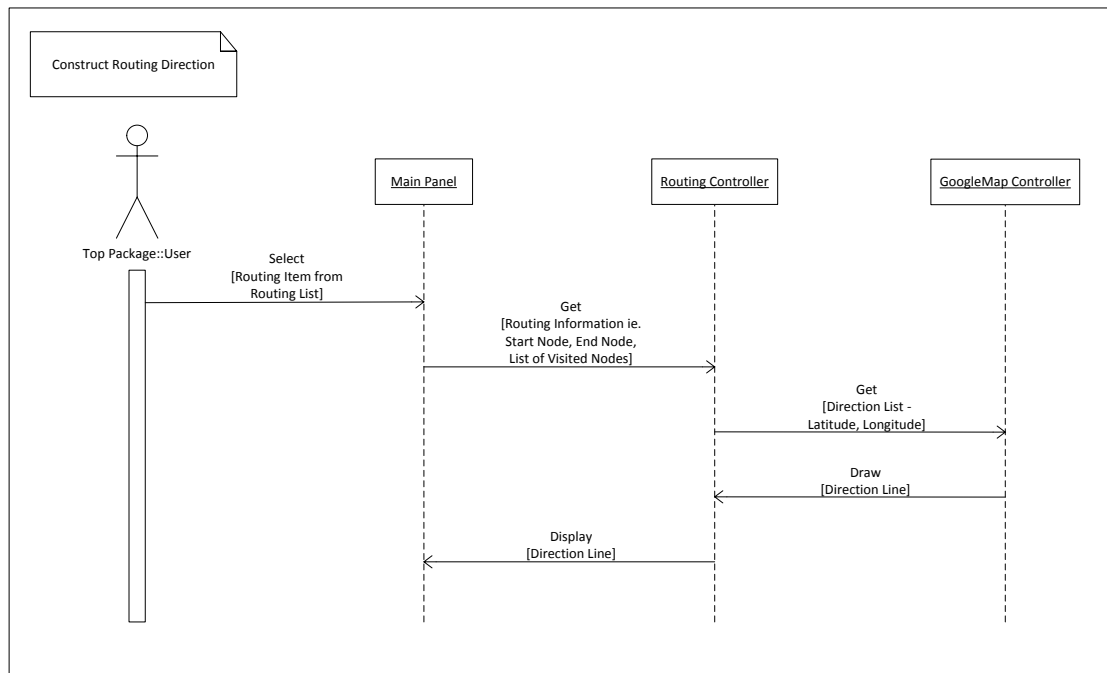
Figure 3.6: Construct Routing Direction Sequence Diagram

The above figure is explaining on the sequence of constructing routing direction. The sequence activity starts when the user selects the desired routing item from the routing list. Then, the application will get the routing information such as start node, end node and list of visited nodes for getting the direction list from the GoogleMapV2 web services. Next, the application will draw the direction line on the map and visualize it to the user.

3.3.1.4 State Chart Diagram
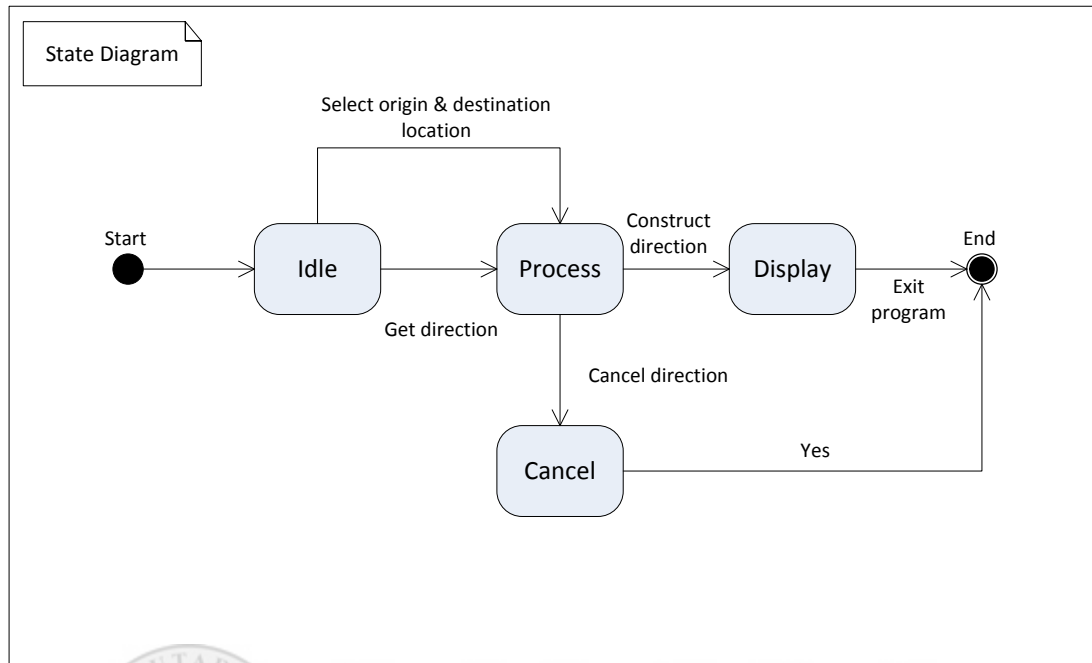
Figure 3.7: State Chart Diagram

The above state chart diagram shows that the system is in idle state before user start to select origin & destination location. Select origin & destination location has invoked the system in process state which is required to determine the nearest node for start and finish routing direction. Then, the system is in process state again when the user execute get direction function. Get direction means that the system update node average speed & node travel time, create node tree and produce routing list. Lastly, the system is in display state after constructing the routing direction for visualizing to user.

3.4 System Prototype

Road Traffic Routing application has been produced after going through all the stages in Prototyping Methodology. The application is compatible with any mobile devices that are equipped with Android version 2.2 and above. The size of the application is only 8MB and it can be installed easily on the devices. To ensure that the application is working efficiently, the minimum requirements of running the application should be considered such as internet connection with minimum bandwidth of 64kbps, GPS accessible is turn on and location is shareable. To operate the application in correctly manner, the user manual will be prepared and attached together with the application that can be accessed through the "Help" link.

3.4.1 How it work

The application starts when the user clicks on the icon "Traffic" in the application list menu. Below figure showed the icon stated in the application list menu after installing the application

Figure 3.8: Application List

Next figure will show how the application is looks like after executing. The looks and feel of the application interface is developed using the android menu drawer package and fragementable layout.

Figure 3.9: Traffic Application Ver1.0

In order for the application to produce the optimum routing direction between the originating and destination points, the user needs to select the desired origin and destination location by clicking on the map layout. Then, the application will response to the user with an address, latitude and longitude of the location. Next, the user has to click on the "Get Direction" button for the application start processing the sequences activities of 1) Formulating and calculating node's travel time for all

available sensors, 2) Scanning and getting the possible nearest nodes according to the originating and destination points, 3) Creating the node search tree based on directed graph that the nodes are connected each other's and 4) Producing the list of visited node using the A* algorithm. If there is many possible nearest nodes found during the scanning activity, the application will suggest more than one optimum routing for user to select. Finally, to visualize the optimum routing direction between the originating and destination points, the user has to select the suggested routing that can be found in "Routing List" menu. Next figures will illustrate all the sequences activities explained above.
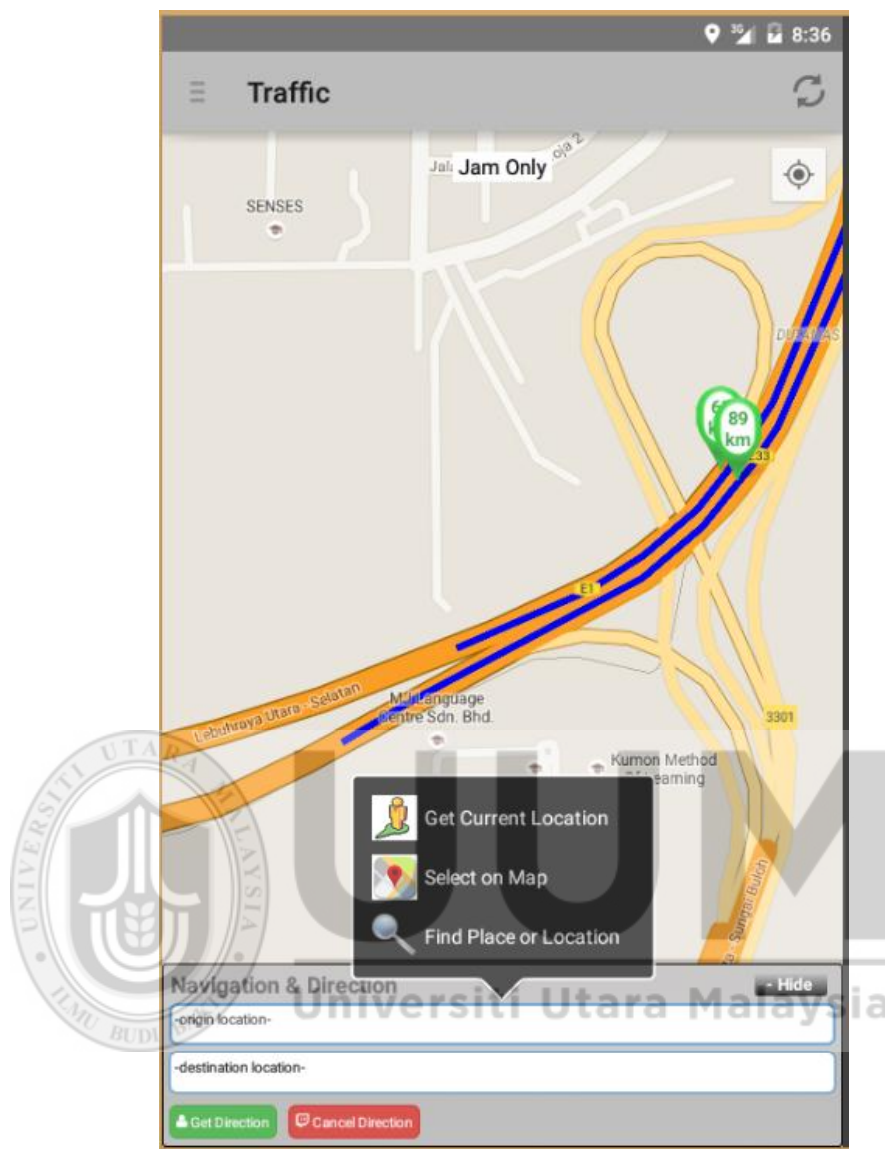
Figure 3.10: Select Origin and Destination Location
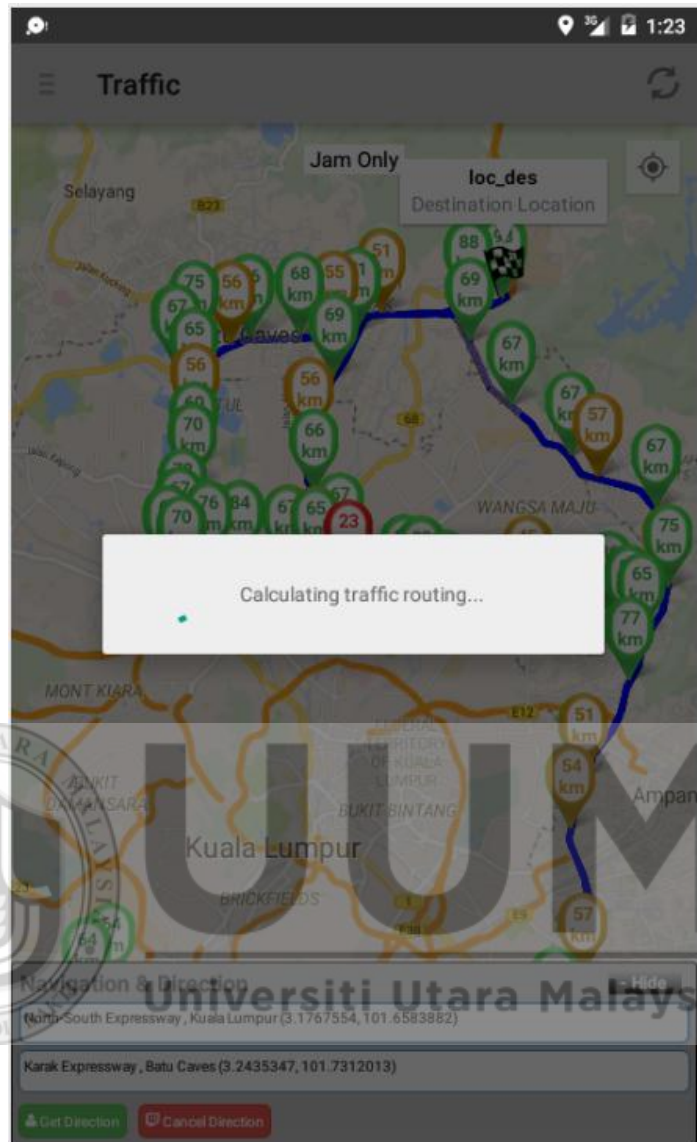
Figure 3.11: Calculate Traffic Routing
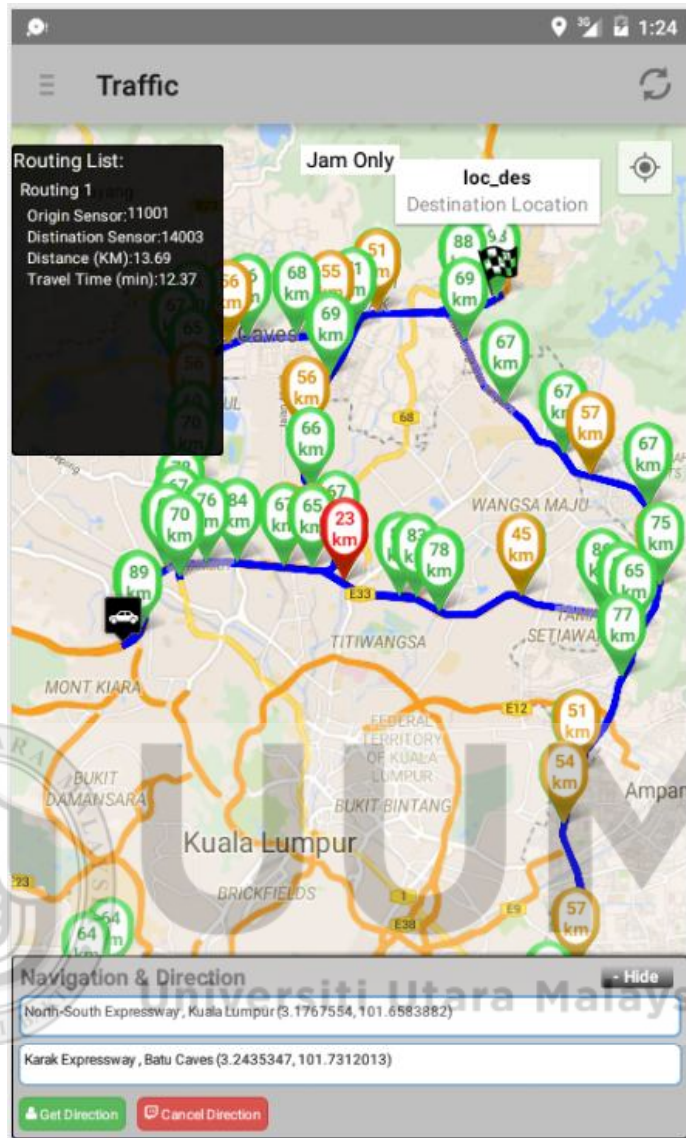
Figure 3.12: Routing List
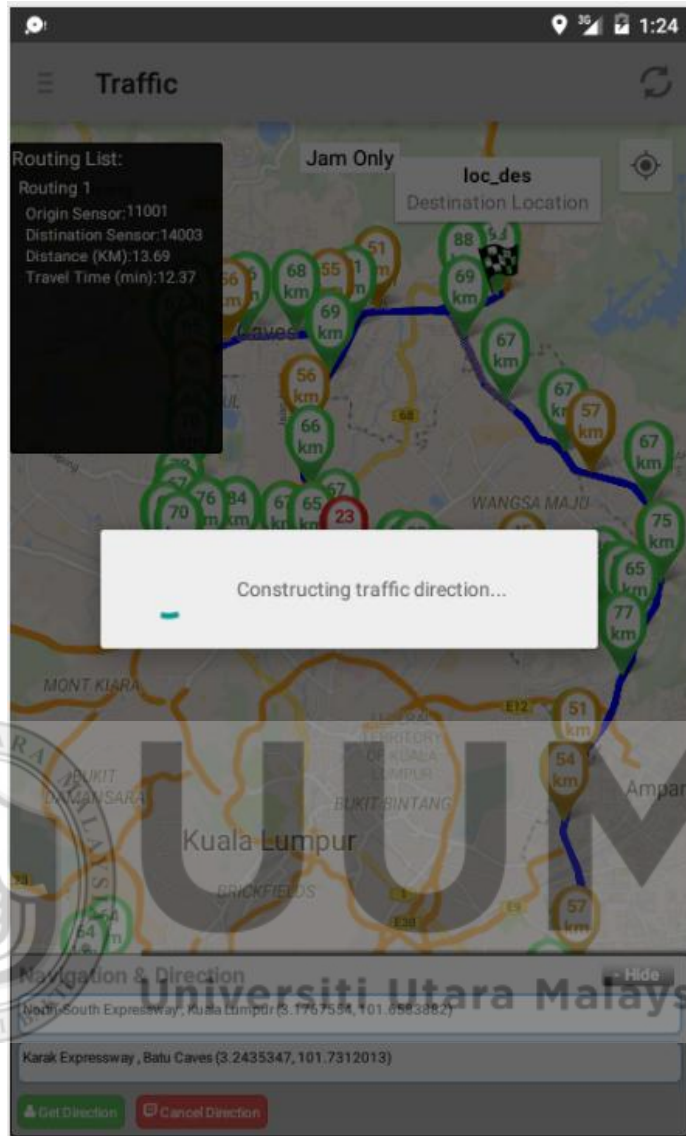
Figure 3.13: Construct Routing Direction
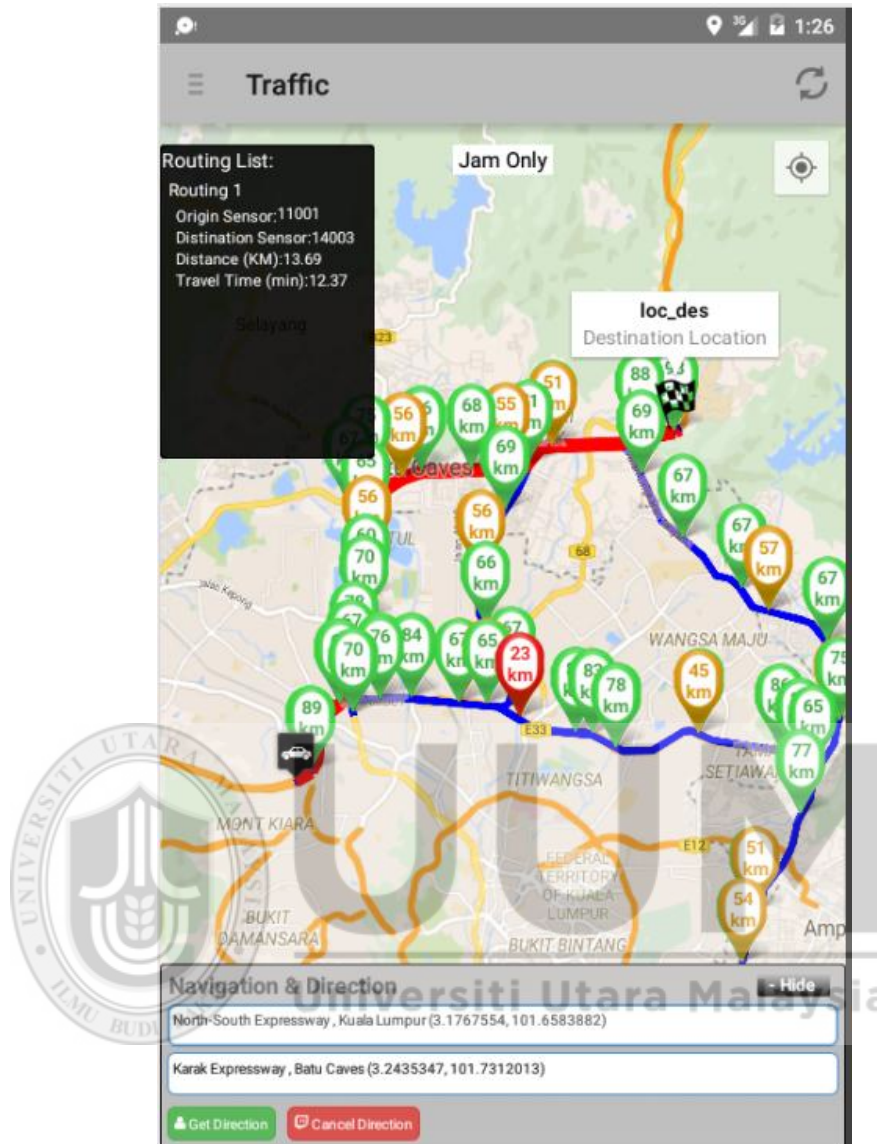
Figure 3.14: Optimum Routing Direction

3.5 Summary

This chapter discussed about the research methodology that been used by the researcher throughout the research. The researcher choose Rapid Application Development (RAD) Prototyping model for this research methodology. Besides, this chapter also described about the process taken for requirement analysis which result

to the design of use case diagrams, class diagram, sequence diagrams, state chart diagrams, activity diagrams and the system prototype.

CHAPTER FOUR
EVALUATION

In order to evaluate the system prototype, a testing will be done by randomly select the participant of Modenas staff that are working in Klang Valley area that normally travelling using MRR2, Duke Highway and Jalan Kuching Highway. Since it can be installed at mobile devices and operate easily with minimum bandwidth of internet connection, the testing can be done at anytime and anywhere. The testing is conducted using the data captured through the fixed detection sensors are currently installed and the simulated sensors that placed virtually in the proposed system.

4.1 Evaluation of System Prototype

Firstly, a walkthrough of the prototype system is done by the researcher to the respondents before they started to test it. This walkthrough is done so that the respondents understand how to use the application and the flow of the application. Besides, the used of combination fixed detection sensors and simulated sensors and the objectives of developing the application also been shared so that the users have an initial idea how to test it precisely. After that, the respondent tested the prototype system by themselves. After finished the testing, a survey of the system thorough the questionnaires, are given to the respondents for a feedback regarding the system. The results of the questionnaires are used to show whether this research's objectives is met or not.

4.2 Evaluation Objective

The aim for this survey is to measure that the proposed system meets the requirements and objectives in term of functionality, reliability, usability and efficiency. If there are added requirements and recommendations, it can be used in the future recommendations section for future research.

4.3 Population and Sample

With time limitation for this research, the population and sample of the system evaluation consist of only 6 Modenas staffs that are working in Klang Valley area that normally travelling using MRR2, Duke Highway and Jalan Kuching. The meeting was done between the researcher and the users when they attended monthly meeting for month of April, 2015 in Modenas Headquarter, Gurun.

4.4 Summary

This chapter described about the evaluation of the system prototype that has been carried out with the set of population and sample of respondents. A walkthrough of the prototype was done before the respondent test the prototype. After that, a questionnaire was given to get their feedback regarding the prototype system.

CHAPTER FIVE
RESULTS AND FINDINGS

In this chapter, the project findings and results from the testing are discussed and presented. The results that the researcher gets from this research are the requirement model, system prototype and result of the survey conducted with selected participants.

The result of requirement model of this research consist of use case diagram which described the basic functions and activities that performed by the users of the application, sequence diagram that illustrated the objects that participate in use case and the messages pass between them, class diagram that is used to show the classes and relationship among classes, state diagram that is used to show the different states of an object passes through and activity diagrams that is used to model both computational and organizational processes.

For system prototype, the result of this research is the Road Traffic Routing application that can be installed in Android phone that getting the originating and destination points based on latitude and longitude then transmit the data through web services XML structured data files to the server. The server then will calculate the node's travel time and producing the optimum routing direction based on node's information stored in database and current average vehicle speed and passing back the information to the application for constructing the node's direction or path.

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From this system prototype, the set of questionnaires were prepared to gain some knowledge about the application in terms of its functionality, usability, reliability and efficiency. Below are the results from the survey conducted on the selected respondents during the testing that has been done.

5.1 Result Analysis

Table 5.1, table 5.2, table 5.3 and table 5.4 represent the result analysis of the survey that has been conducted thorough the questionnaires.

No	Questions	Means
1	The application does what is appropriate	4.17
2	The application has available all functions required for its execution	4.23
3	The software does what was proposed correctly	4
4	The software is precise in executing its functions	4.3
5	The software is precise in its result	4.1
6	The software interacts with the specified modules	4
7	The software has capacity for multiuser processing	4

4.11

Table 5.1: Functionality

No	Questions	Means
1	The application has frequent failures	4
2	The application reacts appropriately when failure occurred	4.17
3	The application informs users concerning invalid data entry	4.17

4.11

Table 5.2: Reliability

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No	Questions	Means
1	It is easy to understand the concept and application	4.33
2	It is easy to perform its function	4.5
3	It is easy to learn how to use	4.33
4	It is easy to operate and control	4.17

4.33

Table 5.3: Usability

No	Questions	Means
1	The application's response time is appropriate	4
2	The application's execution time is appropriate	4.17

4.09

Table 5.4: Efficiency

Based on above tables, according to the scale of (5) Strongly Agree, (4) Agree, (3) Neutral, (2) Disagree and (1) Strongly Disagree, it showed that all six participants agreed with the functionality of the application with mean is 4.11, for application reliability the users experienced that they do not have any significant system interruption during operating the application with mean is 4.11, for usability test, the application is easy to understand the concept, smooth in performing its functions, easy to learn and to operate with mean is 4.33 and the application has good response and execution time with mean is 4.09. That is mean the users do not have to wait for a long time to get the output. With all the means gathered it showed that the users believe and agree the Road Traffic Routing application has achieved its objectives completely.

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5.2 Summary

This chapter discussed about the analysis of the results and findings on the system prototype from the testing and survey that has been conducted thorough the questionnaires.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

This chapter discusses the conclusion of overall outcome and findings of the study. There is also limitation and recommendation for future research stated in this chapter.

6.1 Conclusion

As a conclusion, the Traffic Status system through the road traffic routing application could offer a solution to users of planning and suggesting the optimum routing direction in Klang Valley road which can minimize the aggregated travel time of the journey and reduce the traffic jam, avoid the congested area and save the fuel. With the application that can be installed and operate in Android phone, it is can be easily used by the users at anytime and anywhere.

6.2 Limitation

There are several limitations on the current prototype of road traffic routing application such as formulating the node's travel time and calculating the optimum routing direction which are based on current data captured by the sensors at the time it start processing.

Besides, the application is only applicable to Android phone only. For users that use other mobile devices such as Windows phone and iPhone IOS do not have a

chance to use it. Other than that, the real fixed detected sensors are only available and located along the MRR2 highway and Federal highway.

6.3 Future Recommendation

For future work regarding the prototype application, the researcher recommends that the application is able to re-formulate the node's travel time and re-calculating the optimum routing direction for every time the travelers reach the node. For supporting devices, the researcher also recommends to develop a new version of the application that is applicable to all mobile devices whether in Android phone, Windows Phone or iPhone.

Thus, to acquire precision in optimum routing direction the use of additional fixed detection sensors should be extended to all routes in the Klang Valley instead of simulated sensors.

In order to get significant results and finding, comparative study should be done with the existing tools to compare whether the system reliability is on par with Google Map or Google Waze.

6.4 Summary

This chapter concluded the research project and recommends some aspects that can be added for future work.

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