Roadway Weather Information System and Automatic Vehicle Location (AVL) Coordination

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16 . ABSTRACT

Roadway Weather Information System and Automatic Vehicle Location Coordination involves the development of an Inclement Weather Console that provides a new capability for the state of Oklahoma to monitor weather-related roadway conditions. The goal of this development is that motorist safety might be improved and the damage to highways and bridges caused by the application of deicing agents minimized through the use of the IWC and Decision Support Systems built upon it.

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3. Table of Contents

4. Table of Figures

5. Summary

This project, "Roadway Weather Information System and Automatic Vehicle Location Coordination", involved the development of an Inclement Weather Console (IWC) that provides a new capability for the state of Oklahoma to monitor weather-related roadway conditions. The initial version of this Inclement Weather Console, the culmination of the milestones for Year 1 of this project, is shown in Figure 1.

This console merges data from Automatic Vehicle Location (AVL) instrumentation within Oklahoma Department of Transportation vehicles, weather sensor data from a network of Road Weather Information System (RWIS) stations currently being deployed and other real-time weather data including data from the National Oceanographic and Atmospheric Administration (NOAA) and the Oklahoma Climatological Survey into a single visualization framework. During the beta testing of this console it is available only to ODOT personnel. Additionally, during this project, we have developed the capability to display non-sensitive portions of this data via ODOT's Advanced Traveler Information System (ATIS) website.

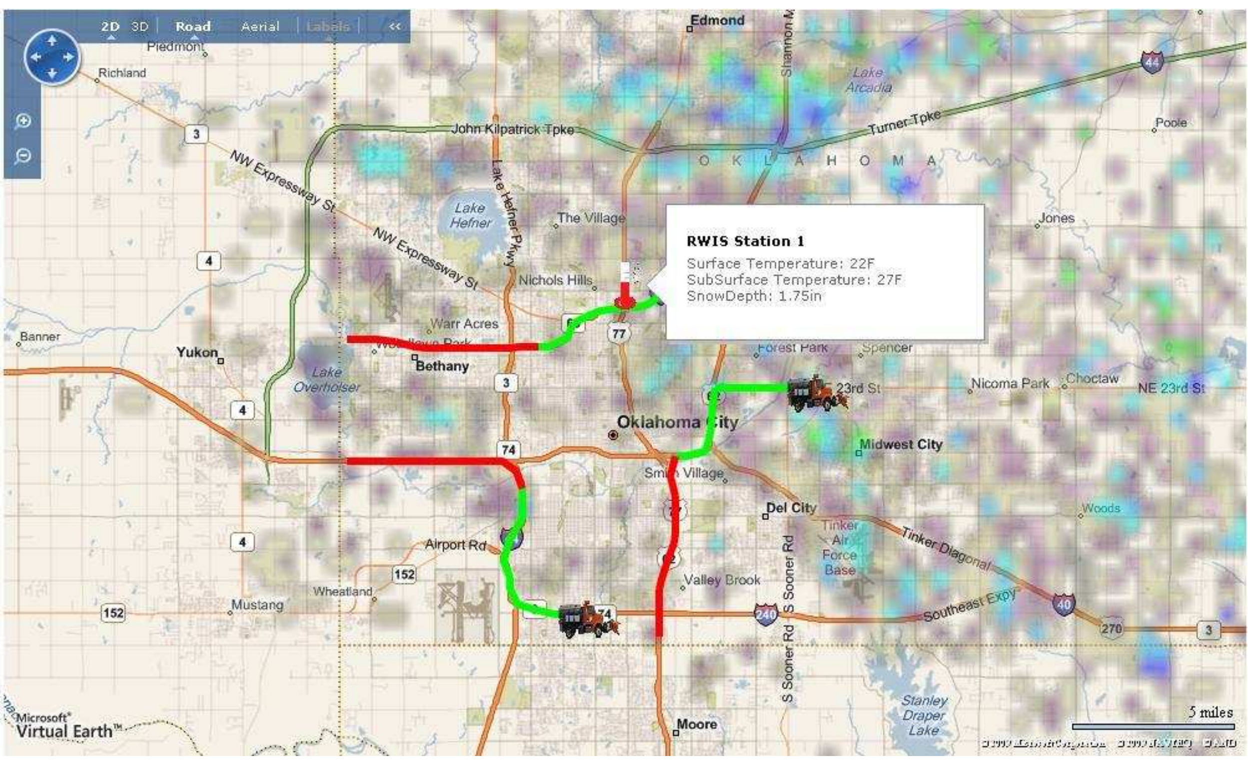

Figure 1: The Inclement Weather Console

The goal of this development is that motorist safety might be improved and the damage to highways and bridges caused by the application of deicing agents minimized through the use of the IWC and Decision Support Systems built (DSS) upon it.

Key accomplishments completed during this project include:

- Supported the initial deployment of RWIS stations along Interstate Highways in Oklahoma.
- Incorporated data from deployed AVL and RWIS devices into an integrated visualization framework. This framework includes the color coded display of current and historic GPS-based location information of ODOT vehicles as well as measurement taken by deployed RWIS stations.
- Developed database storage and retrieval of AVL locations and routes as well as RWIS measurements. This database allows both the simulated display of a synthesized weather event as well as the off line analysis of real world weather and the effectiveness of the response.
- Correlated AVL and RWIS data for use in decision support systems (DSS) to advise ODOT personnel on pending roadway hazard conditions.
- Integrated other weather information from NOAA and Oklahoma City Micronet [6].
- Developed support for displaying complete RWIS sensor data as well as weather data from external sources on the Oklahoma ATIS website.

As this project is jointly funded by the Oklahoma Transportation Center (OTC) and will continue as an OTC project until May 2010, we expect that the impact of this project will continue as non-sensitive information is made available to travelers to improve their decision-making during inclement weather, as the use of weather information is enhanced, as the display of additional instrumentation readings (beyond location) is made possible and as DSS are developed to the point where they can assist planners and decision makers.

Additionally, under the continued funding from OTC for this project, we intend to use winter storms during the winter of 2009-2010 as a pilot for real world testing of the Inclement Weather Console.

6. Inclement Weather Console

The goals of the project "Roadway Weather Information System and Automatic Vehicle Location Coordination" were to provide a new capability for the state of Oklahoma for the real-time observation of both roadway conditions and the location of vehicles engaged in roadway treatment activities. These capabilities have been merged into a common map console available only to ODOT personnel, called the Inclement Weather Console. Additionally, portions of this data can also be made available to the public via ODOT's Advanced Traveler Information System (ATIS).

Using this new capability, ODOT personnel will be able to more efficiently direct road treatment crews to road segments, bridges, etc. that are in the most danger of icing and/or flooding. Data from Roadway and Weather Information Systems (RWIS) sensors has been integrated, along with data from Oklahoma Mesonet [7, 9] sensors, the Oklahoma City Micronet [6] sensors and NOAA weather radar images into a complete view of roadway status. Vehicle location from on-board Global Positioning System (GPS) sensors will be sent from each vehicle using cellular radio. Integration is performed by ITS server computers, providing merged displays as well as a complete historical log of weather parameters and treatment activities.

The result of these activities provides ODOT with new capabilities for directing road treatment crews. The primary aims of this system are **to improve motorist safety and to minimize damage to highways and bridges caused by the application of deicing agents**. The software developed as part of this project offers the capability to inform the public in real-time of current road conditions, thereby giving them and other public, private, and reporting agencies the ability to make informed decisions regarding the use of public thoroughfares during inclement weather. Further, increased efficiency in the application of Oklahoma's limited resources to respond to inclement weather will result in increased public safety while doing as little damage to the transportation infrastructure as possible. Real-time data and data logging is provided in addition to hosting the basis for institutionalizing best-practices for roadway treatment and developing a fine-tuned set of decision support systems for chemical mixes and vehicle deployment.

6.1. Objectives

The objectives of this project were to:

- Assist ODOT contractors with the deployment of RWIS stations along Interstate Highways in Oklahoma, particularly in the areas of networking, communication, and integration into ODOT's ITS network.
- Establish mechanisms to feed data from deployed AVL and RWIS devices into an integrated visualization framework.
- Develop database storage and retrieval of both AVL locations and routes as well as RWIS measurements.
- Develop an AVL system for ODOTs weather-response vehicles using GPS networked data via GPRS

cellar communication and perform AVL map plotting using an internet-based mapping API.

- Develop color-coded visualization for these routes and measurements using the mapping API.
- Provide public Advanced Traveler Information System (ATIS) with basic RWIS data and travel-time predictions
- Develop decision support systems (DSS) to advise ODOT personnel on pending roadway hazard conditions requiring chemical application, strategic and/or optimal resource routing, chemical mixes, application rates, etc.
- Utilize RWIS information in the formulation of travel-time estimates
- Study vehicle instrumentation options for chemical weight, chemical spreading rate, vehicle speed, plow blade status (up or down), etc. and networking options.
- Design console views and logs of traction and deicing treatment effectiveness.
- Integrate other current weather conditions and pending weather conditions from Mesonet and the Oklahoma City Micronet into the visualization framework and DSS.

1.1. Accomplishments

Year 1 of this project consisted of 10 proposed milestones:

1. Assist ODOT contractors with RWIS deployment, networking and communication, and integration into the ITS network.
2. Develop database storage and retrieval of RWIS measurements.
3. Develop AVL using GPS networked data via GPRS cellar communication.
4. Develop AVL map plotting using Bing Maps APIs.
5. Develop database archiving of vehicle routes.
6. Develop RWIS color-coded measurements and plotting using Bing Maps.
7. Integrate RWIS and AVL data onto common map plots.
8. Provide public Advanced Traveler Information System (ATIS) with basic RWIS data.
9. Perform weather data correlations on RWIS stored data for future design of decision support systems (DSS).
10. Study vehicle instrumentation options for chemical weight, chemical spreading rate, vehicle speed, plow blade status (up or down), etc. and networking options.

Each of these milestones was completed. During this project, we provided support to ODOT contractors for the deployment of several Road Weather Information System (RWIS) stations and their network integration. Figure

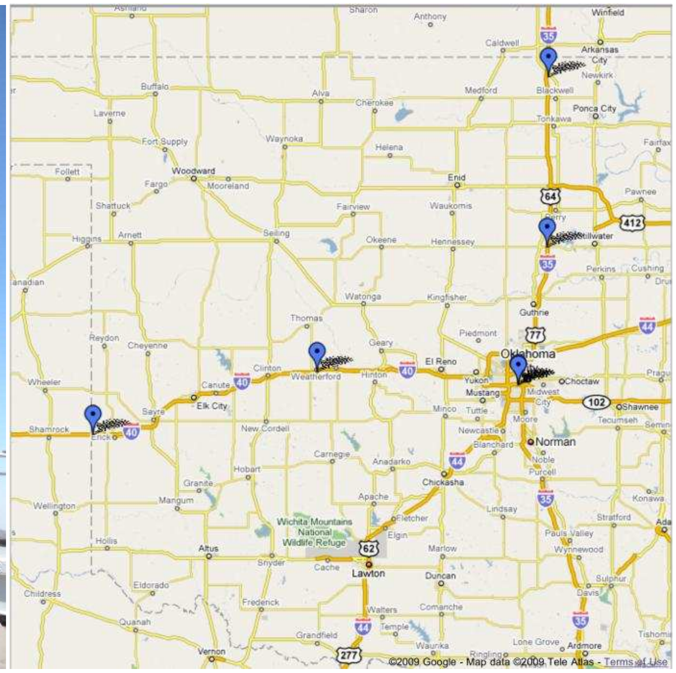

Figure 2: RWIS Deployment in Weatherford, OK **Figure 3: Location of the 6 deployed RWIS stations**

2 shows the deployment of an RWIS station near Weatherford, OK being deployed by Vaisala, one of the two vendors of RWIS stations ODOT has currently deployed. This deployment was performed with consultation and participation of the OU ITS Lab Manager. We are further assisting ODOT in the evaluation of the deployed RWIS stations, manufactured from various vendors. Figure 3 shows the locations of the 6 RWIS sites deployed in Oklahoma at the end of Year 1 of this project. Note, two RWIS sites are co-located in Oklahoma City.

Two different vendors have been contracted thus far to install RWIS stations along Oklahoma Highways, Vaisala and Surface Systems (SSI). By working with both of these vendors, we have established mechanisms to automatically retrieve RWIS sensor data from stations manufactured by Vaisala and are still working on retrieving data from those manufactured by SSI. Note that stations from each vendor feature different measurement capabilities, as well as how they are presented to us; Vaisala provides us XML data using the National Transportation Communications for ITS Protocol (NTCIP) [4]. A sample of this data is shown in Figure 4. SSI can only provide us with a website from which the data must be extracted and parsed. We have developed a mySQL database for the storage and retrieval of this sensor data.

We initially developed a prototype system using Google Earth [1] and Google Maps [2] for mapping AVL data and co-displaying those locations with RWIS station readings. However, deploying our console using as either an ODOT internal, access-controlled site or as a publicly available traveler information site would require the licensing of the Google Maps Premier API. For this reason we investigated various mapping platforms and demonstrated two options to Alan Stevenson, ODOT Technology Services Division. One based on Google

```
<ntcipMessage source="example_station"
lat="4252792"
lon="-11140372"
type="obs"
dataTime="20061206T223603"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="http://ice.tmi.vaisala.com/ntcip.xsd">

<value name="essSubSurfaceTemperature.1">-17</value>
<value name="essSubSurfaceMoisture.1">101</value>
<value name="essSubSurfaceSensorError.1">2</value>
<value name="essSurfaceStatus.1">4</value>
<value name="essSurfaceTemperature.1">56</value>
<value name="essSurfaceWaterDepth.1">0</value>
<value name="essSurfaceSalinity.1">0</value>
<value name="essPavementTemperature.1">31</value>
<value name="essSurfaceConductivity.1">1</value>
<value name="essSurfaceFreezePoint.1">0</value>
<value name="essSurfaceBlackIceSignal.1">2</value>
…
```


Figure 4: Sample segment of NTCIP XML data from an RWIS station.

Maps and one based on Microsoft Bing Maps [3]. Bing Maps proved to be superior in both capabilities and licensing terms and price.

When evaluating each platform's capabilities we focused on three main areas: ease of programming, speed of the map, and features available from the API. Both mapping applications provided the main features needed to implement the Inclement Weather Console. This includes the ability to display icons on the map using latitude/longitude, the ability to render shapes (especially lines) on the map and the ability to overlay other data, such as weather radar, on the map. Programming the maps also proved to be similar. Both provided detailed API documentation on how to place elements on the map as well as how to overlay other images. With both the API features and ease of programming being relatively similar, the critical differences in the two platforms were in the speed/performance of drawing a map. Google Maps showed significant slowdown when creating maps with a large number of tracked objects. This was especially true when drawing lines that each contained anywhere from 5 to 10 points.

Displaying historical trails for tracked vehicles required a large number of points to be plotted.

Because we break these trails into 15-minute segments, displaying a 3-hour trail requires 180 to 360 points to be plotted. This took approximately 10 seconds for Google Maps to draw the map and, often resulted in the crashing of our Inclement Weather Console site. Bing Maps shows no measureable slowdown when adding the same number of points. Sample code to draw this historical train behind vehicles is shown in Figure 5.

```
eval("polyLineT" + truckID + "g" + oldGroup + " = new VEShape(VEShapeType.Polyline,
mapPoints);");
eval("polyLineT" + truckID + "g" + oldGroup + ".SetLineWidth(6);");
eval("polyLineT" + truckID + "g" + oldGroup + ".HideIcon();");
eval("polyLineT" + truckID + "g" + oldGroup + ".SetDescription(\"Average Speed:
"+avgSpeed+"\");");
eval("polyLineT" + truckID + "g" + oldGroup + ".SetLineColor(colorObject);");
eval("ShapeLayerT" + truckID + ".AddShape(polyLineT" + truckID + "g" + oldGroup +
");");
```

Figure 5: Microsoft Bing Maps API calls to draw the historical vehicle trail. truckID is the unique ID for the truck, oldGroup is the hour group the line segment belongs to (lessthan 1 hour ago, between 1 and 3 hours ago, more than 3 hours ago) and thus controls the color of the particular line segment. avgSpeed is calculated as the line segment is built. Additional parameters could be added to this as the segment is built (such as spread rate, chemical mixture etc) and then added to the segment in the same manner. Note that each truck belongs to its own shape layer, allowing all of the lines and icons pertaining to a particular truck to be removed at once with relative ease.

Bing Maps further improves performance by not drawing icons that are located off of the currently displayed map, whereas Google Maps draws these point regardless of whether it will be on the visible map or not. The significant performance difference makes Microsoft Bing Maps an attractive choice for the implementation of our console. Due to this reason, combined with more reasonable licensing terms of Microsoft Bing Maps, we were directed by our ODOT technical advisor to continue development using the Bing Maps substrate.

Figure 1 showed an example of the Inclement Weather Console implemented using Bing Maps. Note that because the mouse is over the simulated RWIS station, selected temperature and precipitation sensor readings are displayed. On the advice of the Oklahoma Climatological Survey, we are adding a timestamp to the visualization of these sensor readings to prevent data which is out-of-date due to network connectivity issues from influencing decision makers. This figure also displays two-hour historical location information for the tracked vehicles (green—one hour old; red—two hours old). The display of this information is adjustable, and allows the console operator to see which roadways have been treated within the chosen timeframe. Figure 1 further demonstrates the NOAA base reflectivity radar image that we have incorporated into our console.

Figure 6 shows the current interface to control which weather and vehicle information is displayed. Our current interface allows each vehicle that is being tracked to be selected or deselected, allows the historical location trail to be displayed as a single fading line segment or as three distinct segments, and controls the appearance of the weather radar image. Because this visualization system is being developed while the RWIS and AVL deployments are ongoing, it was necessary to develop the ability to replay events from data stored in our database. This is an important aspect of the decision support system being developed as planners and decision makers will require the ability to analyze the effectiveness of inclement weather response strategies. However this was first used to display simulated vehicle and weather sensor readings while the feed for these sensors was not online. Using AJAX, we are able to update our map console seamlessly without requiring the reload of the webpage. A C# application was written to support both real-time vehicle travel simulation as well as to support the input of large synthetic latitude and longitude data sets. GPS-derived latitude and longitude data sets were provided by ODOT for several vehicle routes the can be controlled by the same interface shown in the bottom of Figure 6. Initially, the simulation times were slow when plotting large amounts of data points. This performance issue was largely solved by moving the data point encoding to a PHP script. Weather readings from RWIS stations are being correlated with AVL information as well as with vehicle speeds taken from Remote Traffic Microwave Sensors. This correlation is the first step in the formulation of decision support systems that can improves the effectiveness of the treatment of road surfaces and the routing of weather response vehicles.

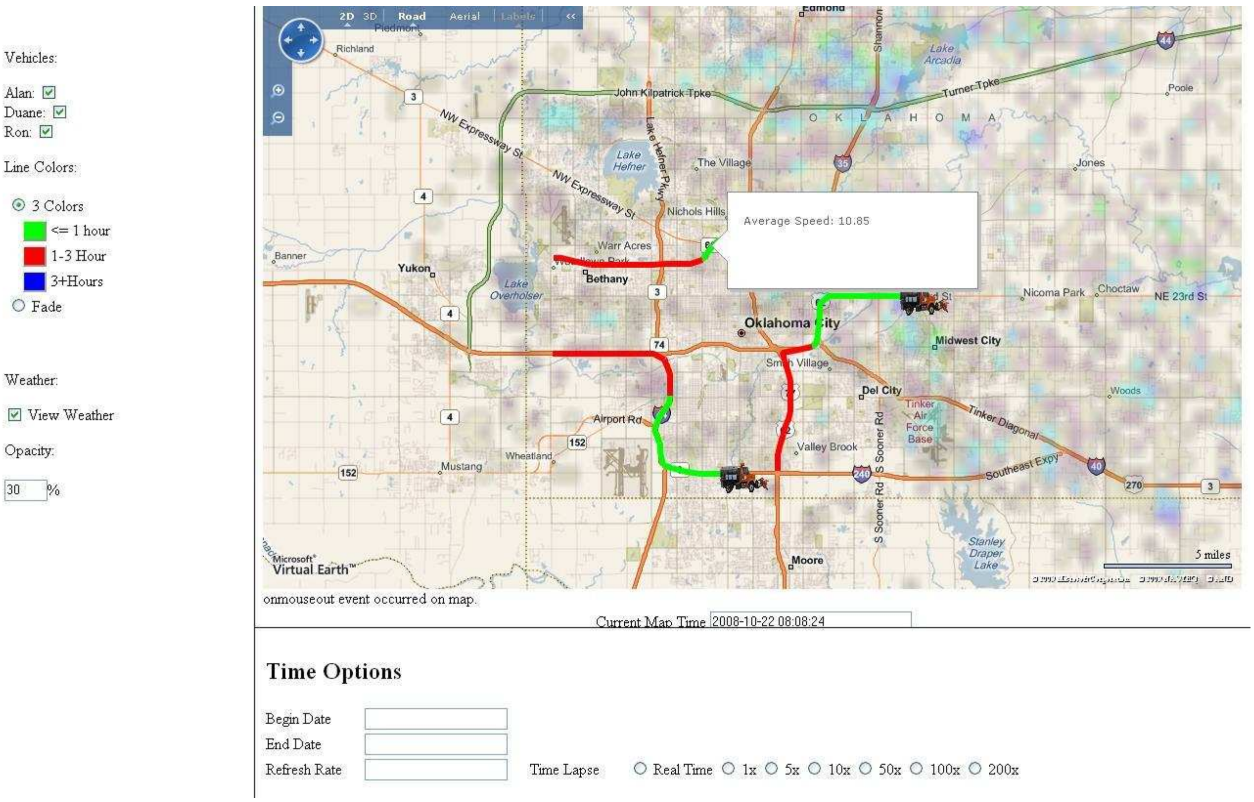

Figure 6: Control of the display of information on the Inclement Weather Console (left) and the simulated replay of stored historical data (bottom).

Additionally, similar systems can inform the traveling public regarding weather-impacted travel times and can thereby increase the likelihood of safe travelling decisions.

Many vehicle-specific opportunities exist for sensing various characteristic of the tracked vehicle and reporting that back to our system both to be visualized and to be utilized in Decision Support Systems.

Various aspects that comprise the status of the vehicle have been considered for instrumentation:

1. The condition of plow (degree up or down)
2. The content and quantity of the deicing agent payload
3. The mix ratio of deicing agents currently being applied
4. The current spread rate of deicing agent application

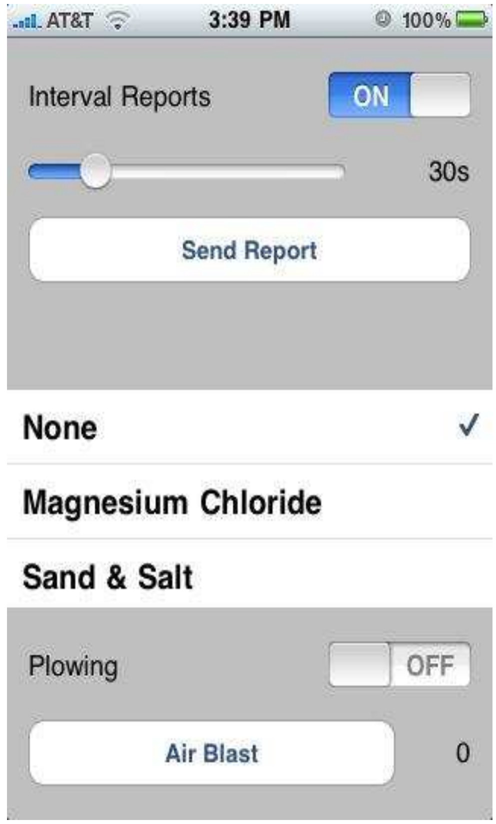

Figure 7: iPhone application used to simulate instrumented vehicles.

Instruments for these various measurements are, by necessity, custom to the vehicle being instrumented. The vehicles that are desirable to track during inclement weather consist of different types of vehicles (including plows and spreader trucks) with a variety of makes of each type. Additionally, many features will be missing from particular vehicles. For example, some trucks may not feature a movable plow, and some spreader vehicles always apply the same mix of salts and sand at the same rate.

Our study of vehicle instrumentation was simulated using custom-written mobile phone applications. We chose to develop two different mobile phone apps, an iPhone application and a java application based on the current BlackBerry. The first instrumentation simulation platform we developed was for the iPhone. The iPhone was chosen as the first platform as several members already had iPhones, which allowed us to rapidly and immediately begin developing an iPhone prototype while we waited for development iPhone and BlackBerry devices to be procured. The final iPhone application is shown in Figure 7. The interface provides automated reporting based an interval set by the user using a slide bar. It also provides a button to manually send a report, the ability to choose which type of mixture is being deployed (the options are retrieved from the web server), a switch to designate the plow as up or down, and the ability to count the number of air blasts performed during a reporting interval. The initial testing based on the iPhone was a success. We were able to simulate and display a vehicle as it drove from north OKC to south OKC while sending data at regular intervals. Unfortunately there were some phone limitations that proved problematic, most notably the inability to run the application in the background and the phones inability to maintain a GPS lock, resulting in “approximate” locations being sent using cell phone tower triangulation rather than actual GPS coordinates.

A second instrumentation platform is currently under development using the Blackberry. This application is being developed for the java subsystem made available by the Blackberry. This application will be more robust and portable to other java enabled cell phones/devices making it a more practical solution.

This project, “Roadway Weather Information System and Automatic Vehicle Location Coordination,” has met of the deliverables proposed for the contract. We have developed an IWC integrating vehicle location data and instrumentation as well as various weather sensors from both ODOT and Mesonet. We have assisted in the deployment of RWIS stations for ODOT. We have developed a preliminary instrumentation platform to test our overall system design. Through a demonstrated port of ATIS to the Microsoft Bing Maps platform, we have also further developed support to display complete RWIS weather information to the public ATIS along with as additional weather information sources such as NOAA weather radar and Mesonet and Micronet weather readings. Of course, the use of this data in the public ATIS would require authorization from the respective sources.

7. Conclusions and Impact

Through the prototype IWC we have provided decision makers with a system that will improve transportation safety through efficient response to inclement weather conditions on highways and bridges. This impact will increase as information from this system is provided to the public to enhance their ability to make safe travel decisions.

Now that this platform is available a platform for decision support system research as well as research into areas such as intelligent travel time prediction and routing, we anticipate increased opportunities for publication and for attracting additional sources of funding for further development of the IWC.

8. Future Work

The activities of this project centered on the creation of polled data feeds for weather sensor and AVL position readings, a database to store these readings and a geographic based visualization using Microsoft Visual Earth. However, the roll out of ODOT’s network of RWIS stations is a lengthy process and the stations, once deployed, will be relatively sparsely arranged along Oklahoma’s Interstate highways. For this reason, the Oklahoma Mesonet[7], and the Oklahoma City Micronet[6] can provide a more immediate and comprehensive observation of statewide weather. Using models developed at the Oklahoma Climetological Survey[11], we intend to use this information interpolate pavement and bridge conditions where there are no RWIS stations located. This information will further be used to validate sensor readings taken at RWIS sites [10].

In the course of this project, we developed an aggregate approach to traffic flow prediction which generates a prediction from one or more component predictors [8]. These feed-forward neural network predictors combine temporally local information with the predicted mean value estimated from a limited set of historic data. In the future we hope to utilize this aggregate approach to combine RWIS sensor data with Remote Traffic Microwave Sensor (RTMS) readings. The aggregate traffic flow information will be utilized to form travel-time predictions. These predictions will be able to adapt not only to traffic congestion because of peak commute-times and accidents, but also to weather events including rain and snow that impact travel time. These travel time can be communicated to motorists via dynamic message signs on interstates and highways as well as through the ATIS site.

Through the Oklahoma Advanced Traveler Information System (ATIS) [5], ODOT currently provides travelers with real-time information about Oklahoma's Interstates and other highways. This information is currently limited to still images from cameras deployed along highways in Oklahoma metropolitan areas. The ability to monitor current road conditions can soon be enhanced by providing traffic speed information and travel time predictions, as well as the ability to monitor Smart Work Zones.

Now that this study has been completed, we hope that RWIS sensor data will be added to the ODOT internal ATIS site. Once the RWIS stations are more fully deployed and validated, we can integrate weather-related road conditions with the currently provided road condition information to motorists. By presenting this integrated outlook, the ATIS/RWIS site will further inform traveler's decisions. The weather data will likely be a critical piece of information provided to travelers through the ATIS site to improve safety through improved traveler decisions (including the decision not to travel) and improved routing. Additionally, the improved statewide travel-time prediction described above can further increase the usefulness of the system. The improved routing through the state will be particularly useful for interstate commercial vehicle traffic.

Lastly, during the winter of 2009-2010, we will use the opportunity of continued funding for this development from the Oklahoma Transportation Center to collect end-user feedback on the Inclement Weather Console and derived Decision Support Systems. The console will be made available to key planners and decision makers for this testing purpose and we will record all vehicle data and weather sensor reading for further analysis and review. This pilot is needed to provide an opportunity to evaluate the system under non-synthetic conditions.

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