MARICOPA ASSOCIATION of GOVERNMENTS

MAG NON-RECURRING CONGESTION STUDY

MAG Contract No. 418 Project No. PL10-1
Technical Memorandum No. 2 – DRAFT Methodology for Quantifying Non-Recurring Congestion & Data Collection Plan

INTRODUCTION

The Lee Engineering/TTI team is conducting a study on non-recurring congestion (NRC) for the Maricopa Association of Governments (MAG). This technical memorandum is the second in a series to document the effort on the study. This technical memorandum summarizes the work completed for Task 2 – Methodology for Quantifying Non-Recurring Congestion & Data Collection Plan. The data collection plan is further subdivided into three components: field traffic data collection, obtaining/reviewing historical traffic data, and simulation-based traffic data.

The overall goal of the study is to identify appropriate countermeasures that would help recover lost roadway capacity due to NRC. This could effectively delay the immediate need for costly new road capacity construction.

The first objective of the study is to gain a better understanding of the role played by various random incidents related to traffic, weather, and special events that result in non-recurring traffic congestion on the freeway system and on the arterial systems in the region. Such an understanding is recognized as a prerequisite for a more focused approach in applying operational countermeasures. Thus the study will need to quantify the types and magnitude of NRC for the MAG region. The second objective of the study is to identify countermeasures, or mitigation strategies, that address NRC causes and develop a corridor pilot test to demonstrate the effectiveness of the various strategies.

This Data Collection Plan will outline the approach to be used to analyze NRC, including the existing (historical) data and new data (to be collected) that are necessary to address the two objectives stated above. The Plan will be presented to the Study Advisory Group (SAG) for approval prior to beginning any data collection as described herein.

BACKGROUND

As learned from Task 1 of the NRC study, there have been a variety of attempts to quantify NRC and mitigate the congestion from non-recurring events. However, a study to do the same specifically pertaining to the MAG region has not been conducted previously. Moreover, the investigation of NRC at the arterial roadway level, which accommodates two-thirds of all vehicle travel in the region, has been secondary in other studies. From Task 1, the national studies estimate that the sources of congestion are as follows:

- Bottlenecks account for 40 % of total congestion
- Incidents account for 25 % of total congestion (42% of NRC)
- Work zones account for 15% of total congestion (25% of NRC)
- Poor signal timing accounts for 10 percent of total congestion (17% of NRC)
- Bad weather accounts for 5% of total congestion (8% of NRC)
- Special events account for 5% of total congestion (8% of NRC)

Therefore, this study will assess the total occurrence of NRC across the MAG region with respect to freeways and arterials for an entire calendar year.

Non-recurring congestion (NRC) is defined as follows:

> *Congestion caused by atypical events such as highway crashes, sudden lane or road closures, weather conditions, or sudden traffic demand increases induced by a special event such as a football game. Non-recurring congestion can occur at anytime, including midday, overnight, weekends, and also during peak periods when it adds to already present recurring congestion.*

One point concerns the relationship between “congestion” and “delay.” Characteristics of congestion include over-capacity traffic volumes, slow speeds, numerous stops, and long delays to motorists. Delay is the amount of time it takes to traverse a roadway segment minus the amount of time it would take to traverse that roadway segment at free-flow conditions (i.e. the posted speed limit). The delay incurred is usually the measure of effectiveness selected to represent the extent, or magnitude, of the congestion. Thus, the two terms may be thought of interchangeably, at least in context of freeway traffic operations where free-flow conditions result from the absence of congestion.

For urban arterial roadway environments, recurrent congestion and non-recurring congestion can be expressed similarly to freeways. The elements/events that cause non-recurring congestion on a freeway would still be the same potential causes of non-recurrent delay on an arterial, although the applicability and effects of each type of NRC is likely different. Traffic on an uncongested arterial roadway will likely incur some delay from signalized intersection traffic control.

The combination of NRC and recurrent congestion (or inherent delay) makes up the overall congestion/delay experienced by the motorist as shown in Figure 1. This delay to the motorist can be measured at any point or time given the right data inputs. What cannot be discerned without further information is the proportional share due to NRC. In order to do this, a baseline representation of typical, non-NRC influenced conditions, must be developed. The same data then needs to be collected during a NRC event, and preferably multiple occurrences of the same type of NRC over a period of time to generate an average effect. When these data sets are compiled and compared, the resulting difference (increase) in delays experienced by motorists can then be attributed to the associated NRC event.

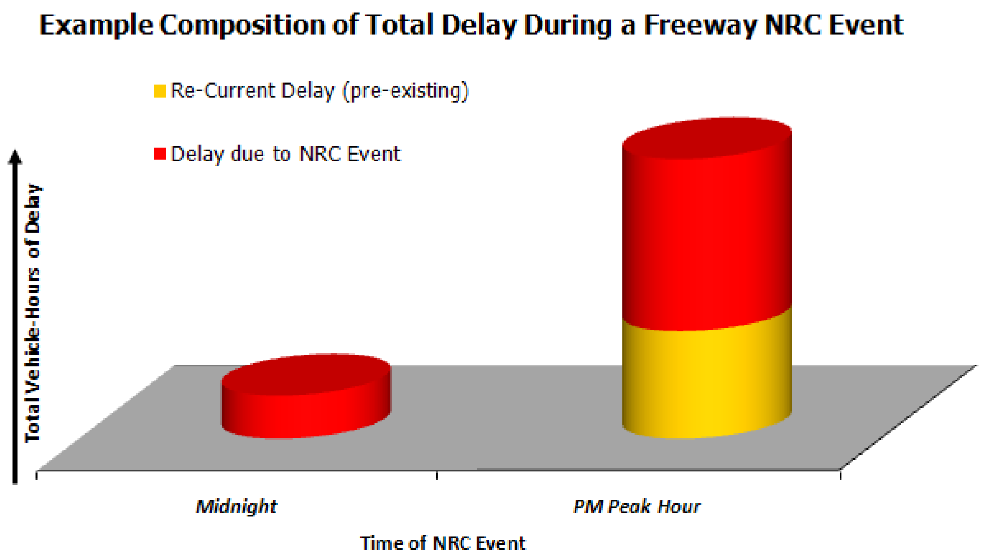

Figure 1. Example Composition of Delay at Different Time Periods

METHODOLOGY FOR QUANTIFYING NON-RECURRING CONGESTION

The general approach for quantifying NRC is to quantify congestion on "normal days" (i.e., days that do not have a non-recurring event) to compare with congestion on days with non-recurring events. The difference between congestion levels will be the congestion attributable to the non-recurring conditions. Travel time and speed data will be the primary data source for quantifying congestion.

The methodology for obtaining speed and travel time data is divided into two separate approaches for freeways and arterials due to the available data. For the freeways, the methodology will rely on historical data that is available from the Arizona Department of Transportation (ADOT). Freeway data used in this study originates from lane-specific freeway sensors that are part of Arizona's Freeway Management System (FMS). The FMS gathers data from roadway sensors located between 1 mile and one-third of a mile on local freeways. Every twenty seconds, speeds, volumes, and occupancy (i.e., the duration of time that a vehicle is present at the sensor) are gathered by the FMS from each traffic controller, and archived for later retrieval.

The procedures for assessing NRC on the freeway are as follows:

1. Obtain freeway link travel time / speed data from the ADOT FMS database.
2. Segment the link data into morning peak period, evening peak period, and off-peak.
3. Divide the data into time periods affected by non-recurring events and time periods without any non-recurring events. Time periods without non-recurring events with be nominally considered "normal" days with the associated recurring congestion.
4. Calculate the congestion for "normal" time periods by corridor.
5. Calculate the congestion for time periods affected by non-recurring events by corridor.
6. Calculate the difference in congestion for "normal" time periods and non-recurring event time periods. This difference will be the congestion due to non-recurring events.

Non-recurring events will be determined from the following databases (each of these data sources are discussed in more detail in subsequent sections of this technical memorandum):

- Incidents – Private Data Sources in conjunction with the Arizona Location Identification Surveillance System (ALISS) and ADOT's Highway Condition Reporting System (HCRS)
- Work Zones – ADOT's HCRS
- Poor Traffic Control / Signal Operation – Agency signal maintenance records
- Inclement Weather – National Climatic Data Center
- Special Events – published schedules of major sporting and festival events

The arterial speed and travel time data will be obtained by a combination of newly collected travel time data and data from the most recent MAG travel time study. The collection of new data can only be accomplished on a limited number of corridors due to the scope of the project. Thus, NRC congestion results from the new data collection will be extrapolated to the other corridors with the help of historical data from the MAG travel time study and any other available data sources.

The newly collected arterial travel time data will be from an arterial monitoring system that uses readers to anonymously collect media access control (MAC) addresses from Bluetooth devices as travel probes in the traffic stream. The travel times will be captured continuously, thereby capturing data sets pertaining to "normal" operations (i.e., typical recurrent delay) and pertaining to non-recurrent events. Similar to the freeway methodology, a baseline computation of the average delay incurred on the roadway will be compared against the data collected during NRC events. The resulting difference is the magnitude of delay attributable to the NRC event. The difference for the arterial methodology from the freeway methodology is the shorter data collection period. The freeway data covers an entire year of data. The arterial data collection will rely on data collection during a 16-week period from June 2010 to October 2010 in addition to data collected during the pilot test from May 2010 to June 2010.. The non-recurring events will also have to be monitored in each arterial corridor during the data collection period.

DATA COLLECTION PLAN

The data collection plan will consist of gathering data from existing databases and collecting new data on arterial corridors. For the freeway corridors, existing travel time / speed databases for the year 2009 are available through ADOT. Previous years will be examined to fill any data gaps in the 2009 data.

For the arterial corridors, the Project Team plans to collect data in five different arterial corridors. Because there is uncertainty in the types of non-recurring events that might be captured, the Project Team plans to vary the data collection periods by corridor. (The proposed four arterial corridors are discussed subsequently in the Initial Corridor Screening section.) At least one arterial corridor will be monitored for the full 20-week duration to provide a more robust data sample under varying conditions. The remaining high priority corridors will be monitored in sequence. The data collection duration for these corridors is estimated to be three (3) weeks, but the exact duration will be dependent on the incident data obtained.

The methodology for the arterial travel time data collection is highlighted in Appendices A and B. Appendix A provides a sample of data collected on 35th Avenue and on Bell Road in the City of Phoenix. Appendix B provides a complete description of the data collection unit installation.

Non-Recurring Congestion Data Sources

The factors impacting NRC must be collected and correlated with the travel time / speed data. The following NRC factors and data sources will be used in quantifying the causes of NRC. Each data source is described in more detail below.

Traffic (Volume, Speed and Travel Time)

With respect to freeways, ADOT's Freeway Management System (FMS) will be utilized to obtain and extract traffic operations data (vehicle volume, speed, and lane occupancy) for the subject location/segment. The FMS gathers data from roadway sensors located about every one-third mile on local freeways. Every twenty seconds, speeds, volumes, and occupancy (i.e., the duration of time that a vehicle is present at the sensor) are gathered by the FMS from each traffic controller, and archived for later retrieval. It is anticipated that historical FMS data will be used starting with 2009 and going to earlier years to fill any data gaps, if needed.

Some of the arterial roadways in the MAG region have been outfitted with enhanced monitoring equipment as well. These SMART corridors, as implemented through the AZTech™ Model Deployment Initiative, may be able to provide arterial traffic operations data similar to the FMS data. Otherwise, arterial traffic operations data will be gathered in the field during the data collection task of the study.

The arterial field data will be in the form of travel times for a significant sample of vehicles. The travel times will be captured by performing anonymous wireless address matching (AWAM) of the MAC addresses of Bluetooth devices (see Appendix C for more details). Field data in the form of traffic volumes will also be collected periodically. A relationship between captured travel time readings and the recorded volume will permit an estimate of the traffic volumes during a NRC event when the actual traffic volumes may not have been recorded. Due to limited time and resources, it's envisioned that data collection will last between two (2) to four (4) weeks per corridor. Field data collection should be completed by mid to late November 2010.

Construction/Work Zones

Freeway construction activity will be gathered by querying private data and historical data from ADOT's Highway Condition Reporting System (HCRS). This data will be used to determine if any lane closures or related construction activity contributes to NRC.

It was indicated at the April 7th SAG meeting that most cities have website postings of work zone/closure activities on arterials. A search of the city's website for construction activity/work zones will be conducted for each identified corridor and any immediate parallel routes. To the extent possible, field data collection efforts can be coordinated with scheduled work zone activities. Once data collection has initiated on a given corridor all work zone activities will be logged and tracked. Private data may be used to track the "unscheduled" or temporary construction/work zones (e.g. broken water main, etc.).

Incidents/Crashes

Considering that the majority of NRC is related to traffic crashes or incidents, it is critical to compile a comprehensive crash database that considers not only crashes but also incidents such as minor breakdowns or any non police-reported events that may affect traffic. There are three possible crash/incident data sources to be used with the historical data. ADOT has two sources of incident data: the HCRS and the Accident Location Identification Surveillance System (ALISS). However, the HCRS source only reports incidents on the state highway system (freeways and arterials), and ALISS compiles and reports all roadway system crashes, albeit at a rate lagging behind present time since it is based on the receipt/input of law enforcement reports. Consequently, they will not include incidents like the examples cited earlier. The third source is private data which integrates most of this information in real-time including incidents off the state highway system. The three sources will be evaluated but it is anticipated that the private data will be utilized with the other two sources used to supplement or clarify any data gaps in the private data.

For the arterial data collection being conducted on the project, the Project Team will subscribe to the publically available private sector data. An email alert for incidents by corridor will be established for the project. The real-time email alerts will be archived by the Project Team and subsequently matched with the travel time data. Incident data for the data collection period will be obtained from the corridor host city whenever possible.

Weather

Weather information will be obtained from the available public website of the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA). NCDC is the world's largest active archive of weather data. NCDC produces climate publications and responds to data requests from all over the world. The data consists of hourly weather observations (e.g., precipitation, temperature, wind, fog) at multiple points within the urban areas. Another possible source to supplement NCDC data is a web based database called Weather Underground. Weather Underground has developed the world's largest network of personal weather stations (almost 10,000 stations in the US and over 3,000 across the rest of the world) that provides its users with the most localized weather conditions available. These data sources have been used successfully in previous research for the United States Department of Transportation (US DOT).

The nearest available weather stations from either source above will be identified for each corridor. The historical data on these corridors will be collected and monitored throughout the data collection process.

Special Events

All known major special event venues (e.g., stadiums, Phoenix International Raceway, Arizona State University, etc.) that could impact the test corridors are displayed in Figure 2 under the Initial Corridor Screening section. The team will coordinate with venue operators to get schedules and monitor planned events during the field data collection phase. Any major planned community event (e.g., parades, festivals, state fairs, etc.) will also be noted as these types of event may also affect traffic patterns.

Traffic Control / Signal Operation Data

According to the National Traffic Signal Report Card 2007, timings are poorly maintained, monitored, and updated across the nation. This NRC study will be among the first of its kind to attempt to quantify the effects of signal malfunctions.

Signal malfunctions and out-of-sync signal timing result in less than optimal operations, causing congestion. As a worst case, the malfunction can result in flashing or all-way stop operation. This would result in stops for every vehicle on the street, creating long queues as capacity was reached. Out-of-sync operation of a signal running free with no coordinated cycle length could result in more stops and delay on the arterial. Out-of-sync operation with a clock that has drifted, resulting in a less than ideal offset, or from loss of communication would also result in more stops and delay on the arterial street.

To collect this type of information, maintenance records from individual cities and ADOT will be reviewed to determine the frequency and duration of these events.

Data Gaps Simulation Approach

The simulation studies will utilize VISSIM to supplement and fill in gaps the historical data and field measurements. Simulation studies will be conducted for both a segment of the regional freeway system and for a sample arterial street system. The simulations will be for a two-hour period (minimum) and each will include a minimum of 10 runs with different seed numbers. The systems will be calibrated to the volume and travel time data collected for the system.

Incidents identified in the field data collection tasks will be classified based on their impact on the roadway system. A comprehensive list of impacts will be developed for the freeway system and for the arterial street system. It is anticipated that this list will include:

Freeway system:
- Shoulder blockage
- Single lane blockage
- Multiple lane blockage

Arterial system:
- Midblock lane blockage
- Midblock multiple lane blockage
- Complete midblock roadway closure in one direction
- Complete midblock roadway closure in both directions
- Signalized Intersection with one lane blocked on each street
- Signalized intersections with multiple lanes blocked on each street
- Signalized intersection on Flash and operating as an all-way stop
- Signalized intersection out of synchronization

The field data will be reviewed to identify types of incidents observed and the durations of those incidents. The goal will be to have durations ranging up to one hour in five minute increments. For those incidents types that are not observed in the field or for which the field data does not provide a complete range of durations, simulation studies will be conducted.

Up to five (5) different scenarios (incident type or combinations of incident types) will be simulated. For each incident type simulated, the incident will be inserted into the system at the beginning of the first hour and then removed from the system after the desired duration. Incidents lasting up to one hour will be simulated. The second hour of simulation will be used to allow the system to return to normal operations after the incident is removed from the system. Travel time and speed data similar to that collected in the field will be collected and compiled from the model results.

Freight and Transit Data

In order to estimate the impact of NRC on freight and transit operations, the Team will gather necessary data to estimate the person hours of delay on the major freight and transit routes. MAG's Regional Freight Assessment Study will be used to identify freight routes. This study may also be used to assess typical truck volumes on major freeway and arterial routes. Valley Metro is the major transit provider within the MAG region. Transit ridership data will be utilized on major routes that fall within the test corridors shown in Figures 2 and 3. Some buses are equipped with Automatic Vehicle Locators (AVL) that might make it possible to capture travel time data on specific routes. Additionally, any logs of en-route bus breakdowns may be used to assess possible impacts relative to NRC.

INITIAL CORRIDOR SCREENING

The project objective is to make recommendations on candidate corridors for a pilot test of mitigation strategies for non-recurring congestion. During the data collection planning, the Project Team did some initial screening of corridors. In order to get the most out of the available data sources for the study, it is important that the corridors analyzed be carefully selected where there is known high traffic variability to capture the full impacts of NRC. The team considered three sources of information in indentifying these arterial corridors.

Through existing partnerships with private traffic data providers, the Project Team reviewed available private traffic data for the MAG region. The data showed inconsistent standard deviations for travel times/speeds, and thus did not reveal any clear trends that could be used to identify corridors. However, the Team was able to utilize the MAG 2007 Travel Time Study in identifying the corridors with high variability (i.e., standard deviations) in their travel time for both freeway and arterials.

MAG provided a recent list of top 100 crash prone (crash risk) intersections and a map with the top 50 intersections. These intersections were identified based on MAG's Network Screening Methodology (NSM-I). This methodology is provided in Appendix D. These intersections crash records were instrumental in identifying the arterial corridors with potentially unreliable travel.

Through coordination and consultation with various municipalities and local knowledge of the region, the Project Team has identified some corridors with known/perceived variability due to high frequency of NRC. Based on the information gained from these sources, four arterial corridors were identified and are shown in Figure 2.

In addition, an initial assessment of available data on the travel reliability of freeway corridors in the MAG region was conducted by the Project Team. An initial list of corridors was identified from previous work done on urban mobility in the Phoenix area. The following five corridors were determined to have the greatest unreliability in travel:

1. Loop 202 WB: 46th St to 22nd St
2. US 60 EB: I-10 to Loop 101
3. I-17 SB: Stack @ I-10 to I-17/I-10 Split
4. I-10 WB: Ray Road to Southern Ave
5. I-10 WB: Mini Stack @ L202/SR 51 to Stack @ I-17

These corridors are displayed in Figure 3.

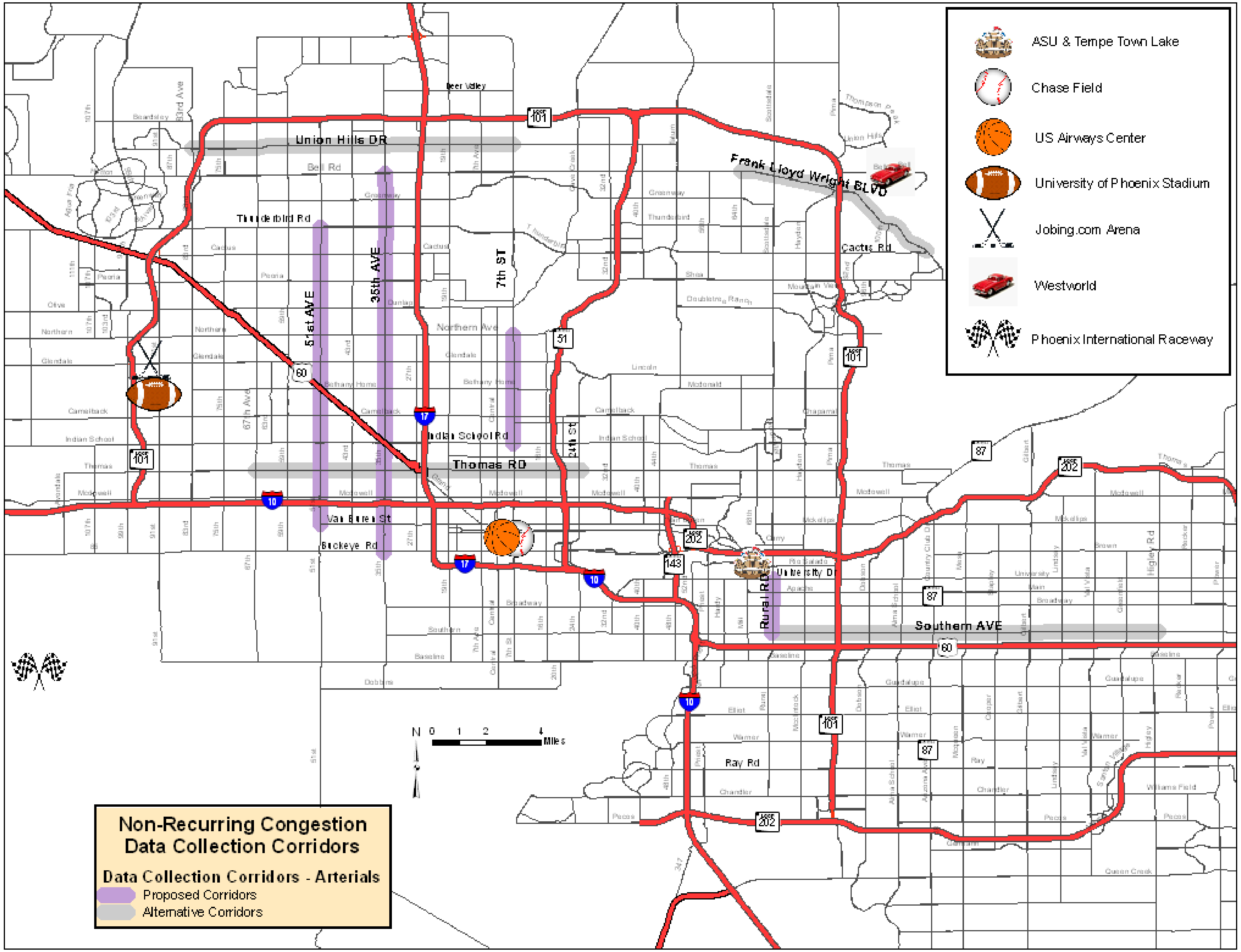

Figure 2. Candidate Arterial Corridors

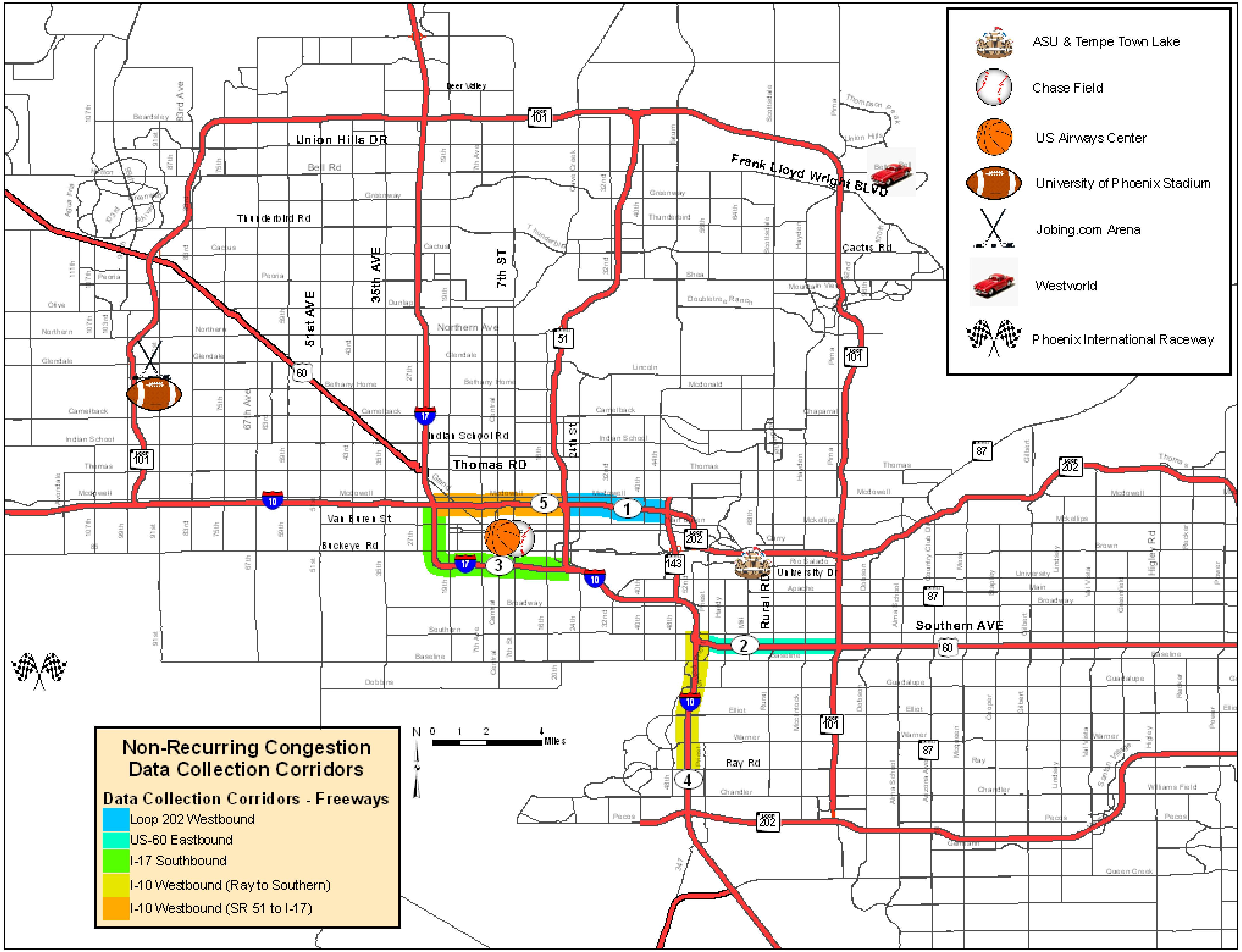

Figure 3. Candidate Freeway Corridors

APPENDIX A:

Pilot Test of Data Collection

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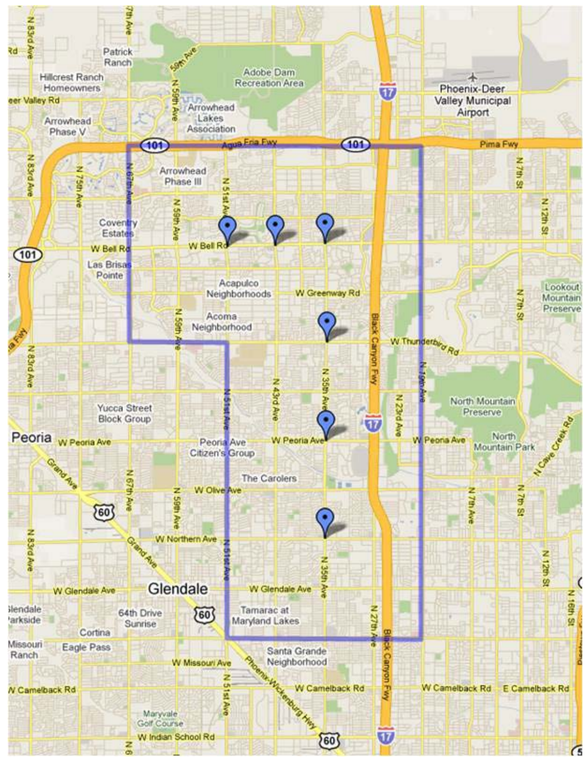
LEE ENGINEERING
Texas Transportation Institute

Darryl Puckett of Texas Transportation Institute met with representatives of the City of Phoenix and Lee Engineering on Thursday, May 20, 2010 at 9am local time at the intersection of 35th Avenue and Northern Avenue. After a brief explanation of the installation procedure, the reader equipment was installed inside the signal cabinet and the antenna protector affixed with silicone adhesive. Connector cables were deployed through the hinge side of the cabinet door without penetrations in the cabinet itself. Cellular service was somewhat minimal at this location so the cellular modem was deployed externally in the protector as well. This condition was repeated at 51st Avenue and Bell Road where a similar installation was performed.

Subsequent installations were accomplished at all of the planned locations shown on the concept drawing below and names as follows:

1. 35th Avenue and Northern Avenue
2. 35th Avenue and Peoria Avenue
3. 35th Avenue and Thunderbird Road
4. 35th Avenue and Bell Road
5. Bell Road and 43rd Avenue
6. Bell Road and 51st Avenue



All of the installations (except for 51st Avenue and Bell Road) were completed by 2pm local time on Thursday.

While data was successfully transmitted back to the server in Houston on Thursday, it was determined that due to the relatively low traffic volumes, matches could be improved with the substitution of higher gain antennas on the Bluetooth adapters. Arrangements were made with the City of Phoenix staff to meet on Friday morning to assist with the antenna substitutions and complete the installation at 51st at Bell. The substitution consisted of removal of the exterior protector, exchange of the antenna and reattachment of the protector. This was all accomplished between 7:30 and 11am local time, and the signal technician returned to the shop. While the field work only consumed about 1 hour total on Friday, the technician was held on site in order to confirm operation, just in case a visit to one of the cabinet sites might be required. That was not the case and subsequent visits were not required.

Final interface configurations were accomplished and the data site is now available for access. It can be gained at http://ttihouston.tamu.edu/bluetooth/bluetooth_monitor_matches.aspx?i=phoenix.

A sample of the results from Monday, May 24th is shown below.

Bluetooth Travel Time Monitor - Matches

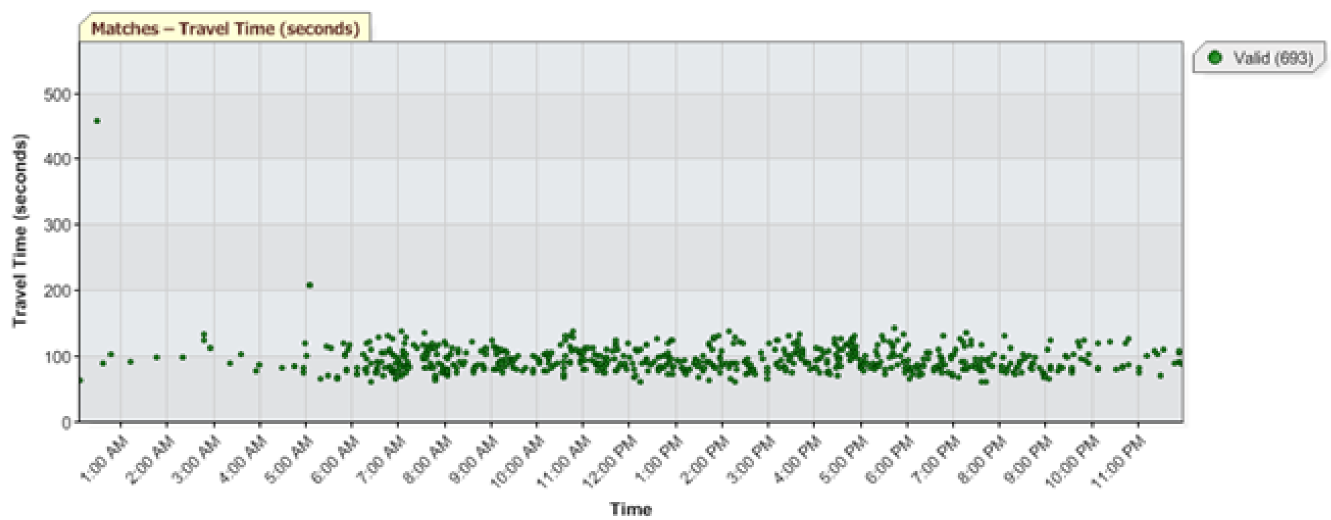
Roadway: W Bell Rd
Direction: Eastbound
Roadway Segment: All Segments

Date: 5/24/2010
Data Type: ○ Daily 15 Minute Averages ◉ Individual Matches
Y-Axis: ○ Speed ◉ Travel Time
Show Invalid Matches: ○ Yes ◉ No

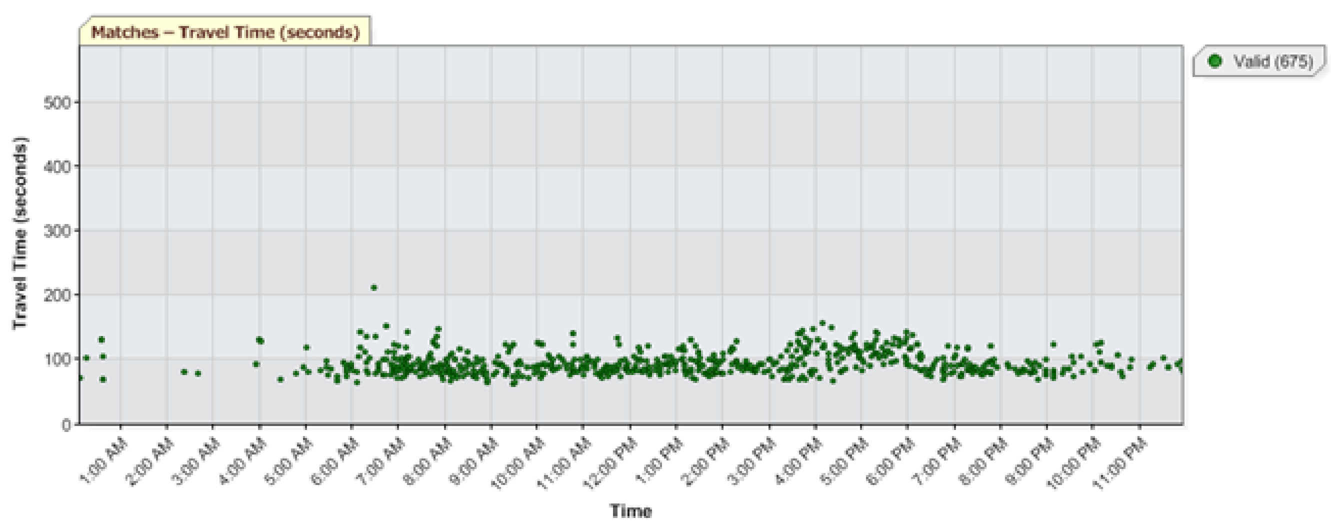
Get Chart

W Bell Rd Eastbound

From 51st Ave to 43rd Ave (1 miles) - Individual MAC Address Matches - 5/24/2010



From 43rd Ave to 35th Ave (1 miles) - Individual MAC Address Matches - 5/24/2010



Photos of the actual installations are shown in the following figures:

35th Avenue & Northern Avenue

35th Avenue & Peoria Avenue

35th Avenue & Thunderbird Road

35th Avenue & Bell Road

Bell Road & 43rd Avenue

Bell Road & 51st Avenue

APPENDIX B:

Travel Time Monitoring System

Travel Time Monitoring System

The travel time monitoring system is placed inside traffic signal cabinets with a power connection available. Although a rare occurrence, the travel time monitoring system can be disrupted if the GFCI outlet trips the circuit and cuts off electricity. An external antenna is required for most installations. The external antenna will be accommodated within an 'antenna protector' as shown on the next page. The image to the right shows the travel time monitoring system installed in a City of Phoenix traffic signal cabinet.

The permanent equipment installation (i.e. long-term installations) requires an external antenna. These installations have a cabinet penetration that is waterproofed with silicone sealer and a standard PVC conduit connector. In the cases where the antenna is removed later, the penetration opening is closed with an oil-tight gasketed conduit hole seal, such as a WAS100 by Hubbell Wiegmann. There are side penetration options also, but they still require that the antenna extend up and past the roof of the cabinet.

The temporary installations require no cabinet penetration as the antenna cable is routed around the cabinet door frame or other penetration (like a vent opening or other). The base is attached with silicone sealer and can be removed without damage to the cabinet as shown to the left.

Our field software is designed to 'push' the collected data to the Host IP address in the form of UDP datagrams. The device comes equipped with an Ethernet port and contains a full TCP/IP stack. To minimize issues with firewalls or other integrations in the short term for temporary deployments, cellular communications with a modem are provided and used. In practice, the deployment will work with virtually any form of standard TCP/IP protocols and take advantage of cellular, fiber, WiFi, WiMax, or whatever may be available.

While data rates can vary greatly based on the volume of Bluetooth devices being read, we estimate approximately five (5) megabytes per day on a heavily traveled roadway, somewhat less on roadways with low to moderate traffic volumes.

The host processing in Houston, Texas gathers all the incoming data from the field collection units and processes it for subsequent distribution to specific applications that may reside outside of the hosting environment, typically with an XML feed, designed for that purpose.

Overhead power lines, or other causes of cellular service interference can prevent the travel time monitoring system from delivering the collected data. An alternative collection point may have to be selected if this occurs.

APPENDIX C:

Anonymous Wireless Address Matching (AWAM)

Anonymous Wireless Address Matching (AWAM)

AWAM, developed by the Texas Transportation Institute, utilizes the Media Access Control (MAC) address of enabled *Bluetooth™* devices to determine average travel times and speeds on roadways instrumented with the proper equipment. The methods used by AWAM simply search for device addresses and do not poll any other information from the *Bluetooth* device. Each *Bluetooth* device read contains the timestamp, device reader location, and MAC address of the device. A sample record generated by AWAM might look like the following:

01/01/2010 10:00:00 AM,Highway10_FirstStreet,00:1E:7D:E7:6E:6D

In theory, the MAC address is a unique identifier assigned to every Ethernet network interface, including Bluetooth adapters. MAC addresses read by AWAM are not directly associated with a specific user and do not contain any personal data or information that could be used to identify or “track” an individual’s whereabouts. Several issues with AWAM make it even more difficult to trace a MAC address to an individual device.

1. Occasionally, manufacturers do not ensure that MAC addresses are unique, so multiple network interfaces can have the same MAC address. This is not a common occurrence but it does happen.

2. MAC addresses can be assigned by software in many network interfaces meaning that the original MAC address can be changed by the user.

In addition, all addresses collected by AWAM are anonymized through encryption immediately upon receipt. This ensures that actual device addresses are not sent or stored anywhere—rather a random set of characters. For example, a device with the address *00:24:9F:E1:FE:98* might be changed to *MDA6MjM6RDc6REQ6MzI6QkM* at the instant it’s read by the field controller.

Users with additional privacy concerns are able to turn off the *Bluetooth* discovery function of their device which prevents it from being read by AWAM.

APPENDIX D:

MAG Network Screening Methodology for Intersections