Shortest Path Algorithm for Transportation Networks, Case Study: Kumasi Metropolitan Assembly.

[1] N.F Darquah
Department of Computer Science, Kwame Nkrumah University of Science and Technology, Kumasi
University Post office (PMB) Kumasi, Ghana – West Africa
[2]*Jonathan Annan
Lecturer
Department of Information Systems and Decision Science -School of Business
Kwame Nkrumah University of Science & Technology Kumasi
University Post office (PMB) Kumasi, Ghana – West Africa
(**Corresponding Author**)
[3] K. Baah Gyamfi
Lecturer
Department of Mathematics, Kwame Nkrumah University of Science and Technology,
University Post office (PMB) Kumasi, Ghana – West Africa

ABSTRACT
*In a metropolis such as Kumasi, the transport network is massive, dynamic, and complicated. Route finding is not an easy task, especially when routes comprise several modes. This problem is even more important for e-tourism tourists, security services and moving workforces, who may need to visit unfamiliar parts of the metropolis. In this research paper, we present shortest path algorithm for transportation networks, of the Kumasi Metropolitan Assembly (KMA)**. U**ser friendly extension of ArcGIS and Visual Basic Dot Net with Dijkstra's algorithm was used to provide the shortest path from one node to the other.*

Key Words:
ArcGIS Network Analyst, Shortest path, Dijkstra's algorithm and VB. Net

INTRODUCTION

Shortest path problems are one of the most fundamental and important problems in network theory. Many applications have been modelled as variants of the shortest path problems. Travelling is part of daily life and people (especially in large cities) rely heavily on public transport. In a metropolis with a complicated transportation network, it is difficult to select the most economical route. It is always advisable for drivers to use the most economical route to their destinations.

RELATED WORKS

Shortest path problems are the most fundamental and commonly encountered problems in the study of transportation and communication network (Syslo et al., 1983). There are many types of shortest path problems. For example, we may be interested in determining the shortest path (i.e, the most economic path or fastest path or minimum –fuel consumption path) from one specified node to another in a network. We may also need to find the shortest paths from a specified node to all other nodes. Optimal routes are determined by comparing metrics, and these metrics can differ depending on the design of the routing algorithm used (Parker, 2001). Different algorithms have been proposed to find the optimal routes, such as: Dijkstra's algorithm, used by Network Analysts, is a greedy algorithm that solves the single-source shortest path problem for a directed graph with nonnegative arc weights (Dijkstra, 1959). Miller (2005) compared the RouteSmart 4.40, the ArcLogistics Route and the ArcMap Network Analyst extension on the ability of either software package to create routes usable by the Solid Waste Department in a timely, efficient manner for the city of Richardson in Texas.

Arrival time dependent shortest path finding is an important function in the field of traffic information systems or telematics. However, a large number of mobile objects on the road network results in a scalability problem for frequently updating and handling their real-time location. (Mobile Ad – Hoc Network, 2005).

Kyoung-Sook, So-Young and Ki-Joune (2005) proposed a query processing method in Mobile Ad-hoc Network (MANET) environment to find an arrival time dependent shortest path in respect of both traffic and location in real time. The authors proposed time dependent shortest path query that was processed by in-network way. In order to reduce the number of messages to forward and nodes to relay, the control introduced an on-road routing, where messages were forwarded to neighbouring nodes on the same or adjacent road segments. This routing method allows to collect traffic information in real time and to reduce the number of routing messages. Matthews (1942) was first to introduce a method for optimisation of road spacing based on minimisation of road and skidding cost.

Ghaffarian (2000) found the best road network for a district harvested by skidder. The skidding model developed by stepwise regression model, was used to predict the cost of skidding per cubic metre for the thirty nine (39) nodes, which were planned in the district map. The harvesting volume and road cost per node were computed. The data were entered into network 2000 and the shortest path algorithm; simulated annealing and great deluge algorithms were run to find the optimal of logging of the district. The result showed which roads could be eliminated from the existing forest road network.

Dijkstra's Algorithm

Dijkstra's Algorithm was then coded in Visual Basic Dot Net as follows:

```
function Dijkstra (Graph, source):
    for each vertex v in Graph:          // Initializations
        dist[v]:= infinity               // Unknown distance function from
                                            Source to v
        previous[v]:= undefined          // Previous node in optimal path
                                            From source
    dist[source] := 0                    // Distance from source to
                                            Source
    Q := the set of all nodes in Graph
    // All nodes in the graph are unoptimized - thus are in Q
    while Q is not empty:                // The main loop
        u := vertex in Q with smallest dist[]
        if dist[u] = infinity:
            break                        // all remaining vertices are
                                            inaccessible
        remove u from Q
        for each neighbour v of u:       // where v has not yet been
                                            removed from Q.
            alt := dist[u] + dist_between(u, v)
            if alt < dist[v]:            // Relax (u,v,a)
                dist[v] := alt
                previous[v] := u
    return previous[]
```

DATA COLLECTION AND ANALYSIS

The proposed routing system for Adum, Kumasi includes three subsystems, namely, ArcGIS Network Analyst (for the digitized map), Dijkstra's algorithm and VB.Net for the software development. A digital road network of Adum was used within the ArcGIS map with a scale of 1: 2000. The road network was represented as connections of the nodes and links. Geometric networks were built in the ArcGIS model to construct and maintain topological connectivity for the road data in order to make possible the path finding analysis. Historical data on average traffic volume at surface streets within the area under study were used. The segment lengths were extracted using Environmental Systems Research Institutes (ESRI's) ArcGIS software. The average volume of each link in the network was obtained from Kumasi Metropolitan Assembly (KMA) Traffic Unit. Summation of the travel distance (times) for all the segment of a particular path between an origin and a destination provides the total distance (time), which is minimized by the shortest path algorithm. The routing macro uses Dijkstra's routing algorithm.

When creating a network routing system, specific spatial data were collected for the accurate completion of the network. For example, a complete road network, where all the roads within the network are connected, is significant because it allows connection throughout the system.

ASSUMPTIONS

The following assumptions were made:

(i) Traffic congestion not considered

(ii) Calculations were based on road distances and

(iii) State of the road not considered

Adum map was taken from the Town and Country Planning Department of KMA and was digitized by the Geodetic Department (KNUST) to convert the map into a road network.

Figure1: The City Centre Road Network of Kumasi

Figures 1 and 2 are the city centre road network of Kumasi and the extract map of Adum respectively.

EXTRACT MAP OF ADUM

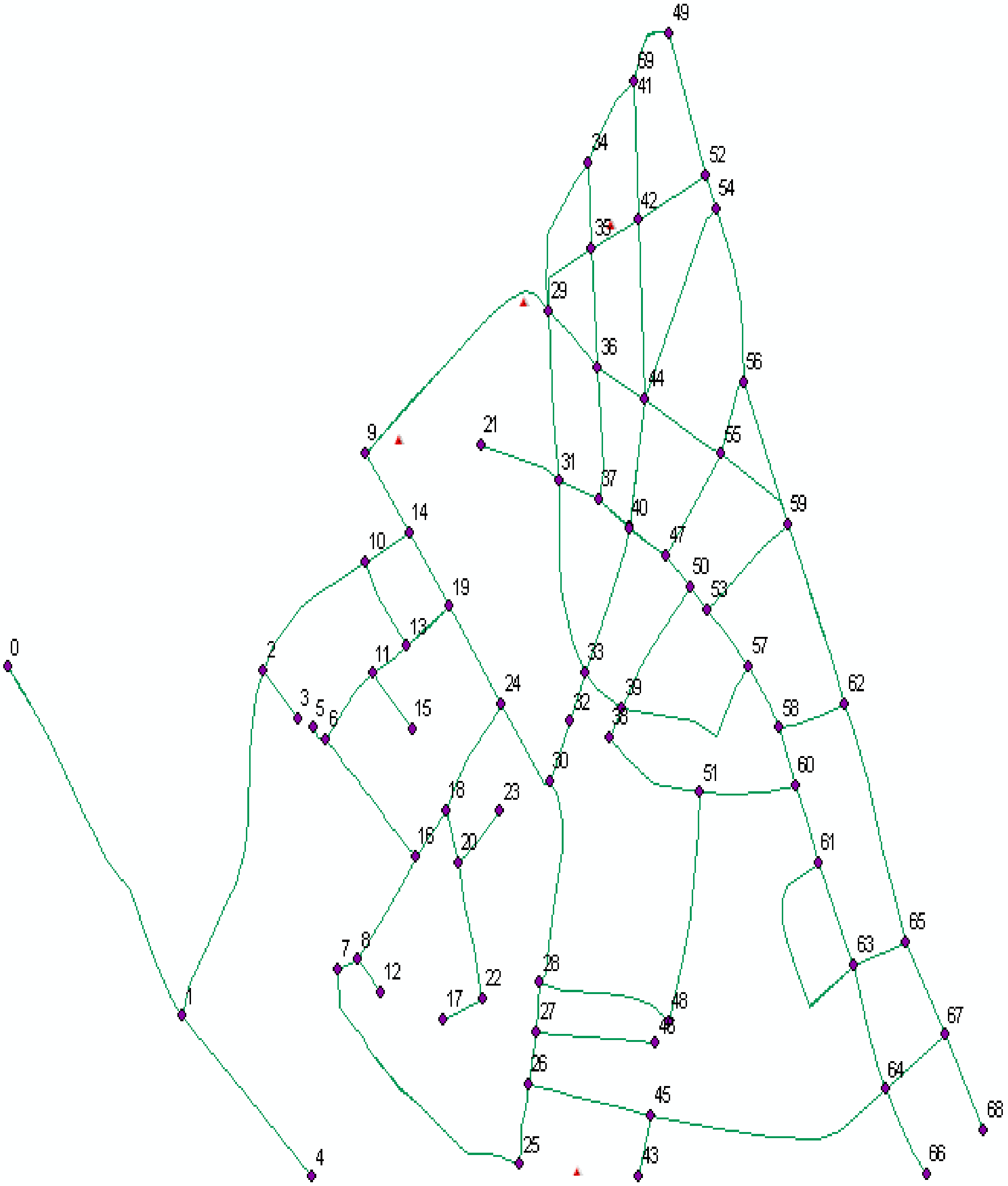

Figure 2: The Extract Map of Adum

SOFTWARE DEVELOPMENT

The proposed routing system has been of three subsystems including:

(i) ArcGIS Network Analyst
(ii) Dijkstra's Algorithm and
(iii) VB.Net

For the software development

SOME FEATURES OF THE INTERFACE

Here the user is allowed to select the needed map from the dialogue box, which consists of various maps to open as shown in Figure 3.

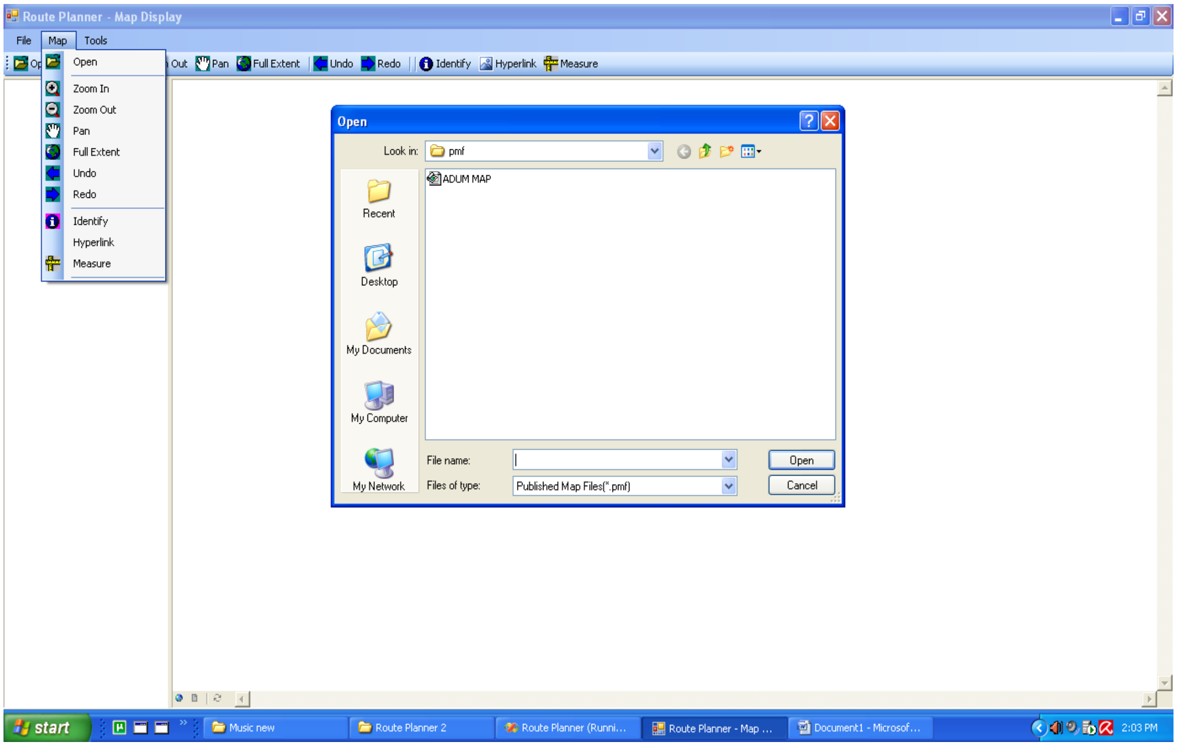

Figure 3: Selection of maps.

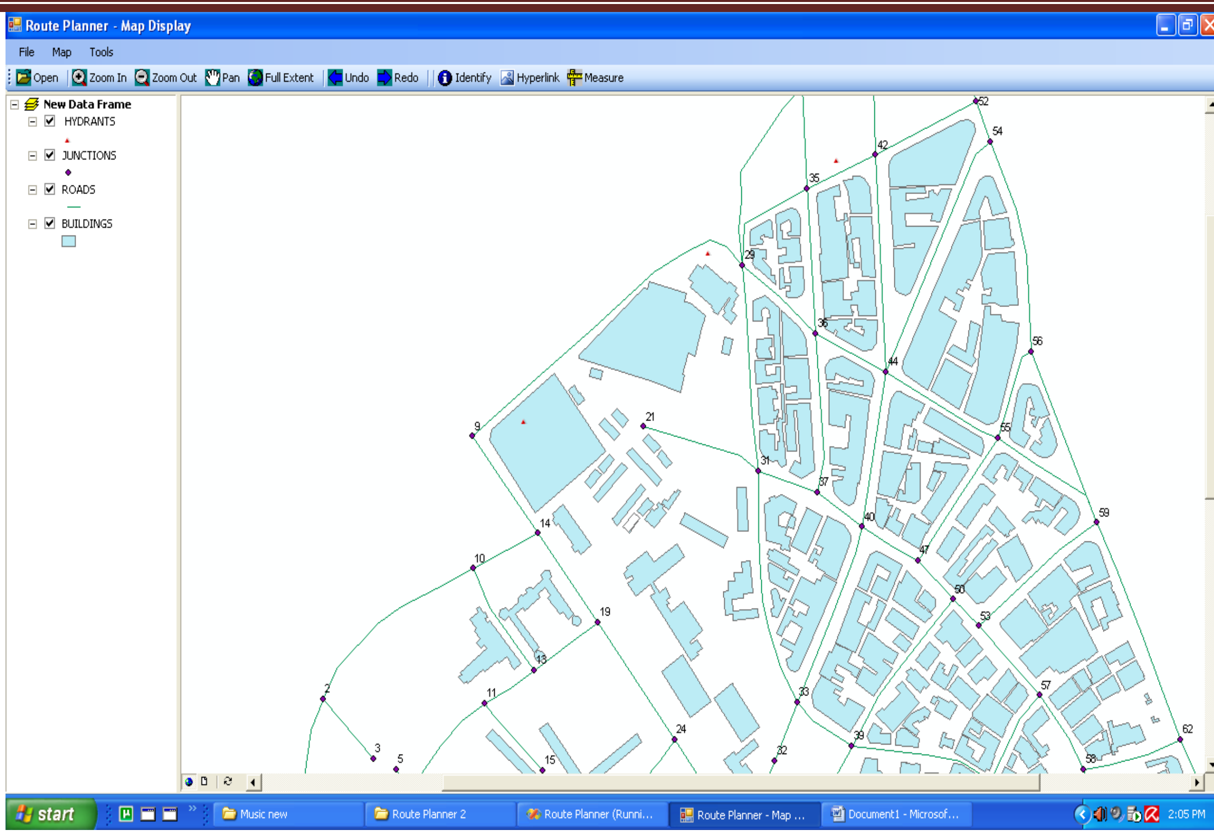

Figure 4: Display of the selected map

Figure 4 depicts the display of the selected map.

The user can use the tool menu to select the Shortest Path Navigator where the user can select the source street and the destination as shown in Figure 5. The flash bottom flashes the selected street and the Flicker also flicks the selected street. The Go button is used to calculate the shortest distance from the source street to the destination street on the map, and then displays the distance on the blank space. The Flash Features show the shortest path on the map.

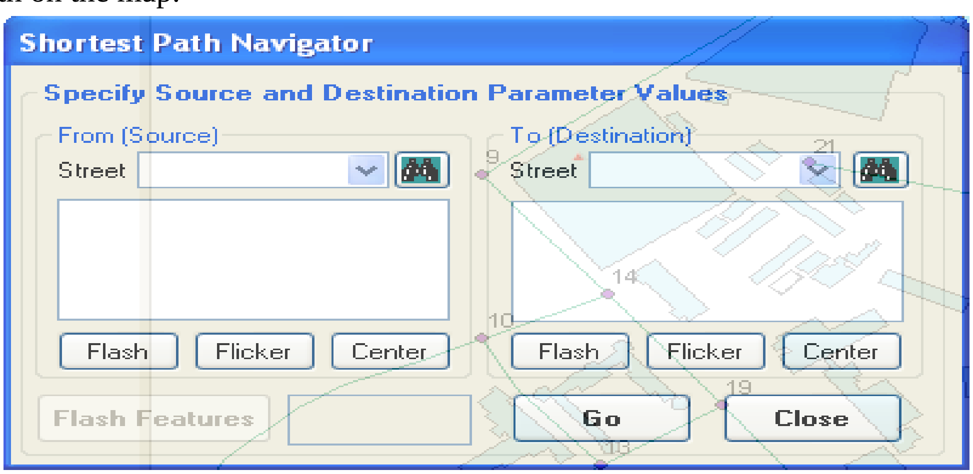

Figure 5: Selection of the Source and the Destination Streets

Figure 5 displays the select source node and the end node.

A selected street is being shown in Figure 6.

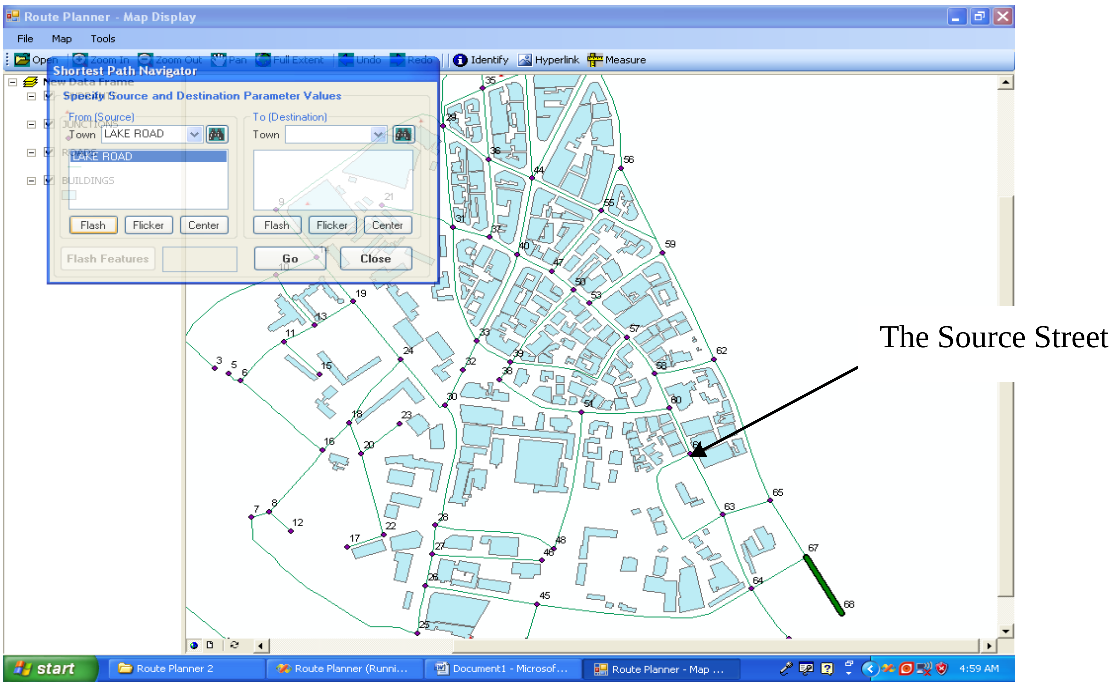

Figure 6: A Source Street.

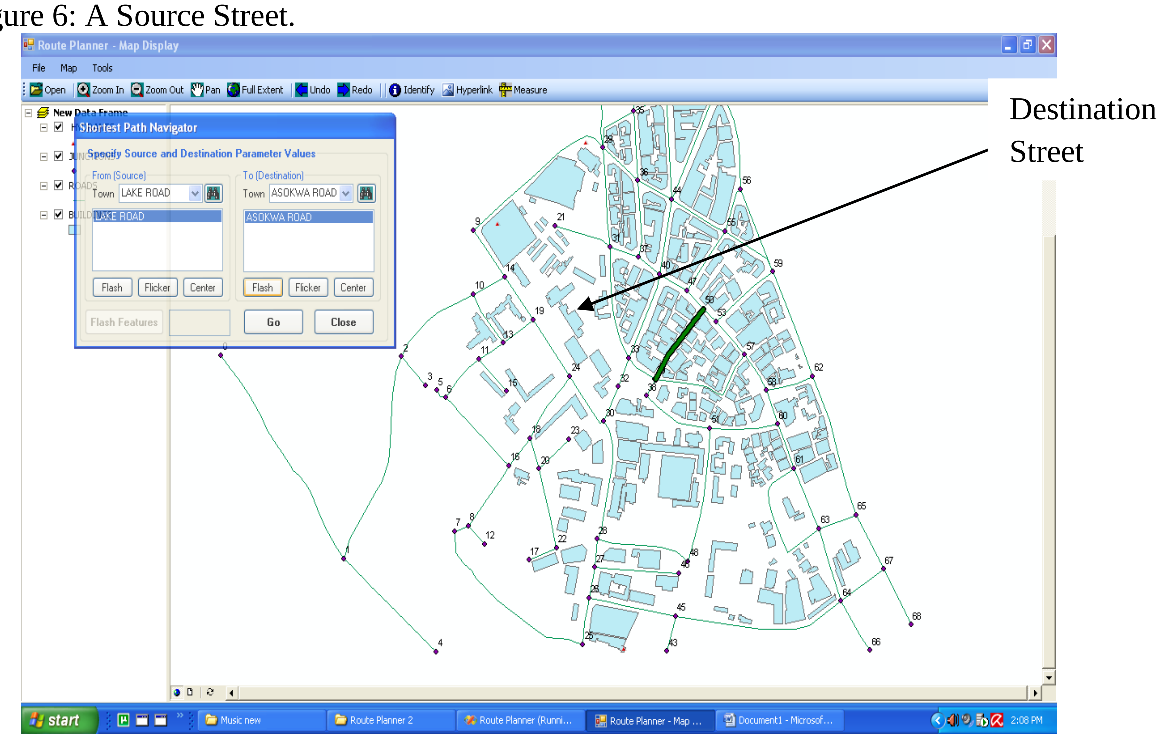

Figure 7: Selected Destination Street.

DISCUSSION

Computation of shortest paths is a famous area of research in Computer Science, Operations Research and Geographic Information Systems (GIS). There is a great number of ways to calculate shortest paths depending on the type of network and problem specification. Network Analyst is not only capable of reproducing a satisfying number of scenarios, but also it is easily adaptable to new conditions.

CONCLUSIONS AND RECOMMENDATIONS

This research work addressed the problem of determining dynamic shortest path in networks, where arc travel times vary over time. The study proposed a dynamic routing system which is based on the integration of GIS and real-time traffic conditions. It uses ArcGIS for improving the visualization of the urban network map and analysis of car routing. ArcGIS was used as a powerful functionality for planning optimal routes based on particular map travel information.

The Network Analyst gives the user the ability to produce a map and direction for the quickest route among several locations. The user can define the locations either manually or through a database with the approximate locations in respect to geographic coordinates – this database includes information such as the address and street name for each location. A second way was selected to distribute the locations, after acquiring them (with the exception of the dead-ends) and also, the fact that the vehicles should follow true-shape route (i.e. it mustn't pass over the squares).

Moreover, the Network Analyst was asked to show the results in meters, as the distance criterion was selected, and to reorder the stop-points in order to find the shortest route. It is worth mentioning that, in the special case where some vehicles may causes traffic problems, Network Analyst can be asked to find the shortest route starting from this certain point, so as to relieve the traffic. Network Analyst calculates the optimal route by means of Dijkstra's Algorithm. In particular, ArcGIS Network Analyst's route solver attempts to find a way through the set of stops with minimum cost. Developing a dynamic routing system for all vehicles in urban road network has some special considerations which is the subject of our future work

REFERENCES

1. Ahuja, R. K., Magnanti, T. L., Orlin, J. B., (1993). Network Flows: Theory, Algorithms and Applications, Prentice Hall, Englewood Cliffs, N. J.
2. Bellman, R., (1958). On a Routing Problem, Quart. Appl. Math. 16, 87-90.
3. Cherkassky, B. V., Goldberg, A. V., Radzik, T., (1996), Shortest path algorithms: Theory and experimental evaluation, Mathematical Programming 73, 129-174.
4. Husdal, J. (2000). Fastest Path Problems in Dynamic Transportation Networks, *http://www.husdal.com/mscgis/research.htm, last accessed November 22, 2005.*
5. Vonderohe, A. P., Travis, L., Smith, R. L. and Tasai, V. (1993). NCHRP Report 359, Adoption of Geographic Information System for Transportation, Transport Research Board, National Research Council, Washington, DC.
6. Skiena, S. (1990). Implementing Discrete Mathematics: Combinatorics and Graph Theory with Mathematica. Reading, MA: Addison-Wesley, pages. 135-136.
7. Dijkstra, E. W. (1959). A note on two problems in connexion with graphs Numerische Mathematik 1, pages. 269-271.
8. Hart, P. E., Nilsson, N. J., Raphael, B. (1972). Correction to "A Formal Basis for the Heuristic Determination of Minimum Cost Paths", SIGART Newsletter, 37, pages. 28-29.
9. Young-Hwan Lee (1994). A Study on the Development Plan of the New Yong-Jong Island International Airport.