Passenger Bus Industry Weather Information Application (PBI WxApp)

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Final Report — March 2011

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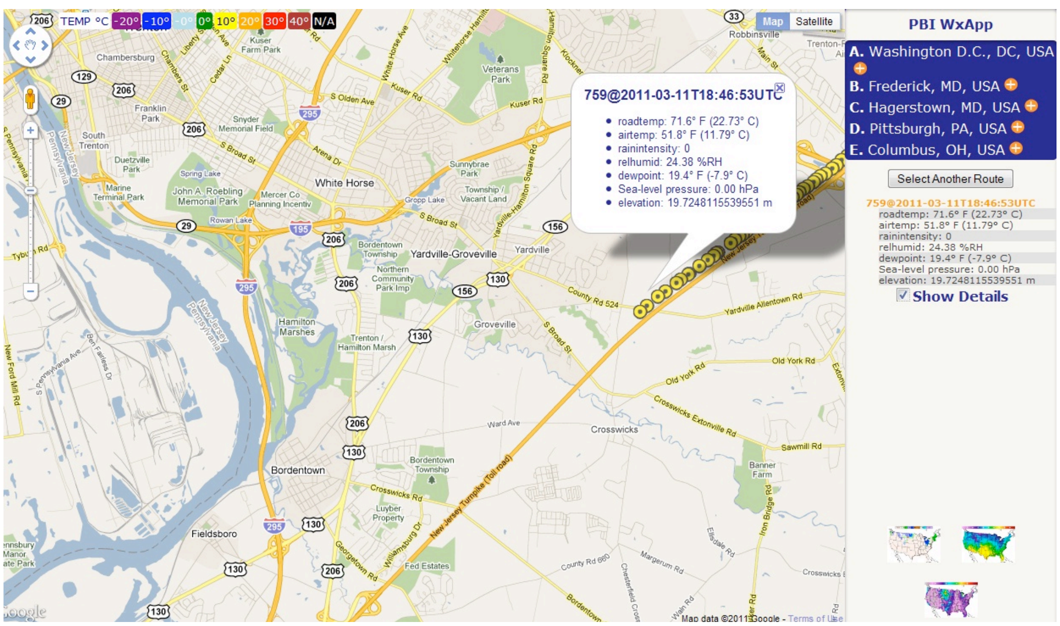

U.S. Department of Transportation
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Front cover image: Example of Mobile Platform Data in the PBI WxApp (Source: GST)

Notice

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16. Abstract

Adverse weather significantly affects the United States national transportation system, including commercial companies that rely on highways to support their enterprises. The Passenger Bus (Motorcoach) Industry (PBI) is one such affected user whose operational efficiency, occupant safety, and the cost of services can be compromised by adverse weather.

The primary objective of the Passenger Bus Industry Weather Information Application (PBI WxApp) is to integrate mobile platform environmental observations with fixed-site (airports and road-weather stations) observations in order to create a window of meteorological information along a commercial vehicle's intended travel route. The expected outcome is situational awareness for drivers, passengers, and dispatchers or other operations personnel, including those who use decision support systems. Mobile platform observations describe environmental conditions in locations not sampled by fixed-site road-weather equipment. Consequently, the PBI WxApp includes input data that is dynamic and oft times rapidly changing when the vehicles encounter storms and precipitation.

This report will describe the development of the PBI WxApp and its general outcomes. The findings show that mobile platform data are reliable and provide a weather window that is more complete than any single source of data.

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Preface/ Acknowledgements

Preface

Adverse weather significantly affects our nation's highways and consequently causes problems for commercial companies that rely on highways to support their enterprises. The Passenger Bus (Motorcoach) Industry (PBI) is one such affected commercial user. Operational efficiency, occupant safety, and the cost of services are all compromised by adverse weather.

Conditions such as snow, ice, fog, rain, and black ice greatly impair public safety, reduce travel capacity, and cause travel delays. Weather-related accidents and delays are directly responsible for thousands of lives lost, hundreds of thousands of injuries, billions of dollars of property damage, and countless business disruptions on an annual basis in the United States (US). PBI generates over $55 billion dollars annually in the US and accounts for over 751 million passenger trips, moving more people in most years than commercial airlines. Adverse weather presents logistical problems, public safety concerns, and economic disruption at both the national and local levels.

Accurate weather information is critical for enhancing safety and operational efficiency associated with passenger bus travel. Providing better and more timely weather information to operations, drivers, and the traveling public will have positive societal and economic benefits. Weather information, delivered as meaningful and relevant information products, has national implications of improving the efficiency and safety of an entire industry and local implications of providing better transportation services in our communities.

Acknowledgements

This research project was sponsored by the United States Department of Transportation, Federal Highway Administration (FHWA) *Broad Agency Announcement (BAA) DTFH61-10-R-00015: Research on* Clarus *System Data*. The goal of the BAA is to support research and scientific study on the use of *Clarus* system data to improve surface transportation weather management/operations, create innovative interfaces, and/or develop new applications including weather-responsive traffic management tools.

Global Science & Technology, Inc. (GST) is extremely grateful for the contributions and support of the following organizations and stakeholders during the research project:

Federal Highway Administration
Research and Innovation and Technology Administration
Clarus Initiative Stakeholder Group
Weather Telematics, Inc.
Greyhound Bus Lines, Inc.

Disclaimer

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Executive Summary

Surface-weather and road-pavement conditions are of paramount interest to the traveling public, particularly during times of adverse weather. Storms and other meteorological phenomena, such as fog, present hazards to vehicles and their occupants.

The primary objective of the Passenger Bus Industry Weather Information Application (PBI WxApp) is to integrate mobile platform environmental observations with fixed-site (airports and road-weather stations) observations in order to create a window of meteorological information along a commercial vehicle's intended travel route. The expected outcome is situational awareness for drivers, passengers, and dispatchers or other operations personnel who communicate with fleet vehicles. Furthermore, decision support systems can benefit from the addition of mobile platform observations as input data that describe environmental conditions in locations not sampled by fixed-site road-weather equipment.

The PBI WxApp was developed in a rapid-prototype software engineering environment. Functionality and features were added in each software build. At the conclusion of the third build, GST had an application that was suitable as a proof of concept for the primary objective.

The findings show that fixed-site station data are generally available and reliable. Mobile platform data were limited during the period of software development, but they have shown to be reliable and also of good quality. At times, any reporting site, whether fixed or mobile, is subject to data inaccuracy. The PBI WxApp does not filter observations or in any way limit data input. Therefore, data are passed to users as they are reported by their respective source. Future software versions might consider the introduction of data quality control at the input level.

The development of the software application revealed the need to understand the reconciliation of expression of data from disparate systems. The term "temperature," for example, has different meaning across multiple information systems. Also, where multiple sensors are involved for a single attribute, such as pavement surface temperature, there can at times appear to be data conflict when values vary significantly. Site metadata would be extremely useful for the interpretation of certain *Clarus* system data attributes. Mobile platform observations are provided with siting and equipment metadata.

The PBI WxApp includes links for National Weather Service (NWS) warnings that affect the area of interest traversed by the vehicles. The fixed-site and mobile platform observation data displayed by the application along routes are then placed in the context of broader hazards that are forecast. Future versions of the software application might consider highlighting impact areas (when triggered by observational data, such as icing) and hazard notification tools (such as text messages or console visual display).

Overview

Global Science & Technology, Inc. (GST) is providing this Final Report as part of its activities to fulfill order number DTFH61-10-R-00015 with the Federal Highway Administration (FHWA).

Purpose

The purpose of this Final Report is to provide a summary of Passenger Bus Industry Weather Information Application (PBI WxApp) project activities and findings. This report also includes recommendations for follow-up development of the application.

Scope

The PBI WxApp project is part of the FHWA *Research on* Clarus *System Data* program. One of the objectives of the program is to demonstrate the viability of enhanced road-weather forecasting enabled by the *Clarus* system. To that end, the PBI WxApp is a software application that demonstrates the concept of integrating *Clarus* system data with mobile platform environmental data. Situational awareness is improved by environmental detection and sampling by mobile platforms when combined with observations from present-day *Clarus* system fixed-site assets. Decision support systems might directly benefit from the increased data granularity provided by mobile platforms that record observations while conducting routes.

The PBI WxApp in and by itself is not a system. The software application was designed as a proof of concept for the FHWA and PBI communities, with broader implications for the entire road-weather community. Weather conditions such as snow, ice, fog, rain, and black ice can greatly impair public safety, reduce travel capacity, and cause travel delays. Accurate weather information is critical for enhancing safety and operational efficiency associated with passenger bus travel.

The PBI WxApp demonstrates how FHWA *Clarus* system data and mobile platform environmental data can provide decision support for Greyhound Lines, Inc. (Greyhound). The Greyhound fleet has equipment that samples and records environmental conditions while its buses travel their routes, and Greyhound data are then processed by the GST Mobile Platform Environmental Data (MoPED) system. Weather information along routes is delivered as meaningful and relevant information by the PBI WxApp. Some design consideration was directed toward weather that might significantly impact travel, such as winter precipitation, heavy rain, and fog. The implication is that high-impact weather events, which might potentially affect safety and travel schedules, will be of the most interest to PBI users.

The scope of the project is limited to PBI; however, providing better and timelier weather information to operators, drivers, and the traveling public will benefit a broad cross-section of society. The PBI WxApp is designed to be available for Greyhound personnel and their customers via Web and mobilephone displays. The application addresses the problem of the resolution of weather information along Greyhound's bus routes. This problem is not exclusive to Greyhound; it is a problem for all public and private transit organizations. This project focuses on mobile platform data assets provided by Greyhound, but the findings are applicable to other passenger bus and transit organizations. This report provides recommendations for follow-up development of the application for broader cross-sections of the traveling public and transportation agencies (see the Recommendations section).

Stakeholders

GST leveraged input from stakeholders to define the requirements and objectives for the PBI WxApp. GST then worked through three software sprints (see the Application Design and Development section) to produce a software application that is suitable to demonstrate to Greyhound and other stakeholders.

Primary Stakeholders

The PBI WxApp is intended for the direct benefit of PBI. Primary stakeholders for this project include FHWA, Greyhound, and third-party designate Weather Telematics, a company that works closely with Greyhound in order to acquire and communicate mobile platform environmental data.

Weather Telematics provides GST with insight into Greyhound operations based on work with Greyhound and through knowledge of Greyhound's needs. GST leveraged input from both Weather Telematics and Greyhound to define the requirements and objectives for the PBI WxApp. Greyhound's needs parallel those of the larger road-weather community: situational awareness of weather conditions along routes, particularly hazards, is important to drivers and those who manage operations because certain hazards, such as roadway icing, flooding, and poor visibility, can cause danger to passengers and to the operation of equipment.

Secondary Stakeholders

The broader group of stakeholders includes the road-weather community at large.

The information gleaned from interactions with the secondary stakeholders during the early months of the PBI WxApp project helped shape the application's requirements and general development philosophy. The GST project team understood the stakeholders' articulation that applications need to break technology barriers in order to be accepted by their user communities. Significant learning curves can be involved with new software or new systems; therefore, application developers need to consider ease of use when designing graphical user interfaces. This philosophy was adopted by the PBI WxApp team. For example, the overview screen is meant to provide users with a high-level, quick understanding of weather along routes. Then, if users want more information, detailed data are accessible and viewable.

The following subsections summarize two meetings with the broader group of stakeholders.

Road Weather Policy Forum

The Road Weather Policy Forum (November 8-9, 2010; Washington, DC) focused on the development of technology and research objectives that will ultimately benefit the road-weather community, including PBI. Stakeholders acknowledged the importance of both fixed-site and mobile platform observations for *Clarus* system users.

At this meeting, the owner-operator of the Independent Drivers Association expressed that there are significant barriers to the acceptance of new technology. Many commercial-vehicle operators still communicate via Citizens' Band (CB) radio. If operators encounter problems such as adverse weather, they broadcast the information over CB to fellow operators.

One of the objectives of the PBI WxApp is to provide information to drivers ahead of what might be obtained via CB. If a mobile platform or fixed site—Automated Surface Observing System (ASOS) or Road Weather Information System (RWIS) station—detects adverse weather along the route ahead, the PBI WxApp collects that data so drivers can be informed before reaching the area. The PBI WxApp also helps to quantify the environmental attributes, such as road temperature and visibility. For example, if precipitation is falling, the PBI WxApp user can see if the pavement temperature is above or below 0°C.

Some discussions at this forum centered on driver distraction: technology in the cab is great to have, but the driver's eyes need to be on the road. A driver's eyes can be on the road while he or she is using CB, which attests to its popularity. Many states have hand-held or no-texting laws on the books, so use of mobile devices while driving is generally discouraged. To this end, the PBI WxApp is not designed for direct use in the vehicle while the operator is driving. The PBI WxApp is designed more for the dispatch environment or for drivers who are taking a break or otherwise not driving. In the future, a high-level display of the PBI WxApp might be a useful screen on vehicle dashboards.

At this forum, stakeholders discussed the impact of fog and poor visibility on driving. Trucks tend to put on four-way hazard lights when traveling through fog, so the four-way hazard light status was considered as a possible vehicle attribute that might offer valuable information for applications such as the PBI WxApp. In the PBI WxApp project, however, only environmental attributes directly sensed (e.g., air temperature, relative humidity) are included as data inputs.

IntelliDrive^{SM} Mobility and Environment Workshop

The IntelliDrive Mobility and Environment Workshop (November 30 – December 1, 2010; Arlington, VA) dealt with the IntelliDrive program as a whole; however, there were discussions that pertained to road-weather applications. FHWA has programs for data capture and dynamic mobility applications, both of which are relevant to the PBI WxApp: when integrated with fixed-site stations, mobile platform data from Greyhound buses create weather windows on the dynamic PBI WxApp.

FHWA expressed a need for developing mobile platform data sources because very few vehicles today actually report conditions along routes. Commercial fleets can fulfill that need by processing mobile environmental observations from thousands of mobile platforms conducting routes. The inclusion of mobile platform environmental data into Maintenance Decision Support Systems (MDSS) used by state departments of transportation will improve forecasts of weather and road conditions. In addition to safety benefits, considerable cost savings might be realized by more precise model outcomes resulting from the inclusion of mobile platform observations.

Also at this meeting, stakeholders discussed the need for information systems to communicate current, relevant data to drivers so they can make informed decisions. Drivers need the ability to react to information about environmental conditions that is presented to them. With the PBI WxApp, dispatch operators can communicate to the driver that the PBI WxApp indicates poor travel conditions along a certain section of the route. Variable Message Signs (VMS) can present generic weather hazard information, such as poor visibility; however, these signs are infrequently spaced and have a significant installation cost. Observational data used by the PBI WxApp to trigger messages to drivers would be extremely useful, particularly if data trigger a threshold for adverse conditions. Future versions of the PBI WxApp might consider additional monitoring and notification tools, in addition to a high-level dashboard display (see the Recommendations section).

Project Activities

The PBI WxApp project team created an Internet-based application that processes data that identify weather conditions and hazards along scheduled bus routes. Data are acquired from three sources: ASOS stations, *Clarus* system stations, and mobile platforms (via the MoPED system). The application displays a map, weather icons, and text that describe existing conditions along user-selected bus routes.

This section describes PBI WxApp project methodologies and activities. For more detailed information regarding the development environment, computing environment, and data acquisition and display, please refer to the PBI WxApp Software Requirements Specification (SRS).

Application Design and Development

The PBI WxApp integrates Greyhound mobile platform data, furnished by the MoPED system, with fixed-site data, as available from FHWA and the National Oceanic and Atmospheric Administration (NOAA). The *Clarus* system provides environmental data from RWIS stations sited along transportation routes. NOAA provides ASOS station observations from airports.[1] Therefore, the combined PBI WxApp data assets include both mobile platforms and fixed land sites along travel routes. Attributes from the three data sources are described more fully in the PBI WxApp SRS and listed in APPENDIX B: Data Attributes by Source below.

The PBI WxApp was developed using methodology based on the iterative Agile Software Development Lifecycle (SDLC). Known as Scrum,[2] this methodology builds up a system from a core of functionality. Very short development cycles, where requirements and features are added to each build, are known as sprints. Version 1.0 of the SRS represented the first set of requirements, which iterated with the sprints. At the conclusion of the project, the final snapshot of requirements as captured in version 2.0 of the SRS represents the composite application as developed through the sprints. The final product backlog defines final set of requirements.[3]

After requirements were defined, they were incorporated into the analysis and design of the application. An initial design document based on the first product backlog was submitted to FHWA prior to starting development of the PBI WxApp. Each sprint consists of software development and testing, and the version of the application produced during each sprint can be demonstrated. Throughout the PBI WxApp project, the GST project team leveraged its experience with Capability Maturity Model Integration (CMMI) Level 3 processes to manage requirements. This approach minimized risk as it allowed the team to work in partnership with FHWA.

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[1] Although the *Clarus* Initiative lists ASOS as an available data type, GST did not find ASOS data in the *Clarus* system. Therefore, GST seeks ASOS data directly from NOAA sources.
[2] www.scrumalliance.org
[3] In Scrum terminology, the product backlog is the master list of all functionality desired in the product.

Planning

At the initial PBI WxApp development meeting, the team developed a list of requirements that was presented to FHWA during December in the form of the SRS.

The approval of the requirements by the customer allowed GST to perform the first meeting using Scrum methodology. The Scrum team was composed of a ScrumMaster, a Product Owner, and a team of developers.[4]

The first Scrum activity was to generate the product backlog, which defined what the team was developing, sorted by importance and including an estimation of labor hours for each desired feature of the application.

After the product backlog was complete, the team met prior to the start of each sprint to develop sprint backlogs. The sprint backlog is the list of work the team must address during the sprint. Features listed in the product backlog were broken down into detailed tasks for individual team members to complete during the sprint.

Before beginning subsequent sprints, the team re-examined the product backlog and noted the features that were addressed in the prior sprint(s) in order to discuss if any new features should be considered.

Development

After the creation of the product backlog and the sprint backlog, the development team began work developing and coding the PBI WxApp.

During the development phase, the team held regular stand-up meetings to discuss what the developers had worked on since the last meeting, what they were planning to achieve next, and what (if any) problems and difficulties the team encountered during the development process.

All tasks and relevant documents were made available to the team using Microsoft SharePoint.

Scrum Sprint Activities

The following subsections describe the activities and deliverables of each Scrum sprint.

First Sprint

The team started the development of the first Scrum sprint on November 29, 2010, and all tasks were completed by January 07, 2011.

During the first sprint, the team developed a solid foundation for the following sprints. The main purpose of the first sprint was to integrate data from the *Clarus* system, the MoPED system, and

[4] The Scrum Master is responsible for coordinating the Scrum process, and the Product Owner is responsible for representing the interest of the stakeholders.

ASOS stations into the PBI WxApp, as shown in Figure 3-1: PBI WxApp Screenshot (First Sprint, 12 January 2011).

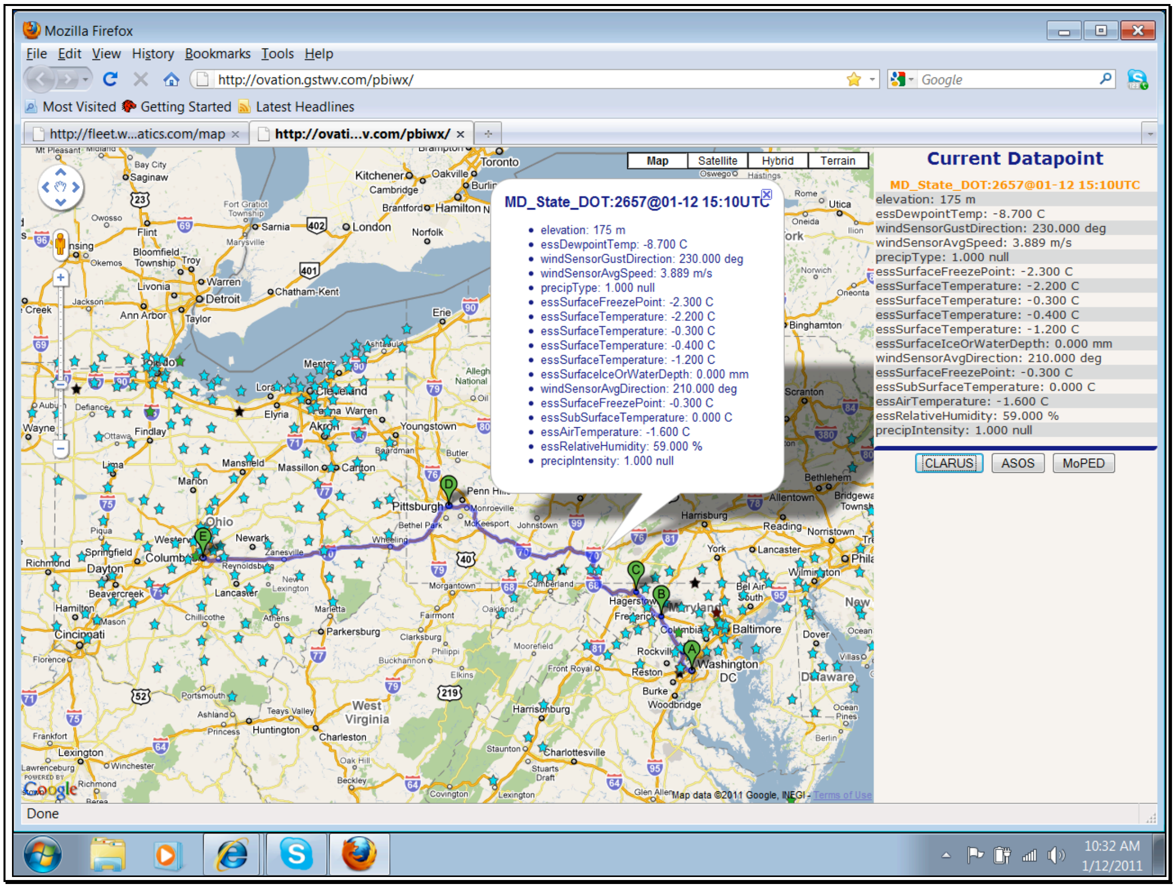

Figure 3-1: PBI WxApp Screenshot (First Sprint, 12 January 2011)

In addition to data integration, the team created a list of routes and lag times along with their respective Keyhole Markup Language (KML) files for the PBI WxApp demonstration. Only a limited number of starting and ending points are provided for selection. Routes made available for this proof-of-concept application were chosen based on concentrations of available data from the three sources (ASOS stations, *Clarus* system, and MoPED system).

The team also established a domain name, a hosting server, and source-code version control (Subversion (SVN)).

At the beginning of the sprint, the team started PBI WxApp development using the open-source OpenStreetMap. However, after comparing OpenStreetMap to the Google Maps Application Programming Interface (API), the team concluded that Google Maps would be more advantageous. The team expressed concerns to the Product Owner about licensing if the PBI WxApp will be operational in the future because Google Maps carries a fee for commercial applications.

Second Sprint

The team started the development of the second Scrum sprint on January 24, 2011, and all tasks were completed by February 14, 2011.

During the second sprint, the team was tasked with developing and enhancing the desktop-browser version of the application.

The team implemented a pop-up dialog box for selecting the desired route. The selection view provides an entry form that was moved from the sidebar to the insert window (see figure below).

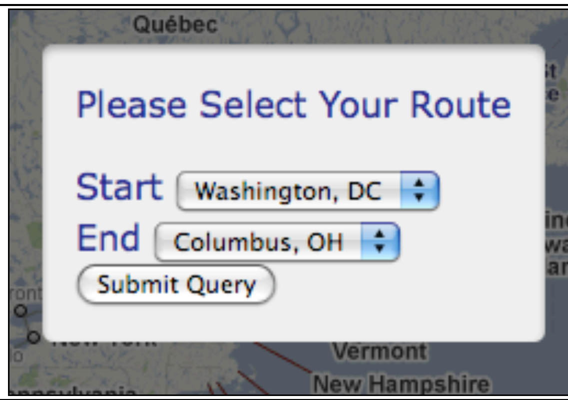

Figure 3-2: PBI WxApp Route Selection Screenshot (Second Sprint, 14 February 2011)

Once the user selects starting and ending points, the overview (shown in the figure below) provides high-level information about the weather conditions along the desired route.

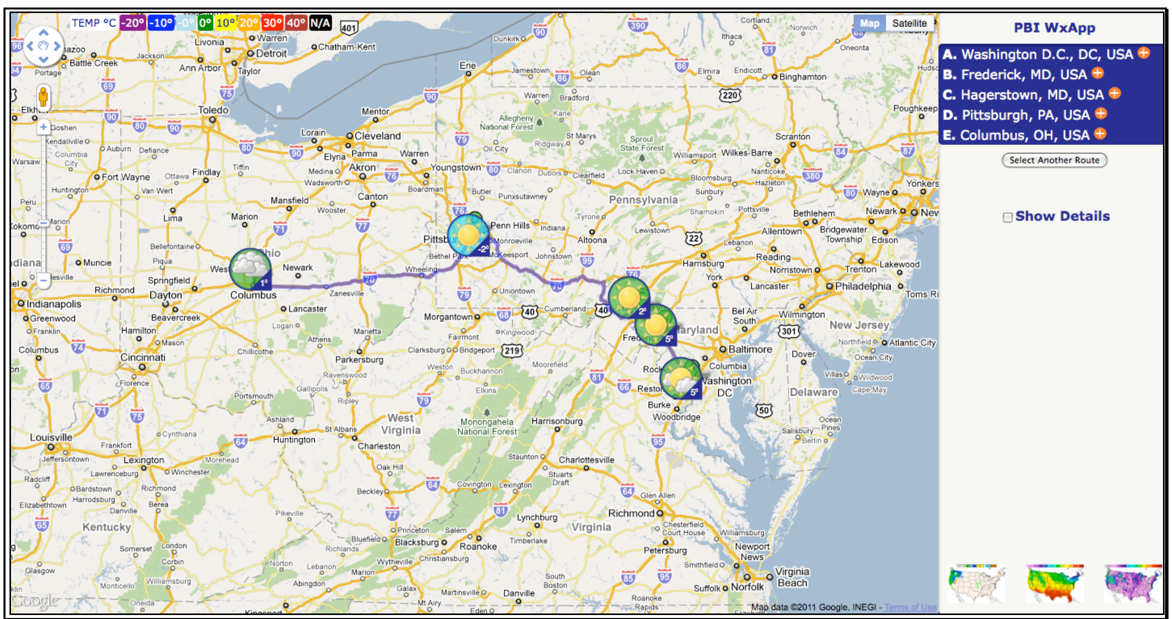

Figure 3-3: PBI WxApp Overview Screenshot (Second Sprint, 14 February 2011)

New icons, created dynamically using Hypertext Transfer Protocol (HTTP) 5, were added to deliver weather data to users. Each icon illustrates current weather and temperature information based on the ASOS station that is closest to that waypoint or terminal. ASOS data were chosen because they are the most complete and defined of all three data sources for present-weather information. Also, ASOS data include attributes for precipitation and sky conditions, and ASOS equipment is generally well maintained with established quality control and design standards to support aviation.

The sidebar on the right side of the screen was enhanced to include information about each waypoint. A “Select Another Route” button was added so that users can return to the route-selection view, and small icons were added at the bottom of the right sidebar with links that redirect users to NOAA maps for additional national information.

For details about any given observation along the route, users can click the “Show Details” button to access individual data points (ASOS, *Clarus* system, MoPED system). When the “Show Details” button is selected, a detailed view is presented to the user (see Figure 3-4: PBI WxApp Details Screenshot (Second Sprint, 14 February 2011)). In the detailed view, the overview icons are removed and the individual stations and mobile platforms appear.

A filtering algorithm was implemented to show fixed-site weather stations (ASOS and *Clarus* system stations) that are less than 10 miles away from the chosen route. The mobile platforms travel on the selected route itself, so any mobile platform data acquired along the depicted route are displayed. In the detailed view, triangles depict ASOS stations, stars depict *Clarus* system stations, and circles depict MoPED system observation points.

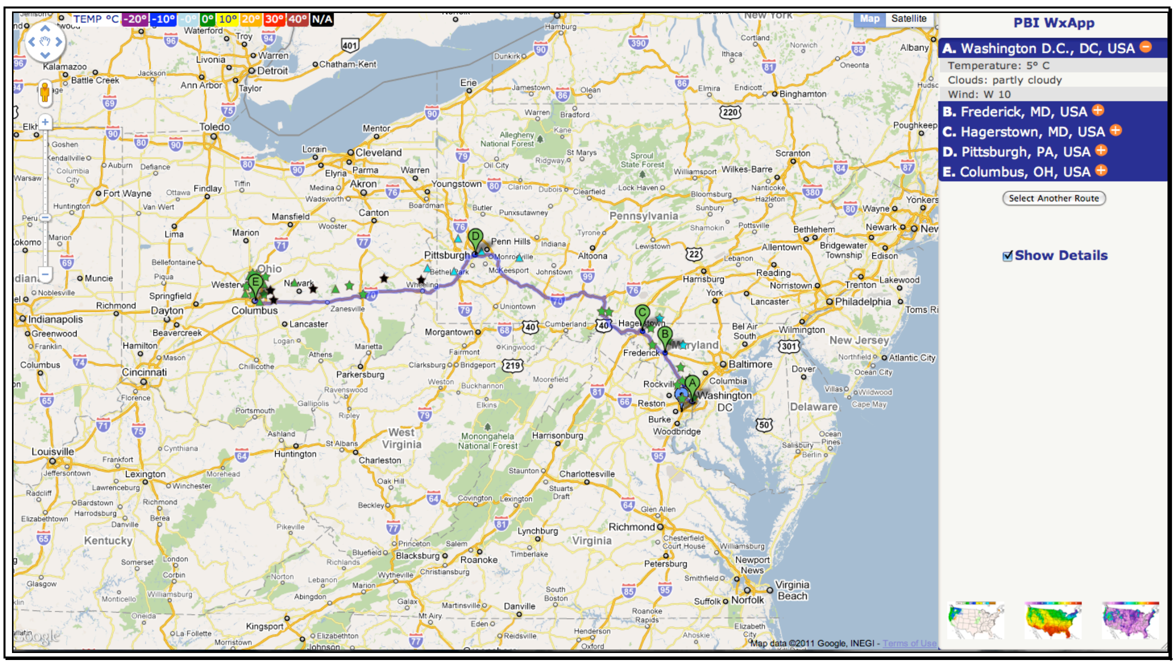

Figure 3-4: PBI WxApp Details Screenshot (Second Sprint, 14 February 2011)

If the user clicks on an individual station icon, that station’s data appears in a pop-up bubble, fully expanded to capture all attribute details (see Figure 3-5: PBI WxApp Pop-up Details Screenshot (Second Sprint, 14 February 2011)).

The attributes are listed as they are expressed by their native hosting systems. For example, essAirTemperature in the figure below represents the RWIS expression for ambient air temperature.

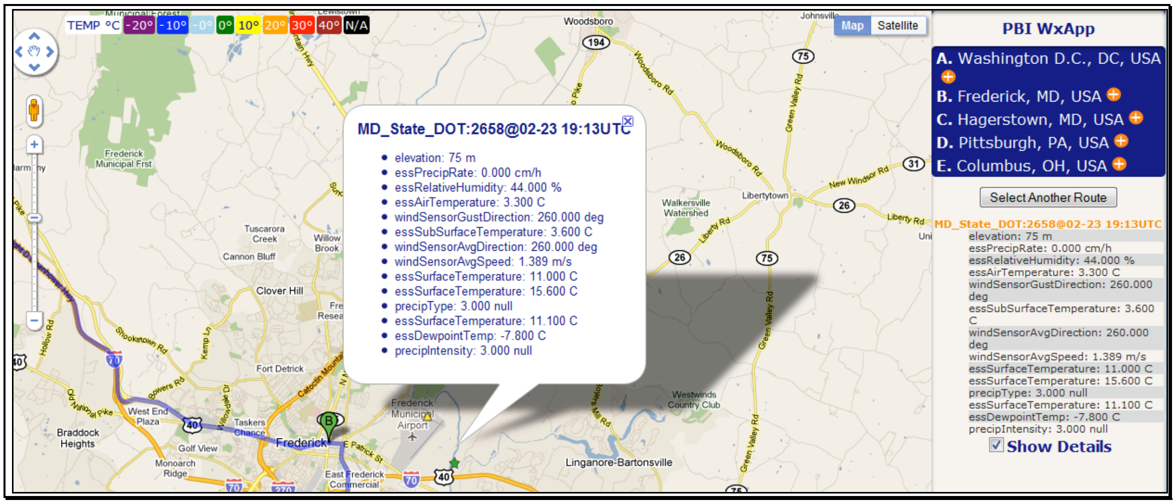

Figure 3-5: PBI WxApp Pop-up Details Screenshot (Second Sprint, 14 February 2011)

Third Sprint

The team started the development of the third Scrum sprint on February 16, 2011, and all tasks were completed by March 09, 2011.

Third-sprint tasks included improving the visual aspects and functionality of the application. During the second sprint, the initial interface was changed to add a pop-up dialog box that allows users to choose a desired route. During the third sprint, this initial interface was visually enhanced.

Additional changes were made to the overview screen, which appears after a route is selected. A Greyhound logo was placed on the top of the right sidebar, and the layout of the page was made more visually appealing (see the figure below).

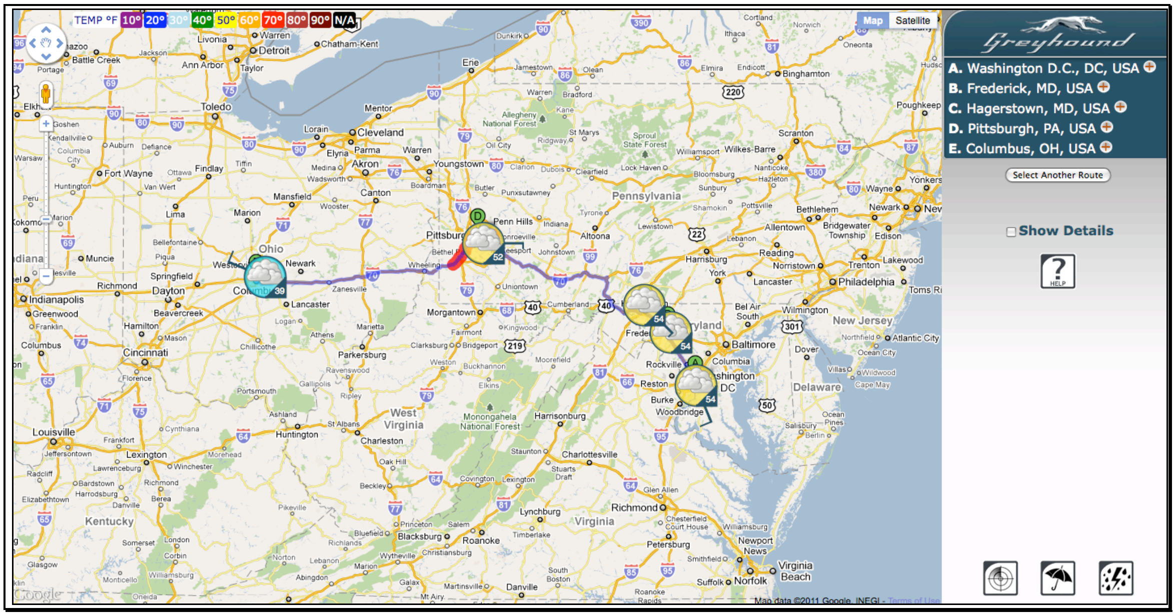

Figure 3-6: PBI WxApp Overview Screenshot 1 (Third Sprint, 10 March 2011)

The third sprint also included changing the unit system from metric to English. The unit system was changed for all data displays, and in some places, data displays include metric unit values in parentheses.

As shown in the figure above, the third-sprint deliverable also updated the set of icons at the bottom of the right sidebar. These icons direct users to the NOAA radar, precipitation forecast, and warnings maps. Also, wind speed (in increments of 5 mph) and wind direction were added as graphical weather icons.

The right sidebar still lists all waypoints along the selected bus route, and users can still check current weather conditions at the Greyhound stations. Greyhound station conditions are collected from the closest ASOS station. The figure below illustrates the waypoint weather data delivered on the sidebar.

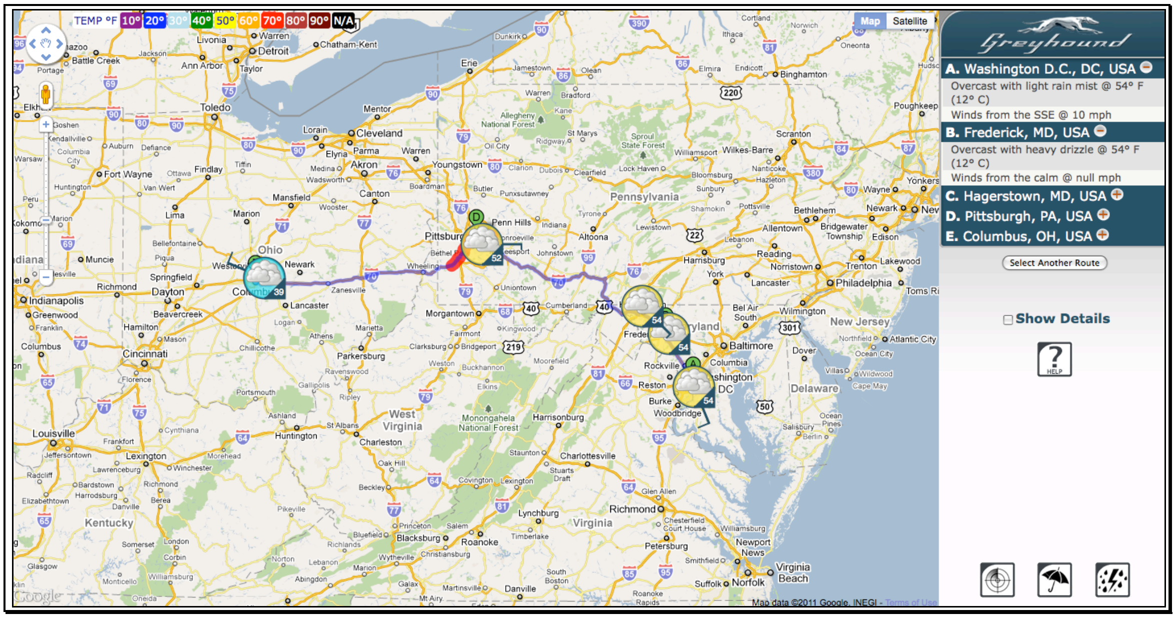

Figure 3-7: PBI WxApp Overview Screenshot 2 (Third Sprint, 10 March 2011)

The team re-prioritized attributes in the pop-up boxes that display ASOS and *Clarus* system stations after users click on the “Show Detail” box. Precipitation, present weather (including sky cover), visibility, and temperature attributes receive the highest listing priority. The new pop-up box can be seen in the figure below. The figure below also illustrates the new legend used for differentiating the three different sources of data: ASOS station (Airport), *Clarus* system (Road Weather), and MoPED system (Greyhound).

GST researched the ability to highlight segments of travel routes that present hazardous situations, but the team is still developing the algorithm that would perform highlighting automatically. Therefore, the red segment highlighted next to Pittsburgh in the figure below is an example of how this tool might appear in future versions of the application. Future versions might also include more sophistication and programming for graphical alerts or visual depictions of severe conditions (see the Recommendations section).

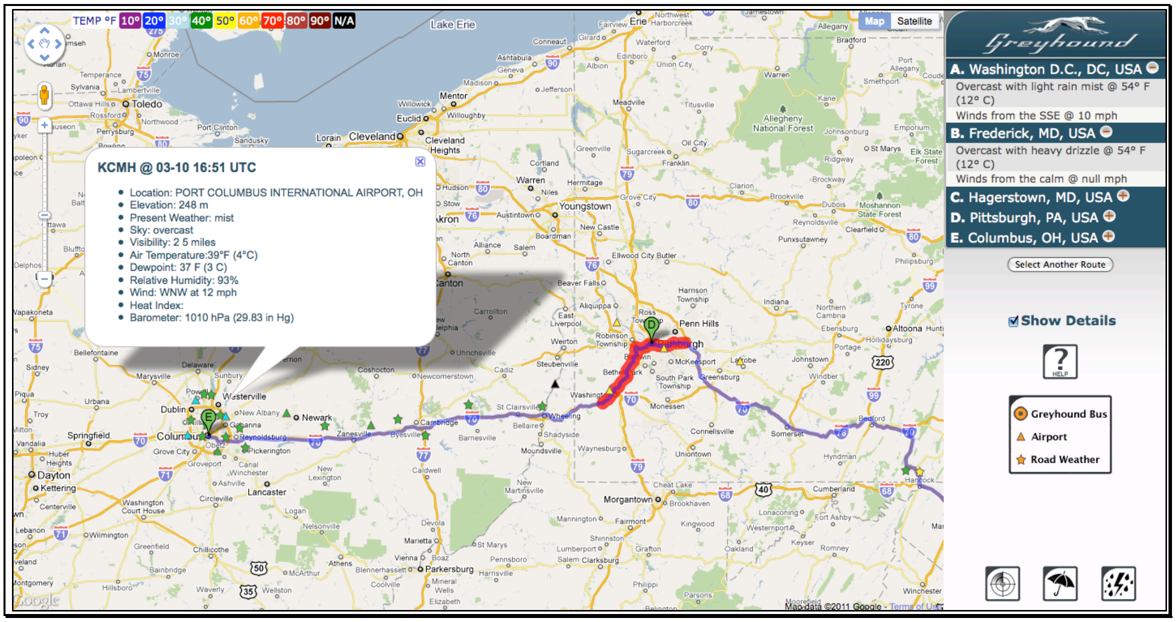

Figure 3-8: PBI WxApp Details Screenshot (Third Sprint, 10 March 2011)

Underneath the “Show Details” checkbox, the team added a help button that directs users to the help tool shown in the figure below. This tool steps users through application functionality.

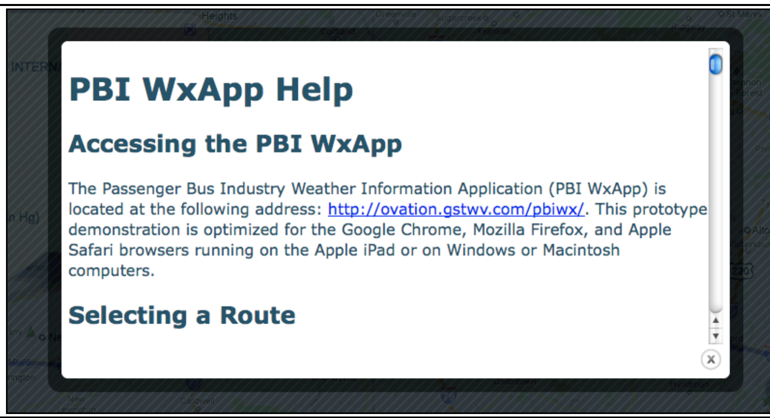

Figure 3-9: PBI WxApp Help Tool (Third Sprint, 10 March 2011)

Data Attributes

The attributes available from the three data sources (ASOS stations, *Clarus* system, MoPED system) are listed in APPENDIX B: Data Attributes by Source. This listing represents source availability as of the writing of this report. Attribute availability depends on sensor configuration at individual sites, and attribute names are native to source origination.

Standards

Fixed-site stations make use of NOAA standards for ASOS and FHWA standards for RWIS. Mobile platform observations use the standards developed by GST for the MoPED system. These standards documents are listed in the References section.

Quality Control

No specific quality controls are placed on data acquired for the PBI WxApp. ASOS and RWIS values are listed as presented by their respective systems. The *Clarus* system does not filter or remove suspect values from RWIS stations; however, the *Clarus* system does provide attribute quality flags that were not acquired or integrated into the PBI WxApp. The integration of *Clarus* system quality flags can be considered for future versions of the PBI WxApp so that PBI users can be made aware of RWIS attributes that might be suspect in value (see the Findings section below).

MoPED data are subject to internal quality control procedures by GST, but only for evaluation of data quality. Like ASOS and RWIS data, all mobile platform data observations are passed to the PBI WxApp without filtering or removal by quality control procedures.

Findings

This section details findings from the PBI WxApp project. These findings are in the context of developing a proof-of-concept software application for demonstration purposes only, and they indicate challenges and outcomes that were encountered during the engineering process.
Each finding is listed below in one of two broad categories: data or application.

Data Findings

This section describes initial impressions related to data used for the PBI WxApp.

Gauging Data Availability

The first sprint combined ASOS and RWIS data for the PBI WxApp. During the subsequent sprints, GST was able to evaluate data availability. The result is that both data sources (NOAA's ASOS and FHWA's RWIS) are generally consistent with regard to availability. There are no significant outage periods when data are unavailable. However, during PBI WxApp testing, GST did notice sporadic occasions when RWIS stations in Ohio did not report essAirTemperature.

GST is able to acquire and display both sources of data using a time criterion limiting data to observations made within the last hour.

There is currently a limited amount of mobile platform environmental data available to the PBI WxApp, but mobile data from vehicles with installed instrumentation packages does appear. For example, in the figure below, bus 715 is providing mobile platform observations while traveling along the New Jersey Turnpike.

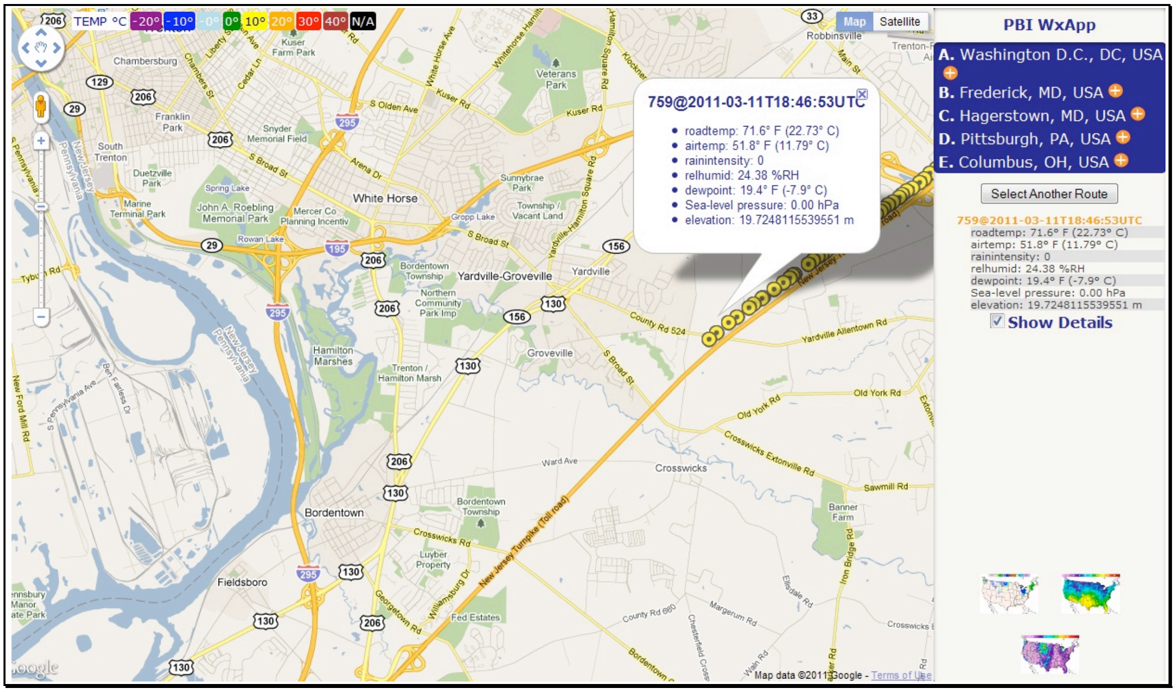

Figure 4-1: Example of Mobile Platform Data in the PBI WxApp

Understanding Geographic Coverage

The PBI WxApp can provide national coverage, but there are limitations related to the domains of the individual data sources that comprise data input.

The *Clarus* system is national, but there are a few states that do not provide data. For example, in the figure below, there are no RWIS stations depicted in Pennsylvania. Therefore, the PBI WxApp will not be able to show PBI users any RWIS information from the state of Pennsylvania owing to RWIS data unavailability from the *Clarus* system.

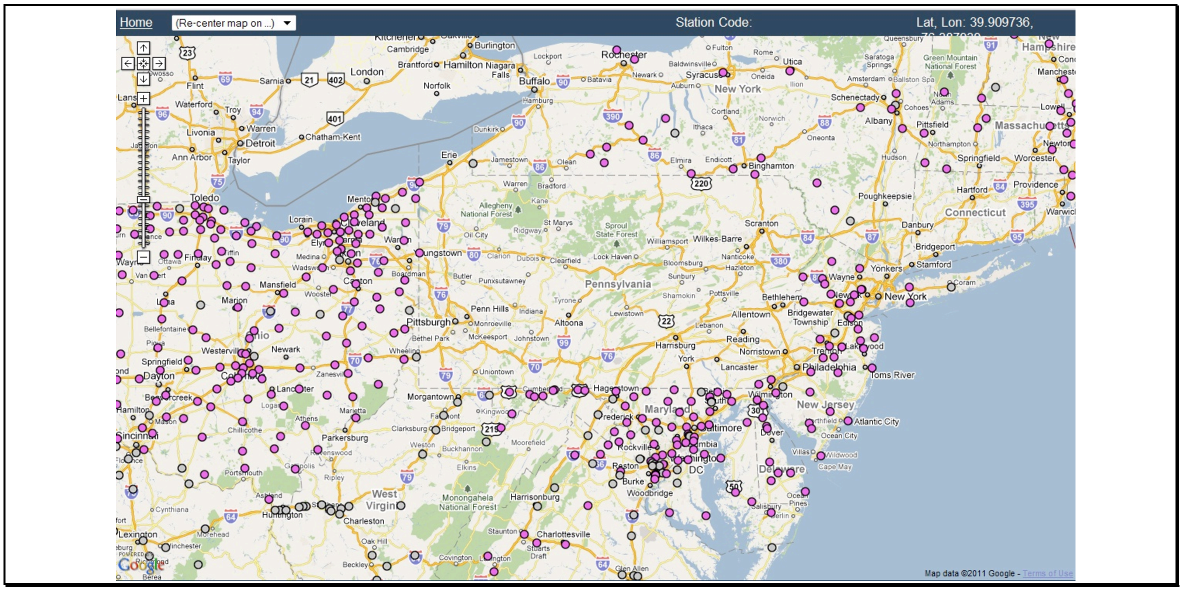

Figure 4-2: RWIS Geographic Coverage from the *Clarus* System

ASOS stations provide national coverage, and as Greyhound deploys instrumentation on its fleet nationally, mobile platforms will provide coverage for all states where Greyhound conducts business. According to Greyhound's route schedule, there might be coverage gaps in the northern Great Plains states, such as North Dakota.

Recognizing Data Accuracy

At times, a fixed site or mobile platform provides inaccurate data. The PBI WxApp relies on direct value input from RWIS stations, ASOS stations, and mobile platforms. Therefore, if any of these data sources provide inaccurate data, they will be carried into the PBI WxApp. No additional quality control is placed on the data by the PBI WxApp.

In the screenshot below, RWIS site 2457 in Ohio is clearly too warm when compared to the nearby James M. Cox Dayton International Airport (KDAY). The RWIS site reports an air temperature of 31.6°C while it is 3°C at the airport.

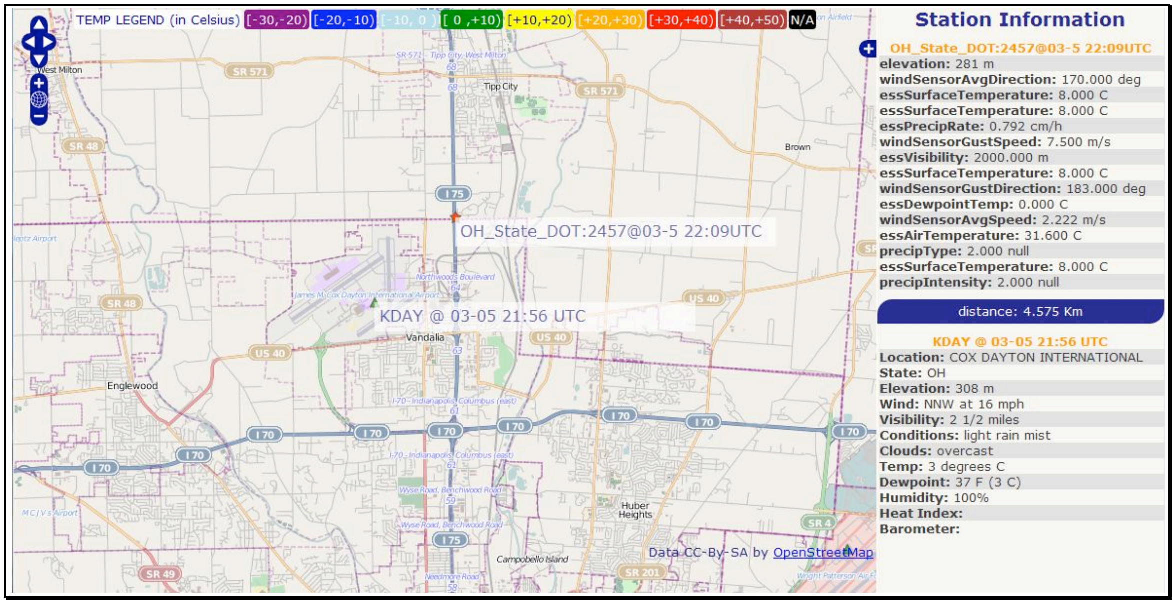

Figure 4-3: Example of Inaccurate Data (Source: GST)

There is also a significant problem associated with the visibility as reported by RWIS stations, especially when compared with ASOS data: many RWIS stations only report short-range visibility. In the figure below, New Jersey Department of Transportation (DOT) RWIS site 5922 reports a visibility of 1770 meters (approximately one mile) while the nearby South Jersey Regional Airport (KVAY) reports a visibility of 10 miles. There were no obstructions to visibility at the RWIS site: the visibility value of one mile is purely attributed to the device's sensing limit. However, the casual observer who is not aware of that limitation might believe there is poor visibility in the vicinity of station 5922. (For further discussion on visibility, see Section 5.4: Addressing Visibility.)

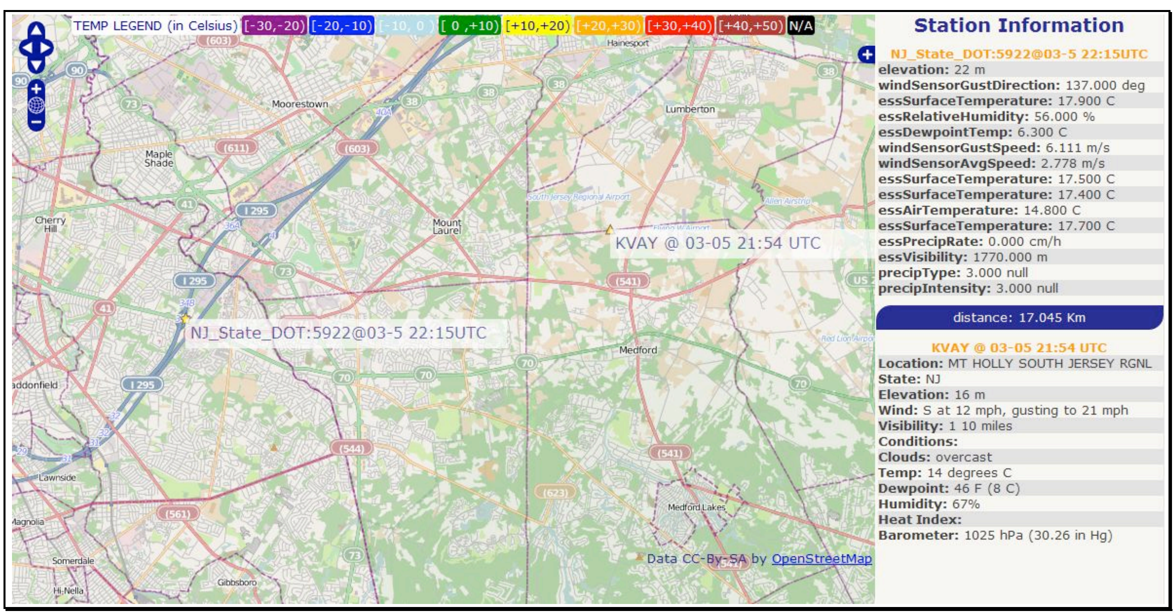

Figure 4-4: Example of Visibility Limitations (Source: GST)

Occasional data inaccuracies are not restricted to RWIS data. During the course of PBI WxApp testing, the Frederick ASOS location reported a temperature value that was clearly too warm on one given occasion.

Quality control of mobile platform observations is at a very early stage. The instrumentation being deployed on the Greyhound fleet will undergo rigorous quality control testing. Initial findings show the quality of the mobile platform data to be very good. There might be some differences in air temperature and barometric pressure from the testing controls, but the magnitude is small.

Understanding Data Conflict

RWIS stations can report multiple surface status (essSurfaceStatus) conditions and multiple surface pavement temperatures (essSurfaceTemperature). With multiple sensors on the pavement, there can be conflicting information. In the following example at Ohio DOT RWIS site 2492, there are four surface status readings at 13:19 Coordinated Universal Time (UTC) on March 21: the values for the four sensors are 3, 4, 5, and 5, respectively. According to the *National Transportation Communication for ITS Protocol (NTCIP) Environmental Sensor Station (ESS) Interface Standard 1204* document, a surface status of 3 translates to the status "dry," 4 to "trace moisture," and 5 to "wet." If a value from one sensor contradicts the value from another sensor at the same site, users are left to wonder which value is correct—a difficult challenge if metadata are not provided to show if any of the road sensors are sheltered in any way.

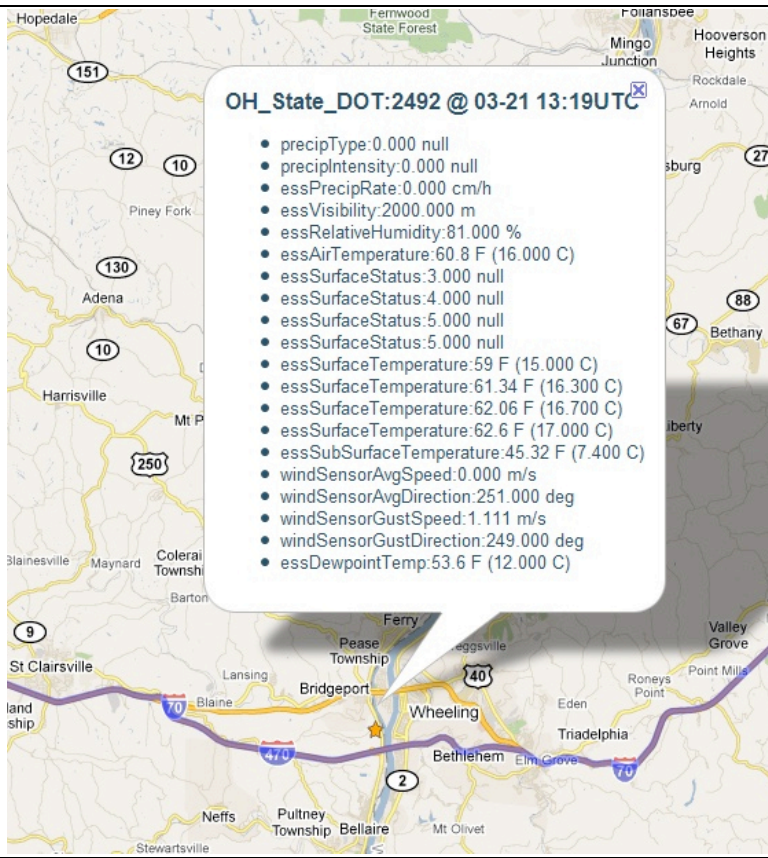

Figure 4-5: Example of Data Conflict in PBI WxApp

Multiple subsurface temperature readings have also been seen at some RWIS sites, depending on site sensor configuration. On one occasion at one site, there were concurrent surface temperature readings of -2ºC and +7ºC. Assuming these are true readings, it is unclear how PBI users should interpret the data without accompanying metadata, especially when values are close to critical thresholds such as 0ºC.

Accounting for Data Quality Flags

The PBI WxApp does not filter data, remove data, or alert users to data quality issues based on data quality flags for any data source (ASOS stations, *Clarus* system, or MoPED system).
ASOS data are provided by NOAA without data quality flags.

Mobile platform observations from the MoPED system do not have data quality flags as quality checking is performed by the target systems serviced by the MoPED system.

The *Clarus* system has several data quality checks, per description in the *Clarus Quality Checking Algorithm Documentation Report*. However, the PBI WxApp obtains unadulterated RWIS data and does not make use of *Clarus* system quality flags. If a value is suspect (i.e., it failed a quality check), it is still included in the PBI WxApp. Some sophistication might need to be considered to either filter out RWIS data that do not pass certain quality checks or to provide visual notification of such data to PBI WxApp users.

Application Findings

This section describes initial impressions related to the PBI WxApp graphical user interface.

Focusing of Displayed Data

During the design period, the PBI WxApp team concluded that once a bus route is selected, only data along and near the selected route need to be presented (see Figure 3-4: PBI WxApp Details Screenshot (Second Sprint, 14 February 2011)). This approach helps users focus areas of interest by removing data points that do not assist interpretation.

Reconciling Attribute Expressions from Disparate Systems

Each of the three data sources has attributes that are used by the PBI WxApp, but they each have different native naming conventions. For example, what RWIS titles “Air Temperature,” ASOS simply calls “Temperature.” Reconciling the attribute expressions presents a challenge. Using temperature as the example, PBI users are interested in both air temperature and road (pavement) temperature. Therefore, a naming distinction is necessary: the title “Temperature” is not precise enough in this context.

Prioritizing the Most Significant Attributes

Because present weather (including precipitation), visibility, and temperature attributes have the greatest impact on PBI users, these attributes are given higher priority in list orderings as shown in the figure below. The priority ordering applies to all pop-up bubbles from all data sources (fixed or mobile).

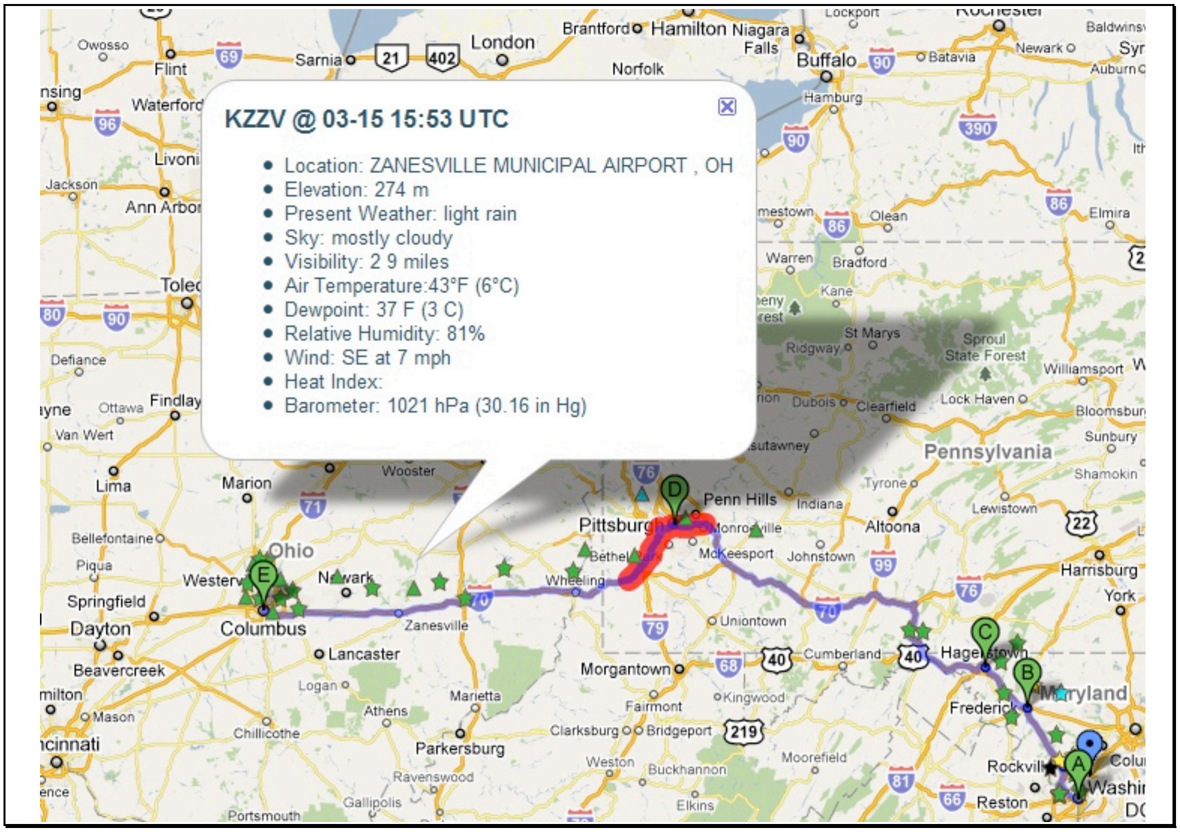

Figure 4-6: Example of Attribute Prioritization in PBI WxApp

Choosing Measurement Units

The majority of PBI users in the United States are most comfortable with English units of measurement. The first sprints of PBI WxApp development left the data measurement units in their native metric. However, during the third sprint, when attribute content was reorganized, GST made English units dominant and included metric units in parentheses.

Interpreting Raw Data

Some RWIS attributes, such as precipitation type (precipType) are expressed numerically; however, these numeric values have no meaning to most PBI WxApp users. If "precipType = 3.0" means no precipitation was recorded, then it might be best to express that clearly to the users.

Likewise, some mobile platform attributes, such as rainfall, are expressed on a scale of 0 to 250, but those values might not be readily understood by PBI WxApp users. ASOS stations provide an interpretation of intensity (light, moderate, heavy) that might be adopted for the mobile platform rainfall attribute.

Because the first three sprints dealt only with raw data, this issue of interpretation will be further discussed in the Recommendations section.

Optimizing for the iPad

GST chose to optimize the PBI WxApp for the Apple iPad. While the PBI WxApp works in most Web browsers, the iPad is ideal for the PBI user who is not in an office environment. Because the iPad is portable and has more screen real-estate than mobile phones, the PBI WxApp team believes that it will provide an optimal platform for remote PBI users.

Accessing Warnings

GST determined that quick access to NOAA warnings and watches would be of value to PBI WxApp users. When interpreting PBI WxApp information, users might want to see if an area of interest is under a watch or warning. The following figure displays the NOAA page accessed by the PBI WxApp NOAA Warnings icon, which is located at the bottom of the application's right sidebar.

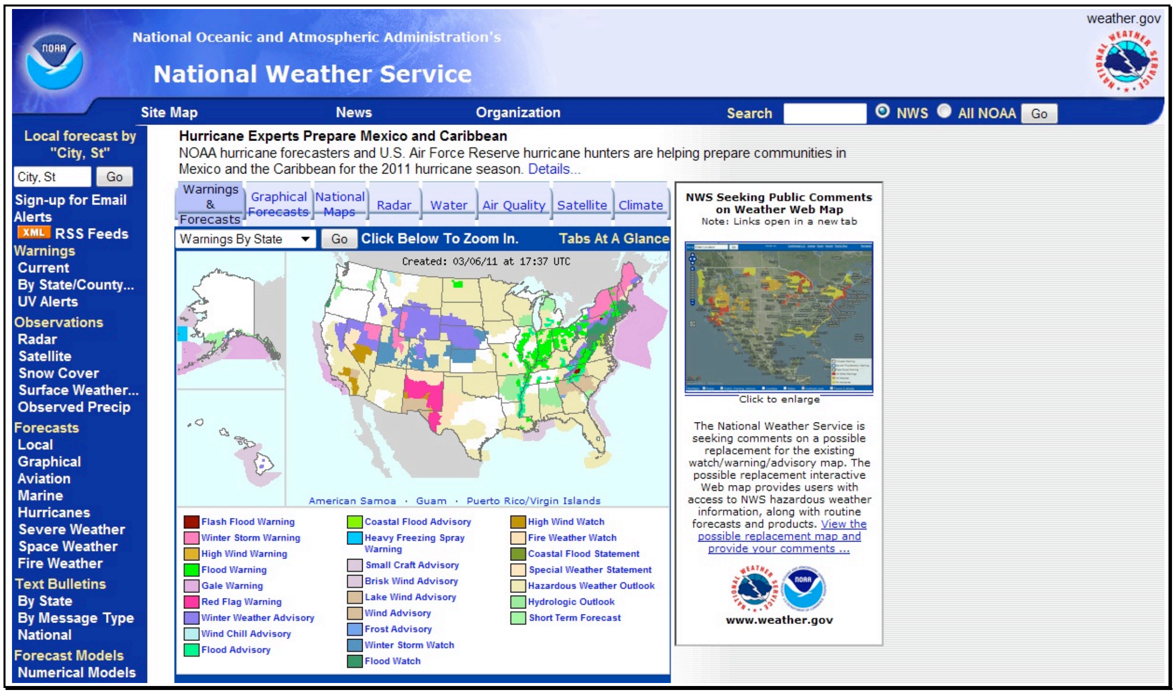

Figure 4-7: NOAA Website

Recommendations

The PBI WxApp findings illustrate the importance of environmental conditions along routes for the PBI community. The PBI WxApp provides both quick overview information and detailed information from individual fixed sites and mobile platforms.

As a proof-of-concept application that is designed and intended for demonstration, the PBI WxApp team embarked on a software development path that is positioned for enhancement and further development. Feedback from stakeholders will continue to influence the specifications that drive that enhancement.

This section outlines recommendations for follow-up development of the PBI WxApp. These recommendations are made with the assumption that Greyhound is the target user, but these recommendations also include implications for the broader cross-section of transportation agencies and the traveling public.

Highlighting Impact Areas

One of the goals of the PBI WxApp is to provide the ability to detect and graphically highlight hazards. During the third sprint, GST developed the graphical approach for hazard highlighting along affected segments of travel routes, but GST is still developing the algorithm that would perform highlighting automatically. Future versions of the PBI WxApp can include more sophistication and programming for graphical alerts or visual depictions of severe conditions.

Integrating Mobile Platform Observations into the *Clarus* System

Pavement forecast modeling and decision support systems, including MDSS, will benefit from the integration of data acquired by mobile platforms into the *Clarus* system. Mobile platforms can sample the environmental conditions of vast amounts of geography in between fixed-site stations and can also effectively sample road and weather conditions near critical infrastructure (e.g., bridges, overpasses, low areas).

Mobile platforms can acquire data at 10-second intervals, which leads to a spatial resolution of 275 meters at highway speed. Geographic fencing can be defined with programming that increases spatial resolution in urban areas or near critical infrastructure, but decreases resolution (e.g., one observation per 2,000 meters instead of 275 meters) in rural areas.

The mobile platforms' equipment includes sensors for traditional meteorological attributes (e.g., air temperature, relative humidity, barometric pressure), but the equipment also might include a sensor to sample pavement temperature, which is critically important to MDSS. Furthermore, ambient light and precipitation sensors can detect areas of precipitation that might enhance detection by other means, such as radar.

Displaying Radar

A link to NOAA's radar Website was included in the third sprint of the PBI WxApp, but future sprints might consider radar overlay capability on the geographical display itself. Radar data fit into the schema of data that are recorded at the time of observation. On the geographical display, the PBI WxApp user would be able see the spatial relationship of radar-depicted precipitation to the roadway being traversed, as well as the actual observations along that path.

Displaying radar precipitation data with aircraft position and flight (Jeppensen) routes is a common practice in aviation meteorology. GST recommends investigating a similar approach with PBI road weather.

Addressing Visibility

Mobile platforms do not directly report visibility. RWIS stations are limited in their visibility detection, and, as previously described in Section 4.1.3: Recognizing Data Accuracy, RWIS visibility values can be misleading. A reported value of 1770 meters visibility at a RWIS site is really 1770 meters *or greater*. Similarly, an airport reported visibility of 10 miles is really 10 miles *or greater.* Both of these values represent the upper limits of the sensing equipment.

Typical PBI users, who are not meteorologists, will generally not understand the equipment limitation and might take the upper-limit reported value literally as the absolute value. Because visibility is critical to road-weather applications, more work with this attribute (both at the data-sampling level and at the graphical-representation level) is recommended.

Acquiring and Integrating Metadata

The issue regarding RWIS visibility sensor limitation, discussed in Section 5.4: Addressing Visibility, illustrates the need to acquire metadata from the *Clarus* system. Sensor range limits need to be available to PBI users, particularly when the limitation of a sensor from one source is significantly different than the limitation of a sensor from another source.

Metadata are also needed to clarify information for users (e.g., when resolving data conflict issues, such as described in the Understanding Data Conflict section). If PBI WxApp users understand the limitation and siting of a given sensor, they can be better informed about how to interpret the data.

The need to acquire and integrate metadata is true of all PBI WxApp data input sources. In addition to *Clarus* system metadata, mobile platform and ASOS sensor limitations are equally important to users and should be expressed via metadata from the MoPED system and NOAA, respectively.

Addressing Data Clutter

Zoomed out on the detail view, mobile platform data are stacked because observations are taken frequently. Data clutter can also be an issue where ASOS and RWIS sites are in close proximity, particularly in metropolitan areas. A data-thinning function should be implemented for optimization at different zoom levels. The further the users zoom in, the less data should be thinned. Priority might be given to ASOS data because they include present weather (e.g., cloud cover, precipitation) details.

Interpreting Numeric Values

Some attributes are expressed in numeric values that have no units or that represent states. For example, ASOS stations report precipitation types in English-language states, but RWIS data are provided in raw numeric value. The PBI WxApp needs to consider mapping raw data to verbal states for easier interpretation by users.

In the following example, the essSurfaceStatus is given with a value of 5. This value maps to a state of "wet" according to the *NTCIP ESS Interface Standard 1204* manual. The PBI user, not being expert in NTCIP or having that manual, would not likely know the common expression for this numeric value. Also in the following example, the essPrecipSituation and essPrecipYesNo are given with numeric values, but they map to different states.

Beddington
State Hwy 9, 1 mile east of State Hwy 193
Lat, Lon: 44.84191, -68.07093
Elevation: 95 m

Timestamp (UTC)	Observation Type	Ind	Value	Unit	Conf	Complete	Manual	Sensor Range	Climate Range	Step	Like Instrument	Persistence	IQR Spatial	Barnes Spatial	Dew Point	Sea Level Pressure	Precip Accum
2011-03-07 20:50	essAirTemperature	1	4.10	C	100%	●	–	●	●	●		●	●	–			
2011-03-07 20:50	essDewpointTemp	0	3.90	C	100%	●	–	●	●	●		●	●	–			
2011-03-07 20:50	essPavementTemperature	1	4.90	C	100%	●	–	●	●	●	●	●	–	●			
2011-03-07 20:50	essPavementTemperature	2	4.90	C	100%	●	–	●	●	●	●	●	–	●			
2011-03-07 20:50	essPrecipRate	0	0.84	cm/h	100%	●	–	●		●			–	●			
2011-03-07 20:50	essPrecipSituation	0	10.00		0%	●	–	✗									
2011-03-07 20:50	essPrecipYesNo	0	1.00		100%	●	–	●									
2011-03-07 20:50	essRelativeHumidity	0	99.00	%	100%	●	–	●	●	●		●	–	●	–		
2011-03-07 20:50	essSurfaceFreezePoint	1	0.00	C	100%	●	–	●		●							
2011-03-07 20:50	essSurfaceFreezePoint	2	0.00	C	100%	●	–	●		●							
2011-03-07 20:50	essSurfaceStatus	1	5.00		100%	●	–	●									
2011-03-07 20:50	essSurfaceStatus	2	5.00		100%	●	–	●									
2011-03-07 20:50	essSurfaceTemperature	1	5.40	C	100%	●	–	●	●	●	●	●	–	●			
2011-03-07 20:50	essSurfaceTemperature	2	5.40	C	100%	●	–	●	●	●	●	●	–	●			
2011-03-07 20:50	essVisibility	0	200.00	m	100%	●	–	●		●			–	●			
2011-03-07 20:50	windSensorAvgDirection	0	223.00	deg	100%	●	–	●		●		●					
2011-03-07 20:50	windSensorAvgSpeed	0	1.50	m/s	100%	●	–	●	●	●		●	●	–			
2011-03-07 20:50	windSensorGustDirection	0	251.00	deg	100%	●	–	●		●		●					
2011-03-07 20:50	windSensorGustSpeed	0	3.10	m/s	100%	●	–	●		●		●	–	●			

Figure 5-1: Example RWIS Observation from the *Clarus* System

Future versions of the PBI WxApp should consider rendering common names for precipitation and other states that will be more intuitive for PBI WxApp users. For example, if a mobile platform registers a value of 150 on a scale of 0 to 250 for rainfall, the expression might be more intuitive to users if the phrase "moderate precipitation" is used instead of a number.

Developing Monitoring and Notification Tools

As the alerts become more sophisticated in the PBI WxApp, monitoring and notification tools can be developed that reference observed weather to the position of the vehicle. For example, if a given RWIS station indicates the potential for icing, a text-message notification can be sent to the bus driver when the bus is within a configurable distance of that RWIS station. Other notification mechanisms on the PBI WxApp graphical user interface can also be considered.

Providing Live Views

The webcams.travel API provides the ability for Webcam images to be added to the PBI WxApp Google Maps visualization, allowing users to view real-time weather and road-surface conditions live via Webcams in certain locations. In future versions of the PBI WxApp, links to available Webcams might be provided so that users can see conditions at available points along selected routes. An example screenshot from a Maryland DOT Webcam is provided below.

Figure 5-2: Screenshot of Maryland Department of Transportation Webcam

References

The PBI WxApp is based upon internal project documentation for specification and design, including MoPED standards. The following documents are identified for additional information regarding the PBI WxApp project:

National Weather Service: 1998. *ASOS User Guide.*

Federal Highway Administration: 2010. *Clarus Quality Checking Algorithm Documentation Report.*

National Transportation Communication for ITS Protocol: 2009. *NTCIP ESS Interface Standard 1204.*

National Weather Service: 2010. *NWS Instruction 10-1302: Requirements and Standards for NWS Climate Observations.*

APPENDIX A. List of Acronyms

API	Application Programming Interface
ASOS	Automated Surface Observing System
BAA	Broad Agency Announcement
CB	Citizens' Band
CMMI	Capability Maturity Model Integration
DOT	Department of Transportation
ESS	Environmental Sensor Station
FHWA	Federal Highway Administration
Greyhound	Greyhound Lines, Inc.
GST	Global Science & Technology, Inc.
HTTP	Hypertext Transfer Protocol
KDAY	James M. Cox Dayton International Airport
KML	Keyhole Markup Language
KVAY	South Jersey Regional Airport
MDSS	Maintenance Decision Support System
MoPED	Mobile Platform Environmental Data (prototype project)
MoPED-IC	Mobile Platform Environmental Data Initial Capability
NOAA	National Oceanic and Atmospheric Administration
NTCIP	National Transportation Communication for ITS Protocol
NWS	National Weather Service
PBI	Passenger Bus (Motorcoach) Industry
PBI WxApp	Passenger Bus Industry Weather Information Application
RWIS	Road Weather Information System
SDLC	Software Development Lifecycle
SRS	Software Requirements Specification
SVN	Subversion
US	United States
VMS	Variable Message Signs

APPENDIX B. Data Attributes by Source

This table lists attributes available from the three data sources (ASOS stations, *Clarus* system, MoPED system). This listing represents source availability as of the writing of this report. Attribute availability depends on sensor configuration at individual sites, and attribute names are native to source origination.

Table B-1: Data Attributes by Source

ASOS Stations	*Clarus* System	MoPED System
Visibility	essPrecipYesNo	Road Temperature
Present Weather	essPrecipSituation	Air Temperature
Sky Cover	precipType	Rain Intensity
Temperature	precipIntensity	Relative Humidity
Dew Point	essPrecipRate	Light Level
Relative Humidity	essSnowfallAccumRate	Atmospheric Pressure
Wind	essAdjacentSnowDepth	Dew Point (derived)
Heat/Chill Index	essVisibilitySituation	Sea Level Pressure (derived)
Barometric Pressure	essVisibility	
	essRelativeHumidity	
	essAirTemperature	
	essSurfaceStatus	
	essSurfaceTemperature	
	essPavementSensorError	
	essPavementTemperature	
	essSubSurfaceTemperature	
	essSurfaceIceOrWaterDepth	
	essSurfaceFreezePoint	
	icePercent	
	essSurfaceBlackIceSignal	
	essSurfaceSalinity	
	windSensorSituation	
	windSensorAvgSpeed	
	windSensorAvgDirection	
	windSensorGustSpeed	

ASOS Stations	*Clarus* System	MoPED System
	windSensorGustDirection	
	windSensorSpotSpeed	
	windSensorSpotDirection	
	essAtmosphericPressure	
	essDewpointTemp	
	essWetBulbTemp	
	precip10min	
	essPrecipitationOneHour	
	essPrecipitationThreeHours	
	essPrecipitationSixHours	
	essPrecipitationTwelveHours	
	essPrecipitation24Hours	
	essPrecipitationStartTime	
	essPrecipitationEndTime	
	essInstantaneousSolarRadiation	
	essTotalRadiation	
	essSurfaceConductivityV2	
	essMinTemp	
	essMaxTemp	

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