2003

Status Report on TRANSIT INTELLIGENT VEHICLE INITIATIVE STUDIES

U.S. Department of Transportation

ITS Joint Program Office

FTA Federal Transit Administration

INTELLIGENT VEHICLE INITIATIVE

Technical Report Documentation

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16. Abstract

This 2003 Status Report provides an overview and updates on studies in the transit Intelligent Vehicle Initiative (IVI) area. IVI emphasizes the significant and continuing role of drivers in roadway safety. IVI is aimed at accelerating the development, availability, and use of driving assistance and control intervention systems to reduce vehicle crashes. IVI systems' ultimate goal is to help drivers process information, make decisions, and operate vehicles more safely.

The emphasis of the transit IVI program can be divided into two major areas. Projects in the first area include the frontal collision warning system, side collision warning system, rear impact collision warning system, and integrated collision warning system. These projects are intended to reduce "imminent crash situations" in the transit operating environment. The second area of emphasis for the transit IVI program is to assist bus operators in "degraded driving conditions." One example is the vehicle-lane assist technology project. Vehicle-lane assist technology is intended to improve the safety of transit vehicles as they operate in difficult environments, such as bus-only shoulders. Vehicle-lane assist technology is likely to be one of the first IVI technologies to be implemented for Bus Rapid Transit (BRT) operations.

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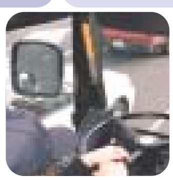
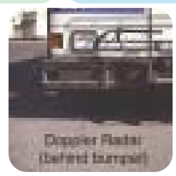
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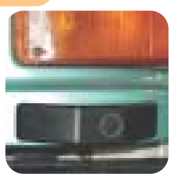
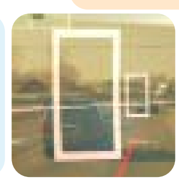





I INTRODUCTION

In 1997, the U.S. Department of Transportation (DOT) began merging vehicle-safety focused Intelligent Transportation Systems (ITS) activities into a multi-agency research and development program, entitled the Intelligent Vehicle Initiative (IVI). The 1998 Transportation Efficiency Act for the 21st Century (TEA-21) officially authorized IVI as part of DOT's ITS program.

IVI emphasizes the significant and continuing role of drivers in roadway safety. IVI is aimed at accelerating the development, availability, and use of driving assistance and control intervention systems to reduce vehicle crashes. IVI systems' ultimate goal is to help drivers process information, make decisions, and operate vehicles more safely.

The emphasis of the transit IVI program can be divided into two major areas. Projects in the first area include the frontal collision warning system, side collision warning system, rear impact collision warning system, and integrated collision warning system. These projects are intended to reduce "imminent crash situations"[1] in the transit operating environment.

The ultimate goal for transit collision warning systems is to provide bus operators effective and timely warnings regarding potential accidents. Transit travel will become safer and more efficient if the number of transit accidents can be effectively reduced. According to the National Transit Database (NTD), the number of bus accidents from 1991 to 2000 has been reduced by more than 50% (see Figure 2).

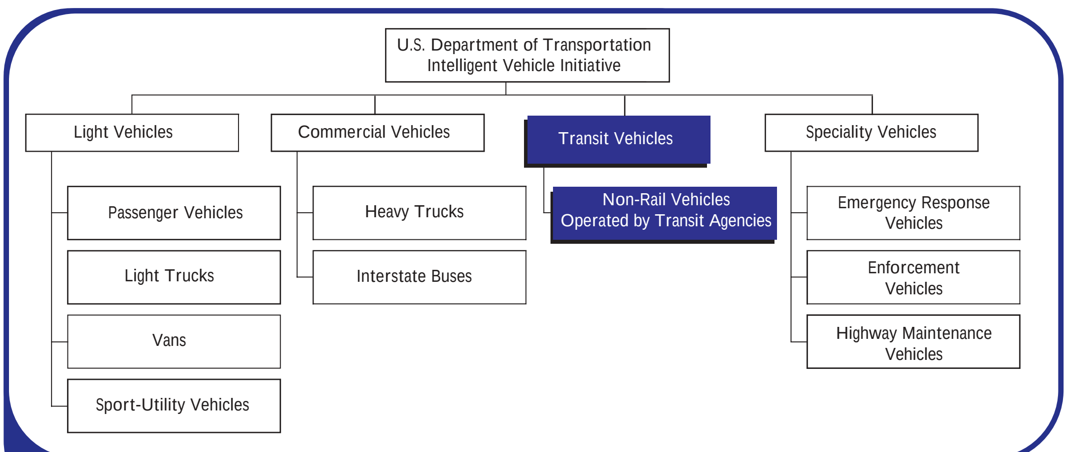


FIGURE 1. Vehicle Platforms for the Intelligent Vehicle Initiative

Four DOT agencies participate in the IVI: the Federal Transit Administration (FTA), the Federal Highway Administration (FHWA), the Federal Motor Carrier Safety Administration (FMCSA), and the National Highway Traffic Safety Administration (NHTSA). The DOT's ITS Joint Program Office coordinates the IVI activities. IVI addresses four classes or "platforms" of vehicles: light vehicles, commercial vehicles, transit vehicles, and specialty vehicles (see Figure 1). Information presented in this report will focus on the status of projects under the transit platform of IVI, overseen by the FTA.

Much of the bus accident reduction in that ten-year span can be credited to transit agencies placing stronger emphasis on safety resulting in better training for bus operators.

Although bus accident reduction was significant from 1991 to 2000, Figure 2 also reveals that the total number of bus accidents remained relatively stable since 1995 and thus prompted motivation to examine other methods to further reduce bus accidents. The collision warning systems being developed under the transit IVI program are excellent examples of the transit industry's continual effort to improve the safety of transit travel.

[1] To prevent crashes in dangerous situations (for example, lane changing and merging and intersection crossing) where they otherwise would occur, IVI encourages accelerated commercialization of crash avoidance systems.

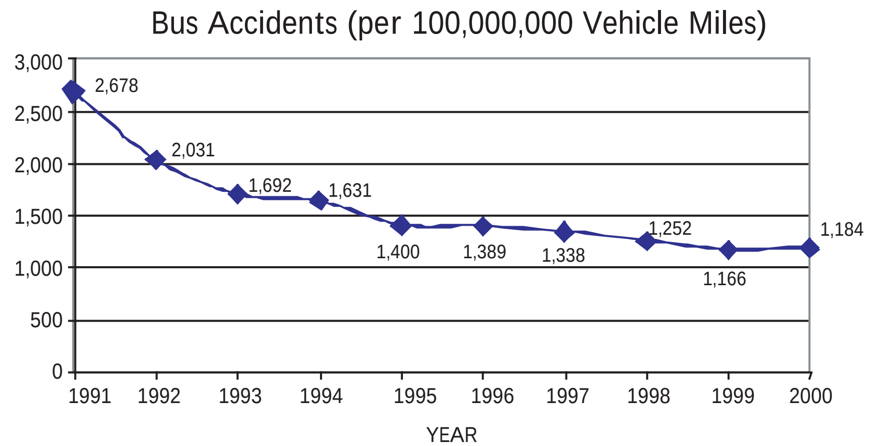


FIGURE 2. Bus Accident Trend from 1991 to 2000 (Source: National Transit Database)

According to NHTSA's General Estimates System (GES) crash database, the points of impact for transit vehicle crashes can be divided into four major categories: front, right side, left side, and rear. A five-year GES review (1997 to 2001) showed that the most frequent point of impact for transit vehicle crashes is on the right side, followed closely by the left side, the front of the vehicle, and the rear of the vehicle (see Figure 3). Consequently, transit IVI research placed strong emphasis on developing collision warning systems that would address each of these accident types.

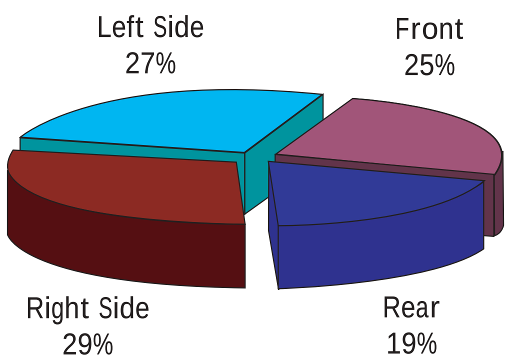


FIGURE 3. Distribution of Transit Vehicle Crashes by Points of Impact (Source: General Estimates System Crash Database)

The second area of emphasis for the transit IVI program is to assist bus operators in "degraded driving conditions."[2] One example is the vehicle-lane assist technology project. Vehicle-lane assist technology is intended to improve the safety of transit vehicles as they operate in difficult environments, such as narrow lanes and bus-only shoulders. This technology would allow transit vehicles to bypass other vehicles on congested adjacent lanes, run at the desired speed, and still maintain the safety of bus passengers and the motoring public. Vehicle-lane assist technology is likely to be one of the first IVI technologies to be implemented for Bus Rapid Transit (BRT) operations.

Various project teams are collaborating on different components of transit IVI research. Experts from academia, transit agencies, state departments of transportation, and private companies are all contributing to transit IVI efforts. Working together and using the transit IVI program as a catalyst, FTA and its research partners will be able to move these cutting-edge transit technologies from specification development, operational testing, and evaluation, to actual product development and system deployment in the next several years.

"The public we serve has a real love affair with good transportation whether by car or transit and expect their public transportation systems to be equipped with the latest in technology to improve ease of use, safety, and effectiveness."

-John M. Inglish, General Manager, Utah Transit Authority

[2] *Examples of degraded driving conditions include reduced visibility and narrow lanes. To increase safety in conditions where the risk of a crash is increased, IVI encourages accelerated commercialization of driver warning systems.*

Frontal collision warning system software runs on a standard Pentium computer accessible via a door in the side of the bus. (Prototype shown in this photo.)

II TRANSIT IVI PROJECTS – ADDRESSING TWO DRIVING CONDITIONS

Imminent Crash Situations

Frontal Collision Warning System

FTA's Project Partners for this Study: California Department of Transportation, Gillig Corporation, San Mateo County Transit District, and University of California at Berkeley's PATH.

Background

Frontal collisions account for approximately 25% of all accidents in transit bus operations. To address this problem, transit operators, stakeholders, and the FTA are cooperatively developing collision warning systems for transit buses under the U.S. DOT's IVI program. Collision warning systems have been studied over the past ten years for passenger vehicles. The frontal collision warning system technology will extend these efforts to meet the needs of transit buses operating in urban environments, where unique solutions to obstacle detection are required.

Overview of Technology

A frontal collision warning system uses sensors to detect obstacles in front of the bus and to determine if these obstacles are potential collision hazards. It then provides the bus operator with warnings, which change in severity as the likelihood of a collision increases. A prototype frontal collision warning system was developed to permit field-testing of different system elements and for future validation of the final performance specifications. The prototype includes: sensors that detect the presence of objects; algorithms that identify and interpret potential hazardous targets, determine threat levels, and generate warnings; and a Driver Vehicle Interface that communicates the warning message to the operator. The Driver Vehicle Interface must provide warnings without unduly interfering in the operator's control of the bus.

Tasks and Status of the Study

The objectives and the current status of this study are listed below:

Understanding frontal collision crashes: A thorough review of national accident statistics and selected transit accident records was conducted to define the operating environment for transit buses. Findings confirmed that frontal collisions result in significant property damage and liability.

Field-testing was also conducted, using data acquisition systems installed on three buses. These systems collected both engineering and video data about the movement of the bus, surrounding vehicles, and obstacles relative to the bus. Behavioral data from a pool of operators was also collected. These tasks established potential accident scenarios and a foundation for sensor performance, system specifications, and definition of performance requirements.

Front view of a San Mateo County Transit District bus equipped with the frontal collision warning system.

Interior view of a San Mateo County Transit District bus equipped with the frontal collision warning system. Driver Vehicle Interface lightbars warn driver of impending collision.

Photo Credits: Gerald Stone, California PATH Program

Corner sensor installed on a Port Authority of Allegheny County bus.

Study of operator needs: There is little current human factors research on frontal collision warning systems within the transit environment. Researchers therefore worked closely with bus operators to understand their needs and expectations because they are the intended users of this technology. Operators' inputs to different design options greatly contributed to the prototype Driver Vehicle Interface.

Development of performance specifications: Functional performance specifications are being developed for a frontal collision warning system that provides warnings for imminent crashes, smoother maneuvering, and following too close to a vehicle. Preliminary performance specifications were delivered in 2002, and the final version of the specifications is expected in the near future.

Field tests of prototype frontal collision warning system: A prototype was developed and deployed on three buses to verify the preliminary performance specifications. Prior to the field test, operators were trained and then assigned on each bus for every phase of testing. Driver Vehicle Interfaces were turned off for the first period to collect baseline data, followed by testing with the fully functional Driver Vehicle Interface. The tests resulted in the development of a warning that does not unduly interfere with operating the bus.

"Successful deployments of IVI in widely varying environments demonstrate the utility of collision avoidance and driver alert systems."

-Louis F. Sanders, Director of Research and Technology, American Public Transportation Association

Continuing Development

The frontal collision warning system team continues to develop the system incrementally to ensure that it will effectively help reduce both the frequency and severity of collisions. Frontal collision warning system elements that need further development include visual display placement, warning thresholds for advanced cues and critical warnings, and the impact of transit-specific driving tasks. The updated version of the frontal collision warning system and associated specifications are expected within the next year.

Side Collision Warning System

FTA's Project Partners for this Study: Carnegie Mellon University's Robotics Institute, CleverDevices Ltd., Pennsylvania Department of Transportation, Port Authority of Allegheny County, and Transportation Resource Associates, Inc.

Background

The side collision warning system project was initiated by the Pennsylvania Department of Transportation to understand whether existing crash avoidance technologies could work in a transit context by installing commercial rear- and side-looking collision warning systems on a bus. After several attempts, a transit-specific obstacle detection system was developed. One hundred Port Authority of Allegheny County buses were equipped with ultrasonic sensors on both sides to investigate the operation and maintenance issues as well as operator acceptance of this technology.

In parallel with equipping the 100 buses, work was also started by Carnegie Mellon University to develop an advanced side collision warning system. The preliminary performance specifications and testing requirements of a fully functional side collision warning system were drafted.

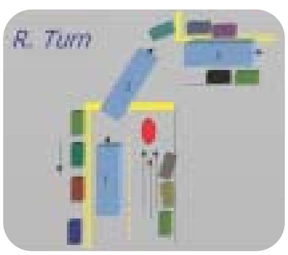
Overview of Technology

The prototype on the Allegheny County buses uses ultrasonic sensors as such sensors offer relatively inexpensive, off-the-shelf means to detect conflicts that are just to the side of a transit bus. Placed intermittently along either side, these sensors provide coverage for detecting objects and pedestrians during close maneuvers, whether in or out of blind spots, and for monitoring lane markers to help the operator negotiate lane changes and turns. When the sensors detect potential obstacles, bus operators are alerted via audible or visible warnings.

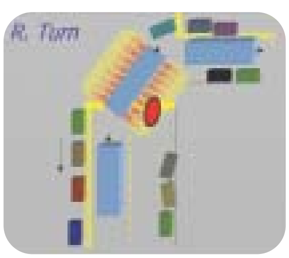
The Carnegie Mellon University analysis does not presuppose a specific sensor, but considers all components and processors for detecting motion, assessing conflicts, and generating appropriate warnings. Applicable sensor technologies examined in this study included: video detector, motion detector, radar, sonar, and laser diode.

Tasks and Findings of the Study

A one-year field operational test of the side obstacle detection system project began in April 2001. Additionally, operating and maintenance employee feedback on the technology was gathered. Findings are summarized below.



Schematic representation of ultrasonic sensors detecting objects on the sides of a right-turning bus.



Driver acceptance: The first goal was to identify the operation and maintenance issues, toward achieving driver acceptance of this technology. Through responses from system evaluation questionnaires, bus operators and maintenance staff provided encouraging feedback on the side obstacle detection technology:

- Nearly 70% of the drivers who participated in the study had favorable reactions toward this technology
- 66% reported the side obstacle detection system reinforced safe driving habits
- 63% reported the side obstacle detection system help detect objects in the blind spot
- 78% said if their concerns about the audible alarm, zone sizes, and sensor placement of the side obstacle detection system could be resolved, the technology would "make sense"

A Port Authority of Allegheny County bus equipped with ultrasonic sensors.

Cost versus benefit: Another objective for the field operational test was to assess economic viability to determine if further installations would be justified. Pre- and post-system installation data of bus accidents and claims were analyzed. Findings suggest that side obstacle detection systems contribute to lower side collision accident and claims rates.

Carnegie Mellon University's work on the side collision warning system concentrated on developing engineering performance specifications. Detailed analysis of the accident data collected from national and state sources was carried out. In addition, a test bus equipped with a video camera, a laser scanner on both sides, and a curb detector, was used to gather data about the operating environment for transit buses.

Based on the information gathered from the test bus, preliminary performance specifications for the side collision warning system include:

- Sensing and predicting bus motion
- Sensing and predicting object (e.g., other vehicles, pedestrians) motion
- Assessing the likelihood of a collision
- Generating interfaces that accommodate different levels of warnings

Continuing Development

The detailed work for advancing the side collision warning system has continued with lessons learned from the one-year field test. Currently, five Port Authority of Allegheny County buses have been equipped with an enhanced system to address specific technical issues:

- Add sensing capability and alerts for tight turns and close maneuvers
- Offer different modes of system operation so that detection zone granularity better addresses situations that are speed related – stop, urban-slow, urban-fast, and highway
- Redesign the audible warning alerts and schemes

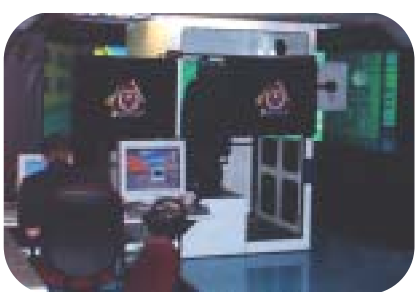
Carnegie Mellon University is updating the performance specifications for the side collision warning system in accordance with results of the accident data analysis and information gathered from the test bus. The specification update is expected to be completed within the next year. A Driver Vehicle Interface for this system is also being examined, and a prototype system is currently being tested.

Findings from the tasks described above will be used in developing a future integrated collision warning system.

Driver Vehicle Interface Study

This project is awarded to Foster-Miller, Inc., through the Small Business Innovation Research (SBIR) Program.

Other Partners Contributing to this Study: FAAC Incorporated, Massachusetts Bay Transportation Authority, and New York Metropolitan Transportation Authority.



Driving simulator for the Driver Vehicle Interface study.

Background

A critical challenge for transit vehicle collision warning systems is the development of a seamless operator-machine interface for the bus operator. Vehicle performance before a potential crash is determined more by how well the operator processes the warning information as to the precision of the warning itself.

A single warning demands enough attention from the operator, and requires an almost automatic response. If the operator is receiving a sequence of warnings, attention demands increase and operator responses become more complex. The role of an integrated Driver Vehicle Interface is to assist the operator to respond with an appropriate reaction when warnings are issued. The goal of this project is to design an effective Driver Vehicle Interface for frontal collision warning and side collision warning systems.

Tasks and Findings of the Study

Phase one of this project developed a group of preliminary Driver Vehicle Interface display concepts for collision warning systems. In addition to literature reviews, operational requirements were developed using a set of crash scenarios. Collision warning systems were defined in terms of types of information they will present to the bus operator. At a minimum, the display should provide cautionary alerts as well as critical warnings. Consequently, a multi-stage collision warning approach was proposed, which makes use of two levels of display: *caution* and *warning*. The cautionary alert sounds first. If the operator makes no adjustment in response to the cautionary alert sounds, and the threat of a collision increases, the display will provide collision warning information three different ways — visual, auditory, and haptic (by sense of touch).

A computer-generated scene from the driving simulator experiment.

Continuing Development

This project is currently in the second phase. Tests for this portion of the study will be carried out using a driving simulator to assess the robustness of the collision warning systems. The driving simulator being used for this study is converted from an existing simulator used for operator training purposes. Primary tasks for this phase of work include:

Design simulation experiments: Work under this task includes defining independent and dependent variables, generating specifications of vehicle behavior, establishing simulator inputs/outputs, determining desired number of participants, and developing data analysis strategy.

Develop Driver Vehicle Interfaces: Experimental Driver Vehicle Interfaces will be selected based on feedback from the research team. Displays will be limited to visual, auditory, and haptic. After likely Driver Vehicle Interface designs have been selected, a prototype will be developed for use in the driving simulator, and simulation experiments will be conducted.

Analyze simulation data: This task involves analyzing data with a focus on safety performance and user preference data.

Develop Driver Vehicle Interface specifications: The project team will produce a set of Driver Vehicle Interface specifications to be used in a future collision warning system research effort using the results from simulator experiments. Final specifications will be available by the end of 2003.

Rear Impact Collision Warning System

FTA's Project Partners for this Study: Ann Arbor Transportation Authority and Veridian Corporation.

Background

The primary goal of this project is to generate performance specifications for a rear impact collision warning system to be applied on transit buses. Major tasks of this study include: assessment of crash data, assessment of warning devices, development of a data collection system, development of a functioning warning system, field validation tests, and data analysis. Two buses from the Ann Arbor Transportation Authority are being used for the field validation test.

Laser radar sensor used as part of the data collection system.

Rear view of an Ann Arbor Transportation Authority bus equipped with the rear impact collision warning system.

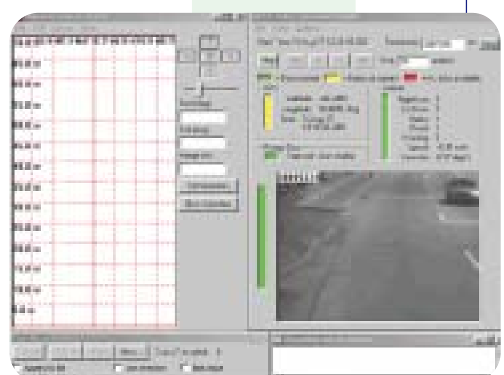
Overview of the Technology

The rear impact collision warning system senses the rearward scene of transit buses and provides warnings to the following vehicles about potential rear-end collisions. Interestingly, early research indicated that the most common rear impact collisions occur under benign driving conditions, where the bus is traveling in a straight line or is stopped. Typically, there are no obvious causes for such types of collisions. This suggests that driver distraction is a major contributing factor in these types of crashes.

Tasks and Status of the Study

Primary tasks and preliminary results associated with this project include:

Crash data analysis: Assessments of rear-ended crash data were completed and the particulars of 20 different parameters, including vehicle dynamics, environmental conditions, and accident consequences, were accumulated and summarized. Crash data analysis showed that 67% of rear-ended crashes occurred when buses are stopped in lane. In addition, approximately 80% of rear impact crashes took place during daylight hours and under no adverse weather conditions. Finally, close to 60% of these crashes happened on level roadways with posted speed limits between 30-to-45 miles per hour.



Data collection system developed for the rear impact collision warning system project.

Data collection system: A data collection system was developed for use on test buses. This system consists of a computer and disk storage, an automotive laser radar sensor, a video camera, Global Positioning System, and digital and analog input/output ports for bus signal inputs and control of the warning device.

Specifications: Preliminary performance specifications and evaluation criteria have been established. A warning algorithm has been developed and coded into the data collection system.

Benefit estimation: System deployment benefits of the rear impact collision warning system have also been calculated. The research team estimated that if a rear impact collision warning system is deployed across the entire transit bus fleet, the annual savings per bus could be close to $9,700. This figure provides an upper limit in justifying the implementation and operation of rear impact collision warning systems for transit agencies.

Continuing Development

Currently, data collection for field validation tests is underway. Data gathered from the field validation tests will provide valuable information on the potential reduction of rear impact collision and help the research team to assess the effectiveness of warning algorithms used in this study. In addition, data collected on vehicles traveling behind buses could provide important insights on the behavior of drivers who rear-end buses. Performance specifications for the rear impact collision warning system will be updated based on the findings from the field validation tests. This study is scheduled to be completed by the end of 2003.

Degraded Driving Conditions

Vehicle-Lane Assist Technology

FTA's Project Partners for this Study: Metro Transit and University of Minnesota's ITS Institute.

Other Partners Contributing to this Study: AC Transit, California Department of Transportation, Central Florida Regional Transportation Authority, Connecticut Department of Transportation, Gillig Corporation, Lane Transit District, Los Angeles County Metropolitan Transportation Authority, Pennsylvania Department of Transportation, San Diego Transit, and University of California at Berkeley's PATH.

Background

Metro Transit and the Minnesota Department of Transportation cooperatively run a BRT-like operation throughout the Minneapolis/St. Paul metropolitan area. Buses travel in High Occupancy Vehicle (HOV) lanes and on specially designated bus-only roadway shoulders. Presently, nearly 200 bus-only shoulder miles are approved for BRT with metered ramp by-pass capabilities. Approximately 20 miles of approved bus-only shoulder miles are added annually.

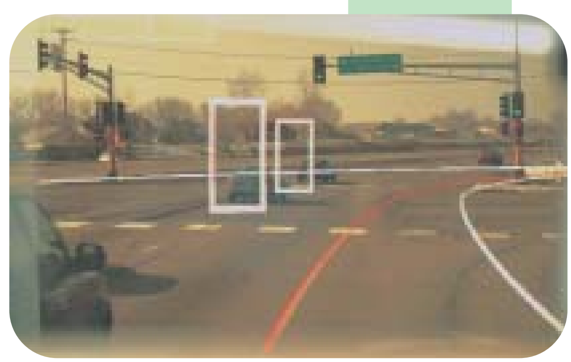
Interior view of a Metro Transit bus equipped with the vehicle-lane assist technology.

Although the bus-only shoulder policy is a successful program, emerging driver assistant technology can be used to increase safety and further improve operation on bus-only shoulders. For instance, most of the bus-only shoulders are no more than 10 feet wide, while a transit bus measures 9 feet across the rear view mirrors. These narrow lanes require that an operator maintain a lateral error of less than one-half foot to avoid collisions. This is a difficult task under normal driving conditions, and degrades to impossible during conditions of bad weather, low visibility, high traffic congestion, etc. Consequently, bus speeds on the bus-only shoulder are often considerably lower than expected.

To address difficult driving conditions faced by bus-only shoulder operators, the research team for this project studied issues associated with the deployment of vehicle-lane assist systems for BRT applications.

Overview of Technology

Vehicle-lane assist technology is likely to be one of the first IVI technologies to be implemented for BRT operations. Lane assist technology is intended to increase the safety of BRT vehicles as they operate in difficult environments such as narrow lanes, HOV lanes, and bus-only shoulders. Lane assist technology allows BRT vehicles to operate at the higher speeds in congested areas, while maintaining the safety of the passengers, the BRT vehicles, and other drivers.



Vehicle-lane assist technology generates projected travel path for the transit bus.

Tasks and Findings of the Study

Five primary tasks associated with this project are presented below:

Requirements for lane assist systems: The goal here was to document national requirements for lane assist systems. Two approaches were used to solicit input from transit properties. First, a requirements survey was developed and sent to 48 U.S. transit agencies. Second, a requirements workshop was held in May 2002 where stakeholders were given the opportunity to address issues and concerns regarding lane assist systems. An important conclusion reached was that while transit agencies have similar requirements regarding system reliability, cost, and maintenance, they differ on issues of environmental conditions, operational expectations, and performance capabilities.

Available technologies for lane assist systems: This task looked at the systems both presently available and under development for lane assist technologies. The main finding is that no one system or technology will satisfy all of the requirements determined in the first task, and significant research and development are required before full-scale deployment.

Lane assist versus precision docking technologies: This task compared lane assist and precision docking technologies on system performance and regulations governing their use. Functionally, both technologies provide a means to accurately and consistently position a bus in a lane; the difference between the two is the speed at which this occurs. There are also differences in operation requirements between the two technologies. Very little legislation or official government policy regulate lane assist systems, while the Americans with Disabilities Act governs precision docking technology because it affects the passage of riders onto and off of the bus.

Technology assessment: Three activities were carried out in this task. First, the technologies were compared to highlight differences between the various approaches to lane assist and precision docking systems. Second, a technology survey was developed which allows a transit agency to solicit specific, relevant information from a lane assist/precision docking system provider or technology developer. Third, description of the performance of a prototype bus was generated to provide a measure of the lane assist capabilities that can be achieved.

Human factors issues: This task focused primarily on the development of performance measures to quantify operator performance, stress and workload, and on the execution of a pilot study to validate the measures in an operational context. Significant findings from this task include:

> "Today's lane-assist technologies for transit buses will enable precision docking at bus stops, safe operation on narrow rights-of-way, and low-speed bus maintenance. In the long-term, platooning of buses on dedicated lanes will move closer to the goal of 'think trains, use buses.'"
>
> -Greg Larson, Chief of Office of Traffic Operations Research, California Department of Transportation

- Driving on authorized bus-only shoulders increases operator stress
- Bus operations on the bus-only shoulder can facilitate faster and more reliable travel speeds
- Lane assist systems improve driving performance of bus operators when traveling on bus-only shoulders

Continuing Development

Findings from this project are being utilized by various research partners to plan for additional technology studies on BRT. Additional work to investigate system requirements, validate previous findings, and estimate cost-benefit of the technology is expected. Ultimately, the goal is to deploy the vehicle-lane assist technology commercially to enhance the safety and efficiency of transit vehicles traveling on bus-only shoulders.

A Metro Transit bus, equipped with the vehicle-lane assist technology, driving on bus-only shoulder.

III FUTURE OUTLOOK

Preliminary performance specifications related to the collision warning systems have been generated. Project teams are currently working on refining and validating the performance specifications as well as the cost-benefit analysis of the collision warning systems. In parallel to the activities mentioned above, work has also begun to study an integrated collision warning system (frontal and side collision warning systems). Project objectives related to the integrated collision warning system are briefly discussed below.

> "The real challenge for IVI technology is getting it mainstreamed into our industry. Heading into the future, IVI has the chance to be a part of fleets across the county, raising safety features of our service in the communities we serve."
>
> -Gregory E. Cook, Executive Director, Ann Arbor Transportation Authority

Next Generation of Transit IVI Technology: Integrated Collision Warning System

The integrated collision warning system is built upon the frontal collision warning system and side collision warning system technologies. Bus operators need to interact with a single common interface to effectively provide warnings for both frontal and side hazards. The integrated collision warning system program has been initiated to develop a system that is both acceptable to bus operators and commercially viable. Using a partnership approach to insure commercial viability, the program will advance the state of technologies for integrated collision warning systems as described in the following steps:

Integrate the advanced side collision warning system and frontal collision warning system into a unified whole with one driver interface: This effort will lead to a unified collision warning system specification and limited prototype operational testing.

Specify and build a usable Driver Vehicle Interface prototype: During this crucial step, specifications will be developed based on operational tests of a commercial interface, simulation testing by operators, potential Driver Vehicle Interface design options, and design guidelines generated by human factors research.

Conduct operational testing and evaluation of enhanced commercial systems in transit use: Five buses equipped with commercial side collision warning systems will be updated to the newest commercial technology, covering the left and right front corners of a transit bus.

Reduce the development risks and accelerate the deployment of collision warning systems: Work with transit stakeholders continues to evaluate market potential in deploying collision warning systems. This includes incorporating manufacturing perspectives early in the design and development process, facilitating discussion on technology transfer, researching development and cost-benefit tradeoffs, and further refining specifications for the integrated system with industry.

> "Not long ago IVI was a glimmer in someone's eye. And now transit authorities are implementing IVI with amazing results. The first time I saw a bus dock with the precision of a rail car, I knew we had found a tool that could make buses competitive – and attractive."
>
> -Harriet R. Smith, Advanced Public Transportation Systems Coordinator, ITS America

Test collision warning systems leading toward commercialization: Work with a manufacturer to develop, produce and install a number of prototype systems for field operational testing and evaluation. The integrated collision warning system project is scheduled to be completed by 2005.

Moving Forward...

Research and validation testing results from collision warning system projects show real promise in reducing transit accidents. Findings from the vehicle-lane assist project suggest that such technology can be very useful for BRT and other narrow lane express service. This is all very encouraging, and research on transit IVI technologies will continue. Soon these technologies will be transferred from "laboratory" to commercial deployment. Eventually, the collision warning systems and lane assist technologies will become standard features on bus fleets, continuing the efforts of both the FTA and industry to enhance the safety and quality of transit travel.

KEY CONTACTS FOR INFORMATION RELATED TO TRANSIT IVI STUDIES

For more information about the U.S. Department of Transportation's Transit Intelligent Vehicle Initiative Studies, please contact one of the representatives listed below.

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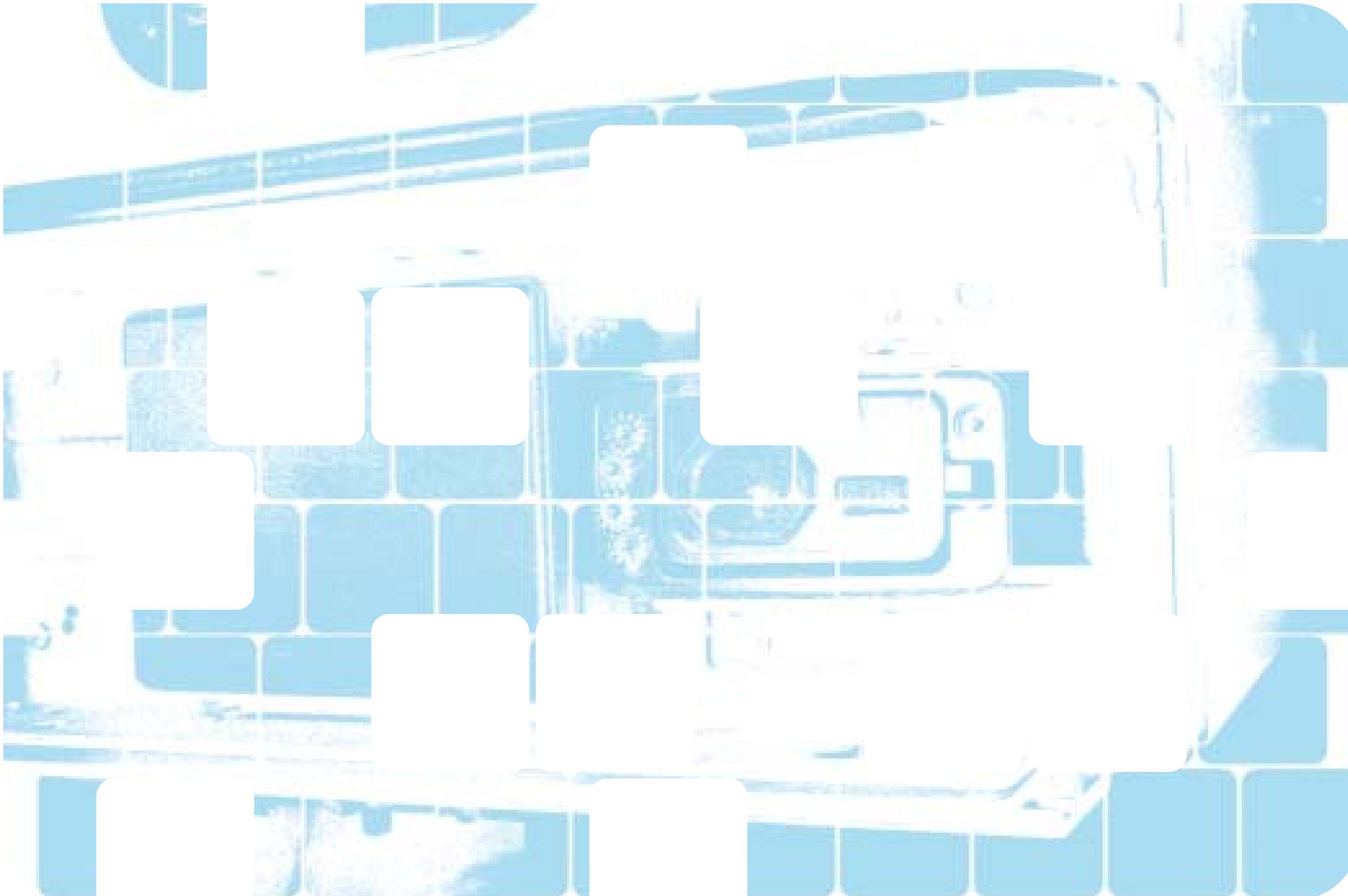

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