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16. Abstract
TxDOT's Transportation Planning and Programming (TPP) Division routinely tests a wide variety of devices for counting axles or vehicles; measuring vehicle speed, headway, and gap; classifying vehicles by length and/or axle spacing; and weighing vehicles in-motion. However, TPP needs a traffic monitoring equipment evaluation facility to enhance its capabilities in conducting these tests, in facilitating training, and in allowing vendor comparisons and demonstrations. This project investigated funding sources, design options, and viable locations for this traffic monitoring equipment evaluation facility. The project provided research and development to design a generic facility to evaluate traffic data collection equipment and sensors and perform traffic data collection research. This report covers the first 9 months of this 2-year project, identifying potential funding sources and candidate sites for further consideration. The most prominent funding sources are construction funds (include the site as part of a TxDOT construction project) and State Planning and Research (SPR) funds. The most promising sites identified thus far are on I-35 north of Georgetown near the Bell County line. Future research will include an evaluation of Kistler Lineas Quartz weigh-in-motion (WIM) sensors, a determination of minimum pavement structural support to ensure adequate sensor service life, and a forensic evaluation pertaining to failure mode of East Texas in-pavement traffic monitoring sensors.

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INITIAL INVESTIGATION FOR TRAFFIC MONITORING EQUIPMENT EVALUATION FACILITY

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CHAPTER 1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the first phase of this project was to identify candidate sites and funding sources and design a facility. The facility will provide a much needed test bed to research the performance of various types of traffic monitoring systems and sensors including off-the-shelf production systems and prototype units, conduct training, and perform traffic data collection research.

1.2 BACKGROUND

Statewide data collection programs are the foundation for many uses of data within state Departments of Transportation (DOTs) and their external customers. Within a state DOT, these statewide data are used to report vehicle-miles traveled (VMT) and truck activity to the Federal Highway Administration (FHWA) for appropriations; design roadways for adequate geometric and pavement needs; and provide needed traffic information in those urban areas failing to meet National Ambient Air Quality Standards for their transportation/air quality modeling processes. It is important that a state DOT deploys traffic monitoring equipment that consistently returns accurate results and is also able to correlate the unique data differences during the time of collection between devices of different manufacturers.

From the perspective of the Texas Department of Transportation (TxDOT), the purchase of equipment to effectively collect the needed data occurs in a complex environment. Not only is there a large number of traffic monitoring systems and vendors to choose from, but also each piece of hardware from one vendor could be matched to traffic sensors from a completely different vendor. The resulting combination of these systems, whether due to incompatibility or other reasons, sometimes does not produce the desired result. This research, when implemented, will provide TxDOT with a tool to validate the operation of traffic data collection systems prior to committing large sums of money to the purchase of the equipment. The ultimate significance of this work is to save money for TxDOT by focusing resources on critical traffic data acquisition systems that satisfy the needs of TxDOT's traffic data collection program.

The Transportation Planning and Programming Division (Traffic Section) (TPP(T)) could significantly improve its data collection with the necessary tools to properly evaluate existing and proposed data collection equipment. This project investigated funding sources, design options, and viable locations for a traffic monitoring equipment evaluation facility. The preferred location for this facility is near the Austin area where TPP(T) has ready access to the site. However, if researchers cannot find the appropriate combination of location and funding, TPP(T) could still utilize one of the existing test beds created by earlier research activities, one of which is in Austin and the other in College Station. A combination of new sites and existing test beds might also be viable.

1.3 OBJECTIVES

Overall project objectives were to:

- identify potential funding sources for a test facility,
- develop site selection criteria,
- utilize the selection criteria to identify the best site(s),
- develop plans and specifications to indicate pertinent site components,
- evaluate Lineas Quartz weigh-in-motion (WIM) sensors,
- establish pavement structural support criteria, and
- evaluate piezoelectric sensor failure modes.

1.4 ORGANIZATION OF THE REPORT

This research report consists of five chapters organized by topic. Chapter 2 provides an overview of test sites installed in other states. Chapter 3 presents findings related to funding sources. Chapter 4 provides a discussion of site selection criteria and the weights of each criterion. Chapter 5 is a discussion of the most promising candidate sites and the one recommended for TPP(T) use.

CHAPTER 2.0 EXISTING TEST FACILITIES

2.1 INTRODUCTION

The text that follows reflects the information gathered by the research team from literature sources and from jurisdictions that have installed devices that TPP uses. The information is organized by literature findings first, followed by input from states. Most of the individual findings pertain to one of a limited number of aspects of a TPP-like test site. For example, there are recent references pertaining to installation and maintenance of weigh-in-motion systems and other recent references that discuss installation of non-intrusive sensor test sites. Not all the agencies contacted or the literature findings produced useful results.

2.2 LITERATURE SEARCH

Of the equipment that TPP will evaluate at the test site, WIM equipment is the most challenging due to the various requirements to achieve optimum performance. For that reason, the literature search resulted in information mostly on the installation of WIM.

2.2.1 General Criteria for WIM Installation

A quote cited by McCall and Vodrazka *(1)* underscores the importance of site selection for WIM: "The quality of the WIM data is dependent on the quality of the site selected" *(1)*. Designers should select the site for a WIM system based upon meeting the required "site design life" and accuracy necessary to support user needs. The roadway pavement condition is important in minimizing vehicle bounce near the WIM sensors. According to Deakin, "Vehicle bounce, resulting in variations in the vertical load imposed by a moving axle, increases with road roughness, leading to greater variations in the instantaneous axle loads *(2)*. The American Society for Testing and Materials (ASTM) standard *(3)* specifies the use of a 20-ft straightedge to establish pavement smoothness before and after the WIM system.

A candidate site for WIM data collection should possess several characteristics in order to collect good data. These characteristics pertain to grade, curvature, cross-slope, width, speed, and visibility. The pavement grade at the WIM site should be level, to the extent possible, and more specifically, the longitudinal gradient of the road surface 200 ft in advance and 100 ft beyond the WIM sensors should not exceed 2 percent for permanent or site-specific WIM installations. No rutting should be evident in the roadway surface. The horizontal curvature of the roadway lane 200 ft in advance of and 100 ft beyond the WIM sensors shall have a radius not less than 5700 ft measured from the centerline of the lane for the WIM system. The cross-slope of the road surface shall not exceed 3 percent. The width of the paved roadway lane for 200 ft in advance of and 100 ft beyond the WIM sensors shall be between 12 and 14 ft. The roadway lane should be designated with a uniform speed limit. No exits or onramps should be near the WIM site. The requirement for constant vehicle speed is primarily due to the fact that braking and acceleration causes shifts in load from one set of axles to another. This speed requirement has limited the use of WIM equipment in many urban and suburban areas where routine congestion occurs. Finally, operators of the WIM system should have an unobstructed view across the entire roadway *(4)*.

Other needs of WIM sites pertain to the infrastructure. The needs can be categorized as surface smoothness, pavement structure, power source, data communication, and system calibration. The surface of the paved roadway 200 ft in advance of and 100 ft beyond the WIM sensors shall be smooth before sensor installation and maintained in a condition so that a 6-inch diameter circular plate 0.0125-inch thick cannot be passed beneath a 20-ft long straightedge. Smooth, flat pavements that reduce vehicle dynamics significantly improve WIM accuracy *(3)*.

Decreases in pavement strength invariably decrease system accuracy. To accommodate WIM sensors, the responsible agency must provide and maintain adequate pavement structure and surface smoothness throughout the service life of the system. These agencies should also install and maintain the sensors in accordance with the recommendations of the system vendor. A Portland cement concrete (PCC) pavement structure generally retains its surface smoothness over a longer period of time than a flexible pavement structure under heavy traffic conditions at a WIM site. Installations in pavements likely to rut are a poor investment of limited state data collection funds. Permanent WIM sites on highways and principal arterial highways should have a 300-ft long continuously reinforced concrete pavement or a jointed concrete pavement with transverse joints spaced 20 ft or less. Installers should grind the surface of the roadway smooth after curing and before installing the WIM sensors. The installing agency should also ensure that the skid resistance of the roadway surface after grinding is as good as the adjacent surfaces *(4)*.

An adequate power source must be provided and maintained. The power required would be 230V 150 amp service for the project if a building is involved. If there is no building, the minimum service required is typically 15 to 20 amps per cabinet, depending on the expected power consumption of the equipment. There must also be an adequate data communication link between the WIM site and the remote host computer where data can be transmitted and processed. The availability of power and communications allows for extended operation of the WIM system.

A significant calibration effort is required each time WIM equipment is placed on a site. If the scale is not calibrated, the static weight estimates provided by the scale can be very inaccurate, even if the scale accurately reports the vertical forces applied to its surface. Because pavement conditions change over time, and because those changes affect WIM performance, the responsible agency must periodically calibrate even permanently installed WIM sensors. It should check the WIM system calibration annually, and more often if possible *(4)*.

2.3 STATE CONTACTS

2.3.1 California Department of Transportation (Caltrans)

Caltrans has three test sites that offer opportunities for testing detectors, but they are primarily for testing non-intrusive detectors. They are: 1) the University of California at Irvine (UCI) facility on I-405 northbound, 2) a site on a two-lane freeway connector at Highway 5 northbound to Highway 80 north of Sacramento, and 3) a test facility in District 7 (Los Angeles).

One conclusion that the Caltrans representative admitted was that finding a suitable site for this type of testing is very difficult.

2.3.1.1 Caltrans WIM Installation Procedures

Quinley documented methods and procedures that have been developed by the California Department of Transportation (Caltrans) for the planning, design, and installation of weigh-in-motion systems *(5)*. Caltrans began installing permanent WIM systems for its high-speed data collection master plan in 1987. As of February 1996, Caltrans had installed 63 WIM bending plate systems for high-speed data collection and eight WIM bending plate systems for high-speed weigh station bypass screening. Some of the points Quinley covered are pertinent to identifying and installing a test center for TxDOT. Most of the Caltrans systems are main line, high-speed, single-threshold bending plate systems, and the emphasis of Quinley's paper was on these same systems. Even so, much of his discussion applies to piezoelectric or other systems.

Caltrans attempts to minimize conflict with traffic, so there is always an attempt to re-open lanes as quickly as possible. The Caltrans system designs and installation techniques reflect this requirement.

Power and communication are two very important first considerations. Caltrans has not installed any solar powered WIM systems; all sites require standard 110V AC power. Three of the Caltrans systems utilize cellular phone service (9600 bps). Caltrans attempts to locate sites that can reasonably be served by AC power and land line telephone utilities *(5)*.

Caltrans guidance on the location of the controller cabinet is as follows. They should:

- not be subject to being hit by errant vehicles,
- be easily and safely accessible and have adjacent vehicular parking,
- be in full view of the roadway in which the WIM sensors are installed,
- not be subject to flooding during heavy rains or be too near irrigation systems, and
- not require long conduit runs for the required sensors.

Bending plate systems must have adequate drainage of water from under the plates. Ideally, the lanes to be instrumented should all slope to the outside in a roadbed on an embankment to easily remove outflow. Crown section roadbeds need drains on both sides of the roadway. Installers should not consider bending plate systems in roadways in flat or cut sections unless they can tie the WIM drain pipes into existing drainage facilities or the soil conditions make a “sump” or a “French drain” feasible.

Traffic conditions are another critical consideration. The best WIM performance occurs when all traffic is traveling at a constant speed and vehicles are staying near the middle of each lane. Tangent sections of roadway with little or no grade in rural areas normally best meet this condition unless there are only two lanes and passing is significant. Conditions to avoid include: stop-and-go traffic, slow-moving traffic, lane changing, and passing. Vehicles stopping over the sensors result in useless data. The problem with slow-moving traffic is that WIM systems cannot compensate for accelerations or decelerations, compromising accuracy. Lane changing can result in partially or totally missing one or more sensors. Passing on two-lane roadways can result in crossing the loops in reverse order. Neither of the bending plate WIM systems marketed by International Road Dynamics (IRD) correctly classifies these vehicles. For roadways with two or more lanes in each direction, passing is only a problem if passing vehicles are changing lanes over the WIM system *(5)*.

Roadway geometry is also critical for optimized WIM performance. Installers should only consider tangent (straight) sections of roadway. Lane width is a consideration in that weigh pads in a side-by-side configuration must be able to fit the available pavement width. Being too close to interchanges and intersections may increase lane changing and speed change and may be a factor in controlling traffic during setup or maintenance operations.

Grade is an important determinant in the accuracy of WIM. Anything in excess of 1 percent grade results in weight transfer from the steer axle to the drive axle of loaded trucks. Weight transfer can easily exceed 1500 lb, with resultant errors in the WIM's reporting of axle and axle group weights. The higher recording of weight for the drive axle will often result in a weight violation for the drive axle group. Other problems that may occur as a result of grades involve initial calibration and calibration monitoring. The grade may decrease the number of faster moving trucks and adequate calibration requires the entire range of speeds. For Caltrans, which uses a software program to track truck weights by speed distribution, a larger speed range makes the weight/speed analysis much more difficult. Finally, grades that result in slow-moving trucks will result in increased passing within the WIM system by faster vehicles *(5)*.

The pavement profile and condition are critically important for WIM accuracy. The goal of the installation process is to minimize the dynamic effects induced by pavement roughness and profile, and approach what would be measured statically. Caltrans avoids areas where major roadway reconstruction would be required to achieve the desired WIM performance. However, Caltrans considers pavement resufacing and/or grinding appropriate items of a WIM installation contract. Caltrans recommends that a potential WIM site have a minimum 1000 ft of approach roadway with even profile. Pavement should be stable, considering that roadways settle around bridge and drainage structures.

If the roadway profile and overall pavement condition are acceptable, designers should next evaluate the pavement in the immediate vicinity of the WIM system. Caltrans criteria require that the pavement be absolutely smooth for 150 ft in advance and 75 ft beyond the bending plates. The pavement type is important to Caltrans as well; it only uses concrete. Caltrans considers roadway improvements in terms of a "strategic importance" scale. For sites with high truck volumes on the upper end of this scale, the pavement should be improved to the highest quality that is affordable in terms of cost. Lower volume sites would justify less pavement improvement.

Pavement preparation criteria used by Caltrans are as follows *(5)*:

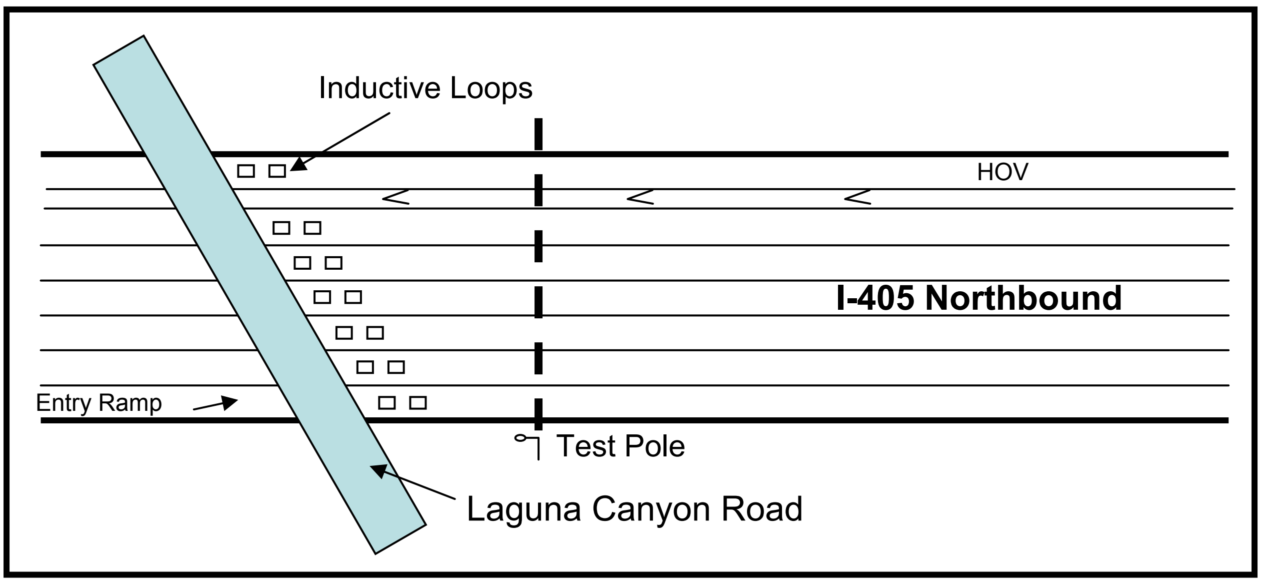
- For existing PCC pavement:
  - If in excellent condition (stable and smooth), grind 150 ft in advance of and 75 ft beyond the bending plates.
  - If in less than excellent condition, replace existing pavement with seven sack concrete as follows:
    - Remove existing PCC pavement and first level base, but no less than 12 inches in depth. Replace a minimum 50 ft preceding and 25 ft beyond the bending plates; longer replacement based upon the condition of the existing pavement and importance of the truck weight data. Caltrans' longest replacement to date was 200 ft.
    - Grind existing and new PCC pavement, starting 100 ft upstream of the new pavement and end 50 ft beyond the new pavement.
- For existing asphalt cement concrete (ACC) pavement, replace existing pavement with seven sack concrete as described above for PCC pavement replacement. Grind existing ACC pavement and new PCC pavement beginning 25 ft upstream of new pavement and ending 25 ft downstream of new pavement.

The Caltrans document recommends that, when reviewing a potential WIM site, that the reviewer observe the traffic flow at various times of the day, watching for undesirable traffic conditions. The observer should carefully watch trucks passing through the site to determine if they are traveling at a fairly constant speed and that they are not bouncing due to pavement roughness or profile. The document also recommends contacting traffic engineers and maintenance personnel who are familiar with the traffic characteristics at the site for their knowledge and observations. It is also very important to confirm that there are no plans to widen or reconstruct the roadway soon after the WIM system installation *(5)*.

2.3.1.2 The UCI Test Facility on I-405

Testing of two non-intrusive detectors by the Detector Evaluation and Testing Team (DETT) of the California Department of Transportation *(6)* reveals some "dos" and "don'ts" of detector installation. Even though the TPP site will not primarily test non-intrusive sensors, the findings of this report will be helpful for both intrusive and non-intrusive detector testing and installation.

The Caltrans facility on I-405 near the University of California at Irvine has seven lanes northbound that serve the needs of a test site. Traffic volume at this site is about 3 million vehicles per week. Some testing at this site involved the Wavetronix radar sensor and the Remote Traffic Microwave Sensor (RTMS), as well as the Inductive Signature Technologies (IST) product that has the capability of tracking vehicles using inductive loop signatures. With successful re-identification of vehicles, UCI is determining the feasibility of determining travel times using link travel speeds. The UCI tests used facilities at Sand Canyon and Laguna Canyon for re-identification of vehicles. Figure 1 indicates the layout of the Laguna site, showing that the inductive loops in each lane fit the angle of the bridge. Caltrans installed the loops in this fashion so they are located immediately under a video camera mounted to the bridge and centered over that lane for verification purposes. This factor caused difficulties in testing of the radar products because the sidefire radar needs to be oriented at a 90-degree angle with the direction of passing vehicles. Loops farther from the test pole are increasingly separated from the detection zone of the non-intrusive detectors. This separation, and the fact that vehicles in each lane had different time stamps, created challenges for researchers in comparing test device counts with baseline counts. The complex site layout made it very difficult to collect accurate 30-second data. The unique processing by different detector technologies also caused a difference in the timing of detection of large trucks. These problems were not evident at longer time intervals of five minutes or longer. The lesson learned is keep the test device's detection zone and the baseline system very close to each other and separated by an equal distance across all lanes.



Source: Reference (6).

Figure 1. UCI Test Site in Irvine, California.

Due to the problems with tests of the radar detectors at the initial site, Caltrans moved from the UCI site on I-405 to another site to facilitate better measurement of the typical parameters of volume, speed, and occupancy. The new site was not a full-blown test site and still required much frame-by-frame manual analysis to accomplish the necessary evaluation. Results indicate that the ground truth inductive loops at this site overcount by 1.0 to 1.5 percent. This is due at least in part to lane changers that cross sensors in two adjacent lanes. The Wavetronix undercounted by as little as 1.0 percent to as high as 4 or 5 percent due to occlusion in the center lane and other lanes farther from the detector. At the closest lane to the detector, the Wavetronix detection zone is relatively short (as measured along the vehicle paths) so it missed some vehicles. Overall count accuracy was almost always within 95 percent of true counts and within 98 percent on some lanes. Speeds were also within 95 percent.

One difference between the Wavetronix and the RTMS X3 detectors was the difficulty of setup and calibration. The Wavetronix only required 15 to 20 minutes total to set up, whereas the factory representative took about one hour per lane for the RTMS. One of the complaints of Caltrans personnel regarding both of these systems is there is no verification of accuracy from remote locations during data collection compared to video imaging, which provides an image. [1]

More specifically on the subject of weigh-in-motion, Caltrans has installed some piezoelectric sensors in the past for WIM, but it was not pleased with the results so now it uses either bending plate or load cell WIM systems. Most of the problems have not been associated with the pavement itself but with the subgrade below the pavement. Some of the WIM systems are in PCC pavement as thick as 15 inches, but piezoelectric sensors are only in ACC pavements. The Caltrans spokesperson was not aware of any states with WIM or automatic vehicle classification (AVC) test sites. Caltrans is realizing a significant need for testing new devices because the agency has installed over 400 new units (all or mostly RTMS) statewide with little evaluation of detector accuracy.

Another lesson learned at the UCI site was to minimize the number of lane changers in the vicinity of the detection zones. Detection of lane-changing vehicles may occur in two lanes by some systems and in only one by another system. The ground truth loop system is likely to detect the same vehicle twice if it straddles the loops. A simple solution is to locate the site away from interchange ramps. At the UCI site, detection occurred where the onramp merged into the mainline such that only part of a car might be present over a loop or a truck could occupy loops in two lanes. Yet another consideration is to place cameras to minimize occlusion of vehicles in far lanes by vehicles (especially trucks) in near lanes. This requirement means planning for mounting of cameras well in advance of their actual installation.

2.3.2 Florida Department of Transportation (FDOT)

The Florida Department of Transportation has a WIM test site in ACC pavement on I-10 near the Suwannee River about 65 miles east of Tallahassee.[2] FDOT was unable to provide detailed plans for the site because no formal plans were available. FDOT used a contractor that had successfully installed all the components before at other locations, reducing the need for such plans. FDOT used a task ordering agreement and simply listed the number of devices by type to be installed. FDOT provided digital photos of the site showing the cabinet and the Kistler sensors that were installed. The photos (see Figures 2 and 3) show two complete sets of Kistler quartz sensors in the right lane. The photos provided by FDOT do not show the Measurement Specialties, Incorporated (MSI) “BL” sensors, which are located about 100 ft from the Kistlers. Each Kistler system has the sensors staggered, with the first (as encountered by passing vehicles) in the right wheel path and the second in the left wheel path, with a square inductive loop (6 ft by

[1] Phone Conversation with Mr. Bill Wald, California Department of Transportation, date: October 21, 2003.
[2] Phone Conversation with Mr. Richard Reel, Florida Department of Transportation, date: October 17, 2003.

Source: Florida Department of Transportation.

Figure 2. Kistler Sensor Layout Before Installation.

Source: Florida Department of Transportation.

Figure 3. Kistler Sensor Saw Cuts During Installation.

6 ft) located between the two sensor sets. There appears to be about 2 ft of separation between the sensors and the inductive loop. The site also has power and phone connections.

The original intent was to test these two types of sensors along with the Peek ADR and PAT DAW 100 WIM electronics. The two sets of sensors (including the necessary inductive loops for presence detection) are about 100 ft apart. FDOT chose this site due to a weight enforcement site about 5 miles upstream (to the west of the site). Trucks exit the truck enforcement site and then encounter the WIM sensors. FDOT used static weight data from over 100 Class 9 trucks to calibrate the systems installed at the test site.[3]

At the time of this phone call, FDOT had only monitored the Kistler sensors for about four or five months, but at that time the Kistlers appeared to have accuracy comparable to bending plate systems. The initial cost was also comparable, but FDOT hopes the long-term maintenance of the Kistler system will be less. Florida DOT has significant problems with pavement rutting in ACC pavements, so it expects that the Kistler sensors will require maintenance to address the rutting issue. The real question in everyone's mind seems to be how long the sensors last, especially in asphalt. The FDOT spokesman indicated that bending plate systems need to go in concrete (either an existing concrete pavement or a concrete pad built specifically for the WIM), but he already has WIM systems in all the available concrete. From all indications, FDOT pavements personnel will probably not build any more concrete pavement, and there seems to be reluctance to even build concrete pads for WIM systems. The I-10 test site will not have a bending plate WIM since the pavement is asphalt. [3]

FDOT does not plan to use any more standard piezo sensors for WIM because the results indicate more than the desired amount of scatter. The FDOT spokesman gave the following recommendations:

- If a DOT uses piezoelectric sensors, they should be quartz.
- If a DOT is planning on installing WIM in a good pavement, choose bending plate.
- If a DOT cannot allocate sufficient resources to maintain the system, do not even install the WIM in the first place.

2.3.3 Illinois Department of Transportation (IDOT)

The Illinois Department of Transportation has a "test site" on I-55 but the site has only been used once – for an IRD system a few years ago. There are no as-built drawings or plans of the site. IDOT has a total of 14 Long-Term Pavement Performance (LTPP) WIM sites that use nothing but piezoelectric sensors. IDOT plans to install one bending plate WIM system in 2004 to complete its LTPP installations.[4]

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[3] Ibid.
[4] Phone Conversation with Mr. Rob Robinson, Illinois Department of Transportation, date: December 10, 2003.

An interesting feature of the IDOT data collection plan is its use of a length-based classification scheme for short-term 24- and 48-hour counts. IDOT does more actual vehicle counts (as opposed to estimates) than other states do, and that is probably why the FHWA allowed Illinois to use lengths of vehicles rather than the standard FHWA Scheme F for its short-term counts. In the 1990s, the Illinois count results were erratic because of the small samples, so the state increased the number of classification counts being done every year. Today, Illinois conducts about 5000 actual counts each year on its 13,000-mile road network, which is probably a higher percentage of its total network than other states. Illinois chose Nu-metric Hi-Star devices with five length bins (four without motorcycles) for classification. IDOT uses the Hi-Star devices instead of road tubes everywhere except the Chicago area.[5]

2.3.4 Minnesota Department of Transportation (MnDOT)

2.3.4.1 Non-Intrusive Detector Test Site on I-394

The Minnesota Department of Transportation installed an equipment test facility for testing non-intrusive detectors on I-394 at Penn Avenue near downtown Minneapolis. Phase I of the MnDOT Non-Intrusive Tests (NIT) was a two-year field test of non-intrusive traffic detection technologies that was completed in May 1997; Phase II concluded in August of 2002 *(7, 8, 9)*. Figure 4 shows the site used in both research phases and the surrounding road network; Figure 5 shows a zoomed-in plan view of the site.

MnDOT installed a catwalk on the Penn Avenue Bridge for Phase II of this project to provide access to devices installed overhead. The test plan called for installing overhead sensors on three adjustable mounting poles attached to the catwalk, one over each lane of I-394 traffic, at varying heights ranging from 20 to 30 ft above the pavement and facing eastbound (departing traffic). MnDOT also installed an aluminum adjustable tower for testing sidefire-installed sensors. Field personnel can adjust the crank-up tower to accommodate mounting heights ranging from 10 to 45 ft and can move the tower among three bases with offsets of 15 ft, 25 ft, and 35 ft from the curb edge of I-394. Preinstalled concrete pads allowed the retractable tower to be moved as required. The retractable pivots at the tower base provided access to the tower top for sensor installation. Inductive loops on I-394 provided baseline data. Figure 6 illustrates the catwalk on the bridge, and Figure 7 shows the aluminum tower mounted on one of the three bases *(9)*.

Site amenities also included a 14-ft by 26-ft permanent building (as shown in Figure 8) and security fencing. Equipment installed in the building includes computers for running vendor-specific programs, computers for data storage and archive, and equipment components needed to interface with detectors.

The NIT site offered a range of traffic conditions, to include congestion in both the morning and afternoon peak periods and lower volumes with free-flow conditions in the evenings and on weekends. The site also offered a variety of lighting conditions, depending on the time of year. Low-angle sunlight created long shadows in the winter and bridge shadows year-round *(9)*.

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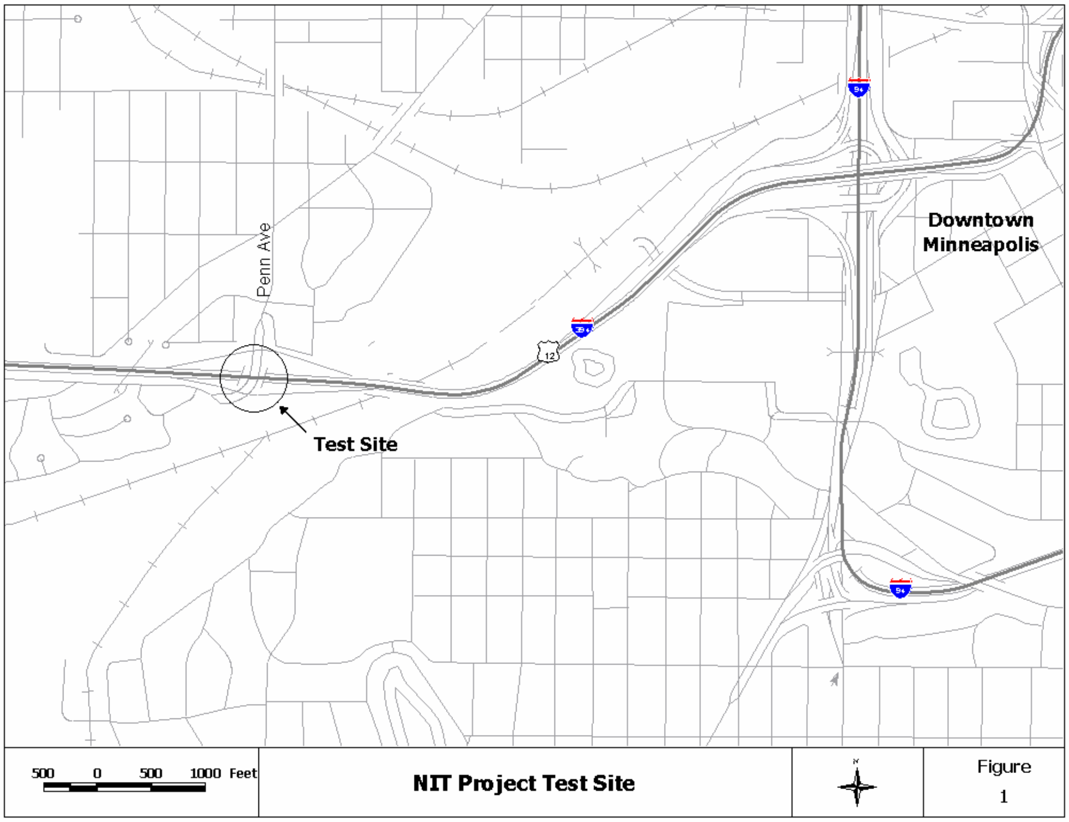
[5] Ibid.



Source: Reference (9):

Figure 4. MnDOT Test Site Location.

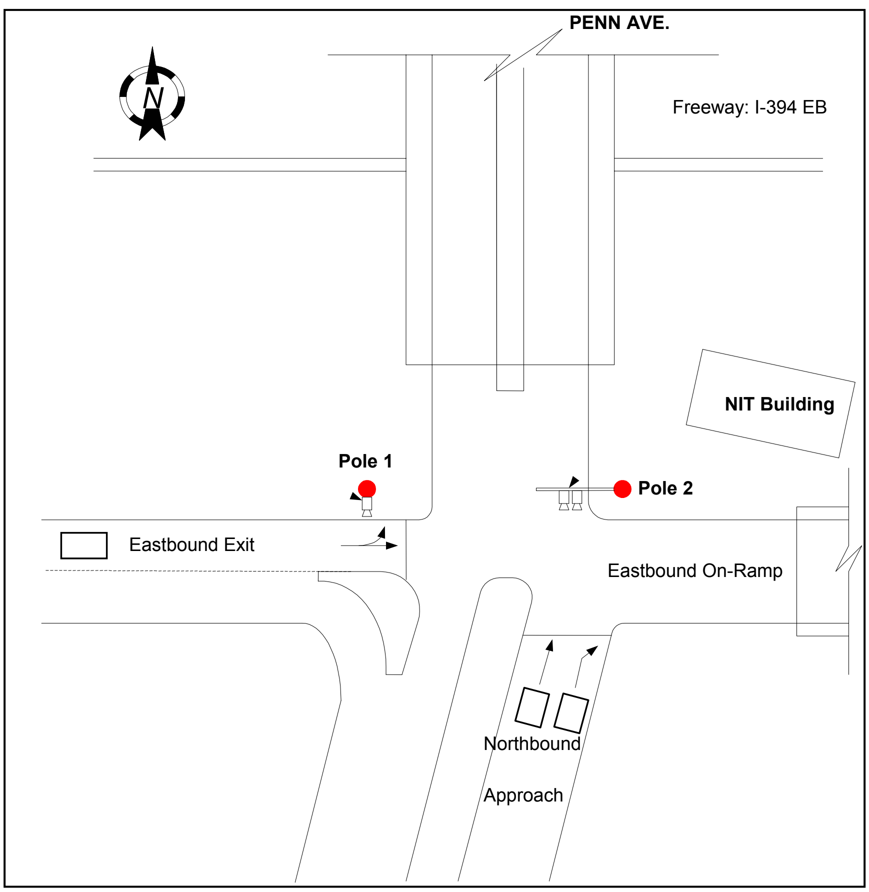
MnDOT's consultant, SRF Consulting Group, Inc., used the following data acquisition hardware inside the building for monitoring the test systems:

- Personal computers: used for sensor calibration, data download, data storage, and process through the interface software of different detectors.
- Television monitors: used for traffic monitoring and video detector calibration.
- Three VCRs: used for recording the traffic images during the official data collection for future data references.
- Equipment rack: used to hold data acquisition components such as TV, VCRs, AC power supplies, loop detector cards, vendor detector cards/processors, and the automatic data recorder.
- PEEK ADR 3000: used to collect all of the loop emulation relay outputs into a single database. It allowed for the collection of all data outputs simultaneously. The ADR was

programmed to collect the data from devices and baseline loops in 15-minute intervals for each 24-hour data collection period. Some data output was in the form of a simple relay contact closure, whereas other data required a serial communication link to a personal computer housed at the shelter.

- A terminal panel: used for power supply and communication between the shelter and testing sensors installed on overhead catwalk or sidefire tower. Terminal ends were numbered on the panel that matched with the numbers of the corresponding ends in the junction boxes on the catwalk and sidefire tower.

Figure 9 shows the shelter schematic layout *(9)*.



Source: Reference (9).

Figure 5. MnDOT NIT Site Layout.

Source: Reference (9).

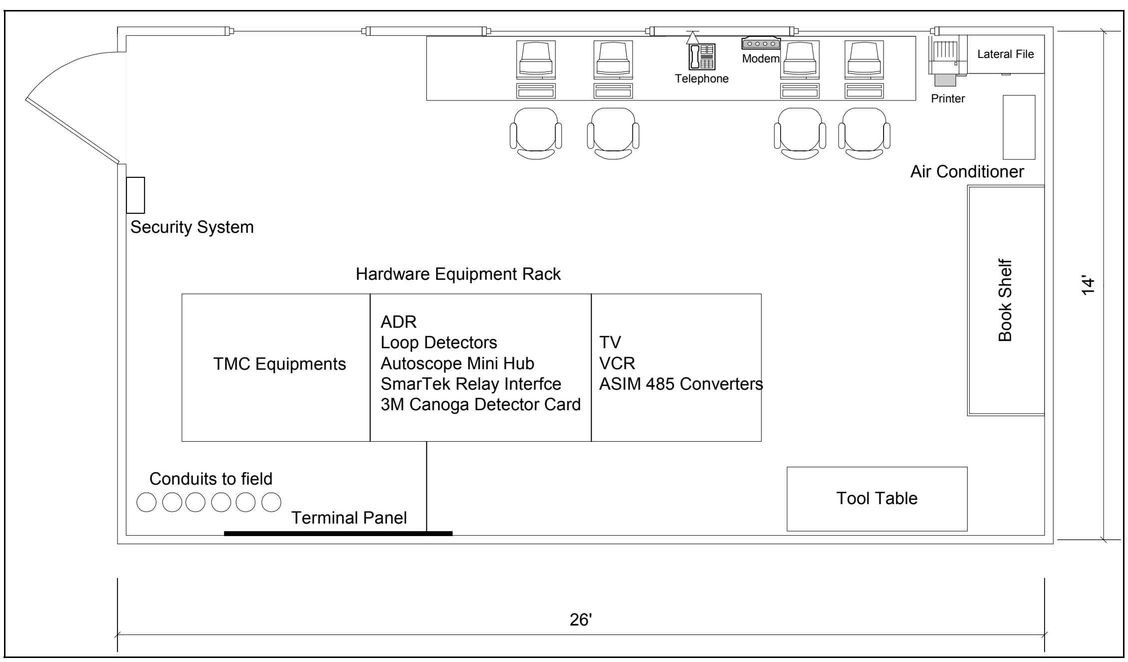
Figure 6. Catwalk for Mounting Detectors Overhead.

Source: Reference (9).

Figure 7. Aluminum Tower for Sidefire Mounting.

Source: Reference (9).

Figure 8. View of NIT Building from the Catwalk.



Source: Reference (9).

Figure 9. Shelter Schematic Layout.

2.3.4.2 Mn/ROAD

Since the summer of 1994, the Minnesota Department of Transportation has operated a large outdoor road research facility called Mn/ROAD. The design and construction of this facility was a joint effort between MnDOT, the University of Minnesota's Civil Engineering Department, the Federal Highway Administration, the U.S. Army Corps of Engineers/Cold Regions Research Engineering Laboratory (CRREL), the Minnesota Local Road Research Board (LRRB), and representatives from the local paving industry *(10)*. Research partnerships at work today or in the recent past at Mn/ROAD include the Finnish National Road Administration, a variety of universities, and private companies such as 3M Corporation. While most of the Mn/ROAD experiments focus on pavements, there is also research in the area of weigh-in-motion that might be helpful to TxDOT in its implementation of a test facility in Texas. Of course, pavements and the sensors that highway personnel place in them are interrelated and need to be studied together.

The actual Mn/ROAD facility, located 40 miles northwest of the twin cities of Minneapolis-St. Paul, consists of two road segments running parallel to I-94 outside Otsego, Minnesota. One is a 3.5-mile mainline roadway carrying live Interstate traffic, and the other is a 2.5-mile low-volume loop where controlled truck weight and traffic volume simulate conditions on some rural roads. These 6 miles of pavement have 4572 sensors embedded within 40 road "cells" of differing pavement composition and depth, generating millions of bytes of data daily. These 40 test cells, each 500 ft in length, consist of concrete, asphalt, or aggregate pavements with varying combinations of surface, base, subbase, drainage, and compaction. There is also an automated weather station to enable roadside computers to capture information on pavement temperature, moisture and frost content, and other ambient environmental conditions. The data from these systems and the weigh-in-motion systems flow via fiber-optic cable to a data management network at the Minnesota Department of Transportation, and they are shared by the University of Minnesota for research purposes *(10)*.

The weigh-in-motion system at Mn/ROAD captures information on trucks traveling westbound on I-94. It consists of four platforms in a sealed frame, four loop detectors, and a microcomputer. Data output on every heavy vehicle includes axle weight, axle spacing, gross weight, vehicle speed, and vehicle length.

Minnesota installed three Kistler Lineas/IRD WIM systems in 2003: 1) one four-lane installation with a turnkey contract, 2) one on a two-lane road using MnDOT personnel, and 3) a single-lane system at the MnROAD research facility, also installed by MnDOT personnel. As noted above, the loading on the Mn/ROAD facility consisted of a test truck of known load, testing for seasonal variations, durability, and repeatability in hot-mix asphalt and Portland cement concrete sections. MnDOT was developing web-based reports for analysts and customers. When MnDOT installs a WIM system, it uses the following checklist of pertinent items:[6]

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[6] Phone Conversation with Ms. Margaret Chalkline, Minnesota Department of Transportation, date: October 21, 2003.

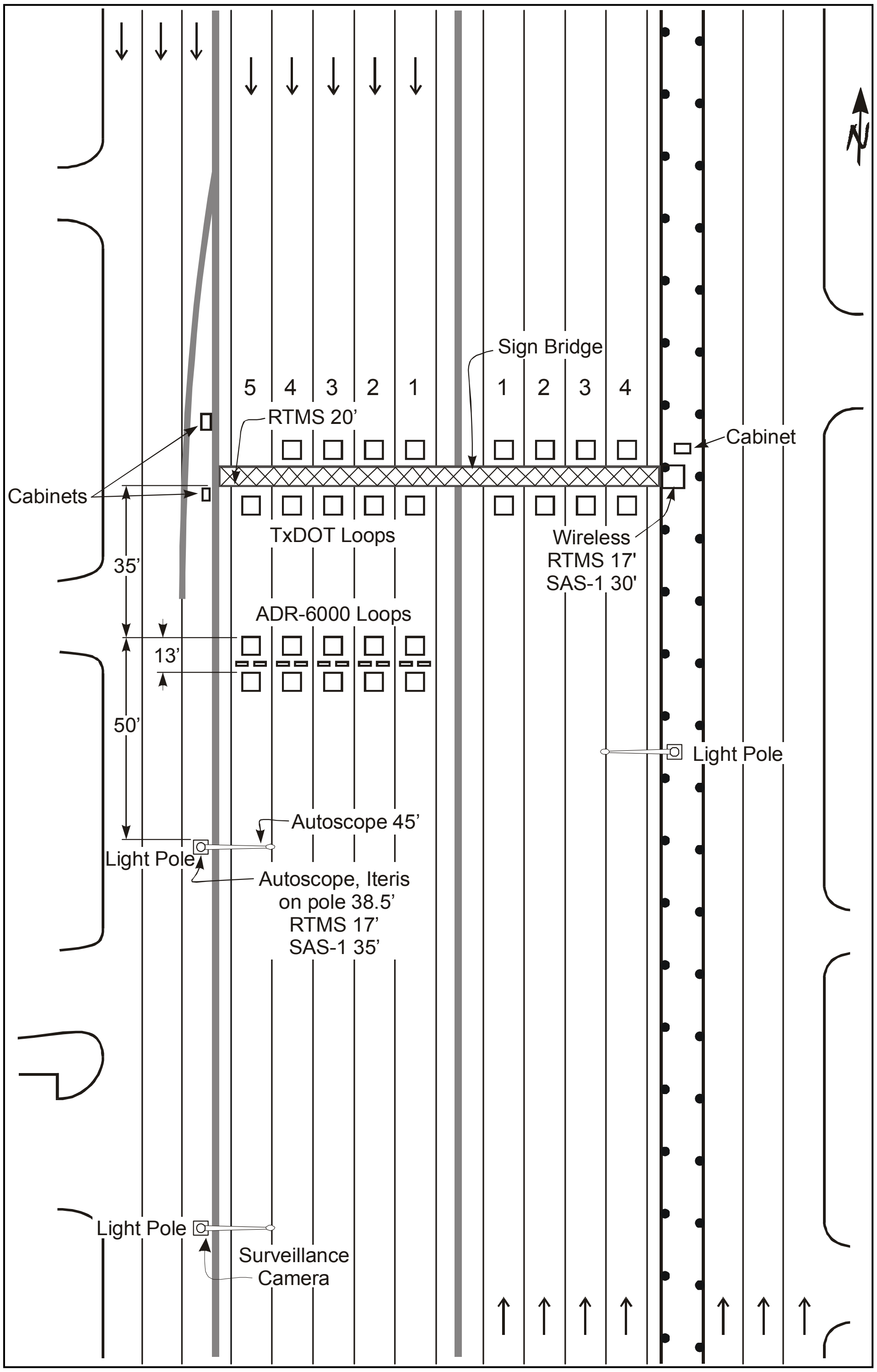
- Hand sketched map
  - Direction
  - All lanes, shoulder, intersecting roads, reference post number
  - Width of lanes, medians, shoulders, lead lengths needed
  - Power, phone
  - Cabinet location (door facing north preferred)
  - Drainage, ditches
  - Parking spot
- Roadway history
  - Age of pavement
  - Planned rehab
  - Type of pavement
  - Smoothness, crown
- Sketch layout
- Location
  - Roadway name
  - Reference post
  - Relative position to nearest intersection
  - Relative position to nearest city
  - Directions from central office
- Calibration truck route

2.3.5 Texas Department of Transportation

2.3.5.1 TxDOT/TTI Test Bed in Austin

Figure 10 is a schematic of the TxDOT/TTI test bed on I-35 in Austin. The freeway has four through-lanes in each direction and a fifth lane on the southbound side, which is an exit lane to Airport Boulevard. This site is near the old Austin airport and near 47th Street, which is just north of the elevated section of I-35. The elevated section is a factor in dispersion of traffic by type and by lane because an unusually high percentage of trucks use the left two lanes to stay on the lower two lanes of the freeway and avoid the elevated section. On most multilane roadways, a higher percentage of trucks are in the right lanes *(11)*.

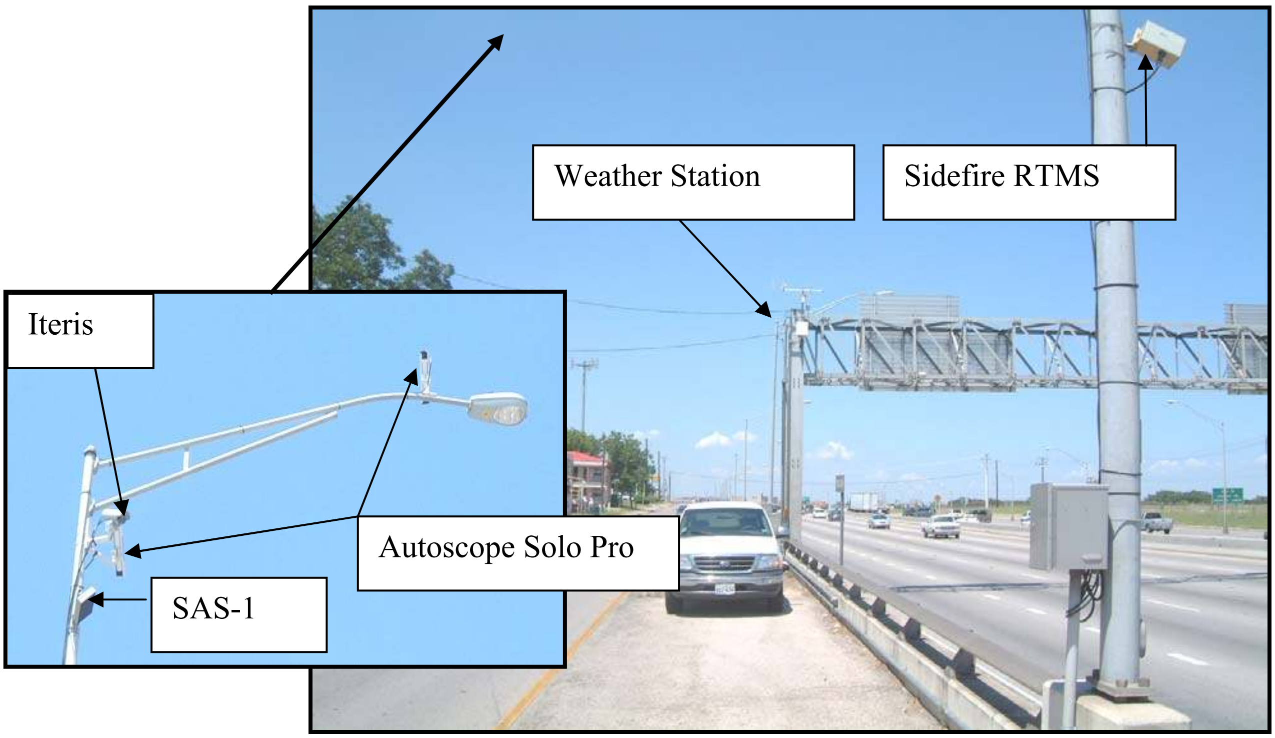
Before installation of the ADR-6000 loops, TxDOT had already installed 6-ft by 6-ft inductive loops under the overhead sign bridge. The through lanes had two loops (traps) installed, whereas the exit lane had only one 6-ft by 6-ft loop. TTI tested the loops prior to installing test equipment and found them all to be in good working order. As shown in Figure 10, the equipment installed on the sign bridge consisted of an RTMS on the west side facing south, an RTMS on the east side facing west (sidefire), and a SAS-1 on the east side facing west (sidefire). Installers also positioned one RTMS unit on the sign bridge to monitor only one lane in Doppler mode. In addition, TTI and TxDOT mounted two Autoscope Solo Pros, the Iteris Vantage, an RTMS, and a SAS-1 on a luminaire pole 85 ft south of the southbound cabinets (west side of the freeway). The TxDOT and TTI field installation crew mounted one Autoscope to the pole at 38.5 ft above the freeway and one to the mast arm supporting the luminaire. The



Source: Reference (11).

Figure 10. Layout of I-35 Site.

reason for placing them at two locations was to evaluate the effect of different offsets. Figure 11 is a photograph of the site looking northward with an enlargement of the pole showing the detectors mounted on it for testing. Both Autoscopes faced oncoming traffic, whereas the Iteris (placed right beside the pole Autoscope) faced departing traffic. The RTMS on this same pole was 17 ft above the freeway and positioned in sidefire. The SAS-1 on this same pole was 35 ft above the freeway. Figure 10 indicates that the detection area for all pole-mounted devices was very close to the baseline ADR-6000 loops to minimize the effect of lane changing and changes in vehicle speeds.



Source: Reference (11).

Figure 11. Photo of I-35 Test Bed.

The field test plan for the northbound side of the freeway involved mounting the RTMS and SAS-1 on the east side of the sign bridge and sending wireless data to the cabinets on the west side of the freeway. Even though most wireless applications can send data over a longer distance, the tests were more a test of latency or other factors than determining the range of the wireless systems. Other items installed for northbound traffic included an equipment cabinet between the mainline and the northbound service road, 110 VAC power from the sign bridge to the cabinet, and conduit across the sign bridge *(11)*.

TTI researchers chose high-speed Internet access to remotely monitor detector systems, upload data, check sensor configurations, and stream live video. This research project revealed many benefits of using Internet communications. One benefit was far fewer trips to the site and the associated travel and labor costs. The result was more productive use of staff time and increased monitoring of detector systems. Another very important benefit was allowing detector manufacturers and vendors remote access to the detector test site. Some of the manufacturers accessed their system remotely from across the U.S. and other parts of the world to check detector setup programs and upgrade algorithms and software. This cooperation with manufacturers helped them and TxDOT get a better product in the end.

2.3.5.2 TxDOT/TTI Test Bed in College Station

The TxDOT/TTI test bed in College Station uses S.H. 6 just south of the F.M. 60 (University Drive) overpass. Figure 12 indicates some of the features of this site and its general layout. Typical weekday traffic (both directions) on S.H. 6 at this location is approximately 35,000 to 40,000 vehicles per day with 10 percent trucks (FHWA Class 5 and above). Traffic conditions are almost always free-flow, but the noise level and the dispersion of vehicles are at desirable levels for many activities such as group demonstrations and studies that need isolated vehicles. This site has ample parking and area for growth, as well as much of the infrastructure for adding new test systems, as indicated in Figures 13 and 14. It is within a 5 minute drive of Texas A&M University for employees and students, and is within 10 minutes of the TxDOT Bryan District offices *(11, 12, 13)*.

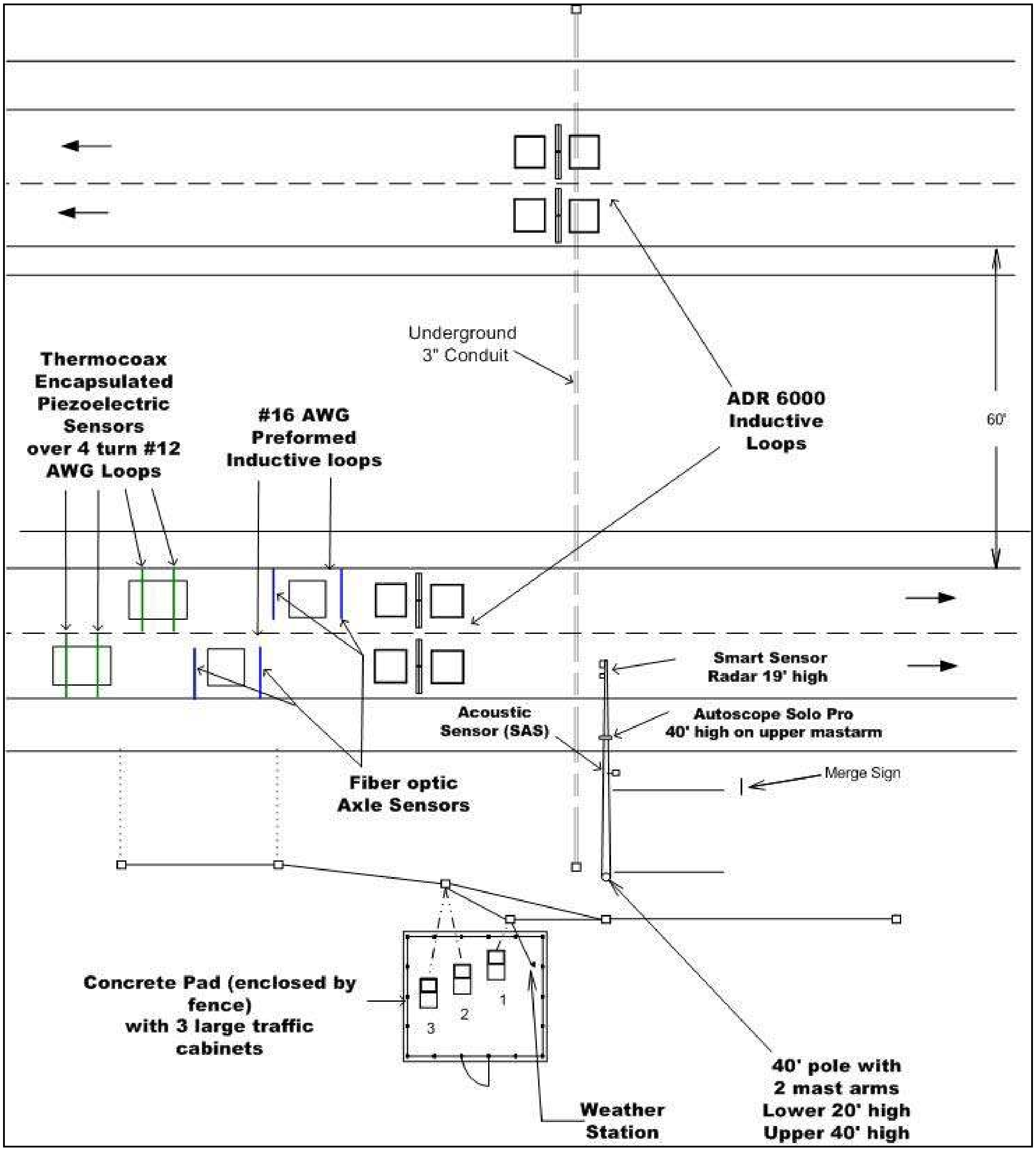
Equipment installed on the west side of S.H. 6 includes:

- three Type P equipment cabinets;
- an enclosed fenced concrete pad;
- a Campbell Scientific weather station;
- a 40-ft pole with two mast arms, one at 20 ft over the road and another at 40 ft over the road;
- pan-tilt-zoom (PTZ) surveillance cameras; and
- roadway sensors that serve as part of the baseline system.

Sensors in or under the roadway include inductive loops, 3M microloops, Class I piezoelectric sensors, and fiber-optic sensors. A Peek ADR-6000 with inductive loops monitoring both the northbound and southbound directions serves as the baseline system. Communications elements include a 768 Kb symmetrical digital subscriber line (DSL) for high-speed communication for data and live video. Non-intrusive detectors installed at the site include a 3M microloop (magnetic) detection system, a SAS-1 (acoustic) detector, two SmartSensor (radar) detectors with one covering a lane in forward mode and the other monitoring four lanes in sidefire, and an Autoscope Solo Pro video imaging vehicle detector. There is a weigh station with static scales about 10 miles to the north on S.H. 6 which is available for WIM verification purposes at the test bed site.

2.3.6 Virginia Tech Smart Road

The Virginia Tech "Smart Road" in southwest Virginia is a unique full-scale research facility that will be used for pavement research and for evaluating Intelligent Transportation Systems (ITS) concepts and products. It is currently a 2.2-mile two-lane road that will be extended to 5.7 miles when the project is completed as a four-lane, limited-access facility connecting I-81 and Blacksburg.



Source: Texas Transportation Institute.

Figure 12. Layout of S.H. 6 College Station Test Bed.

Source: Texas Transportation Institute.

Figure 13. View of S.H. 6 Test Bed Looking South.

Source: Texas Transportation Institute.

Figure 14. View of Equipment Cabinets and Weather Station.

The Smart Road project included the installation of a weigh-in-motion system beginning around 2001. The primary objective for this project was to evaluate the accuracy, durability, and maintainability of a uniquely designed WIM system from a Finnish company, the Omni Weight Corporation (OWC). The test plan devised by Virginia Tech researchers involved a number of test scenarios including different vehicle speeds, acceleration levels, tire inflation pressures, axle loads, and environmental conditions. It also considered the effect of paving materials on the WIM response accuracy. Figure 15 shows the installation of this system on the Smart Road. The project received funding support (to include the cost of the WIM system) from the Virginia Tech Transportation Institute (VTTI), Virginia Department of Transportation (VDOT), and Virginia's Center for Innovative Technology (CIT). At the time of the contact with Virginia Tech, their researchers did not know the current status of OWC. Based on limited information, it would appear that the company no longer has a business address in the U.S.[7]

Source: Reference (14).

Figure 15. Installation of Omni WIM System at Virginia Tech's Smart Road.

As Figure 15 indicates, installing the OWC system in an existing roadway requires significant excavation and disruption to traffic. The Virginia Tech spokesman stated that the excavation length (as measured along the centerline) was about 12 to 13 ft long and the WIM

[7] Phone conversation with Dr. Amara Loulizi, Virginia Tech Transportation Institute, February 12, 2004.

frame length (same direction) was about 5 ft. If this WIM system had been installed as part of a new roadway, it would be installed below the surface then completely covered with a pavement layer. The VT spokesman stated that since asphalt pavement is a visco-elastic material, its load transmission properties differ with temperature. Therefore, the WIM system must monitor and compensate for temperature variations.[8] Since the WIM element is embedded under the pavement, it appears to be more immune to wear and tear as compared to surface systems. A fiber-optic network connects the WIM server for broadcasting real-time information to a users' Web browser. OWC calibrated the system remotely from OWC's office over the Internet. A Global Positioning System (GPS) unit provided accurate vehicle speed and timing for the calibration. The VTTI's Smart Road Control Center provided line-of-sight and video, as well as Internet access to the WIM site. At the time of the contact with Virginia Tech, there was no report available on its accuracy or other performance metrics *(15)*.

2.4 SUMMARY – LESSONS LEARNED

The following bullet list evolved from the information presented earlier in this chapter based on actual installation and use of test facilities for either pavement systems or non-intrusive systems. Researchers discovered these lessons from the literature and from talking to responsible agencies by telephone. The categories under which these items are organized are: site selection, site design, communication and power requirements, maintenance requirements, and baseline data. The last section dealing with electrical specifications comes from TTI's experience in installing detector test sites and from the experience of others.

2.4.1 Site Selection

- Site selection is the first and perhaps most critical decision in installing a weigh-in-motion system. Use the ASTM standard specification E 1318-02 for site selection.

- FDOT located its test site near an enforcement site so that accurate vehicle weights would be available when needed. The other method to check the accuracy of WIM systems and to calibrate the systems is to use at least one and preferably two calibration trucks. This process would require a single-unit truck and a five-axle combination truck to be loaded to a known weight and driven across the WIM systems at a range of speeds.

- If the roadway profile and overall pavement condition are acceptable, the pavement in the immediate vicinity of the WIM system should be evaluated next. Caltrans criteria require that the pavement be absolutely smooth for 150 ft in advance and 75 ft beyond its bending plate WIM. The pavement type is important to Caltrans as well; it only uses concrete.

- When reviewing a potential WIM site, the reviewer should observe the traffic flow at various times of the day, watching for undesirable traffic conditions. The observer should carefully watch trucks passing through the site to determine if they are traveling at a

[8] Ibid.

fairly constant speed and that they are not bouncing due to pavement roughness or profile.

- The best WIM performance occurs with all traffic traveling at a constant speed and when vehicles are staying near the middle of each lane. Conditions to avoid include: stop-and-go traffic, slow-moving traffic, lane changing, and passing.

- Being too close to (especially high-volume) interchanges and intersections may increase lane changing and speed change and may be a factor in controlling traffic during setup or maintenance operations.

- Grade is an important determinant in the accuracy of WIM. Anything in excess of 1 percent grade results in weight transfer from the steer axle to the drive axle of loaded trucks. Weight transfer can easily exceed 1500 lb.

- The grade may also decrease the number of faster-moving trucks, and adequate calibration requires the entire range of speeds.

- The MnDOT I-394 site offered a range of traffic conditions, to include congestion in both the morning and afternoon peak periods and lower volumes with free-flow conditions in the evenings and on weekends. This range of traffic is needed for non-intrusive tests, but it is a problem with WIM and most classification devices.

- Caltrans attempts to locate sites that can reasonably be served by AC power and land line telephone utilities.

- Traffic conditions at the S.H. 6 test bed in College Station are almost always free-flow. An often overlooked positive aspect of lower traffic volume is that the noise level and the dispersion of vehicles are at desirable levels for many activities such as group demonstrations and traffic studies that require isolated vehicles. Also, this site has ample parking with room to expand, as well as an excellent view of traffic in both directions. There is a weigh station 10 miles away that could be used for verification of weights if desired.

- The College Station site is within a 5-minute drive of Texas A&M University for faculty, staff, and students, and is within 10 minutes of the TxDOT Bryan District offices.

- Vehicular access to cabinets is important. TTI found that accessing a cabinet installed on the east (northbound) side of I-35 by vehicle was problematic. Access required using a busy high-speed exit ramp from northbound I-35 then immediately decelerating to a very slow speed to negotiate a 6-inch curb.

- It is highly desirable to place the building and/or primary equipment cabinets at a level that is above the road level such that TPP personnel and visitors can view both directions of traffic flow but not be too close to the roadway. The MnDOT I-394 building was higher than the roadway and well off the I-394 roadway, but it limited the view of eastbound traffic approaching the site.

2.4.2 Site Design

- Bending plate WIM systems need to be installed in concrete (either an existing concrete pavement or a concrete pad built specifically for the WIM).

- The catwalk installed by MnDOT on the Penn Avenue Bridge is an example of how to provide access to devices installed overhead, while maintaining security. Sensors mounted directly over lanes used three adjustable mounting poles attached to the catwalk, one over each lane of traffic, at varying heights ranging from 20 to 30 ft above the pavement.

- The MnDOT building size of 14 ft by 26 ft would not be large enough to house all equipment (used by MnDOT) plus hold workshops of about 20 or more people. Also, judging from the building schematic, it was apparently not equipped with rest rooms.

- Both the DETT site on I-405 and the MnDOT site on I-394 considered in their design the likelihood of vandalism and attempted to keep facilities secure. Caltrans had devised a special camera mount on the I-405 bridge that would minimize theft and vandalism. The MnDOT site used tall security fencing to protect equipment.

- The MnROAD had an automated weather station to enable roadside computers to capture information on pavement temperature, moisture and frost content, and other ambient environmental conditions.

- For the TTI site on I-35, dispersion of traffic by type and by lane is a negative factor because an unusually high percentage of trucks use the left two lanes. This is a factor in testing the occlusion effects, especially due to these large trucks.

- Street lighting and site lighting are important considerations for security reasons and for tests of certain non-intrusive detectors that use the visible light spectrum.

- Equipment installed on the west side of S.H. 6 includes: three Type P equipment cabinets; an enclosed fenced concrete pad; a Campbell Scientific weather station; a 40-ft pole with two mast arms, one at 20 ft over the road and another at 40 ft over the road; PTZ surveillance cameras; and roadway sensors that serve as part of the baseline system.

2.4.3 Communication and Power Requirements

- Providing communication with the site will be a critical element for TxDOT, researchers, and vendors.

- The MnROAD project used fiber optic cable to send data from its various sensors and the weigh-in-motion systems to a data management network at the Minnesota Department of Transportation and shared by the University of Minnesota for research purposes.

- When MnDOT installs a WIM system, it uses a checklist of pertinent items that include access to phone and power (see page 18).

- Collecting data and communicating with the site will be very important. The TTI sites use high-speed Internet access to remotely monitor detector systems, upload data, check sensor configurations, and stream live video. This research project revealed many benefits of using Internet communications. One benefit was far fewer trips to the site and the associated travel and labor costs. Another big benefit is its availability to vendors and manufacturers for remote access to test, modify, and upgrade their equipment.

- The test plan devised by Virginia Tech researchers involved a number of test scenarios including different vehicle speeds, acceleration levels, tire inflation pressures, axle loads, and environmental conditions.

- The Virginia Tech researchers set up a fiber-optic network connecting the WIM server for broadcasting real-time information to a users' Web browser.

2.4.4 Maintenance Requirements

- FDOT recommends that if a state DOT cannot allocate sufficient resources to maintain a (bending plate) WIM system, it should not install it in the first place. Ignoring this need for maintenance can result in traffic hazards and lawsuits.

2.4.5 Baseline Data

- For baseline weights for a WIM test site, FDOT located its site within 5 miles of a weight enforcement site.

- In its DETT report, Caltrans found it necessary to keep the test device's detection zone and the baseline system very close to each other and separated by an equal distance across all lanes.

2.4.6 Electrical Specifications

- Use separate conduit for coaxial video cables and telephone lines, keeping a minimum of 12 inches from any current-carrying conductors.

- Use direct burial gel-filled and copper-shielded telephone cable.

- Use Belden 8281 double shielded coaxial video cable.

- Install lightning arrestors on the telephone lines, video feeds, RS-323, RS-485, or RS-422 communications cables going into cabinets or building.

- Install transient voltage surge suppressor protection on the load side of the building.

- Use one large 6-inch conduit for bore under roadway but partition into 6 partitions with MaxCell form Clifford Cable to increase conduit capacity.

- If test site is constructed in new pavement, during construction install two 3-inch conduits 16 ft apart for 3M microloops.

- Use large 2 ft by 4 ft Quazite pull boxes to allow plenty of room for future conduit.

- Consider using 802.11 wireless high-speed Ethernet for video and serial communications where possible to reduce the need for boring under the roadway.

CHAPTER 3.0 FUNDING SOURCES

3.1 INTRODUCTION

When TxDOT originally developed the Project Statement for Research Project 0-4664, it envisioned that construction of the traffic monitoring equipment evaluation facility would take place as part of this project. It later determined that construction of the facility was not considered research and could not be funded by the project. TxDOT anticipated the need for future funds to finance the construction of the facility and added a task during the development of the original Project Statement, which directed researchers to develop a comprehensive list of funding sources.

Discussions with TxDOT personnel and representatives of other agencies resulted in a number of potential funding sources. The research team investigated a number of alternatives and developed a list of potential funding sources:

- highway trust fund (construction projects),
- capital improvement funds,
- research implementation funding,
- district and division discretionary funds,
- vendor contributions (equipment and installation support), and
- State Planning and Research (SPR) funds.

3.2 HIGHWAY TRUST FUND

It is common for states to use pavement construction projects to pay for the cost of traffic monitoring equipment, installation, calibration, and support. These funds come from the Federal Highway Trust Fund, and they are financed by motor fuel taxes. The use of these funds is generally restricted to the construction, repair, and operations of the highway infrastructure. These funds are not intended to be used for the construction or procurement of buildings, which are financed by Capital Improvement Funds.

The research team met with TxDOT staff in the Waco and Austin Districts to discuss potential funding sources and district participation. In both cases, there was district support for the idea, suggesting that a planned construction project could include the site and the necessary pavement improvements (i.e., continuously reinforced concrete pavement [CRCP]) to accommodate the needs of the test facility.

Several promising construction projects under design are ideal candidates for the installation of the facility. Researchers found attractive alternatives along I-35 in the northern portion of Travis County (Austin District) and the southern portion of the Waco District on I-35. The Waco District is particularly interested in this project as it would provide the district with a bending plate weigh-in-motion data collection system. More details are available in Chapter 5.

There is potential synergy in the traffic detection arena between TPP and state-funded traffic management facilities such as Travis County's Combined Transportation, Emergency and Communications Center (CTECC), as well as the TxDOT Traffic Operations Division. The proposed facility can provide TxDOT with a centralized testing infrastructure close to Austin to safely and effectively train staff, evaluate new hardware and software technologies relevant to traffic sensing and data collection, and provide a venue to share experience and resources between state agencies.

A representative at CTECC provided valuable information to the research team and expressed significant interest in this research project. He identified three traffic management construction projects that have just been let or are currently in the process of being let. Coupling the construction of this facility with an Intelligent Transportation System (ITS) project presents a great opportunity for TPP to partner with the traffic management community and have this facility constructed with a focus on traffic data collection as well as intelligent transportation sensing and hardware.

The principal advantage of using trust fund money is the Federal government's 90 percent contribution for Interstate highway projects versus a 10 percent state contribution. TxDOT could use these funds to purchase and install much of the basic infrastructure for the facility including:

- CRCP and/or other pavement structural improvements;
- conduit, pull boxes, and cabinets;
- equipment enclosures;
- power and telecommunications connections;
- video monitoring system;
- work platform; and
- parking area.

Trust fund monies can be accessed by:

- Change Order – A change order is a modification to an existing construction project that has been awarded and is underway. The advantage of a change order is that it allows construction of the facility to occur fairly rapidly. An area engineer has authority to issue a change order up to $25,000 and a district engineer has authority to issue a change order up to $150,000. Disadvantages of change orders include: 1) they are subject to extra scrutiny for approval, 2) the work must generally fall within the scope-of-work of the original project, 3) they are almost always more expensive (because of lack of competition), and 4) they are generally considered indicators of poor project scope control.

- Design Change – A design change is usually made before the letting while the contract documents are still being prepared. TxDOT prepares Project Plans, Specifications, and Engineering (PS&E) for jobs based on estimated costs for construction and available funds. If the facility were added during this stage, additional funding necessary to complete the new work would have to be pulled from one or more future projects to compensate for the additional cost of the facility. Approval for a design change must go through a TxDOT chain of command starting with the area engineer, followed by the district construction engineer, and finally the district engineer. The Design Division then reviews and approves the change and integrates the change into the project construction documents before the letting.

- Part of Original Scope – In this case, the facility would be incorporated into a construction project during the earliest planning and design phases, worked through the TxDOT project development system and approved by the Advanced Transportation Planning and Development Group at the TxDOT district.

In general, the process for getting this project added to a highway construction project is as follows:

- Design – Technical documents are required to define the proposed facility. The documents would be incorporated into plans and specifications for insertion into the bid documents.

- Cost – A cost estimate for the proposed facility must be prepared.

- Approval – The approval would begin with the area engineer responsible for the project who would take it before the Advance Transportation Planning and Development Office for review.

3.3 CAPITAL IMPROVEMENT FUNDS

Capital improvements are generally applied to construction money for administration buildings, and each asset must be explicitly approved in a spending bill by the Legislature. Because of the coordination and timing efforts that must be made, this is probably not an appropriate source of funds for the facility.

3.4 RESEARCH IMPLEMENTATION FUNDS

Various research projects have recommended the construction of a facility to allow TxDOT to evaluate vendor products and installation procedures and to serve as a service facility for training of technicians from different districts. The director of the Research and Technology

Implementation Office (RTI) stated in comments to TTI staff in March 2004 that RTI has a role in evaluating new technologies by coordinating with responsible divisions. Thus, such a site fits within the scope of "research implementation" and could be proposed as a "research implementation project." A project representative will present the project status at the Research Management Committee (RMC) meeting. This presentation will be followed by another shorter presentation to the Research Oversight Committee (ROC) who will collectively decide if the request is eligible for implementation funds and if they concur with the stated funding request and scope.

3.5 DISCRETIONARY FUNDS

Each TxDOT district and division has discretionary funds available. With sufficient contributions from TxDOT districts, there would be no need for highway trust fund financing, or there would be sufficient funding to pay for components that could not be covered by highway trust fund dollars.

A request from the TPP Division Head to the districts and possibly to the Traffic Operations Division would probably be most successful in soliciting district or division discretionary funds. Accompanying the formal request should be a complete description of the project and the intended use of the facility, to include training and benefits that would accrue to each district and the entire state. Complete funding for the construction of the facility through this mechanism, and not highway construction projects, offers several advantages:

- The facility can be constructed on the most appropriate section of road and not be tied to a road segment just because it is part of the construction contract.
- Construction contracts can take considerable time to complete and/or delays can occur, which means the facility may not be constructed within a desirable time frame.
- There are fewer restrictions on how the funds can be spent for the construction of the facility (i.e. structures, equipment, sensors, etc.).

The disadvantage of this funding mechanism is the uncertainty of getting enough contributions to pay for the facility. The contributions made by the district may not be enough to pay for significant pavement upgrades such as CRCP, so the site might not be able to support a permanent bending plate WIM system.

3.6 VENDOR CONTRIBUTIONS

Vendor contributions will help lower the cost of acquiring software, hardware, sensors, and other related equipment. One vendor has already offered to contribute a WIM system for installation at the site, although this commitment has not been verified. Other vendors will be asked for contributions as appropriate. The researchers anticipate that vendors will contribute both equipment and installation services to prove that their systems perform as advertised. Successful vendor demonstrations provide strong evidence to TxDOT that the purchase of the equipment is an acceptable investment in its traffic data monitoring system.

3.7 STATE PLANNING AND RESEARCH (SPR) FUNDS

State Planning and Research funds represent a possible funding source. FHWA representatives in Austin and Washington D.C. indicated that TxDOT could possibly use SPR funds to finance a portion of the facility, but this would be the first time SPR funds would be used for a facility like this one. SPR funds require a 20 percent local match, but TxDOT could meet the requirement either by direct funding or by innovative financing or their time and services to leverage the federal portion. TxDOT would need to submit the request in the current fiscal year for funding in the next fiscal year. These funds are not eligible for pavement construction and rehabilitation, but they are eligible for the operations building, sensors, electronics, tools, cabinets, pull boxes, and other basic infrastructure.

If TxDOT pursues SPR funding for a portion of the test facility, it would need to first initiate an amendment to its SPR program. The current description for this research project within the SPR document (pg 50 – 51) *(16)* does not include the construction of a test facility. The amendment will have to advance through TPP administrative review and then to the FHWA Division Office for approval. The amendment should state what is proposed and how the completed facility will improve TxDOT's data collection efforts and its Highway Performance Monitoring System (HPMS) program.

3.8 SUMMARY

This chapter identified potential funding sources to finance the construction of the proposed facility. Each potential funding source listed above has its own advantages and disadvantages. The most serious disadvantages are the potential delays associated with construction projects and the uncertainty of district contributions. Despite these concerns, researchers will proceed with plans to combine the construction of the facility with an appropriate highway construction project.

The TTI and Center for Transportation Research (CTR) team will also pursue the other funding possibilities identified herein including discretionary, research implementation, and SPR funds. If other sources are discovered, these too will be considered as the project proceeds. Given sufficient funding from alternative sources, an interim facility could be constructed at a future highway trust fund construction site so that research, testing, and training can commence more quickly. The construction project will provide a permanent CRCP pavement structure for the facility and bid documents could incorporate specifications for the replacement of all facility components damaged by the construction.

Researchers divided the site construction into modules. These modules include the following:

- Module 1 – Pavement construction and rehabilitation, under the road conduit, and guardrail;
- Module 2 – Portable structure, utilities, phone, fencing, parking, base platform;

- Module 3 – Sensors and instrumentation;
- Module 4 – Interconnecting conduit, pull boxes, and cabinets;
- Module 5 – Remote communications and wideband wireless; and
- Module 6 – Additional systems such as video monitoring and a weather station.

CHAPTER 4.0 SITE SELECTION CRITERIA

4.1 INTRODUCTION

Site selection criteria development began with a set of criteria to screen and prioritize candidate sites in order to identify the best possible site for the proposed equipment evaluation facility. The site selection criteria were principally based on general requirements for traffic data collection systems and input from TxDOT staff. The research team also developed additional criteria not normally considered for data collection sites but considered important for a successful research facility. The process applied a rating factor from zero to five to each criterion where a zero value essentially disqualified a site for consideration and a five rating meant the criterion was completely satisfied.

Researchers initially developed the criteria and rating factors under the assumption that the site would be installed with no modifications or improvements to the highway alignment or pavement structure. They later revised this approach because there was a strong possibility of building the test site as part of a pavement reconstruction or widening project. This change meant that the reconstruction project would correct the poor pavement or other problems as part of the project. Researchers modified the related rating factors accordingly.

A final criterion added a requirement for a bending plate WIM system installed in CRCP pavement. This criterion impacted the selection criteria because it limited the sites to those where extended lane closures would be feasible. It also required the facility to be constructed in conjunction with a major pavement rehabilitation or reconstruction project to absorb the cost of CRCP.

4.2 DESCRIPTION OF CRITERIA

Table 1 shows the 21 selection criteria. Section 4.2.2 provides two examples of rating criteria followed by a general discussion of the remaining criteria. Appendix A contains a full list of the rating values used for each of the criteria.

4.2.1 Criterion 1 – Distance from TPP Shop

The distance of the proposed site from TxDOT offices at the Bull Creek Annex, near the intersection of Bull Creek Rd and 45th Street, is important for convenient access of the facility to TxDOT staff. TxDOT used former test sites located in or near Seguin and Jarrell for testing traffic monitoring equipment and sensors, but eventually abandoned these sites because of their distance from their offices. Travel times in excess of 40 minutes do not disqualify a site, but longer drive times reduce opportunities for TxDOT to use the site, so its rating drops respectively. Table 2 shows the values used for Criterion 1.

Table 1. Site Selection Criteria.

Criterion	Objective	Criteria
1	Distance from TPP shop	Drive time (minutes)
2	Roadway geometry	Alignment, cross-slope, lane width
3	Pavement structure	Thickness
4	Traffic mix	Percent trucks and total volume
5	Multiple lanes	Number of lanes
6	Power and communication	Distance to service
7	Right-of-way	Distance to safe parking
8	Adjacent space	Park calibration truck
9	Space for structure	Area for building
10	Sign bridge structure	For mounting overhead devices
11	Roadside pole	For mounting overhead devices
12	Lighting	Security and night visibility
13	Pavement condition	Rutting, cracking, smoothness
14	Pavement rehabilitation	Rehabilitation schedule
15	Circuit time for calibration truck	Cycle time
16	Sight distance	For clear visibility of traffic
17	Proximity to DPS enforcement site	For ground truth weights
18	Bending plate WIM	Existing, buildable, or not buildable
19	Access to satellite sites	Distance from primary site
20	Safety features	Longitudinal barriers
21	Traffic congestion	Free-flow or stop-and-go

Table 2. Criterion 1 – Distance from TPP Shop.

Criteria	Scale	Rating
Drive time from TPP to site	0 < 10 minutes	5
	11 < 20	4
	21 < 30	3
	31 < 40	2
	> 41	1

4.2.2 Criterion 2 – Roadway Geometry

Roadway geometry criteria utilize ASTM E 1318-02, the Standard Specification for Highway Weigh-in-Motion Systems with User Requirements and Test Methods *(3)*. The low weighting values are assigned to conditions that are unacceptable according to the ASTM specification but correctable with alignment and/or pavement improvements. Tables 3, 4, and 5 indicate the values used for horizontal/vertical alignment, cross-slope, and lane width.

Table 3. Criterion 2 – Roadway Alignment.

Criteria		Horizontal Alignment (radius of curvature - ft)			
	Scale	>10000 ft.	10000-8000	8000-5700	<5700
Vertical Alignment - % grade (pos. or neg. grade)	0.0 – 0.5	5	4	1	1
	0.5 – 1.0	4	3	1	1
	1.5 – 2.0	2	2	1	1
	2.0+	1	1	1	0

Table 4. Criterion 2 – Cross-Slope.

Criteria	Scale	Rating
Cross-slope (%)	0 – 1	5
	1 – 2	5
	2 – 3	1
	3+	1

Table 5. Criterion 2 – Lane Width.

Criteria	Scale	Rating
Lane Width (ft)	12.5 – 14	4
	12.5 – 12	5
	12.0 – 11.5	2
	11.5 – 11.0	1

4.2.3 Criterion 3 – Pavement Structure

Pavement structure is a key criterion that directly reflects the usefulness of the site for a TPP research facility. Regardless of CRCP being installed at the site, asphalt pavement at a selected site must provide adequate stiffness to support the installation of various other road sensors.

4.2.4 Criterion 4 – Traffic Mix

Potential sites must have an appropriate traffic volume and mix of vehicle types. High volumes are desirable for evaluating traffic equipment and sensors to get performance results under extreme operational conditions. On the other hand, the volume cannot be so high as to preclude reasonable lane closure opportunities for sensor installations and maintenance. At high volumes, traffic congestion also becomes a problem since most traffic monitoring systems do not collect accurate data during stop-and-go conditions. The classification mix, including a large proportion of truck traffic, is essential.

4.2.5 Criterion 5 – Number of Lanes

The number of lanes is important insofar as it is desirable for the roadway to be divided by a median, which implies four or more lanes. A six-lane site is considered the most desirable, but a four-lane section is also acceptable.

4.2.6 Criterion 6 – Power and Telephone

Access to electric power is essential for powering lighting, air conditioning, test equipment and research hardware, and sensors at the site. Telephone service is also required for remote communications with the facility. Availability of high-speed Internet service is also desirable, but was not part of the selection criteria.

4.2.7 Criterion 7 – Sufficient Right-of-Way (ROW)

Sufficient ROW is important to accommodate the structure and related facilities with adequate line-of-sight to view passing traffic. ROW must also be sufficient to accommodate on-site parking and access for vehicle operators. Safety is addressed elsewhere and is also a factor that affects the need for adequate ROW.

4.2.8 Criterion 8 – Adjacent Parking for Calibration Truck

On-site parking for the calibration truck facilitates communicating with the driver changing drivers, and it offers a secure area for parking the truck. These issues can be handled in other ways so that failure to satisfy this criterion does not significantly impact the site score.

4.2.9 Criterion 9 – Space for Operations Trailer

The use of this site as a training facility for TxDOT is an important factor. It is vital to have space for a structure that provides a comfortable environment – protection from weather and traffic noise – for on-site training purposes.

4.2.10 Criterion 10 – Sign Bridge or Overpass

A sign bridge or overpass structure is important for the installation of certain types of traffic sensors. An overpass would be ideal because it would also provide operators with convenient and safe access to both sides of the road. If a structure is not available, the site plans and specifications will incorporate the construction of a sign bridge and service walkway.

4.2.11 Criterion 11 – Roadside Pole

The availability of one or more roadside poles is important for mounting video cameras that allow remote viewing of passing traffic and evaluation of non-intrusive sensors requiring a roadside setup. This structure could be an existing luminaire support or sign pole with adequate height.

4.2.12 Criterion 12 – Lighting

The presence of street lighting, although not required, would improve safety for times when night work is performed.

4.2.13 Criterion 13 – Pavement Condition

Pavement condition becomes an issue if a lack of funding prevents corrective actions to repair critical deficiencies. Failure to correct such problems would render a site unacceptable.

4.2.14 Criterion 14 – Pavement Rehabilitation Programming

This criterion applies to asphalt or Portland cement concrete pavements that will be resurfaced. Given the opportunity, the state should visit the site prior to the resurfacing operation (including milling if applicable) and create a map to record the location, severity, and extent of existing distresses. After the pavement overlay, the map will provide guidance to position sensors so they are not located on top of buried distresses that can propagate into the new pavement surface. Also, installing sensors in a pavement that is scheduled for rehabilitation in the next 3 years is not desirable.

4.2.15 Criterion 15 – Test Truck Turnaround Time

The site should be located to provide reasonable turnaround times for both calibration trucks and test vehicles making test runs over the sensors to avoid long delays for data collection.

4.2.16 Criterion 16 – Sight Distance

Operators need to see vehicle traffic approach the site before it crosses the sensors to give them the opportunity to collect special research data (e.g., sensor signals) from specific vehicles on specific sensor arrays.

4.2.17 Criterion 17 – Proximity to Department of Public Safety (DPS) Scales

For research on WIM sensors, it is highly desirable to occasionally obtain matching static axle weights from mixed truck traffic to evaluate the accuracy of WIM sensors and systems. One way to meet this need is to locate the site relatively close to an enforcement facility with permanent static scales. However, TxDOT also intends to use this site as a WIM data collection site, so it should not be so close to the DPS activity as to bias the weight data. If a static scale is not available, the next best alternative is to use loaded test trucks of known static weight and have them make multiple runs.

4.2.18 Criterion 18 – Bending Plate System

TxDOT desires that the research facility also have a permanent bending plate WIM system collecting traffic data on all lanes to help satisfy statewide truck weight planning data requirements. If properly maintained and calibrated, this WIM system would also provide a data resource for verification of data from other sensors and devices.

4.2.19 Criterion 19 – Satellite Sites

The use of satellite sites will be an important component of the research facility to effectively evaluate traffic monitoring electronics and sensors. The primary site will permit the evaluation of traffic monitoring systems at normal highway speeds under free flow conditions. Satellite sites will enable operators to evaluate equipment and sensors under different traffic conditions, pavement types, pavement stiffness, environments, and so forth. Researchers do not expect TxDOT to construct satellite sites specifically for this purpose; it would probably use existing traffic monitoring sites and evaluation facilities and connect them to the primary site and to TxDOT offices by communication links.

4.2.20 Criterion 20 – Safety Features

A critical issue in selecting and designing a facility is consideration of safety features. Safety features are important for the operators, who will work at the facility for extended periods of time, and for the traveling public. For example, depending on the physical separation of roadside hardware from traffic, an important safety feature may be a positive barrier to protect people and facilities from errant vehicles. Also, the site selection and design must provide adequate and safe access for operators or visitors arriving by car.

4.2.21 Criterion 21 – Traffic Congestion

The ideal site is one that never experiences stop-and-go traffic. Traffic congestion is sometimes necessary to verify vendor's claims of accuracy under these conditions, but TxDOT could handle this requirement by an appropriate satellite site.

4.3 GLOBAL RANKING FOR SITE SELECTION CRITERIA

The rankings of site criteria described previously only consider how well individual criteria are satisfied. To effectively score a site, researchers needed an overall (global) ranking to address the relative significance of one criterion compared to the others. For example, the proximity or location (criterion number 1) of the facility relative to TxDOT offices is more important than sight distance (criterion number 16). Researchers ranked location with a weight of 5 and sight distance as 3.

Table 6 recommends an overall ranking/rating for the different site selection criteria that identifies the relative importance of each. The most important criteria have a rating of 5, with objectives of lesser importance given a lesser ranking.

Table 6. Overall Ranking of Criteria.

Objective	Ranking
1. Location	5
2 Geometry	5
3 Pavement structure	4
4 Traffic mix	5
5 No. of lanes	3
6 Power and communication	3
7 Sufficient ROW	3
8 Calibration truck parking	2
9 Space for shelter	3
10 Sign bridge	3
11 Roadside pole	2
12 Lighting	1
13a Rutting/Cracking	2
13b Smoothness	3
14 Planned rehabilitation	2
15 Turn around for calibration truck	3
16 Sight distance	3
17 DPS weight enforcement	4
18 Bending plate WIM	2
19 Satellite sites	1
20 Safety features	2
21 Congestion	4

CHAPTER 5.0 RECOMMENDATIONS FOR FACILITY

5.1 INTRODUCTION

Using a general site selection process, the research team selected corridors and locations that might generally fit the needs of TPP(T). Based on the anticipated frequency of trips from the TPP shop to the site, researchers looked first at locations in central Texas as close to Austin as possible but still avoiding congested areas. There were several sites that deserved a closer look. Then, based on the site selection criteria and knowledge of the area highway network, the research team narrowed the number of candidate sites to four. This chapter includes consideration of these four sites. All four sites are on I-35; three are located in northern Travis County (Austin District), and one is in southern Bell County (Waco District).

5.2 GENERAL SITE SELECTION PROCESS

The final selection process used general criteria prior to applying the site selection criteria presented in Chapter 4 to narrow the investigation to corridors that could be surveyed in detail. These general criteria were:

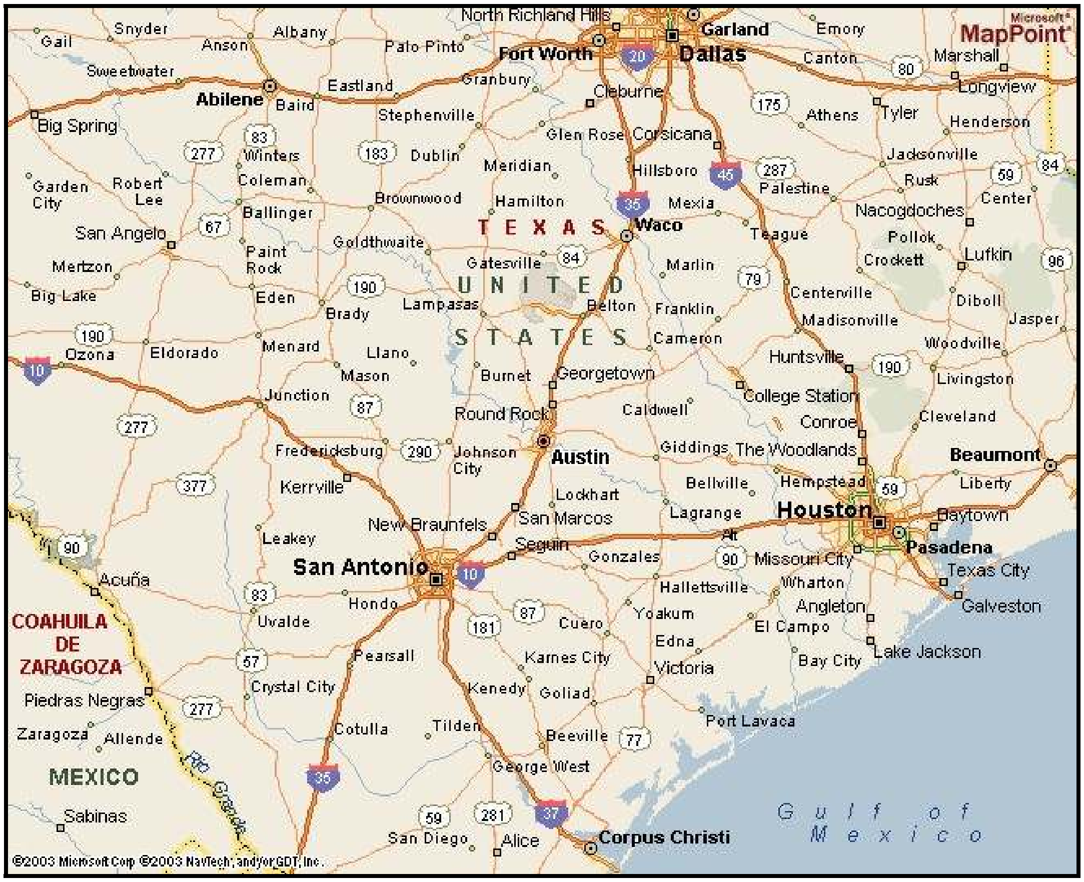
- The TPP(T) Tech Services offices in Austin are the base of operations from which staff will frequently travel to the demonstration facility.
- Locate the site on a roadway with significant daily truck volume and variations of truck types.

The most significant daily truck volumes are on Interstate corridors. The preliminary corridors within a two-hour drive of the TPP(T) Tech Services offices are:

- the I-35 corridor from Hillsboro south to Pearsall,
- the I-10 corridor from Kerrville east to Columbus, and
- the I-37 corridor from San Antonio south to Campbellton.

Figure 16 provides a reference for these corridors in relation to their proximity to Austin.

Project staff performed an HPMS query to find roadway sections with acceptable existing horizontal and vertical geometry to provide as straight and level conditions as possible for the demonstration facility. The HPMS curve and grade criteria were curve class A (degree of curvature is 0.0 to 3.4) and grade class A or class B (0.0 to 0.4 and 0.5 to 2.4). This query used Year 2002 data submitted to FHWA for the initially identified corridors. Figure 17 shows the matching results as a heavier line compared to other roadways. Significant gaps occurred within the query results for sections of roadway. Closer review of these gaps indicated some familiar sections (e.g., Georgetown to the Williamson/Bell County line) that met the query criteria but



Source: Reference (17).

Figure 16. Regional Highway Network around Austin, Texas.

were not included as matching results. In the final analysis, the HPMS dataset did not prove to be a reliable source of information for all sections of roadway, but only for sections in the HPMS sample set.

From the outset, travel time from the TPP shop was a critical consideration in the selection of the site. For that reason, travel times greater than about one hour were considered excessive, eliminating locations in or near San Antonio and along the I-10 and I-37 corridors, as well as the portion of I-35 south of New Braunfels. Sections of the I-35 corridor north of the city of Belton also exceeded the desired drive time. After these exclusions, the only corridor remaining from ones initially selected was I-35 from the city of New Braunfels north through the city of Belton.

S.H. 130, which is presently under construction (May 2004), will be a toll facility from Georgetown (located north of Austin) to I-10 to the south. Traffic forecasts indicate that this road will serve a significant amount of truck traffic from the I-35 corridor through the Austin and San Marcos areas. A 1998 TxDOT study predicted that 27 percent of the through truck trips would choose S.H. 130 *(18)*. More recent TxDOT studies indicate that 13 percent of the projected daily traffic in 2025 will be trucks.[9] The first segments from the S.H. 130/I-35 interchange south to its intersection with U.S. 183 near the City of Austin will open to traffic in 2007.

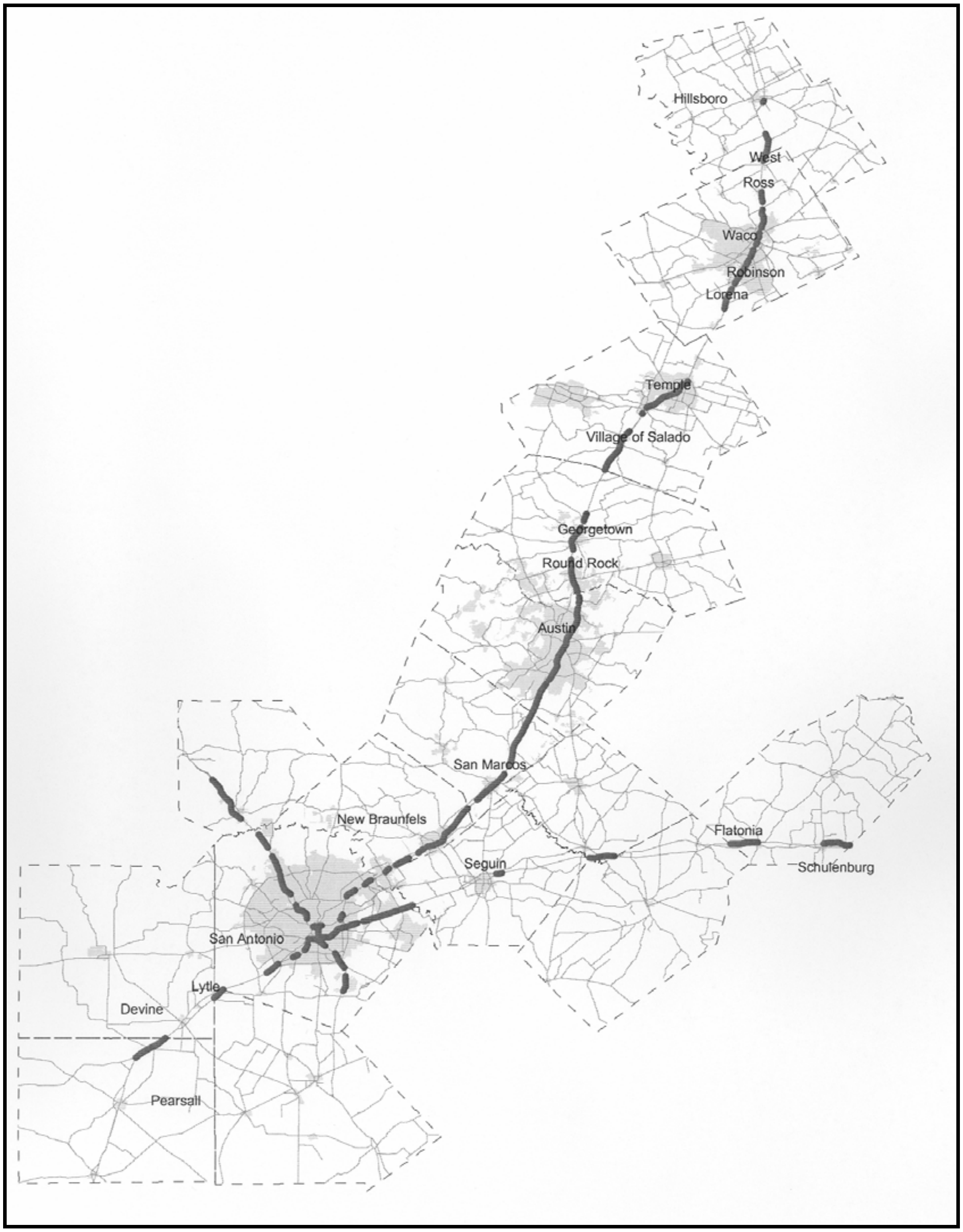
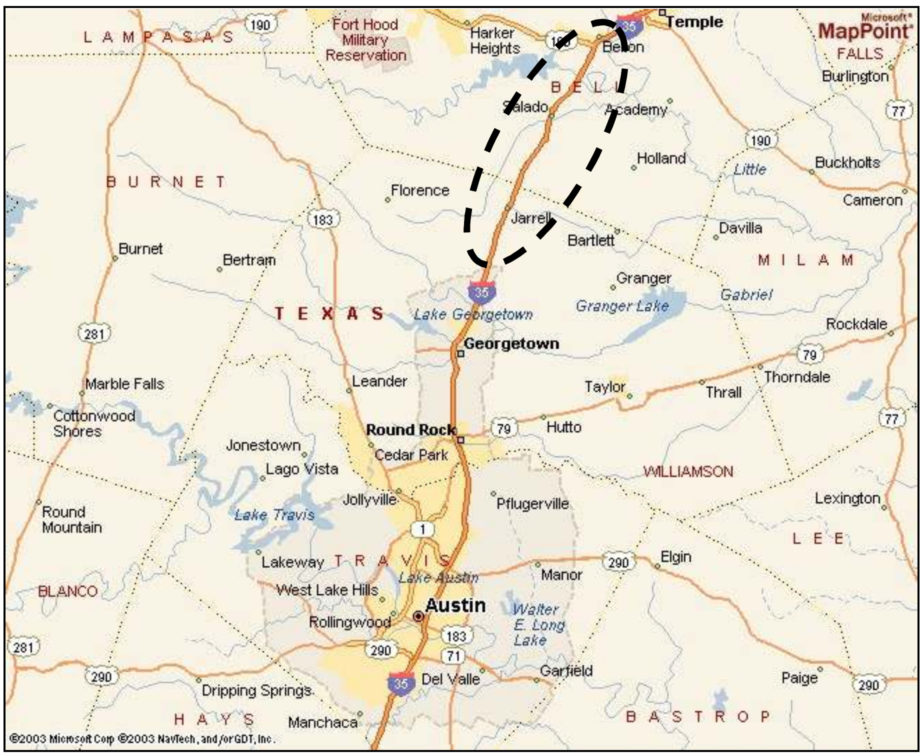


Figure 17. HPMS Query Results.

[9] Personal communication with John Buttenob, March 31, 2004.

Because of this anticipated diversion of trucks, researchers reduced the candidate corridor to sites located north of the proposed S.H. 130/I-35 interchange on the north side of Georgetown. The northern terminus of the candidate section was the shared city limits of the City of Belton and the City of Temple at mile marker 296. By selecting this roughly 27-mile corridor, the location of the demonstration facility maximizes both the amount of total traffic and truck traffic for testing equipment and training TxDOT staff in the use of data collection equipment and reduces excessive travel time to other more remote locations. Figure 18 shows the selected portion of the I-35 corridor.



Source: Reference (17).

Figure 18. I-35 Corridor from Austin to Temple.

Tables 7 and 8 show the criteria used for a second query, which utilized the Texas Reference Marker (TRM) database. The limits of this query along the I-35 corridor were from immediately north of the S.H. 130 interchange to Hillsboro. The selection process used these criteria to locate points along the mainlanes where overhead features were available for mounting overhead traffic sensors. These existing features would reduce the cost of the test facility by mitigating the need to construct an overhead structure. Crossover structures also provide access to staff to walk or drive above the mainlanes to the opposite side of the roadway. Table 9 shows TRM query results.

Table 7. TRM Query Conditions for Rigid Pavements.

Property	Query Conditions
Rural Urban Code	Rural OR Small Urban
Roadway Feature Code	Intersection
Intersecting Feature Type	On-System Mainlane OR Local Road OR Crossover OR Overhead Sign
Intersecting Type	Grade Separated Intersection
Roadway Feature Grade	Feature is Up Above Grade
Shoulder Type	Surfaced with Bituminous (one or two course and ACP) OR Surfaced with Concrete (not tied to mainlane pavement) OR Surfaced with Concrete (tied to mainlane pavement)
Surface Type	High Rigid - Reinforced Jointed Concrete Pavement OR High Rigid - Continuous Reinforced Concrete Pavement

Table 8. TRM Query Conditions for Bituminous Pavements.

Property	Query Conditions
Rural Urban Code	Rural OR Small Urban
Roadway Feature Code	Intersection
Intersecting Feature Type	On-System Mainlane OR Local Road OR Crossover OR Overhead Sign
Intersecting Type	Grade Separated Intersection
Roadway Feature Grade	Feature is Up Above Grade
Shoulder Type	Surfaced with Bituminous (one or two course and ACP) OR Surfaced with Concrete (not tied to mainlane pavement) OR Surfaced with Concrete (tied to mainlane pavement)
Surface Type	High Flexible-mixed, Bituminous 7" Base and Surface

Table 9. TRM Query Results from Proposed S.H. 130/I-35 Interchange to Belton.

Record	Hwy	Marker	Disp	RU	Int_FTyp	Int_Typ	Feat_Grd	R_Sh_Typ	L_Sh_Typ	Surf_Typ	ADT	Trk_Pct	Trk_Vol	TDFO
1	IH0035	267	0.409	1	93		U	2	2	61	52640	26.3	13844	266.85
2	IH0035	267	0.44	1	93		U	2	2	61	52640	26.3	13844	266.881
3	IH0035	268	0.553	1	93		U	2	2	61	49460	27	13354	267.994
4	IH0035	269	0.027	1	21	B	U	2	2	61	49460	27	13354	268.468
5	IH0035	269	0.304	1	93		U	2	2	61	49460	27	13354	268.745
6	IH0035	271	0.782	1	21	B	U	2	2	61	49460	27	13354	271.223
7	IH0035	271	0.782	1	21	B	U	2	2	61	49460	27	13354	271.223
8	IH0035	273	0.867	1	93		U	2	2	61	49460	27	13354	273.308
9	IH0035	274	0.136	1	21	B	U	2	2	61	49460	27	13354	273.577
10	IH0035	274	0.69	1	93		U	2	2	61	47010	27.7	13022	274.131
11	IH0035	275	0.895	1	93		U	2	2	61	47390	27.6	13080	275.336
12	IH0035	276	0.633	1	93		U	2	2	61	47390	27.6	13080	276.074
13	IH0035	277	0.062	1	21	B	U	2	2	61	47390	27.6	13080	276.503
14	IH0035	280	0.213	1	21	B	U	2	2	61	47770	27.5	13137	279.733
15	IH0035	282	0.886	1	11	B	U	2	2	61	47770	27.5	13137	282.409
16	IH0035	283	0.974	1	21	B	U	2	2	61	47610	27.5	13093	283.49
17	IH0035	284	0.889	1	21	B	U	2	2	61	47610	27.5	13093	284.406
18	IH0035	286	0.193	1	11	B	U	3	3	61	47610	27.5	13093	285.712
19	IH0035	287	0.637	3	21	B	U	2	2	61	52300	26.3	13755	287.158
20	IH0035	289	0.29	3	21	B	U	1	2	61	52300	26.3	13755	288.813
21	IH0035	290	0.691	3	21	B	U	1	2	61	52300	26.3	13755	290.219
22	IH0035	291	0.884	3	11	B	U	2	2	61	52470	26.3	13800	291.407
23	IH0035	293	0	3	11	B	U	2	2	61	69070	18.8	12985	292.532
24	IH0035	294	0.434	3	11	B	U	2	2	61	69070	18.8	12985	293.968

Other corridors included in preliminary considerations were U.S. 290 from the east side of Austin toward Houston; U.S. 79 from Round Rock toward Taylor; U.S. 183 from I-35 toward Loop 1; and S.H. 6 in Bryan (the current TTI test bed site). Figure 19 shows all of these locations except for S.H. 6. The upper left shows U.S. 79 (Round Rock to Taylor), the upper right shows U.S. 183 (I-35 to Loop 1), the lower right shows I-35 (Austin to San Marcos), and the lower left shows U.S. 290/S.H. 71 (south Austin).

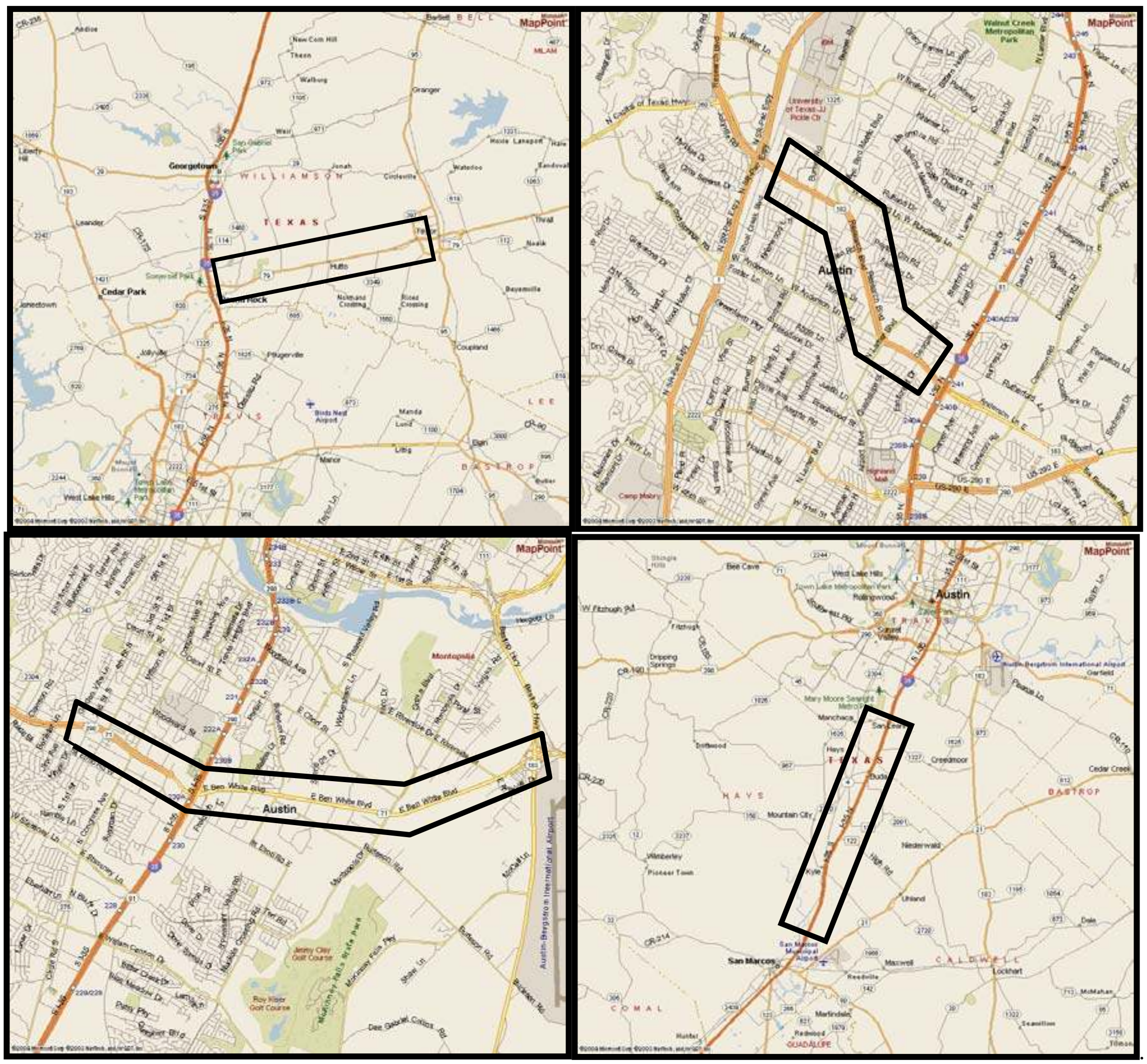


Figure 19. Other Candidate Locations.

U.S. 79 has significant truck traffic but it did not compare closely with I-35, either in truck volume or the variety of truck types. Other shortcomings of this corridor were limited sections of divided roadway and limited right-of-way for building a test and training facility. A possible location west of the F.M. 1460 intersection would require the section be upgraded to four-lane divided.

TxDOT had previously installed some traffic monitoring equipment on U.S. 183 that it was not using. Although this site would provide a very attractive travel time for TxDOT staff, it also has elevated structures, limited right-of-way, and recurrent urban congestion. Also, the vehicle mix at this location would have considerably more passenger cars and light-duty trucks and fewer heavy trucks.

Early discussions included a candidate site located south of Austin on I-35 near San Marcos and the DPS enforcement area. A site visit revealed that the roadway has three travel lanes in each direction separated by a concrete median barrier, and the surface on the mainlanes is asphalt. The diversion of truck traffic onto S.H. 130 when completed is expected to significantly reduce the truck volumes at this location. Discussions with TxDOT indicated that the traffic volume at this site would be excessive for reasonable access to the pavement.

The research team also considered candidate sites on U.S. 290/S.H. 71, but the sites were located in the Austin urbanized area. The section under consideration extended from the Southern Pacific Railroad to the U.S. 183 interchange. Sites within this corridor are not candidates for a permanent WIM system because of: 1) recurrent congestion, 2) limited right-of-way for the placement of a building, and 3) limited sight distance along the roadway. Video surveillance equipment could help overcome the third shortcoming. There would also be a potential benefit of teaming with the Combined Transportation, Emergency and Communications Center (CETECC) in Travis County.

Figure 20 shows the S.H. 6 candidate site, but its distance from Austin of about two hours drive time was an impediment to it being selected as the primary site. However, it would not be expedient to completely ignore the site either. Funding for the significant infrastructure that already exists there came largely through state-funded programs and it is within 5 minutes of Texas A&M University and the Texas Transportation Institute. It is already equipped with surveillance cameras and high bandwidth communication for viewing video or accessing data from operating systems via the Internet.

This site might serve TPP needs as a satellite site where TxDOT personnel could conduct some hands-on demonstrations in an environment of low to moderate traffic volume. Typical weekday traffic (both directions) on S.H. 6 at this location is in the range of 35,000 to 40,000 vehicles per day with 10 percent trucks (FHWA Class 5 and above). Traffic conditions are almost always free-flow, but the noise level and the dispersion of vehicles are at desirable levels for many activities such as group demonstrations and studies that need isolated vehicles. The site has a unique high-end vehicle classifier that uses vehicle signatures to accurately determine vehicle speeds, counts, classifications, and occupancies. The site also has Class I piezoelectric sensors, several overhead non-intrusive sensors, and a 3M microloop detector system under the roadway. While there is no building on-site, the TransLink® Lab in TTI's Gibb Gilchrist Building has served as an ideal venue for teaching purposes by receiving video and data from field test beds, supplemented by specialized equipment inside the lab.

Figure 20. S.H. 6 Test Bed in College Station.

5.3 RESULTS USING SITE SELECTION CRITERIA

As the selection process continued, researchers narrowed the list to the four candidate sites shown in Figure 21, designated as Sites A, B, C, and D. Three of the four sites are located in Williamson County, north of the City of Georgetown, and one is located in Bell County just north of the Williamson County line. The text that follows provides more detail on each of these candidate sites. Considering access and right-of-way needs led to focusing attention at interchanges, and only those interchanges with over-crossing roadways.

Site A (see Figure 22) in Bell County is located at milepost 280.213. The NE and SW quadrants are attractive locations. Figure 22 shows photos indicating some site features. The current cross-section is four-lane, divided with a depressed median. The Waco District is planning to reconstruct this section, beginning around mid-year 2006. Available turnarounds are located 2.66 miles to the north and 1.05 miles to the south. The estimated circuit time[10] is 15.2 minutes. The SW quadrant offers a large flat area that is elevated from the mainlanes, where the NE quadrant is also a large area but is only slightly elevated from the mainlanes. The NE quadrant also poses a drainage issue with the exposed culvert, which opens into an open area and naturally drains toward a storm sewer inlet in the NNE portion of this quadrant. The elevated area in the SW quadrant offers better sight distance of both northbound and southbound traffic than the NE quadrant. Because this section is currently being designed, there is an opportunity to work with the design consultant and the Waco District to incorporate the test facility into the larger process.

[10] Circuit time is calculated as twice the distance between turnarounds divided by an assumed 40 mph average speed times 60 minutes added to an assumed 2 minute delay at each turnaround (4 minutes total).

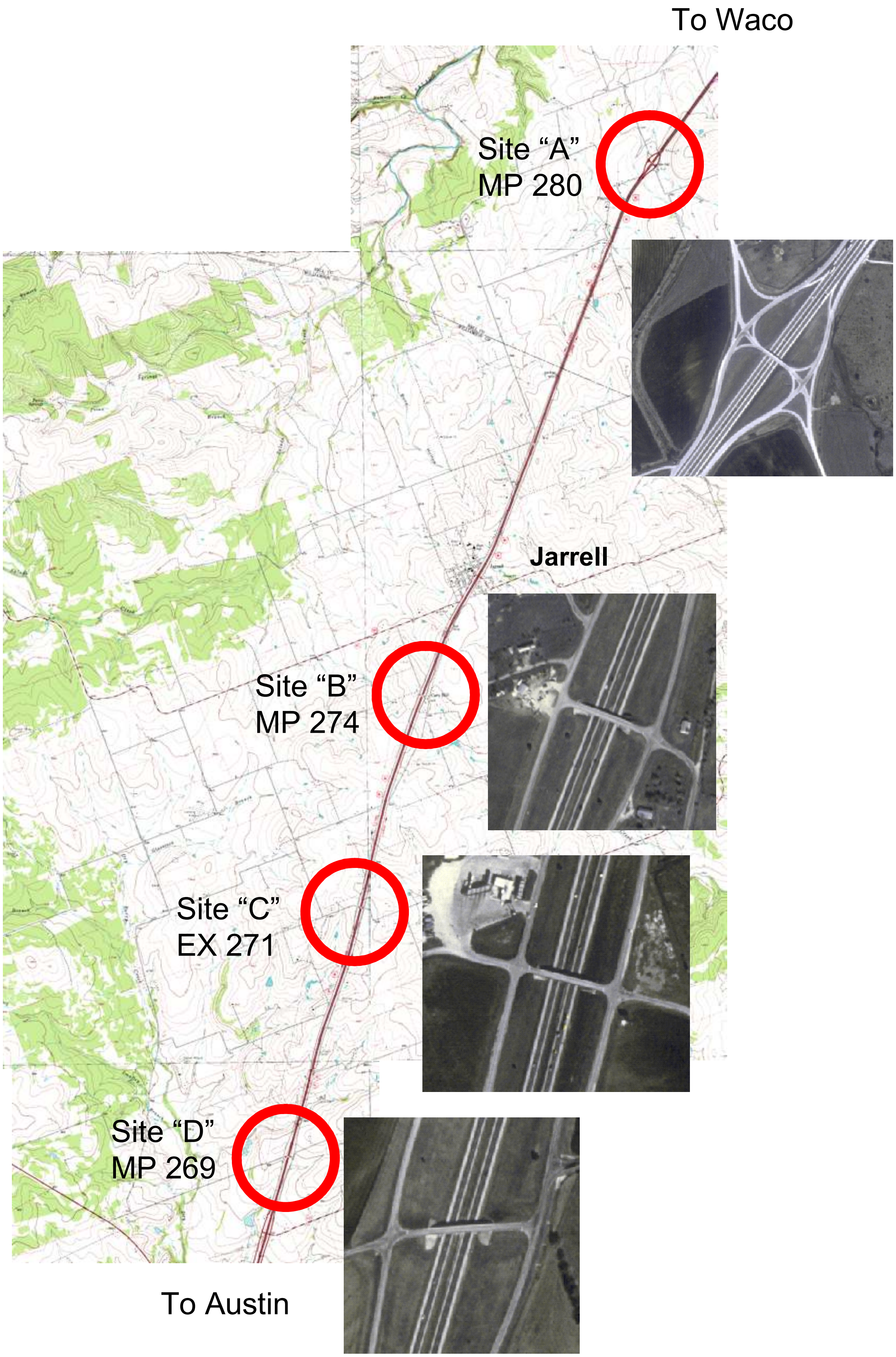


Figure 21. Locations of Proposed Demonstration Facility Sites along I-35.

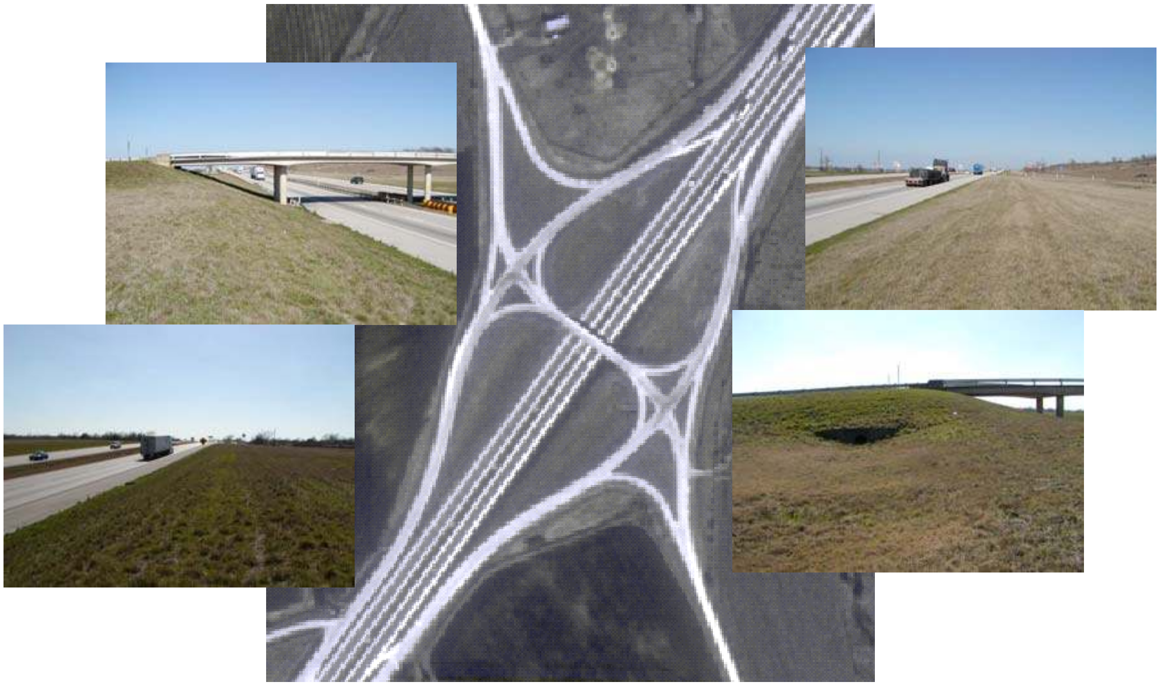


Figure 22. Site "A" Aerial Photo with Ground Photos Looking North and South from the NE and SW Quadrants.

Site "B" (see Figure 23) is located at milepost 274.136. The NE quadrant is the only attractive location within this interchange. The cross-section is six-lane, divided with a permanent barrier. TxDOT reconstructed this section within the last 24 months. Available turnarounds are located 1.4 miles to the north and 2.36 miles to the south. The estimated circuit time is 12.2 minutes. The median barrier located on the north side of this interchange has installed anchor bolts for future overhead median lighting. Power is located on the east side of the right-of-way. The Austin District plans to replace the crossover structure in the near future. Designs are underway to convert many of the diamond ramp configurations to an x-ramp design. Figure 24 displays the difference in these designs.

Site "C" (see Figure 25) is located at milepost 271.782. The NE or SW quadrants are attractive locations. The cross-section is six-lane, divided with a permanent barrier. TxDOT reconstructed this section within the last 24 months. Available turnarounds are located 2.36 miles to the north and 2.75 miles to the south. The estimated circuit time is 19.2 minutes. The slope of the embankment very near the overpass would require considerable work to provide a level and protected base. However, if the facility is located farther north on the east side, this slope becomes less of an issue. Power lines are located on both sides of the right-of-way. The Austin District indicated that it will replace the crossover structure in the future. It also indicated that designs are underway to convert many of the diamond ramp configurations to an x-ramp design.

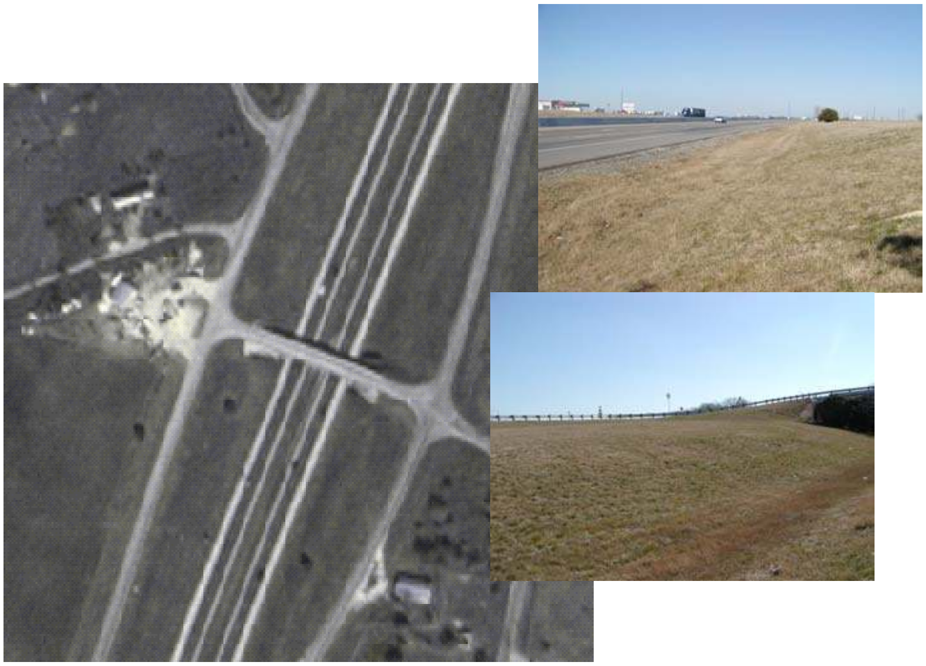


Figure 23. Site “B” Aerial Photo with Ground Photos Looking North and South from the NE Quadrant.

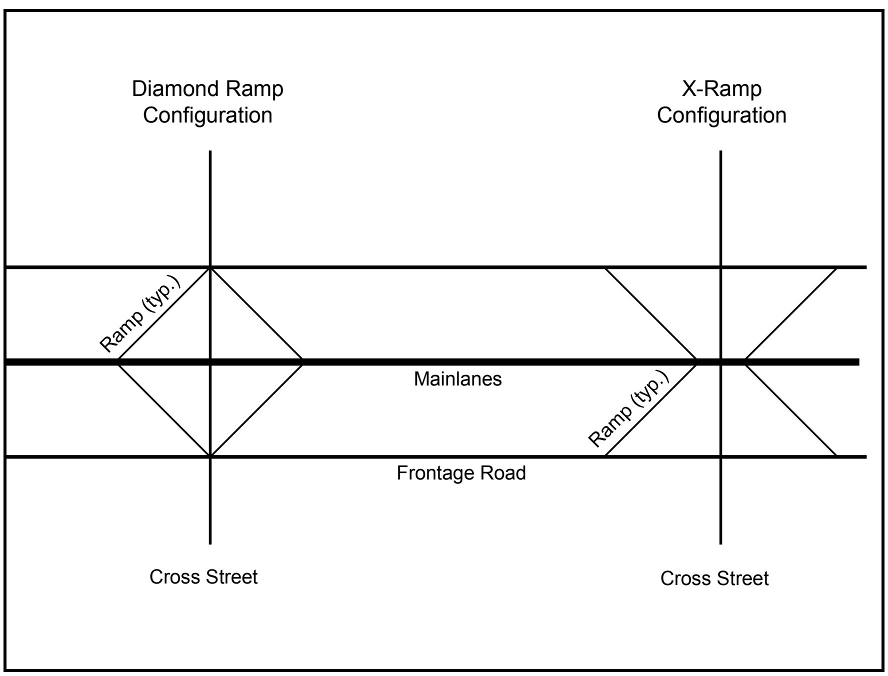


Figure 24. Diamond Ramp versus X-Ramp Configuration.

Figure 25. Site "C" Aerial Photo with Ground Photos Looking North and South from the NE Quadrant.

Site "D" (see Figure 26) is located at milepost 269.027. The NE or SW quadrants are attractive locations. The cross-section is six-lane, divided with a permanent barrier. TxDOT reconstructed this section within the last 24 months. Available turnarounds are located 2.75 miles to the north and 2.49 miles to the south. The estimated circuit time is 19.8 minutes. The area between the mainlanes and frontage road is greater at the NE quadrant than the SW quadrant. Because this area also extends northward, the building could be located slightly farther north of the current overpass to allow greater sight distance upstream and downstream from the selected vantage point. The large ROW area would also provide adequate space for the structure well outside of the clear zone of the mainlanes and provide ample parking for TxDOT staff and calibration vehicles. Another advantage to this location is the existing overhead sign mast north of the overpass on the southbound lanes. Power lines are located on both sides of the right-of-way. The Austin District indicated that it will replace the crossover structure in the future. Designs are underway to convert many of the diamond ramp configurations to an x-ramp design.

Figure 26. Site "D" Aerial Photo with Ground Photos Looking North and South from the NE and SW Quadrants.

5.3.1 Site Rankings

Researchers scored each of the four candidate sites against the previously presented selection criteria. Tables 10 through 30 display the characteristics for each selection criterion.

Table 10. Criterion 1 – Travel Time from TPP Offices.

Site	Travel Time (min)
A	41
B	36
C	34
D	32

Table 11 Criterion 2 – Geometric Characteristics.

Site	Radius of Curvature	Grade (%)	Cross Slope (%)	Lane Width (ft)
A	Tangent	1.8-2.5	2.0	12.0
B	Tangent	0.5-1.0	1.0-2.0	12.0
C	Tangent	1.5-2.0	1.0-2.0	12.0
D	Tangent	1.5-2.0	1.0-2.0	12.0

Table 12. Criterion 3 – Pavement Structure.

Site	Existing Pavement Type	Pavement Depth
A	AC	> 8"
B	AC	> 8"
C	AC	> 8"
D	AC	> 8"

Table 13. Criterion 4 – Traffic Volume and Truck Percentage.

Site	AADT	Percent Trucks	AADTT
A	47,770	27.5	13,137
B	49,460	27.0	13,354
C	49,460	27.0	13,354
D	49,460	27.0	13,354

Table 14. Criterion 5 – Multiple Lanes.

Site	Number of Lanes	Divided/ Undivided
A	4	Divided
B	6	Divided
C	6	Divided
D	6	Divided

Table 15. Criterion 6 – Access to Power and Telephone.

Site	Distance (ft) to	
	Power	Telephone
A	30-100	100-300
B	30-100	100-300
C	30-100	100-300
D	30-100	100-300

Table 16. Criterion 7 – Distance to Safe Parking.

Site	Distance (ft)
A	0
B	0
C	0
D	0

Table 17. Criterion 8 – Space to Park Calibration Truck.

Site	Space for Truck
A	Yes
B	Yes
C	Yes
D	Yes

Table 18. Criterion 9 – Space for Permanent or Portable Structure.

Site	Space for Structure
A	Yes
B	Yes
C	Yes
D	Yes

Table 19. Criterion 10 – Structure for Mounting Detectors or Cameras (within 200 ft).

Site	Structure for Mounting
A	Yes
B	Yes
C	Yes
D	Yes

Table 20. Criterion 11 – Roadside Mast or Street Light to Mount Cameras.

Site	Roadside Mast/Light
A	No
B	No
C	No
D	No

Table 21. Criterion 12 – Lighting.

Site	Lighting
A	No
B	No
C	No
D	No

Table 22. Criterion 13 – Pavement Condition.

Site	Cracking	Rutting	Smoothness
A	No	No	PSR=5
B	No	No	PSR=5
C	No	No	PSR=5
D	No	No	PSR=5

Table 23. Criterion 14 – Pavement Rehabilitation Schedule.

Site	Months To/ From Rehab
A	12
B	12-24
C	12-24
D	12-24

Table 24. Criterion 15 – Calibration Truck Circuit Time.

Site	Circuit Time (min)
A	15.2
B	12.2
C	19.2
D	19.8

Table 25. Criterion 16 – Sight Distance.

Site	Sight Distance (ft)
A	> 1000
B	> 1000
C	> 1000
D	> 1000

Table 26. Criterion 17 – Proximity to DPS Enforcement Site.

Site	Distance to Enforcement (mi)
A	None
B	None
C	None
D	None

Table 27. Criterion 18 – Availability of Bending Plate WIM System.

Site	Bending Plate Availability
A	Buildable
B	Buildable
C	Buildable
D	Buildable

Table 28. Criterion 19 – Access to Satellite Sites.

Site	Distance (mi) to Satellite Sites
A	0.0-0.5
B	0.0-0.5
C	0.0-0.5
D	0.0-0.5

Table 29. Criterion 20 – Safety Features.

Site	Safety Features
A	Mostly in place
B	Mostly in place
C	Mostly in place
D	Mostly in place

Table 30. Criterion 21 – Presence of Congestion/Stop-and-Go Conditions.

Site	(avg times/week)
A	0
B	0
C	0
D	0

5.3.2 Other Considerations

The only site where TxDOT is planning upcoming construction is Site A. The other three higher ranking sites are within recently reconstructed roadway sections. There may be negative public perception associated with pavement replacement in these sections.

The pending x-ramp designs within these higher ranking sites are also a negative characteristic for two reasons. First, the x-ramp designs will increase the circuit time for the calibration truck and drive those scores lower. Second, an entrance ramp located immediately upstream of the test facility is not desirable due to increased vehicular acceleration and lane changing. Lane changing will induce data errors because of incomplete vehicle occupancy in the lane as it crosses the sensors.

5.3.3 Site Selection Recommendations

Table 31 is a summary of the results of applying the site selection criteria to the four short-listed sites. Based on straight summation of scores and criteria, the sites rank from most attractive to least attractive as follows: B, C, D, then A. Upon applying the weighting criteria, the summation of weighted scores shows that the sites' decreasing attractiveness still ranks as: B, C, D, and A.

Site A is the only site located where upcoming construction is expected. Although Sites B, C, and D rank higher, they are located within recently reconstructed roadway sections. There may be a negative public perception associated with pavement replacement in these recently reconstructed sections. With Site A, future opportunities may exist to coordinate final geometric design with the Waco District to accommodate geometric design needs for the demonstration facility. It would also be advantageous to negotiate the placement of CRCP at Site A within the limits of the demonstration facility during reconstruction of a larger section of roadway in order to minimize additional project and construction expenses and motorist delays.

The foregoing text already noted the problems associated with the pending x-ramp designs at the higher ranking Sites B, C, and D. The x-ramp design would increase the circuit time for the calibration truck and decrease the associated site-ranking scores, which is not indicated in the current rankings. Also, an entrance ramp located immediately upstream of the

Table 31. Summation of Criteria Scoring by Candidate Site.

Critiera	Potential Site ID - Direction						General Notes
	A - NB	A - SB	B - NB	C - NB	D - NB	D - SB	
MP	280.213	280.213	274.136	271.782	269.027	269.027	
1	1	1	2	2	2	2	
2a	2	1	4	2	2	2	
2b	5	5	5	5	5	5	
2c	5	5	5	5	5	5	
3a							Not applicable to any candidate sites
3b	5	5	5	5	5	5	
4	5	5	5	5	5	5	
5	4	4	5	5	5	5	
6	4	4	4	4	4	4	
7	5	5	5	5	5	5	
8	5	5	5	5	5	5	
9	5	5	5	5	5	5	
10	3	3	3	3	3	3	Bridge structure located at all sites
11	3	3	3	3	3	3	
12	4	4	4	4	4	4	
13a	5	5	5	5	3	3	Score from FY2004 PMIS Distress Ratings
13b	5	5	5	5	5	5	Score from FY2004 PMIS Ride Score
14	4	4	4	4	4	4	Site A: expect to let in Jan '05; Sites B-D receently reconstructed
15	3	3	4	3	3	3	
16	5	5	5	5	5	5	
17	2	2	2	2	2	2	
18	3	3	3	3	3	3	
19	3	3	3	3	3	3	
20	5	5	5	5	5	5	
21	5	5	5	5	5	5	

Total	96	95	101	98	96	96
Composite	297	292	318	305	301	301

demonstration facility is not desirable because of both vehicle accelerations through the testing sections where uniform speeds are desired and the secondary impact of increased lane changes to accommodate entering traffic. Lane changing will induce data errors because of incomplete vehicle occupancy in the lane as vehicles pass the sensors.

Sites A and D also have the greatest available right-of-way located between the Interstate mainlanes and the frontage roads to accommodate placement of a demonstration facility and its associated parking needs. The natural grades at these locations also are more desirable so that more extensive earthwork (and likely construction of retaining walls) need not be included in the construction costs of the demonstration facility. Despite the ranked scores, the influence of the aforementioned factors and use of judgment indicated the ranking of sites to be from highest to lowest: A, D, B, and C.

5.3.4 Demonstration Facility Site Schematic

The research team conducted several iterations apart from and with the participation of TxDOT staff to develop a list of infrastructure and equipment needs for the demonstration facility. Figure 27 in Appendix B displays the site schematic for the demonstration facility as it would appear at an interchange quadrant, which is the configuration at each candidate site evaluated. Locating the demonstration facility on a downstream interchange quadrant allows the bridge structure to act as a natural visual barrier for oncoming traffic in order to minimize changes in driving behavior. Locating it south of the overhead bridge (as in the four short-listed sites) provides the best sun angle throughout the year as well.

The site layout includes a small portable structure, surrounded by a chain link fence, located 15 to 30 feet from the edge of the roadway shoulder and at a point where occupants within the building are afforded sufficient view of traffic passing through each demonstration zone. The structure will have a small entrance deck equipped with both stairs and a wheelchair accessible ramp.

Parking will accommodate eight or 16 cars or pickup trucks (one parking area versus two), two calibration trucks of varying lengths, and two handicap-accessible parking spaces. It is desirable to locate the calibration truck parking in an area which will easily accommodate both the storage space and turning radii for a single unit and a single trailer calibration truck. Walkways will connect parking areas and the portable structure enclosed area.

The conceptual plan divides the section of mainlanes adjacent to the portable structure into 10 zones, each 50 feet in length. The authors suggest a total of five zones per direction of travel. Zone 0 begins at the near edge of the overhead bridge structure. This zone could be used for non-intrusive devices which are attached to overhead structures. Zone 5 includes a pole for non-intrusive devices which are attached to poles or mast arms located alongside the roadway. Two locations will have cameras. The first location is on a pole 150 ft downstream of the last zone on the nearest mainlane side. The second location will be on the structure on the far side from the portable structure. The plan provides for guardrail on each side throughout the demonstration zones and just beyond the most downstream pole to protect both the traveling public and TxDOT staff or vendors who may be working alongside the roadway.

Other site-specific considerations include pavement type, overhead lighting, and pavement markings. Because it is desirable to test data collection devices in both concrete and asphalt pavements, the plan includes CRCP in one direction – on the near side beginning 375 ft in advance of the structure and continuing 100 feet beyond the last zone. The plan proposes asphalt pavement for the opposite side. The schematic does not include overhead lighting at this time. Although this lighting is not a critical element to the design, it may be desirable in the future to test equipment under conditions that replicate urban freeway lighting. The current schematic does not indicate the use of special pavement markings. However, it may be desirable to have continuous solid white lane stripes through the demonstration zones to discourage lane changing. Lane changing could negatively affect the results of equipment evaluations.

The preliminary cost estimate for this demonstration facility is approximately $450,000. This cost does not include the placement of CRCP, but does include the material and labor costs of other aspects of the demonstration facility. Appendix B shows a breakdown of these costs. If the cost of traffic sensors and related equipment is removed, the estimated cost of the facility drops to $286,000.

5.4 JUSTIFICATION FOR CONTINUING THE PROJECT

At the outset of this project, TxDOT intended to have a "go" or "no-go" decision at the end of six months of work. However, this decision assumed that the remaining work would rely on having a test site available to conduct the research. Researchers proposed ways to make the remaining tasks productive even without the proposed test site. The following sections discuss the remaining tasks and ways to accomplish them without the new test facility.

5.4.1 (Task 6) Evaluate Lineas Quartz WIM Sensors

The research team will contact the state DOTs in Ohio, Connecticut, Maine, Minnesota, and Illinois to examine their experiences with the Kistler Quartz sensors. If information is available, the project team proposed to use telephone interviews to determine: number of sensors installed, number of failures by type, accuracy data compared to baseline at available time intervals, truck and total traffic volume, installation details such as sensor and inductive loop layout, type of epoxy used, pavement type, weather factors, and any other documented information. Phone interviewers will ask each DOT representative whether that state plans on continuing the use of the Kistlers and the exact application. The result will be a summary of sensor information gathered from each state and appropriate comparisons regarding pavement type and observed equipment performance. The performance of these sensors in ACC will be of particular interest.

5.4.2 (Task 7) Establish Pavement Structural Support Criteria

In this task, the research team will establish minimum pavement structural support criteria to ensure suitable traffic data collection using permanent in-road sensors. Researchers will request information from vendors and as many as five state DOTs based on the failures in Texas. In order to best replicate Texas conditions, researchers will first gather information from

TPP(T) regarding the failures that have occurred in Texas. This might include any information specifically pertaining to a sensor type or manufacturer, pavement type, sensor life, failure mode, truck and non-truck volume, axle weight or other site-specific loading characteristics, and level of enforcement activities.

5.4.3 (Task 8) Establish Optimum Techniques for Bending Plate WIM Systems on Three Plus Lanes

At one of the early project meetings, the project director indicated to researchers that this task would no longer be needed because TPP(T) personnel had apparently already found the solution through other means.

5.4.4 (Task 9) Evaluate East Texas Sensor Failure Mode

The research team proposed two possible means of accomplishing this task: 1) by conducting forensic investigations on failed sensors, and 2) by contacting another agency that might have similar conditions to ask for their input. The first option would require collecting data and other available pertinent information to investigate failure modes of permanently installed sensors in East Texas. If the pertinent information exists, the team will perform a forensic evaluation of the failure mode of these sensors on selected installations in East Texas. The information that project staff will request at each selected site would include: date installed, truck and non-truck volume, historical weather data, pavement parameters (rutting, cracking, or other distress information). There also would be an examination of failed sensors.

If TxDOT does not have sufficient documentation to perform a forensic evaluation, researchers proposed contacting other states that either have conducted a scientifically based investigation or have enough data for project research staff to do so. For sensor data to be transferable to Texas, the research will have to locate a state with similar sensor type and installation techniques, weather, pavement, traffic, and soil types. Some equipment vendors might be helpful in this process as well.

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APPENDIX A

Site Selection Criteria

Table 32. Final Site Selection Criteria.

Objective	Criteria	Scale	Rating			
1. Distance from TPP Shop	Drive time from TPP (Min)	0 < 10	5			
		11 < 20	4			
		21 < 30	3			
		31 < 40	2			
		> 41	1			
2. Roadway geometry			Horiz. alignment (radius of curvature - ft)			
			Tangent	10,000-8,000	8,000-5,700	< 5,700
	Vert. alignment	0.0-0.5	5	4	1	1
	(pos. or neg. % grade)	0.5-1.0	4	3	1	1
		1.5-2.0	2	2	1	1
		2.0+	1	1	1	0
	Cross-slope (%)	0-1	5			
		1-2	5			
		2-3	1			
		3+	1			
	Lane width (ft)	12.5-14	4			
		12.5-12	5			
		12.0-11.5	5			
		11.5-11.0	2			
		< 11.0	1			
3. Pavement structure	PCC thickness (in.)	> 12	5			
		12-10	3			
		10-8	1			
		< 8	1			
	ACC thickness (in.)	> 8	5			
		8-7	5			
		7-6	4			
		6-5	3			
		5-4	2			
		< 4	1			

Table 32. Final Site Selection Criteria. (Continued)

Objective	Criteria	Scale	Rating				
4. High truck volume and good mixture of truck traffic (Classes 3-13 Texas 6 Classification)			% Trucks* (4-lane facility)				
			30-20	20-15	15-10	10-5	5-2.5
	Vehicle traffic	> 40,000	5	5	4	4	3
		40,000-30,000	5	4	4	3	1
		30,000-20,000	4	4	3	2	1
		20,000-10,000	3	3	1	0	0
		10,000-5,000	2	1	0	0	0
		< 5,000*	1	0	0	0	0
			*minimum class 9 trucks = 500 per day in truck lane				
5. Multiple lanes		Lanes	Divided	Undivided			
		6	5	3			
		4	4	3			
		2	0	1			
6. Access to electric power & telephone service			Phone (ft. to service)				
			< 100	100-300	300-1000	1000-2000	> 2000
	Electrical (ft. to service)	< 30	5	5	4	2	1
		30-100	4	4	3	2	1
		100-300	3	2	1	1	1
		300-1000	2	2	1	1	1
		> 1000	1	1	1	1	1
7. Sufficient ROW to allow for safe operations and parking for site users	Distance to safe parking (ft)	0-100	5				
		100-500	4				
		500-1000	1				
		> 1000	1				

Table 32. Final Site Selection Criteria. (Continued)

Objective	Criteria	Scale	Rating			
8. Adjacent space (walking distance) to park calibration truck		Yes	5			
		No	3			
9. Space for permanent or portable structure		Yes	5			
		No	2			
10. Sign bridge structure to mount detectors or cameras (less than 200 ft from site)		Yes	5			
		No	3			
11. Roadside mast to mount sensors (min 30 ft from edge of pvmt and 30 ft tall)		Yes	5			
		No	3			
12. Lighting		Yes	5			
		No	4			
13. Pavement condition			Cracking			
			None	Slight	Moderate	Severe
	Rutting (in)	0-1/16	5	4	2	1
		1/16-1/8	5	3	2	1
		1/8-3/16	4	3	1	1
		3/16-1/4	3	2	1	1
		1/4-5/16	2	2	1	1
		5/16-3/8	1	1	1	1
		> 3/8	1	1	1	1
	Pavement smoothness (PSR)	5	5			
		4	5			
		3	3			
		< 3	1			
14. Pavement rehabilitation programming	Rehab schedule (mo. until or since rehab)	6 mo. Before	5			
		0-12 mo. After	4			
		12-24	4			
		24-36	3			
		36-48	2			
		48-60	1			
		> 60	0			

Table 32. Final Site Selection Criteria. (Continued)

Objective		Criteria	Scale	Rating
15.	Turnaround time for test truck (min.)		<5	5
			5-10	5
			10-15	4
			15-20	3
			20+	1
16.	Sight Distance (ft)		> 1000	5
			1000-500	4
			500-300	3
			300-200	3
			< 200	2
17.	Proximity to DPS weight enforcement facility (miles upstream or downstream)		0.5-1.0	5
			1.0-2.0	4
			2.0-3.0	4
			3.0 +	3
			none	2
18.	Bending Plate WIM system		Existing	5
			Buildable	3
			Not buildable	1
19.	Access to satellite sites (mi. from site)		0-0.05	3
			> 0.05	2
20.	Safety features		Mostly in place	5
	(e.g., longitudinal barrier to roadside)		Requires installation	4
			Installation not possible	0
21.	Congestion	Stop-and-go conditions (avg. times/week)	0	5
			1-3	2
			4+	1

APPENDIX B

General Site Layout and Cost Estimate

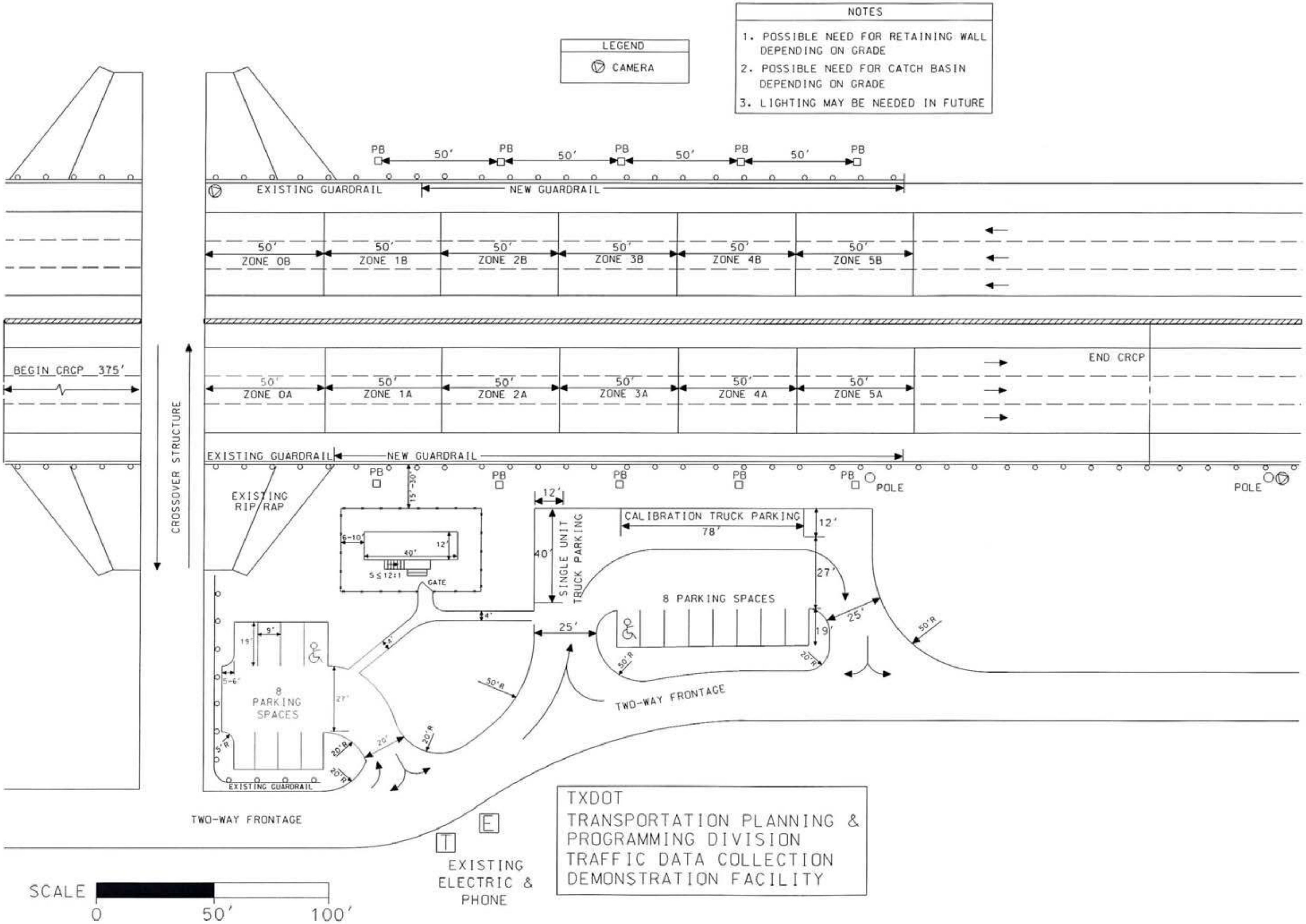

Figure 27. General Site Layout.

Table 33. TPP Test Facility Cost Estimate.

Description	TxDOT Spec#		Unit	Quantity	Unit cost	Total cost
6-inch crushed stone base (Type A, Grade 1) for equipment enclosure, parking and truck parking	247	857	SY	1465	$ 8.00	$ 11,720.00
Operations equipment enclosure (12 ft X 40 ft)	1461	501	EA	1	$27,000.00	$ 27,000.00
Deck with ADA ramp access			EA	1	$ 3,000.00	$ 3,000.00
8-ft chain link fence, 80 ft x 30 ft	550	568	LF	220	$ 12.95	$ 2,849.77
Vehicle gate (DOUBLE) (6 ft X 14 ft)	550	503	EA	2	$ 1,350.00	$ 2,700.00
Pedestrian gate (4 ft X 6 ft) (BARB TOP)	550	552	EA	1	$ 355.00	$ 355.00
Lightning rods and cable			EA	1	$ 250.00	$ 250.00
Hardware firewall			EA	1	$ 650.00	$ 650.00
Industrial computers			EA	4	$ 2,500.00	$ 10,000.00
Computer racks and monitors			EA	1	$ 1,500.00	$ 1,500.00
Weather station			EA	1	$ 5,000.00	$ 5,000.00
802.11 Ethernet bridge base			EA	1	$ 1,500.00	$ 1,500.00
802.11 Ethernet switch			EA	1	$ 1,500.00	$ 1,500.00
Network Ethernet hubs (high temperature)			EA	4	$ 400.00	$ 1,600.00
Direct burial Ethernet cable			LF	2000	$ 0.31	$ 620.00
BJFAS phone line (TWP) (6 PAIR) (19 AWG)	1456	501	LF	1000	$ 1.00	$ 1,000.00
CDMA modem for Internet and communications			EA	1	$ 400.00	$ 400.00
Parking spaces, 2-inch Type D asphalt concrete pavement	354	510	SY	361	$ 1.65	$ 595.77
Guardrail, metal beam gauge 10	540	509	LF	400	$ 13.84	$ 5,535.59
Roadway bore and 6-inch conduit for communications	618	543	LF	120	$ 63.00	$ 7,560.00
Roadway bore and 3-inch conduit for cabinet power			LF	120	$ 50.00	$ 6,000.00
Roadway bore and 3-inch conduit for 3-M micro-loops (2)			LF	240	$ 50.00	$ 12,000.00
6-inch conduit (PVC) (SCHD 40) roadside to trailer (w/ MaxCell)	618	515	LF	180	$ 7.43	$ 1,337.18

Table 33. TPP Test Facility Cost Estimate (Continued).

Description	TxDOT Spec#		Unit	Quantity	Unit cost	Total cost
2 ft x 4 ft pull boxes	624	508	EA	10	$ 549.93	$ 5,499.30
3 ft x 5 ft pull boxes			EA	3	$ 1,328.00	$ 3,984.00
150 amp service with pole			EA	1	$ 1,500.00	$ 1,500.00
Surge protector for power service			EA	1	$ 150.00	$ 150.00
Loop detector (TY 1) (6 ft X 6 ft)	6505	503	EA	24	$ 870.00	$ 20,880.00
Loop lead-in cable IMSA Spec 50-2		684	LF	4000	$ 0.24	$ 960.00
Piezo quartz WIM sensor			LN	4	$ 8,000.00	$ 32,000.00
Piezo ceramic WIM sensors	1211	501	EA	12	$ 1,200.00	$ 14,400.00
Bending plate WIM			EA	1	$50,000.00	$ 50,000.00
Microwave vehicle presence detector	8993	501	EA	1	$15,000.00	$ 15,000.00
RTMS radar vehicle detector	8912	501	EA	1	$ 4,000.00	$ 4,000.00
Color PTZ camera with associated hardware			EA	2	$ 5,000.00	$ 10,000.00
Pole structure 40 ft to mount camera/traffic sensors	1484	501	EA	3	$18,090.00	$ 54,270.00
3/4-inch PVC Conduit (for loop lead-in from roadway)			LF	200	$ 3.10	$ 620.00
3/4-inch PVC Conduit (for phone line)			LF	2000	$ 3.10	$ 6,200.00
2-inch schedule 40 PVC for pull box interconnections, power, coaxial, fiber optic cable runs as needed			LF	2000	$ 3.40	$ 6,800.00
Equipment cabinets, communication cabinet (TY 2)	1484	502	EA	5	$ 2,520.00	$ 12,600.00
Cabinet foundation			EA	5	$ 2,000.00	$ 10,000.00
Construction management (15%)						$ 53,030.49
Subtotal						**$406,567.10**
Contingency (10%)						$ 40,656.71
Grand Total						**$447,223.81**