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16. Abstract

This report summarizes the accomplishments of the Texas A&M Intelligent Transportation Systems (ITS) Research Center of Excellence (RCE) during Fiscal Year 1997-98.

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Texas A&M ITS Research Center of Excellence
Narrative Summary Report
Fiscal Year 1997-98

INTRODUCTION

During Fiscal Year 1997-98, the Texas A&M Intelligent Transportation Systems (ITS) Research Center of Excellence (RCE) continued work on 20 projects funded by five sponsors: Texas Department of Transportation (TxDOT), Federal Highway Administration (FHWA), Metropolitan Transit Authority of Harris County (METRO), Dallas Area Rapid Transit Authority (DART), and Texas Transportation Institute (TTI). Table 1 is a summary of projects active during the year and includes the names and contact information for the research supervisor who can provide additional information. The report is organized into two sections. Section 1 describes key findings from the active projects over the last year. Section 2 identifies products and presentations completed during the fiscal year. Copies are available upon request of any items included.

Table 1 Texas A&M ITS RCE Active Projects: FY 1997-98

Project	FY97-98 Funding	Title	TTI Research Supervisor	Telephone	E-mail
TM-01	TxDOT/FHWA/TTI	Develop Real-Time, Multimodal Traffic Adaptive Diamond Interchange Control System	Tom Urbanik II	409-845-1536	t-urbanik@ttimail.tamu.edu
TM-02	FHWA	Integrate Railroad Information	Jack Webb	409-862-7918	jwebb@ttiadmin.tamu.edu
TM-04	TxDOT/FHWA	CVO Weight Enforcement Screening	Dan Middleton	409-845-7196	d-middleton@ttimail.tamu.edu
TM-05	TxDOT/FHWA	Develop an Intelligent Bus Priority Algorithm for Arterial Street Systems	Kevin Balke	409-845-9899	k-balke@ttimail.tamu.edu
TM-06	TxDOT/FHWA	Evaluate Automatic Vehicle Identification for Travel Time Estimates and Incident Detection	Larry Rilett	409-845-9880	rilett@ttiadmin.tamu.edu
IB-01	TxDOT/FHWA	Improve Transportation Efficiency in the U.S. - Mexico Border Area Through the Use of ITS Technology	Eric Lindquist	409-845-9945	e-lindquist@ttimail.tamu.edu
IB-02	FHWA	ITS Benefits Framework	Tim Lomax	409-845-9960	t-lomax@ttimail.tamu.edu
PT-01	FHWA/METRO	Improve Specialized Transportation Delivery/METROLift Phase II Assessment	Laura Higgins	409-845-8109	l-higgins@ttimail.tamu.edu
PT-02	FHWA/METRO/DART	Integrate Transit into Advanced Traffic Management Systems	Katherine Turnbull	409-845-1535	k-turnbull@ttimail.tamu.edu
PT-03	FHWA	Enhance the Houston Smart Commuter IVHS Operational Test	Katherine Turnbull	409-845-1535	k-turnbull@ttimail.tamu.edu
PT-04	FHWA	Improve Rural Transit Service Delivery	Katherine Turnbull	409-845-1535	k-turnbull@ttimail.tamu.edu
PT-05	FHWA/METRO	Enhance Transit Operations and Innovative Services/Bus Notification System Development	Darryl Puckett	713-686-2971	d-puckett@ttimail.tamu.edu
PT-06	FHWA/METRO	Enhance Travel Demand Management and Transportation Control Measures/Develop Traveler Information System	Bill Stockton	512-467-0946	b-stockton@ttimail.tamu.edu
DO	FHWA/TTI	Director's Office	Tom Urbanik II	409-845-1536	t-urbanik@ttimail.tamu.edu
TI-01	FHWA	Technology Integration Issues	Tom Urbanik II	409-845-1536	t-urbanik@ttimail.tamu.edu
TI-02	FHWA	Establish a Framework for Identifying Unique Routes in the Transportation System	Larry Rilett	409-845-9880	rilett@ttiadmin.tamu.edu
TT-PC	FHWA	Professional Capacity Building	Beverly Kuhn	512-467-0946	b-kuhn@ttimail.tamu.edu
TT-TL	TTI	Technology Transfer Training Lab	Tom Urbanik II	409-845-1536	t-urbanik@ttimail.tamu.edu
TT-TT	FHWA	Technology Transfer	Susan Lancaster	409-845-1734	slancaster@ttiadmin.tamu.edu
TT-WS	FHWA	Workshops/Seminars	Gerald Ullman	409-845-9908	g-ullman@ttimail.tamu.edu

SECTION 1
KEY POINTS AND LESSONS LEARNED

1.1 TRANSPORTATION MANAGEMENT SERVICES

1.1.1 TM-01: Develop Real-Time, Multimodal, Traffic Adaptive Diamond Interchange Control System

Video Imaging Equipment:
The Odetics video imaging equipment was used to obtain turning movement counts by placing loops at strategic locations and developing an algorithm to use the actuations by traffic. However, there were some problems with the traffic counts.

- Loops were being actuated by shadows of vehicles. This was a more consistent problem with bigger vehicles. Hence, it appears advisable to position and point cameras as vertical as possible. This can be done even for cameras placed at a height of 30 feet. While this may allow fewer loop placement opportunities, the accuracy of the data obtained from them will be higher. This tentative finding will be evaluated next year.

- Loops were being actuated by vehicles traveling in other movements and in other directions. This was happening in spite of specifying the video imaging equipment to detect vehicles moving only in one direction. Hence, it is recommended not to place the loops in the traveled way of other traffic movements.

- Placement of numerous loops can create a very complicated algorithm to obtain turning movement counts. Hence, it is recommended to minimize the number of loops located in the intersection area.

- It is recommended to place loops downstream of the intersection. Placing the loops at the stop bar to obtain counts may result in inaccurate counts.

- The video imaging vendors provide proprietary communication protocol with their systems, requiring additional software work to integrate/upgrade equipment from other vendors. Secondly, video imaging systems do not have a standard output for both surface street applications and freeways. It is hoped that with the advent of NTCIP standards, this problem will be alleviated.

Inductive Loops for Turning Movement Counts

- Inductive loops were installed in conjunction with some of the existing loops to obtain turning movement counts. This was done due to inaccurate turning movement counts from the video imaging system.

- Inductive loops have provided very reliable data to compute the turning movement counts at the interchange. A total of 15 loops are being used to calculate the turning movement counts. These loops were placed in each lane, and the data from each detector is required independently to compute the counts.

- It is essential to place the loops in strategic locations at the interchange. Most of the loops were placed downstream of the movement to be calculated. These loops should be placed approximately 70 to 100 feet downstream of the intersection area.

- Care should be taken to ensure proper installation of loops. Loops in adjacent lanes should be adequately separated to avoid detecting a single vehicle by both loops, resulting in erroneous counts.

Microwave Radio

Microwave radio was used to transmit detector actuations in lieu of cables through the conduit. This was done because the conduit was full, and it was too expensive to put in new conduit for just four inductive loops.

- Microwave radio can be useful when it becomes cost prohibitive to layout conduit/cables back to the cabinet. However, they do have some limitations. They can get interference from adjacent structures that may also be using microwave transmissions. They also require a line of sight for proper reception.

PASSER III-98

PASSER III-98 was developed to be used on Windows 95/98 and is being sent to McTrans for distribution. A copy of the software is enclosed. The program will be upgraded to be functional on Windows NT operating system. A draft user manual and report documenting the software and architecture are being developed.

1.1.2 TM-02: Integrate Railroad Information into Advanced Traffic Management Systems

A draft research report has been prepared summarizing activities undertaken by the RCE to integrate highway/railway intersections into an intelligent surface transportation system. Findings include:

- Current state of the practice for rail integration remains as an archaic method of providing information between controllers.

- Institutional barriers have constrained the development of rail-related ITS improvements.

- Utilizing simple, short-way algorithms is not the most efficient approach to adjust the offset of the phase sequence when a preemption event terminates.

1.1.3 TM-04: CVO Weight Enforcement Screening

- Developed software to interpret weigh-in-motion (WIM) serial output to determine possible overweight trucks.

- Developed an alarm mechanism triggered by parameters sent by the WIM system to determine when to send truck weights and image to police vehicle.

- Continued site enhancement by installing concrete pad, security fence, and weather station.

- Determined the effectiveness of using Cellular Digital Packet Data (CDPD) for transmitting pictures of trucks and weight data.

- This project was intended to be a "proof of concept," so continued extensive use of the WIM and camera system requires further refinement.

- WIM accuracy is significantly compromised when only one piezoelectric sensor is used. There should be a minimum of two.

- Camera heights of 10 to 15 feet work well for capturing an image of the side of the entire truck for later identification. Cameras with high shutter speeds are preferred but not essential.

- The time required to send an image via CDPD is sometimes undesirably slow.

- The concept of using an Internet site to send data worked reasonably well.

- The distance range of the image transfer is limited to approximately two to three miles, requiring the police car to remain relatively near the WIM site or a transmitting station.

- For site design, the minimum roadway distance from WIM sensors to the camera is a function of truck detector processing speed. In this case, a distance of 200 feet was sufficient.

- Failure of Preformed Inductive Loops: Preformed loops manufactured by Never Fail Loops were installed under a hot-mix asphalt overlay. As prescribed by the loop vendor, left-lane loop leads that were exposed to open traffic lanes prior to overlay in the right lane were secured in place with bituminous tape. Every left-lane loop with leads running across the open traffic lanes failed within a matter of days.

1.1.4 TM-05: Develop an Intelligent Bus Priority Algorithm for Arterial Street Systems

- The algorithm was designed to operate with TS-2 and NTCIP compliant traffic signal controllers. Standard controller commands were used to implement the priority strategy. No modifications to the internal programming of the controllers were needed to implement the algorithm.

- Laboratory testing of the algorithm was performed using real traffic signal controllers (Eagle EPAC 300) and the TexSIM Traffic Simulation Model in the TransLink® Roadside Equipment Laboratory. The algorithm was tested on a three-intersection network with near-side bus stops and at three volume-to-capacity levels: 0.5, 0.8, and 0.95.

- Algorithm performed successfully for 92 to 95 percent of the buses. Of the "on-time" buses, 100 percent were correctly identified as not needing priority and were not granted priority. Of those buses that needed priority (i.e., were behind schedule), 83 to 91 percent of the buses were granted priority. Most failures of the algorithm were attributed to errors in the TexSIM simulation model. The algorithm never caused the controllers to lose coordination.

- Significant reductions in bus travel times (between 25 and 27 percent reductions) were observed for buses at each volume level. Only minor increases in average stop delay were experienced on the non-priority intersection approaches at two of the volume levels (less than a 10 percent increase in average stop delay). It was not until the volume-to-capacity level of the intersection reached 0.95 that substantial increases in average stop delay were observed.

- An analysis was performed to examine how intersection spacing affected the performance of the bus. The analysis showed that the performance of the algorithm was the same at each of the intersection spacing levels examined.

1.1.5 TM-06: Evaluate Automatic Vehicle Identification (AVI) Data for Travel Time Estimation and Incident Detection

Travel time forecasting models have been developed based on AVI data from Houston, Texas. Findings include:

- Artificial Neural Networks (ANN) can be developed for forecasting link travel times for the near future (i.e., 5-45 minutes). The best models incorporate both the recent travel times on the target link and the recent travel times on links immediately upstream and downstream from the target link.

- The Artificial Neural Networks (ANN) forecasting models outperformed real-time travel time information which is currently displayed on the TxDOT web page. That is, assuming that current travel times will continue to be valid into the near future did not give as accurate a result as the ANN models. The average improvement of the ANN models as compared to the real time data was on the order of 40 percent. While the accuracy of both techniques declined as the forecast time period increased, the decline in accuracy of the ANN models was at a lower rate (i.e., as the forecast period increased, the accuracy of the ANN models improved relative to the real-time information).

- The Artificial Neural Networks (ANN) forecasting models outperformed historical travel time information. The average improvement of the ANN models as compared to historical data was on the order of 100 percent. As the forecast time period increased (i.e., the longer into the future), the accuracy of the ANN models decreased. When forecasting approximately 25 to 35 minutes into the future, the historical travel times gave better estimates than the ANN models. That is, after approximately half an hour, the benefits of the real-time AVI information disappears with respect to modeling link travel times.

- Using a preclustering technique (identifying trends in the travel times before forecasting the travel times) improves the travel time forecasts by approximately 30 percent. In addition, artificial intelligence techniques (spectral basis analysis) are available that make this preclustering automatic.

- When predicting corridor travel times with ANN models, it was found that the error terms are non-additive. For example, while the error of the one-time period ahead forecasting on four links averaged 10.8 percent, the average error of the predicted route travel times was only 8.0 percent.

- It was also found that direct forecasting of route or corridor travel times without link travel times gave better results than the two-step approach used in conventional route/corridor travel time forecasting models.

1.2 INTERNATIONAL BORDER TRANSPORTATION

1.2.1 IB-01: Improve Transportation Efficiency in the U.S.-Mexico Border Area Through the Use of ITS Technology

- Hazardous materials transport and incident response survey and content analysis was conducted on three Texas communities: El Paso, College Station, and Sonora.

- Survey research was conducted for types of tourism sites in the Lower Rio Grande Valley and transportation problems associated with these sites.

1.2.2 IB-02: ITS Impact Framework

The USDOT ITS goals were examined along with the literature on impacts for ITS projects. The research report identifies several areas for improvement if the DOT goals are to be fully quantified. Not all the effects will show up as benefits — thus the term "impacts" is used throughout the report. Key aspects of the conclusions include:

- Private sector impacts must be emphasized in more studies. Economic development and productivity are discussed as goals in many documents, but relatively few measures are used.

- Some impacts are not easily quantified, and because of that, they have not been included. Moving toward a multi-criteria analysis where quantitative and qualitative factors can be included will improve the breadth of the impact assessment.

- A twin improvement strategy of examining case studies in the near term while better project level analyses are being conducted in the long term appears to be a way to improve the information available to project planners and engineers.

- Equity and privacy are two issues that have been discussed in the literature but rarely addressed in any comprehensive manner. These are important impacts to some affected groups.

- Impact estimation has not suffered from an extensive "double-counting" problem yet, but as more data become available, this will affect the validity of the analyses. A common problem is estimating the value of time saved and adding all the increased land value as another benefit (i.e., some of the land value increase relates to the decrease in travel time).

- An observation on the state of the ITS products market is that many individual technologies have a more beneficial effect if implemented as a set of techniques forming a strategy. Many of the larger systems and DOT deployment tests recognize this. It may be difficult to estimate the effect of individual technological elements, but the system effects are more relevant anyway. This may help the private sector suppliers understand the need for a "critical mass" of ITS improvements by integrating the system elements.

1.3 PUBLIC TRANSPORTATION SERVICES

1.3.1 PT-01: Improve Specialized Transportation Service Delivery

- Analyzed Trapeze/PASS paratransit scheduling software and identified available capacity that may be used for same-day trip scheduling. Slack time periods of 15 minutes or more were identified for all vehicles. Researchers are analyzing methods to fill this available capacity through same-day trip scheduling.

- A survey was developed and sent to 35 transit agencies in North America to obtain information on current practices related to real-time paratransit trip scheduling.

- A set of functional specifications was developed for a METROLift in-vehicle traffic information and navigation system.

1.3.2 PT-02: Integrate Transit into Advanced Traffic Management Systems

This project is examining techniques to enhance the integration of transit with ATMS. Using Houston and TranStar as a case study, researchers interviewed key METRO operations, planning, and police personnel, along with staff from TxDOT, TranStar, the city of Houston, and Harris County. A national review of transit and ATMS was also conducted. The following key findings emerged from the Houston case study and the national review. The DART case study is underway.

- METRO and METROLift operations personnel are very interested in receiving real-time information from TranStar. Currently, available information identified that would benefit transit and paratransit staff (operators, on-street supervisors, dispatchers, police, and other personnel) include real-time freeway and HOV traffic conditions; the location and severity of accidents on the freeways, HOV lanes, and frontage roads; flooding conditions; and current weather conditions and forecasts.

- METRO planning and operation staff identified a variety of information from TranStar that could be used in short- and long-term transit route and schedule planning. These include average speeds on freeways and HOV lanes, monitoring scheduling adherence with the AVI system, pinpointing specific bottlenecks and problem areas, and identifying new travel markets.

- METRO currently operates a fleet of 1,200 buses on fixed routes and 153 METROLift vehicles. In addition, on-street supervisors, METRO police, and maintenance personnel are routinely on the local street and freeway systems. TranStar personnel from TxDOT, the city of Houston, and Harris County identified a wide range of information that METRO and METROLift operations could provide to enhance their jobs and functions. These include confirming and expanding on traffic conditions and accidents on freeways and HOV lanes; traffic conditions and accidents on arterial streets; traffic signal malfunctions; blocked railroad grade crossings; flooding and weather-related problems; and other situations.

- Both manual and automated techniques were identified for transmitting information to and from TranStar and METRO operations personnel and vehicles. Manual methods include METRO operations staff communicating with the METRO dispatchers, who are now located in the TranStar control room. Automated methods include the mobile data terminals (MDTs), the AVI system, and the future AVL system.

1.3.3 PT-03: Enhance the Houston Smart Commuter ITS Operational Test

Researchers worked with hotels in the area around George Bush Intercontinental Airport in Houston to test the use of the Smart Commuter Magic Link™ devices and the real-time traffic map with visitors. Surveys were developed to obtain input from visitors and business travelers on the type of traffic and transit information they would find of value and to evaluate the test.

- Although hotel personnel expressed interest in the project initially, it has been difficult obtaining agreement to actually participate in a test. The main issues appear to be related to security and liability for computers or the Magic Link™ devices, and concerns that these devices do not fit into the image the hotels are trying to project in their lobbies.

1.3.4 PT-04: Improve Rural Transit Service Delivery

The following issues are related to the use of AVL technologies:

- The AVL components include a global positioning system (GPS) with correctional differential GPS (DGPS) to provide information on vehicle location through an ultrahigh frequency (UHF) radio operating at 460 MHz. The basic system, which expanded on an AVL configuration developed initially by the Mapping Science Laboratory for a range management project, was deployed without major technical difficulties. Some ongoing operations and maintenance concerns have emerged, however.

- Both technical and institutional issues were encountered with the preliminary testing of the AVL system on Brazos Transit vehicles. Problems encountered included the bus operators periodically turning off the AVL devices, power surges, and difficulties in obtaining time from busy maintenance personnel to install and upgrade the on-vehicle units.

- The AVL system performed well in preliminary tests. Data from the AVL system was monitored at 10-second, 30-second, and one-minute intervals, and vehicles were tracked up to 45 to 60 miles from the antenna site.

- Researchers are now working with the Texas A&M University to test the use of the AVL system in combination with alphanumeric paging technology. The test is focusing on providing advance notification to paratransit riders of an approaching vehicle.

1.3.5 PT-05: Enhance Transit Operations and Innovative Services

- The Gulf Freeway HOV Lane Bus Notification System is using a 390 MHZ RF transmitter, a new overhead mounted sign on the HOV lane, and a button at the Eastwood Transit Center. Pre-tests of the system indicated problems with the RF signal strength. METRO ordered a new radio antenna to address this problem. The antenna will be installed, and the pre-testing will restart in FY 99.

- The Next Bus Passenger Information System project is using commercially available AVL and GIS technologies. The project has been delayed by the need to obtain METRO Board approval of the subcontract with the private company supplying the AVL and GIS technologies.

1.3.6 PT-06: Enhance Travel Demand Management (TDM)

The Downtown/Midtown Construction Traveler Information Plan for use during the major reconstruction of streets in the downtown and midtown areas of Houston was completed. The following highlight the recommendations in the plan.

- The near-term plan for the downtown traveler information system involves the three elements of data collection, data fusion, and information dissemination. Establishing a single clearinghouse for downtown work zone activities and strengthening contract language and permitting procedures to require greater responsibility and accountability for mobility on the part of contractors were recommended. Information dissemination methods include AM/FM radio, television, newspapers, the Internet, voice mail systems, E-mail list servers, changeable message signs, and information kiosks. Costs are included in the report.

- The longer-term implementation plan focuses on the potential use of video cameras and cellular telephones for monitoring downtown construction and traffic. These methods could provide enhanced real-time information to travelers. The number of cameras needed for monitoring and the costs associated with this approach are included in the report.

1.4 TECHNOLOGY INTEGRATION ISSUES

1.4.1 TI-02: Establish a Framework for Identifying Unique Routes in the Transportation System

A draft research report has been prepared, and the major findings include:

- A route selection framework for dynamic and stochastic traffic networks for a decentralized RGS which explicitly takes into account the drivers' various route choice criteria has been developed. The adopted approach first entails identifying reasonable multiple paths which are acceptable from drivers' viewpoints in terms of not only route attributes but also route similarity and then identifying the most promising routes using fuzzy theory.

- It was found that the routes developed by the k reasonable path algorithm are significantly different in terms of links used than standard k-shortest path algorithms that have historically been used.

1.5 TECHNOLOGY TRANSFER

1.5.1 TT-PC: Professional Capacity Building

- An education module was developed that targets an undergraduate engineering audience and was compiled on Microsoft PowerPoint for easy dissemination.

1.5.3 TT-TT: Technology Transfer Outreach

- Exhibits were prepared for the ITS Texas Conference in College Station, Texas, highlighting the RCE research and the efforts of the National Transportation Communications for ITS Protocol (NTCIP).

- Research reports and articles were written, edited, printed, and included on the RCE Clearinghouse web site.

1.5.4 TT-WS: Workshops/Seminars

- Video Detection Technologies Workshop was prepared and is to be presented at the ITS Texas Meeting in Austin, Texas, on November 17.

- A joint Caltrans-PATH-TxDOT-TTI ITS Deployment Research Meeting was held at TranStar on June 16-18. Topics included ITS data use and management, ramp metering, linking state ITS laboratories, and professional capacity building as it relates to ITS.

SECTION 2
PRODUCTS AND PRESENTATIONS

2.1 TRANSPORTATION MANAGEMENT SERVICES

PASSER III-98 version 1.0.

Koonce, P., and T. Urbanik II. Evaluation of Diamond Interchange Signal Controller Setting Using Hardware-in-the-Loop Simulation. Submitted for publication and presentation at the Transportation Research Board 78th Annual Meeting. Washington, D.C. January 1999.

Park, B., C. J. Messer, and T. Urbanik II. Traffic Signal Optimization Program for Oversaturated Conditions: A Genetic Algorithm Approach. Submitted for publication and presentation at the Transportation Research Board 78th Annual Meeting. Washington, D.C. January 1999.

Park, B., C. J. Messer, and T. Urbanik II. Initial Evaluations of New Transyt-7F Version 8.1 Program. Submitted for publication and presentation at the Transportation Research Board 78th Annual Meeting. Washington, D.C. January 1999.

Park, B., C. J. Messer, and T. Urbanik II. Comparisons of GA Based Signal Optimization Program with Transyt-7F Version 8.1 for Closely-Spaced Oversaturated Intersections. Submitted for publication and presentation at the Transportation Research Board 78th Annual Meeting. Washington, D.C. January 1999.

Rilett, L. R., and D. Park. Direct Forecasting of Freeway Corridor Travel Times Using Spectral Basis Neural Networks. Paper submitted for publication and presentation at the Transportation Research Board 78th Annual Meeting. Washington, D.C. January 1999.

Park, D., and L. R. Rilett. Forecasting Freeway Link Travel Times with a Multilayer Feedforward Neural Network. Computer-Aided Civil and Infrastructure Engineering, Special issue on Advanced Computer Technologies in Transportation Engineering. Accepted for publication in August 1998.

Park, D., L. R. Rilett, and G. Han. The Use of Spectral Basis Neural Networks For Real-Time Link Travel Time Forecasting. Paper submitted to the ASCE Journal of Transportation Engineering, August 1998.

Koonce, P. An Evaluation of Diamond Interchange Operations Using PASSER III-98 and Hardware-in-the-Loop. Presented at the TexITE Summer Meeting. Austin, Texas. June 18, 1998. Awarded First Place in District 9 Student Paper Competition.

Webb, J. W., R. T. Bartoskewitz, H. A. Richards, S. P. Venglar, D. E. Bullock, and T. Urbanik II. Summary of Highway/Rail Intersection Research at the Texas A&M University Research Center of Excellence. Draft report. June 1998.

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Park, D., and L. R. Rilett. Forecasting Multiple-Period Freeway Link Travel Times Using Modular Neural Networks. Presentation at Transportation Research Board 77th Annual Meeting. Washington, D.C. January 1998.

Urbanik II, T. Comprehensive Management of the Surface Transportation System. PTI Seminar. State College, Pennsylvania. October 23, 1997.

Urbanik II, T. Smart Diamond, Using ITS to Improve Traffic Signal Control. Presentation at MASITE Central Section. State College, Pennsylvania. October 23, 1997.

Middleton, D. Enhancements to CVO Enforcement. Paper presented at the International Truck Safety Symposium. Knoxville, Tennessee. October 1997.

2.2 INTERNATIONAL BORDER TRANSPORTATION

Lindquist, E. ITS, Hazardous Materials Transport, and Local Emergency Response: Findings and Recommendations. Paper submitted to the 1999 ITS America Conference. September 1998.

Lindquist, E. ITS Applications for Tourism-Related Congestion in the Lower Rio Grande Valley. Paper submitted for the 1999 ITS Annual Meeting. September 1998.

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Turnbull, K. F., and T. Kelly. Integrating Transit with Advanced Transportation Management Systems: The Houston Case Study. Paper presented and published at the 4th ITS World Congress. Berlin. October 1997.

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Butorac, J. An Analysis of Multiple Paths in Transportation Networks. M.S. Thesis, Civil Engineering. December 1997.

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