Lab 1 – Traffic Wizard Description

Thomas J. Kennedy

CS 411

Professor J. Brunelle

15 April 2012

Version 4

Table of Contents

List of Figures

List of Tables

1. Introduction

Traffic Wizard is a smartphone application designed to reduce driver encumbrance resulting from unfavorable traffic conditions. Traffic Wizard will provide users with current congestion data. The user will utilize the data to avoid unfavorable traffic conditions along his or her route.

Nationwide, drivers regularly experience unfavorable traffic conditions – specifically congestion. According to Halsey (2011), $115 billion was the total cost of congestion on drivers in 2009. The current traffic avoidance methods – specifically the methods listed in Figure 1 – are inadequate for preventing and avoiding congestion.

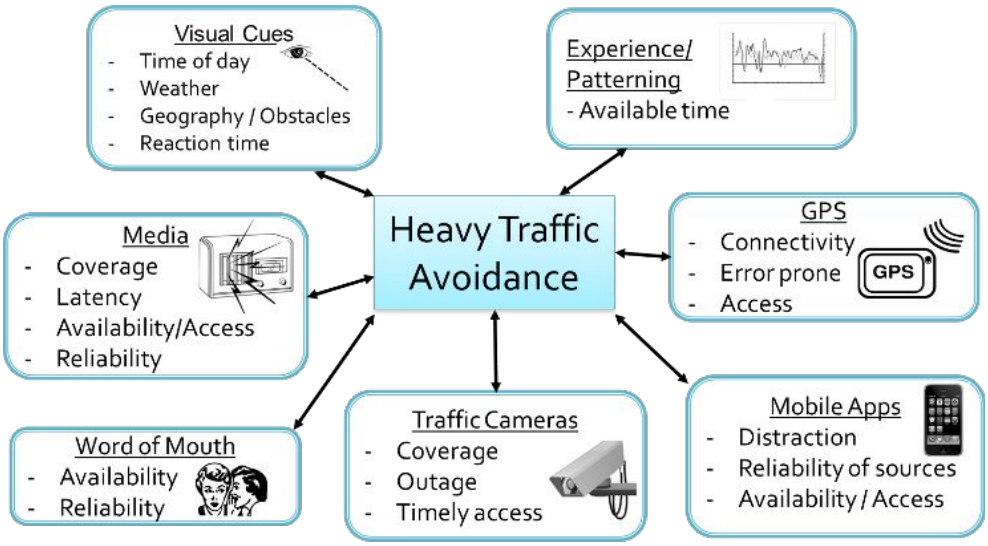

Figure 1: Current Avoidance Methods

Drivers utilize observations about their surroundings as they travel on a road or highway. These observations are temporal in nature and are relevant for short periods of time. When an observation is made regarding changes in traffic conditions, a driver is unable to react in a timely manner.

News and other media cover a limited area and are subject to latency. The temporal nature of traffic congestion data reduces the reliability of any information a driver receives from news and other media. Traffic cameras provide limited information regarding traffic conditions. It is not possible to install a traffic camera at every point of every major roadway. If a driver were to check traffic cameras before traveling a route, the conditions will have change by the time the driver reaches the corresponding section of his or her route.

Current mobile applications introduce a distraction into a driver's vehicle. These applications are only available on smartphones. GPS devices provide a driver directions to facilitate navigation; the traffic data available to these devices is limited and inaccurate.

Some drivers rely on their past travel experience on specific routes. The information obtained through this strategy is limited to traffic conditions at a particular time of day or during specific weather conditions. It is not possible to avoid unexpected events, such as collisions or road maintenance.

Adverse traffic conditions cause delays and wasted fuel. According to Lomax (2011), commuters in large population areas are delayed an average of 52 hours annually. This 52-hour delay is more than an individual with a full-time job works in one week. According to Lomax (2011), twenty-five gallons of gasoline is wasted due to traffic congestion—this is more than one tank of gasoline. The costs of traffic congestion will be reduced by the Traffic Wizard smartphone application.

The Traffic Wizard application will utilize the growth of the smartphone market to reduce the effects of congestion on individual drivers. According to Schroeder (2011), the number of smartphones sold in the first fiscal quarter of 2011, 100.9 million units, is double the number of

units sold in the first fiscal quarter of 2010, 54.6 million units. This increase of sales illustrates a growth in the smartphone market.

Traffic Wizard will reduce driver encumbrance resulting from traffic congestion. The end-user will utilize the Traffic Wizard smartphone application to monitor congestion conditions on a user-specified route. The application will provide the Traffic Wizard server with anonymous speed and direction data through a cellular data connection. The speed and direction information will be aggregated into congestion data by the Traffic Wizard servers.

2. Traffic Wizard Product Description

The Traffic Wizard system will consist of two main components; these components include a smartphone application and a server infrastructure. The smartphone application will be utilized by the end-user. The server infrastructure will process and aggregate traffic congestion data. The server will forward the aggregated congestion data to the end-user's smartphone. The smartphone application will display the received data to the end-user.

2.1 Key Product Features and Capabilities

Traffic Wizard will utilize Virtual Checkpoints to monitor traffic conditions and reduce data usage. A Virtual Checkpoint is a set of longitude and latitude coordinates that specify a checkpoint's location on a road or highway. When an end-user activates his or her copy of the Traffic Wizard smartphone application and selects a route, congestion data at each checkpoint is aggregated by the server. This pre-trip analysis is based on speed and direction data of currently traveling drivers. The aggregated data is sent to the smartphone application, where the virtual checkpoints are overlaid on a map. The checkpoint will denote optimal traffic conditions, moderate traffic congestion, and heavy traffic congestion. The end-user's speed and direction

data will be sent to the server once he or she begins a trip and passes a Virtual Checkpoint.

The use of Virtual Checkpoints will minimize data transmission between the smartphone application and the server. Before an end-user begins travel along a selected route a list of Virtual Checkpoints located on the route will be cached locally by the smartphone application. When an end-user passes a Virtual Checkpoint within a certain proximity, his or her current speed and heading are sent to the server. The server will process the data and send updated congestion information to the smartphone application.

Speed and direction data is received by the Traffic Wizard servers. This data is processed to eliminate values outside the acceptable range prior to analysis. When a large volume of speed and direction data is received, the server will conduct random polling of the data. This polling reduces the volume of data that is passed to the aggregation algorithms. After the data has been verified and processed, it is passed to the analysis algorithms. The analysis algorithms aggregate traffic data for each Virtual Checkpoint. This congestion data is sent to the smartphone application for later use.

The Traffic Wizard application will feature a driver profile to store an end-user's frequently traveled routes. An individual route is selected by the user. The smartphone application allows the user to select route options such as notification method, trip start time, and trip end time.

The Route Tracer is an innovative route entry mechanism. The end-user initiates the route trace by selecting “Start Trace”. The user then drives along the desired route—which is stored in the phone as a set of GPS coordinates. When the user has reached the end of his or her route, he or she selects “End Trace”. The GPS coordinates are sent to the Traffic Wizard server, where

they are mapped to corresponding Virtual Checkpoints. These selected Checkpoints are sent to the smartphone application, where they are stored as a route. This route is immediately available for selection.

2.2 Major Components

Traffic Wizard consists of three main components. The smartphone application is utilized by the end user; the regional server infrastructure handles the aggregation and processing of traffic data. Three databases are utilized by Traffic Wizard, a Driver Profile Database, a Virtual Checkpoint Database, and a Speed Limit Database.

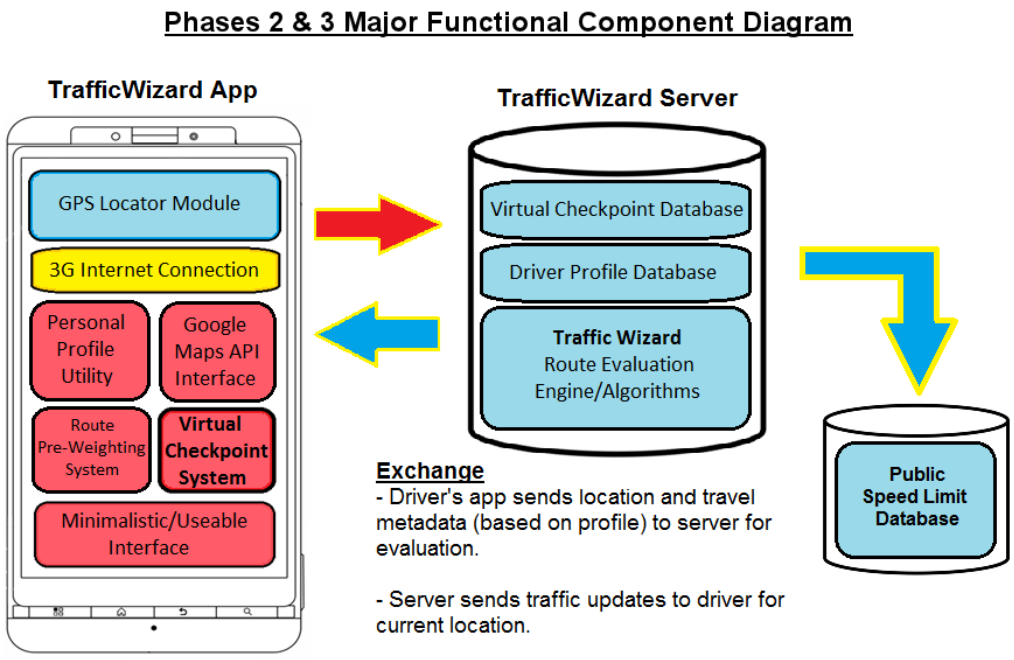

Figure 2: MFCD Phases 2 & 3

[This space intentionally left blank]

Traffic Wizard will utilize the hardware specified in Figure 2. The smartphone application will utilize the GPS module and the 3G Internet Connection module. The route profile and route pre-weighting system will be implemented on the smartphone. A minimal interface will allow for efficient end-user interaction with the application. The regional servers will handle data processing and will interact with three main databases.

Each geographic region will have a server infrastructure that operates independently from the servers of other regions. The regional servers will maintain a separate Virtual Checkpoint Database and a separate Driver Profile Database. All regions will access a third party Speed Limit Database. These databases will be manipulated by the Traffic Wizard algorithms.

The Virtual Checkpoint Allocation algorithm will determine the initial placement of checkpoints for a geographic region. Virtual Checkpoints may be added, moved, or removed dynamically. The checkpoints are created independently of driver routes. The smartphone application maps the appropriate checkpoints to a route. The GPS Data Collection algorithm will collect GPS data from the smartphone's internal GPS module. A collection interval is determined based on an end-user's current speed. The data collected consists of velocity, a timestamp, and a Virtual Checkpoint Identification Number (VCIN) . The VCIN identifies which Virtual Checkpoint an end-user has passed.

The Route Analysis Algorithm will request checkpoint congestion data from the server. Calculations will be performed to determine level of congestion on the analyzed route; red checkpoints, yellow checkpoints, and green checkpoints will specify heavy congestion, moderate congestion, and low congestion respectively. The Congestion Notification algorithm will alert the user when congestion has been found on the specified route. This process occurs in real-time.

The Virtual Checkpoint database is referenced when an application makes a request for checkpoint data. The attributes stored in the database include: GPS coordinates, the speed limit and the checkpoint, and checkpoint statistics. The speed limit data for the Virtual Checkpoint will be mined from a third-party Speed Limit Database. Through the association of a speed limit value with a checkpoint, interaction with the external database will be minimized. All information pertaining to an end-user's routes is accessed from the Driver Profile Database. Requests for Virtual Checkpoint data are based upon the routes stored in this database.

2.3 Target Market Customer Base

The target customer base is drivers with smartphones. The population in a geographic region must be large enough to supply a sufficient amount of data for traffic analysis; the population in metropolitan areas satisfies the requirement. Hampton Roads will be the first area in which the Traffic Wizard system will be implemented. The population in the region causes traffic congestion on the local highways—specifically I-264 and I-64. The traffic data in this area will be sufficient for congestion analysis.

Traffic Wizard will require initial seed traffic data; to obtain this data partnerships with shipping companies will be formed. Shipping companies service large geographical regions. Traffic Wizard applications utilized by these companies will provide initial traffic data during the introduction phase. When Traffic Wizard expands to a new region, local shipping companies will be targeted.

3. Traffic Wizard Product Prototype Description

The Traffic Wizard Prototype will implement all algorithms required for the final product. All driver checkpoint data – specifically speed and direction information -- will be simulated.

The distribution of the smartphone application will be limited to an internal testing team. The geographical area will be restricted to select regions of Hampton Roads. The prototype will allow for algorithm validation, load testing, identification of flaws in design, and identification of flaws in implementation.

3.1 Prototype Functional Goals and Objectives

The objective of the prototype phase is to fully exercise the Traffic Wizard software. The module tests will validate the correctness of the Traffic Wizard algorithms both on the smartphone and the server. All real-world data, speed and direction, will be simulated during the prototype phase. A simulation harness will allow data to be generated to simulated various traffic conditions. The simulated traffic conditions include optimal traffic conditions, moderate congestion, and heavy congestion. The ability to generate intentionally flawed data will be included in the simulation harness.

During prototype development, the covered geographical area will be limited to select areas of Hampton Roads. During Alpha Testing and Beta Testing, the entire region will be utilized for prototype testing. The server infrastructure in the Hampton Roads area will be utilized as a model for future market expansion.

The Graphical User Interface (GUI) of the smartphone application will be implemented in such a manner that driver distraction is minimized. A minimalist interface will be available while an end-user is driving. Voice recognition and text-to-speech technology will be implemented later in prototype development. The Traffic Wizard GUI will be designed for usability and simplicity. An intuitive interface will facilitate user interaction with the smartphone application.

Various traffic scenarios will be tested through use of the simulation harness. These scenarios will test different levels of congestion. The amount of data generated by the simulation harness will be varied by volume to simulate: low congestion, moderate congestion, and heavy congestion. This will allow different network conditions to be simulated; the ability of the server to handle data during heavy congestion events will be evaluated. Validation of the data generated by the server will be performed. The ability of the system to dynamically reallocate Virtual Checkpoints will not be tested.

3.2 Prototype Architecture

The prototype architecture will consist of a virtual server, a set of smartphones, and databases. The prototype databases will be identical in structure to those of the final product. The tuples in these databases will represent a simulated subset of real-world data. The structure of the prototype is depicted in Figure 3.

The smartphone functional components will be identical to those of the final product. A smaller number of phones will run the smartphone application during the prototype phase. All other data exchanges will be simulated through use of a simulation harness.

[This space intentionally left blank]

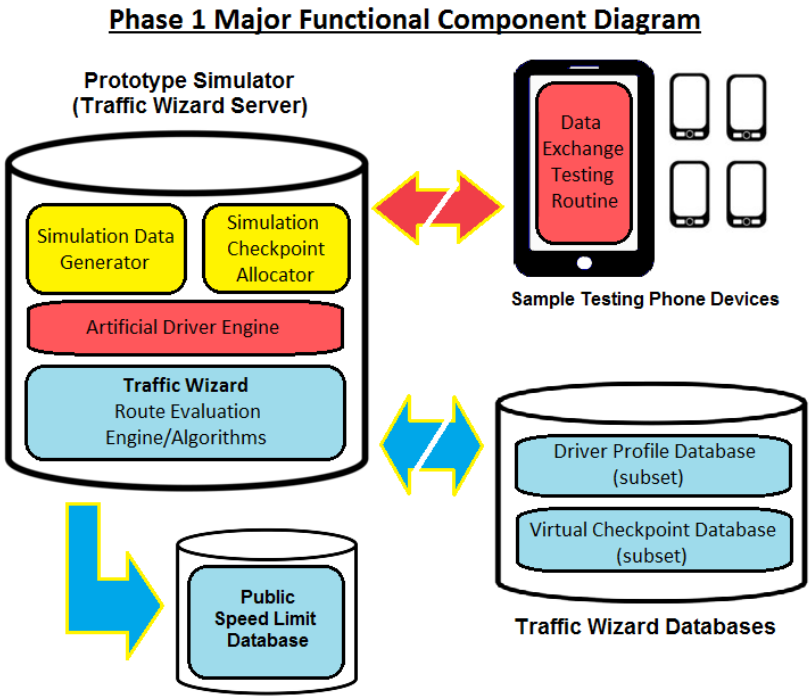

Figure 3: MFCD Phase 1

The prototype algorithms will implement all features found in the real world algorithms. During this phase, the implementation of the algorithms will be refined. The Virtual Checkpoint Allocation algorithm, GPS Data Collection Algorithm, Route Analysis Algorithm, and Congestion Notification Algorithm will be implemented completely.

All features of the mobile application will be implemented completely during the testing phase. The simulated data will necessitate minor modifications made for prototype demonstration purposes. There will be no significant modifications to the application features.

The prototype server infrastructure will be composed of a single virtual machine. This machine will run all database, web server, and proprietary Traffic Wizard server software. The virtual server will satisfy all server requirements of the project. Load testing will be conducted on the server; computational resource constraints will influence the results of the tests.

3.3 Prototype Features and Capabilities

Prototype features will differ from the real world project in scale. Some features will be eliminated from the project due to limited development time. A complete list of features is available in Table 1.

The prototype will perform route analysis on a set of simulated checkpoint data. This simulation data will be varied to perform repeated route analysis under different simulated traffic conditions. All analysis on traffic and routes occurs as expected, in the real-world product, on artificially generated data sets. The simulated communication protocols and data format are the identical to those found in the real-world product. The Virtual Checkpoint Algorithm will be reduced in scope.

During the prototype phase, the initial placement of Virtual Checkpoints will be determined manually by the design team. The reallocation of Virtual Checkpoints will be limited to specific traffic scenarios. The algorithms will be refined during Alpha testing and Beta testing.

The adjustments and modifications to the feature list of the Traffic Wizard are available in Table 1. As previously specified, all prototype features are either reduced in scale or based on simulated data. The prototype contains a simulation harness for testing purposes; the simulation harness is is not available in the real-world product.

[This space intentionally left blank]

Features	Final Product	Prototype
Data Miner		
Traffic Conditions	It will retrieve real-time travel information from drivers using the app.	Simulated driver metadata to use in analysis.
GUI		
Login	Allows user entry of authentication credentials.	Restricted to specific test users.
New User	Allows a user to create an account and select a membership.	Not implemented because of scope.
Settings	Allows user to alter application settings and options.	Not implemented because of scope.
Trip Editing	Allows user to specify a new route to be saved or modify an existing route.	Restricted to limited test area.
Route Tracer	Program function to track a route to be saved as it is driven by the user.	Not implemented because of scope.
Travel Map	Non-interactive screen that displays current traffic conditions while driving.	This is implemented.
Simulation Console	Not implemented in Final Product.	Demonstration interface for simulated driving scenarios.
Virtual Checkpoints		
GPS Latitude/Longitude Coordinates	Associates GPS coordinates along roads with checkpoints.	Simulated coordinates for hand-selected checkpoints.
Driver Acknowledgement	Recognizes drivers passing GPS location (checkpoint) as an event.	This is implemented on simulated checkpoints.
Data Exchange	Upload user velocity at checkpoint being passed / Download necessary traffic updates for checkpoints along the route.	This is implemented on simulated checkpoints.
Database		
Driver Profile Database	Stores customer account information, credentials, and payment method.	This is implemented with test users.
Virtual Checkpoint Database	Stores checkpoint coordinates, current traffic status, and historical statistics.	This is implemented with simulated checkpoints.
Speed Limit Database	Stores static information on speed limits for public access.	This is implemented.
Algorithms		
Aggregate Speeds	Analyzes and filters driver inputs to determine current traffic speed.	This is implemented.
Checkpoint Allocation	Initial assignment of GPS coordinates to initialize checkpoints.	Not implemented because of scope.
Checkpoint Reallocation	Redistribution of checkpoints along roads as determined by current checkpoint statuses and historical patterns.	Only implemented on specific driving scenarios.
Route Analysis	Find blockages, calculate delays, outputs alternate route suggestions	This is implemented.
Next Checkpoint ETA	Estimates time to arrival at next checkpoint from client side for GPS/Data/Battery management.	This is implemented.
Driver Generator	Not implemented in Final Product.	Randomly generates virtual drivers with speeds for testing purposes.

Table 1: Prototype Features

3.4 Prototype Development Challenges

The development of the prototype will require the mitigation of three specific challenges. Data integrity, management of data exchanges, and optimization of the server are the difficulties that necessitate mitigation. The algorithm which sanitizes driver data, speed and direction, must be implemented and refined. The sanitation algorithm must remove ill-formatted and erroneous data. Generated congestion data must be verified before it is sent to the user. Test modules must be developed to mitigate the possibility of outdated or incorrect traffic data being sent to the smartphone application.

The exchange of data between the server and smartphone application will be simulated under various levels of traffic congestion. After each simulation, refinements will be made to the threshold value that specifies when to discard incoming traffic data. All data exchange threshold values will be tested under various scenarios after each modification. The data exchange simulations will provide preliminary server load statistics.

The load the virtual server can handle will be significantly less than that of the real world system. All load tests must be validated on a production server during Alpha and Beta Testing. All server load testing will be based on simulated data exchanges that represent predicted real world conditions.

4. Glossary

3G Internet Connection: a cellular communication technology utilized to send data to and from mobile devices.

Alpha testing: the first prototype test phase. This test will be limited to a select group of users. The goal of this test is to verify reliability of Traffic Wizard and to identify any flaws in the Traffic Wizard system.

Beta testing: the second test phase. This test phase will be open to the public. The focus of this test phase is to verify that the Traffic Wizard system can handle the volume of generated traffic data.

Communication Protocols: specifications that dictate how data is to sent and how connection are established.

Custom Route: a route which has been entered, by the user, for use in the Traffic Wizard application.

Customer Investment: the purchase of the Traffic Wizard application and accompanying subscriptions by users.

Customer Risks: risks that are related to the customer. These include Ease-of-use, driver distraction, and product accessibility.

Data Mining: the process of analyzing the collected traffic data for trends and patterns.

Database: a set of tables, consisting of tuples, used to store information. Traffic Wizard consists of a Driver Profile Database, a Speed Limit Database, and a Virtual Checkpoint Database.

Distraction: any device that causes a redirects a drivers attention from the road to the device.

Driver / End User: the individual or customer who utilizes the Traffic Wizard system.

Driver Profile: a set of frequently traveled routes stored on an end user's smartphone.

Driving Mode: the active mode during which the smartphone application is sending data to the server.

Functionality Testing: a process during which all software and hardware modules will be tested for performance and reliability.

Goal(s): the predetermined objectives to be achieved during the development of Traffic Wizard.

Google Maps API: a programming interface that facilitates interaction with the Google Maps service.

GPS: a set of longitude and latitude coordinates.

GUI Functionality: all the procedures provided by and accessible through the Traffic Wizard interface.

Hardware Failure: an event in which the servers upon Traffic Wizard runs are rendered inoperable.

Incidental Traffic Congestion: an single congestion event that occurs independently from all other congestion events.

Latency: the total delay due to network traffic.

Network Maintenance: the act of upgrading and repairing the infrastructure upon which the Traffic Wizard software runs.

Optimization (Server): allowing the server to analyze and collect data efficiency. This is facilitated through server design and server re-implementation.

Periodic Traffic Congestion: a congestion event that occurs at regular and predictable intervals. This includes events such as rush hour.

Pre-travel Analysis: the analysis of traffic congestion data for a predetermined route that occurs at a user specified time before a trip begins.

Pre-weighting System: that analysis during which multiple routes with similar start points and end points are assigned a rating based on congestion data.

Prototype: a version of Traffic Wizard that has been reduced in scale which will demonstrate the functionality of the completed product in a simulated environment.

Real-time: current traffic data.

Return on Investment: the revenue derived from the sale of the Traffic Wizard software less operating and development costs.

Road Segment: a section of unbroken roadway which has endpoints specified by the intersection of two or more roadways.

Route: a set of connected road segments that specify the path a driver travels from a starting

point to an ending point.

Route Analysis: the process during which traffic congestion data is retrieved at each Virtual Checkpoint along the route, the data is analyzed, and the processed data is sent to the user's smartphone.

Server Infrastructure: the hardware which handles the processing and storage of traffic data.

Server load testing: A test phase in which the server is sent increasing volumes of simulated data to verify system stability.

Simulation Console: the interface through which the prototype will be tested.

Smartphone: a cellular phone with the ability to establish a data connection and run applications.

Software: the Traffic Wizard smartphone application or Traffic Wizard server application.

Still Mode: the smartphone application mode in which no data is sent to the server as a result of the vehicle's lack of motion.

Timestamp: a string that represents the hour, minute, and second at which data is recorded.

Traffic Avoidance: an action in which a driver is not subject to traffic congestion as a result of the selection of an alternate route.

Traffic Scenario: an event during which a specific set of traffic conditions occur.

Traffic Wizard: a software package consisting of a smartphone application and a server infrastructure; the purpose of this package is to facilitate traffic avoidance.

Travel Data Collection: the process during which the speed and direction data is collected from an end-user's smartphone.

Trip: specified by its starting and ending coordinates. A trip will have multiple possible routes.

User Interface: the smartphone interface through which a user utilizes the features of the Traffic Wizard software.

Virtual Checkpoints: a set of longitude and latitude coordinates that specifies a location on a road or highway. When a user is with a set proximity to a checkpoint his speed and direction are sent to the Traffic Wizard servers.

5. References

Halsey, Ashley III. (2011, January 20). Washington area tied with Chicago for traffic congestion, study finds. *The Washington Post* . Retrieved from http://www.washingtonpost.com/wpdyn/content/article/2011/01/20/AR2011012000056.html

Lomax, Time, David Schrank and Shawn Turner. Texas Transportation Institute. (2011). Annual Urban Mobility Report. College Station, TX. Retrieved from http://mobility.tamu.edu/ums/

Schroeder, Stan. "Smartphone Sales Up 85% Year-Over-Year." May 19, 2011. Mashable Tech. Retrieved from http://mashable.com/2011/05/19/smartphone-sales-q1-2011-gartner/