IDEA

Innovations Deserving Exploratory Analysis Programs

TRANSIT

# New IDEAS for Transit

## Transit IDEA Program Annual Report

December 2021

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# NEW IDEAS FOR TRANSIT

## Annual Report of the Transit IDEA Program

The Transit IDEA Program is funded by the Federal Transit Administration as part of the Transit Cooperative Research Program and is managed by the Transportation Research Board.

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The Transit IDEA Program is funded by the Federal Transit Administration as part of the Transit Cooperative Research Program, a cooperative effort of the Federal Transit Administration, the Transportation Research Board, and the American Public Transportation Association. The program is managed by TRB.

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# INTRODUCTION

This annual report presents a summary of progress on investigations conducted as part of the Transit Innovations Deserving Exploratory Analysis (Transit IDEA) program. The program is conducted through the Transit Cooperative Research Program (TCRP), administered by the Transportation Research Board, a unit of the National Academies of Sciences, Engineering, and Medicine. The TCRP program is funded by the Federal Transit Administration and is overseen by the TCRP Oversight and Project Selection (TOPS) Committee.

Transit IDEA program fosters innovation in transit systems and operations. Transit IDEA nurtures new concepts for technologies, methods, and processes for:

1. Improving transit relevance in the context of mobility management;
2. Satisfying current and anticipated customer needs;
3. Improving transit safety, security, and viability; and
4. Delivering equitable, accessible, and environmentally responsible services.
5. Improving transit patron and employee environment for health and safety.

There are two other IDEA programs managed by TRB:

- Highway IDEA program, which focuses on technologies, methods, and processes for application to highway systems in broad technical areas such as highway design and construction, materials, operations, and maintenance (under the National Cooperative Highway Research Program); and
- Rail Safety IDEA program (sponsored by the Federal Rail Administration), which focuses on innovative technologies to improve railroad safety and operations.

All three IDEA programs are integrated to support advances in highway, transit, rail, and intermodal systems.

The IDEA programs can receive proposals from any individual, including entrepreneurs, small and large businesses, and institutions. The program provides funding to investigate new and unproven concepts or to evaluate novel applications of technologies that have not been tried, tested, or used for highway, transit, high-speed rail, or intermodal systems practice.

The selection of each IDEA investigation is made by consensus recommendations from the Transit IDEA Project Panel, which is comprised of national experts in transit and transportation research and, practice, and whose members are listed at the beginning of this report. A technical expert is selected from outside TRB to serve as a voluntary advisor for each IDEA project. The technical project advisor provides continuing advice and counsel on the IDEA investigation to the investigator and the IDEA program office. To begin the product transfer process from the initiation of each IDEA project, a regional panel of experts is nominated to work with the investigator on product development and transfer to transit practice. The products emerging from the Transit IDEA program support a range of innovative developments for transit user services and for advancing transit system.

Section 1 of this report presents short descriptions of projects completed before the 2021 program year. The products and results from these projects have been applied or are available for further investigation for application to transit practice. The product status is described under each project. Because of limitations on IDEA resources, not all IDEA concepts that prove feasible can be accommodated for follow-up funding by the Transit IDEA program for product transfer. Section 2 presents reports of investigations on projects active or are anticipated to be completed during the 2021 program year; several projects in this section are in the initial stages of investigation.

In selecting new concepts, the IDEA program balances the quest for new products with an understanding of the barriers each product may face for application to practice. Assessing the level of readiness for deployment of IDEA products and results is important in deciding on follow-up actions that are necessary to transfer the IDEA product to practice. The annual report is intended to provide transit practitioners with the background on each IDEA investigation and product in development so that a dialogue on its potential transfer can take place between the investigator and transit practitioners.

The IDEA program welcomes your comments, suggestions, or recommendations on Transit IDEA projects, products, and results presented in this report. Please forward them to the Transit IDEA Program (attention: Dr. Inam Jawed), Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001; email: ijawed@nas.edu. General information on the IDEA Programs, including how to apply for funding, may be found on the TRB website at https://www.trb.org/IDEAProgram/IDEAProgram.aspx.

# COMPLETED TRANSIT IDEA PROJECT FINAL REPORTS

The following Transit IDEA projects have been completed. The following project final reports are available on the IDEA Web site at: http://www.trb.org/IDEAProgram/IDEATransit.aspx. Those reports with an NTIS number noted are also available from the National Technical Information Service (NTIS): www.NTIS.gov.

Transit IDEA 1: *Customer Satisfaction Index for the Mass Transit Industry,* Tri-County Metropolitan Transportation District of Oregon, Kathryn A. Coffell, Principal Investigator (NTIS PB97-137541)

Transit IDEA 2: *Adaptive Diagnostic System Project*, BART, Steven Mullerheim, and San Francisco Bay Area Rapid Transit District, Eugene Nishanaga, Principal Investigators (NTIS PB99-113201)

Transit IDEA 3: *Automatic Wheel Inspection Station,* International, Electronic Machines Corp., Zahid Mian, Principal Investigator (NTIS PB97-141865)

Transit IDEA 4: *Management Information Benefits of On-Board Integration of Electronic Fareboxes*, Northeastern University, Peter Furth, Principal Investigator (NTIS PB97-137509)

Transit IDEA 5: *Improved Passenger Counter and Classification System for Transit Applications*, Greneker and Associates Inc., E. F. Greneker, Principal Investigator (NTIS PB97-153563)

Transit IDEA 7: *Wheelchair Restraint System*, Baylor College of Medicine, Thomas Krouskop, Principal Investigator (NTIS PB97-137517)

Transit IDEA 8: *Real-Time Transit Data Broadcast*, Transcom International Ltd., Edward C. Burgener and Norm Goertzen, Principal Investigators (NTIS PB97-137525)

Transit IDEA 9: *The Independent Transportation Network: Alternative Transportation for the Elderly*, Southern Maine Area Agency on Aging, Katherine Freund, Principal Investigator (NTIS PB97-171540)

Transit IDEA 10: *Automatic Data Collection on Transit Users via Radio Frequency Identification*, University of Virginia, Manuel Rosetti, Principal Investigator (NTIS PB97-137533)

Transit IDEA 11: *Customers, Conflicts, and You: A Transit Operator's Guide to Problem Solving*, San Francisco Municipal Railway, Debi Horen, and National Transit Institute, Renee Haider, Principal Investigators

Transit IDEA 13: *Self-Paced, PC-Based Track Safety Training System,* TransTech Management, Daniel B. Mesnick, Principal Investigator (NTIS PB99-113193)

Transit IDEA 14: *Market Study and Operational Test Results for the Instant Rent-A-Car (IRAC) Station Field Tests,* CF International, John Chisholm, Principal Investigator (NTIS PB99-113243)

Transit IDEA 15: *Internet Information Sharing for Transit Maintenance,* Kiernan Transit Associates, Victor D. Kiernan, Principal Investigator (NTIS PB99-113227)

Transit IDEA 16: *Transit Restraint System for Wheelchairs,* Cleveland Clinic Foundation, Steven Reger, Principal Investigator

Transit IDEA 17: *Operational Evaluation of a Rail-Based Wheel Gauge Inspection System,* International Electronic Machines Corp., Zahid Mian, Principal Investigator (NTIS PB99-113250)

Transit IDEA 18: *Pilot Testing Innovative Payment Operations for Independent Transportation Network (ITN)*, Independent Transportation for the Elderly, Katherine Freund, Principal Investigator

Transit IDEA 19: *Field Testing and Evaluation of the Transit Integrated Monitoring System,* University of Virginia, Manuel D. Rosetti, Principal Investigator (NTIS PB99-113268)

Transit IDEA 20: *Non-Contact Sensor for Passenger Counting and Classification*, Greneker and Associates Inc., Gene Greneker, Principal Investigator (NTIS PB2002-106314)

Transit IDEA 21: *Smart Parking Lot with Just-in-Time Bus Service*, Oregon State University, Chris A. Bell, Principal Investigator

Transit IDEA 22: *Sleeved Column System for Crashworthiness of Light Rail Vehicles*, Ronald Mayville, Principal Investigator (NTIS PB2002-106313)

Transit IDEA 24: *Operational Testing of Intelligent Rail Lubrication System,* Tranergy Corp., Sudhir Kumar, Principal Investigator (NTIS PB99-113219)

Transit IDEA 28: *Transit Scratchitti Removal by Controlled Fire Polishing,* Columbia University, Shane Y. Hong, Principal Investigator

Transit IDEA 29: *Fare Machine Tactile/Audio Instruction System,* KRW Inc., George Earnhart, Principal Investigator

Transit IDEA 31: *A Tool for Evaluating and Optimizing Bus Stop Location Decisions*, Northeastern University, Peter G. Furth, Principal Investigator

Transit IDEA 32: *Simulation and Animation Model for Planning and Designing Transit Terminals*, TransAn LLC, Prianka Seneviratne, Principal Investigator

Transit IDEA 33: *Community Visualization in Design of Light Rail Transit-Oriented Development,* University of Kentucky, Ted Grossardt, Principal Investigator (NTIS PB2008-101504)

Transit IDEA 35: *Innovative Bioterrorism Detection Technology for Transit Security,* Science Applications International Corp., Douglas B. Rivers, Principal Investigator

Transit IDEA 36: *Cleaning Device for Electrified Third Rail Insulators,* Arun Vohra, Principal Investigator (NTIS PB2005-107675)

Transit IDEA 37: *Bandwidth Expansion and Real-Time Surveillance for Security on Transit Buses,* Carnegie Mellon University, Yang Cai, Principal Investigator

Transit IDEA 38: *Assessment of Rear-Facing Wheelchair Accommodation on BRT,* Oregon State University, Katharine Hunter-Zaworski, Principal Investigator (NTIS PB2005-107674)

Transit IDEA 39: *Dynamic Timetable Generator*, Systems and Solutions, Inc., Paula Okunieff, Principal Investigator (NTIS PB2006-110548)

Transit IDEA 40: *Counterterrorism Chemical Detector for Rail Transit Systems*, Connecticut Analytical Corporation, Joseph Bango, Jr., Principal Investigator

Transit IDEA 41: *Track Geometry/Design Testing for Transit Applications,* Miles H. Letts, Principal Investigator (NTIS PB2008-101506)

Transit IDEA 42: *Detection of Radioactivity in Transit Stations*, Advanced Fuel Research Inc., Eric P. Rubenstein, Principal Investigator (NTIS PB2008-101507)

Transit IDEA 44: *Cleaning and Recoating Electrified Third Rail Cover Boards,* Arun Vohra, Principal Investigator

Transit IDEA 45: *Chemical and Biological Decontamination System for Rail Transit Facilities*, Foster-Miller Inc., Christos Athanassiu, Principal Investigator (NTIS PB2008-101508)

Transit IDEA 47: *Cleaning Device for Electrified Third Rail Insulators–Phase 2,* Arun Vohra, Principal Investigator

Transit IDEA 49: *SmartSander Enhancement for Commuter Rail,* DeltaRail Group Limited, Graham Curtis, and Local Liaison, Don Minini, Principal Investigators

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Transit IDEA 54: *Detection of Radioactivity in Transit Stations—Phase 2,* Applied Fuel Research, Inc., Eric Rubenstein, Principal Investigator

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Transit IDEA 58: *Google Transit Data Tool for Small Transit Agencies,* PEMCCO, Inc., Prescott Sherrod, Principal Investigator

Transit IDEA 59: *Recoating Electrified Third Rail Cover Boards—Phase 2,* Mini, LLC, Arun Vohra, Principal Investigator

Transit IDEA 60: *TCIP Traveler Information Pilot*, Ayers Electronic Systems, LLC, Robert G. Ayers, Principal Investigator

Transit IDEA 61: *Flexible Carpooling to Transit Stations*, Trip Convergence Ltd., Paul Minett, Principal Investigator

Transit IDEA 62: *Development of Maintenance Training Module for Bus Transit Technicians*, CDX Global, Robert Mann, Principal Investigator

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Transit IDEA 65: *A Context Aware Transit Navigator*, University of Illinois at Chicago, Jakob Eriksson, Principal Investigator

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Transit IDEA 67: *Diesel-Electric Locomotive Energy Recovery and Conversion,* ThermaDynamics Rail LLC, Claudio Filippone, Principal Investigator

Transit IDEA 68: *Light Rail Transit/Street Grade Crossing Safety System,* SIL4 Systems Inc., Carl E. Conti, Principal Investigator

Transit IDEA 70: *Effortless Passenger Identification System*, North Dakota State University, Del Peterson, Principal Investigator

Transit IDEA 71: *Transit Information Access for Persons with Visual or Cognitive Impairments,* University of California, Santa Cruz, Roberto Manduchi, Principal Investigator

Transit IDEA 72: *Handheld Wheel Flaw Detection Device: Noncontact Electronic Wheel Gauge (NEWG),* International Electronic Machines, Zach Mian, Principal Investigator

Transit IDEA 73: *Innovative Operating Strategies for Paratransit Services,* Texas A&M Transportation Institute, Luca Quadrifoglio, Principal Investigator

Transit IDEA 74: *Apparatus for Gap Management,* Rutgers University, Thomas O. Boucher, Principal Investigator

Transit IDEA 75: *Transit Trip Planning Web Application,* Resource Systems Group, Inc., Thomas Adler, Principal Investigator

Transit IDEA 76: *RideScout*, Austin, Texas, John Gossart, Principal Investigator

Transit IDEA 77: *Development of a Prototype Retrofit Bumper for Improved Light Rail Vehicle Safety*, Applied Research Associates, Southwest Division, Silicon Valley Office, Los Altos, California, Steven Kirkpatrick and Robert MacNeill, Principal Investigators

Transit IDEA 78: *Rail Neutral Temperature Monitoring for Rail Transit,* Protran Technology, Newton, New Jersey, Peter Bartek, Principal Investigator

Transit IDEA 79: *Implementation of Smart Card AFC Standards for Small Transit Agencies,* Acumen Building Enterprise, Inc., Walter E. Allen, Principal Investigator

Transit IDEA 80: *Enhancing Safety and Security of Transit Systems Using Computer Vision*, Rutgers University, Dimitris N. Metaxas, Principal Investigator

Transit IDEA 81: *Advanced Locomotive Exhaust Gas Simulator to Fine-Tune Energy Recovery and Conversion Systems,* ThermaDynamics Rail LLC, Claudio Filippine, Principal Investigator

Transit IDEA 82: *Active Safety-Collision Warning Pilot in Washington State*, Washington State Transit Insurance Pool, Jerry Spears, Principal Investigator

Transit IDEA 83: *Track Circuit Monitoring Tool Standardization and Deployment at Chicago Transit Authority,* Rail IT, LLC, Frank Beeck, Principal Investigator

Transit IDEA 85: *Location Aware Networks Optimizing Use of Transit Systems by Blind Travelers,* Yariv Glazer, Principal Investigator

Transit IDEA 86: *Advanced Neutral Temperature Estimation Using Solitary Waves (ANTEUSW),* University of Pittsburgh, Piervincenzo Rizzo, Principal Investigator

Transit IDEA 87: *Development of pathNav: A Pedestrian Navigation Tool that Utilizes Smart Data for Improved Accessibility and Walkability,* Eric Sinagra, Principal Investigator

Transit IDEA 88: *Evaluation of an Automatic, Individual, Computer-Based Operator Education and Training Program,* Virginia Tech Transportation Institute, Matthew Camden, Principal Investigator

Transit IDEA 89: *Dynamic Vehicle to Infrastructure TCIP Communications Laboratory Proof of Concept,* Marilyn Fortin, Principal Investigator

Transit IDEA 90: *sUAS-based GeoINTEL for CR Parking in Rural and Suburban Areas,* Lawrence J. Harman and Uma Shama, Co-Principal Investigators

Transit IDEA 92: *Augmented Reality Train Dispatcher Interface,* MACRO/Ross & Baruzzini; Carl Stanton, Principal Investigator

Transit IDEA 93: *An Open Platform for Transit Agencies to Improve the Quality of Their Real-Time Data,* Interline Technologies LLC, Drew Dara-Abrams, Principal Investigator

Transit IDEA 94: *Evaluation of Transit Vehicle Brake Inspection Through Ultrasonic Emissions Analysis,* BrakeAudit LLC, Brian Hearing, Principal Investigator

# Customer Satisfaction Index for the Mass Transit Industry Transit IDEA Project 1

Kathryn A. Coffel
(formerly with Tri-County Metropolitan Transportation District of Oregon)

This IDEA project developed and tested a customer satisfaction index (CSI) methodology in five transit districts to determine customer satisfaction with mass transit operations. The project was modeled after similar studies by the automobile and airline industries that were designed to improve and track customer satisfaction over time. This CSI application was the first systematic, non-biased, and technically credible measure for comparing customer satisfaction between districts. This verified CSI approach is now available for transit agencies to analyze their performance, compare themselves directly to a total sample average, learn from other transit districts, and understand key factors for improving customer satisfaction and ridership.

The uniform guidelines were applied for the construction and interpretation of the CSI data derived from the investigation. The feasibility of the CSI concept was tested for the three transit modes of bus, light rail, and heavy rail in the following five transit districts:

1. Tri-County Metropolitan Transportation District (Tri-Met), Portland, Oregon;
2. Metro Regional Transit Authority (MRTA), Akron, Ohio;
3. Regional Transportation Authority through the Chicago Transit Authority (CTA), Chicago, Illinois;
4. Metropolitan Council Transit Operations (MCTO), Minneapolis, Minnesota; and
5. Southeastern Pennsylvania Transportation Authority (SEPTA), Philadelphia, Pennsylvania.

The IDEA investigation produced the following results:

- Identified the key attributes and factors reflecting transit customer satisfaction in the five transit districts,
- Developed and tested a uniform method of comparing the performance of each transit district,
- Identified specific priorities for improving customer satisfaction, and
- Developed guidelines for application of the CSI methodology by all transit agencies.

The project identified key attributes that affect customer satisfaction. A uniform method of comparing the performance of each transit district with those of other districts was also developed. In addition, specific priorities for improving customer satisfaction in transit districts were also identified.

The successful conclusion of this study marked the first step the transit industry has taken to establish customer satisfaction benchmarks. Additional data was collected to increase the predictive power of the CSI model from local to national levels. The investigators worked with other transit districts to expand CSI studies. The final report for this project was completed.

An expanded national research application of CSI results occurred under the Transit Cooperative Research Program with TCRP Project B-11: "Customer-Defined Transit Service Quality," which provided answers to several of the specific issues identified in the IDEA project and broadened the application of the CSI concept to a national level. A report on that follow-on project was published in 1999 as TCRP Report 47. More than fifteen transit agencies have used such methods.

# Adaptive Diagnostic System Transit IDEA Project 2

Steve Mullerheim
(formerly with San Francisco Bay Area Rapid Transit District)

Eugene Nishanaga
San Francisco Bay Area Rapid Transit District

This IDEA project developed an automated general-purpose tester with artificial intelligence capabilities that can be adapted to the testing of a variety of transit equipment electronic units.

The artificial intelligence software incorporated in the automated, programmable general-purpose test equipment consists primarily of neural networks that have the capability of being "trained" to recognize certain failures from specific waveform patterns as depicted in Figure 1. The programmable card-based instruments are under the control of a personal computer (PC) with a graphical user interface (GUI). Several graphically based, off-the-shelf software systems from National Instruments greatly simplified the encoding of the needed control and display software. Diagnosis is accomplished quickly, and often quite accurately, without the need for time-consuming probing and circuit analysis procedures.

The project has demonstrated the productivity gains that are possible in the transit environment

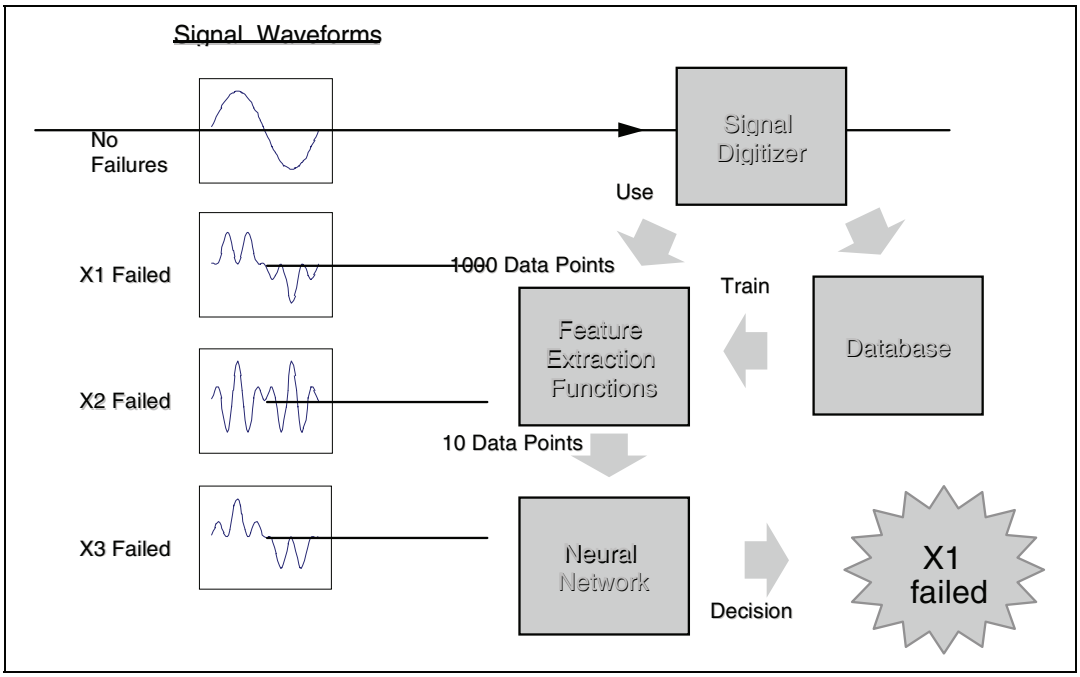


**Figure 1**

*Neural analysis of signal input.*

with PC-controlled programmable test equipment that employs flexible software architecture and a graphically based programming language. With such a system, even technical personnel not proficient in computer programming can configure the equipment. The automated general-purpose tester incorporates software of programmable artificial intelligence tools, such as neural networks and inference generators, to assist in diagnosing circuit failures. Automated, programmable general-purpose test equipment greatly enhances testing efficiency while reducing overall test equipment costs.

The Bay Area Rapid Transit (BART) used the product to test and repair other transit equipment and to make appropriate modifications for troubleshooting electronic operational devices. This product has not experienced much application for transit equipment maintenance.

# Management Information Benefits of Integrating Electronic Fareboxes with Other On-Board Equipment Transit IDEA Project 4

Peter G. Furth
Northeastern University, Boston, Massachusetts

## IDEA Concept and Product

This project investigated integrating fareboxes with other on-vehicle devices for estimating passenger loads and passenger miles. The farebox has great potential as a source of passenger data because nearly every bus has electronic fareboxes and nearly all boardings are registered by fareboxes. By integrating fareboxes with other on-board equipment, the value of the farebox with the vehicle's digital odometer makes it possible to stamp farebox records with the odometer reading for verification of trip length. Likewise, integration with additional devices makes it possible to use the fareboxes as a means of counting boardings by stop, providing valuable information for planning and marketing, and opening up the possibility for estimating passenger loads and passenger miles.

Modifications to the Society of Automotive Engineers (SAE) standards for on-vehicle communication established an industry standard for vehicle area networks (VAN). Those standards better accommodate fareboxes and related data. Developments in the industry toward VAN are generally related to automatic radio vehicle location and enunciator systems. In both cases, the computer that supports that system also serves as a platform for the vehicle logic unit (VLU), which is the brain that manages the VAN. In this IDEA project, the fareboxes are used as the brain for such a network.

The project identified various configurations for enhancing farebox data. By connecting the fareboxes to the headsign, the operator may change route information without dealing with the headsign. Mating the odometer to the farebox to register odometer readings traces route changes. Also, an odometer stamp may be made with every record and is triggered from a door sensor. With the odometer stamp on each record, passenger boardings and miles can be estimated. By incorporating a VAN, all data are shared instead of compiled in each bus. An open standard for communication in a VAN, which includes descriptions of standard messages and message formats, has now been established by SAE.

This IDEA project also developed a method for estimating passenger miles from boarding counts that are odometer stamped. This method was verified on six bus routes provided by Los Angeles Metro. On all six routes, the tests proved that the reliability and accuracy of the method was within 1.5 percent.

## Project Results

The open standards developed in this Transit IDEA project for dedicated communication provide information that is useful in developing specifications for integrating farebox data with other data by transit operators. The method for integrating farebox and other data developed in this project has been used by a major manufacturer of fareboxes, which have been sold to many transit agencies across the country.

# Wheelchair Restraint System Transit IDEA Project 7

Thomas A. Krouskop
Baylor College of Medicine

This IDEA project produced an innovative modular wheelchair restraint system that uses pneumatically driven resilient bristles that engage the wheels and frame of a wheelchair. The system stabilizes movements during acceleration and braking, thereby reducing the risk of injury in collisions. By engaging the bristles with the wheelchair frame and wheels, it is feasible to hold a variety of wheelchair geometries without subjecting the wheelchair to significant sideward loading. The bristles are actuated by a compressor on the vehicle. There is also a vacuum line to accelerate disengagement of the bristles from the chair. The restraint also stows itself with minimum space requirement. The pneumatic operation permits quick release and evacuation in case of a power failure after a collision. The restraint design incorporates sensors that detect when the resilient bristles contact the side of the chair and acts to limit the subsequent travel of the bristles, so the chair will not collapse or bend.

The restraint protocol uses a double-staged activation to engage the bristles with the wheelchair. The first stage of activation extends the bristles in preparation for contact with the wheelchair frame, and the second stage of activation moves each section of the resilient bristles forward to engage the chair. During the second stage of activation, the bristles slide and flex freely when engaging the wheelchair frame and wheels. Any bristle placing a sideward force on the chair is retracted while other bristles continue to advance and further engage the chair. Essentially, the bristles restrain the wheelchair by making a custom mold of the frame that maximizes the area available to restrain the chair, as shown in Figures 1 and 2. In this way, stresses on the wheelchair are kept as low as possible. The excursion of the wheelchair is designed to be limited to less than 1.5 cm (0.59 in.) when loaded to the design load of 26,700 N (6,000 lbs). This design criterion conforms to standards of comfort and safety for wheelchair users.

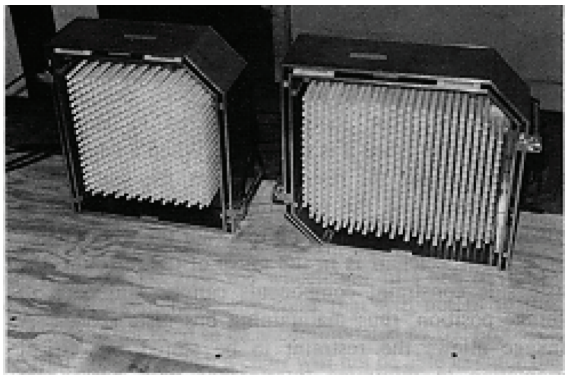

**Figure 1**

*Bristle sections.*

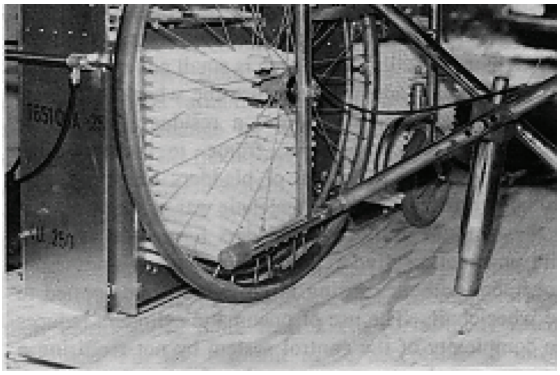

**Figure 2**

*Engaging the wheelchair.*

The wheelchair restraint prototype has been constructed, and preliminary contacts have been made with manufacturers of wheelchairs and wheelchair restraints to identify partners in the commercialization of the product. In addition to increased safety for the wheelchair user, the design of the restraint system reduces ingress and egress times for wheelchairs, resulting in considerable time savings for all passengers. The engagement operation is fully automatic. Dynamic operational testing will be needed to develop a preproduction design for marketing the product.

# Real-Time Transit Data Broadcast
# Transit IDEA Project 8

Edward C. Burgener and Norm Goertzen
Transcom International, Ltd.

This IDEA project developed transit broadcast software for a personal portable receiver that provides real time-to-arrival information to transit passengers at any selected bus stop. The innovative software system transmits bus location to the personal portable receivers by one-way broadcast. The system operates in conjunction with an automatic vehicle location and control (AVL/C) system to locate each operating transit vehicle. Transit location data are then broadcast in a format compatible with the software installed in the portable receivers. These remote receivers convert the locational data into real time-to-arrival information for passengers consonant with input station stop location numbers the users put into their receiver/processors. The actual broadcast method can be any one-way transmission system, such as an FM sub-carrier, a pager network, or the Internet.

This product was tested on the bus system of Winnipeg, Manitoba, Canada, as a sample city of 62 routes, 500 buses, 650,000 in population, 128 patterns, and 4,600 stops. The model developed required a file size within the original estimate of less than 30 Kbytes. As a follow-up, real-time data was collected from Hull Transit in Ottawa, Canada, and the model accurately predicted arrival within less than a 15-sec variance. Application has been made to the Canadian Federal Transportation Development Center for funding of a commercial product that would allow persons with disabilities to determine which buses are wheelchair accessible. Funding is also being sought from interested transit authorities. The funding would be used to (a) enhance the design of a current AVL/C software package being designed for a signpost AVL system in Halifax, (b) modify the standard paging protocol to be compatible with the proposed personal portable receivers, and (c) implement the design to a standard display pager system. Having this transit information system as a pager feature could provide an incentive to the established pager industry.

Transcom worked with NextBus of Emeryville, California on a preproduction system for the transit market.

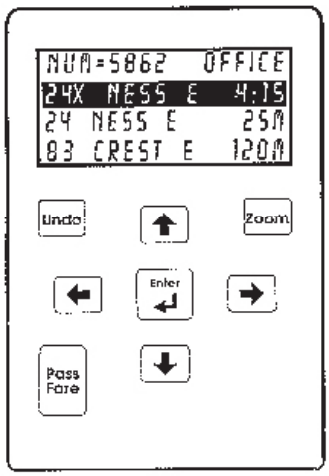


**Figure 1**

*Personal portable receiver.*

# Violence Prevention Training CD-ROM Transit IDEA Project 11

Debi Horen
(formerly with San Francisco Municipal Railway, San Francisco, California)

Renee Haider
(formerly with National Transit Institute[1])

This project developed an interactive multimedia CD-ROM training program, to improve transit bus drivers' ability to handle incidents of violence and aggression and potential problem situations.

This training program was developed by the San Francisco Municipal Railway (MUNI) in cooperation with six other transit agencies, in this Transit IDEA project, and was tested by those transit agencies, in cooperation with the National Transit Institute (NTI).

Critical data on bus operator demographics, incidents, and existing training programs was collected from the seven participating transit agencies. Focus groups at each agency collected qualitative data on positive solutions to violent and potentially violent situations. An analysis of these data was provided to an expert panel work group that included 10 experts from transit, law enforcement, mental health, and public health agencies. Feedback from this expert panel suggested control techniques that can be used by the transit operator. These recommendations formed the foundation of the program that was developed and used in the interactive training program. The CD-ROM format includes video of bus drivers, computer-generated art, animation, music, narration, voice recordings, and stills, edited and digitized for use on a personal computer.

The training program previously was distributed from 2001 through 2007 by NTI of Rutgers University. This interactive multimedia training program, called *Customers, Conflicts, and You: A Transit Operator's Guide to Problem Solving,* has been obtained by more than 200 transit agencies. The training package included the interactive CD-ROM, a video, and an instructor guidebook for a day-long training session for bus drivers. NTI is no longer distributing the training package, due to software compatibility limitations since the CD-ROM was developed in 1999.

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# PC-Based Track Safety Training Transit IDEA Project 13

Daniel Mesnick
TransTech Management

The IDEA project developed multimedia tools for communication over the Internet to improve the education and training of transit track staff responsible for the day-to-day maintenance of track safety. Illustrated below is the Internet home page, which is presented in full color. The training program uses multimedia integrated with text, drawings, schematics, and blueprints that guide track foremen in theory, design, standards, procedures, and maintenance methods to identify and correct track defects. Specific contents of this pilot training software include

1. An instruction scope covering transit track roadway design, drainage, geometry, special work maintenance and component renewal/replacement, inspection for defects and in turnouts and frog welding and rebuilding.
2. Course modules that are self-paced and self-directed.
3. Voice and text integration providing the track worker with visuals, text, and audio guidance on how, when, and where to perform track maintenance action in the field.

The consortium of transit agencies participating in this course development effort include the Massachusetts Bay Transportation Authority (MBTA), New York City Transit/Staten Island Transit Authority (NYCT/SIRTOA), Port Authority Transit Corporation (PATCO), Southeastern Pennsylvania Transit Authority (SEPTA), and the Metropolitan Atlanta Rapid Transit Authority (MARTA). The MBTA tested the product before finalizing the software to confirm that voice, standards, and media will be effective. The American Railway Engineering Association (now AREMA) supported this effort by allowing the use of elements of the AREA Manual and Portfolio of Trackwork Plans, and AREMA received a Web site link. Interest in this technology was expressed by the MBTA, SEPTA, Washington Metropolitan Area Transit Authority (WMATA), NYCTA, AREMA, a few regional and short lines, the Polish State Railways (PKP), and several other railways internationally.

The investigator promoted and demonstrated the pilot version to managers responsible for improving track safety and maintenance.

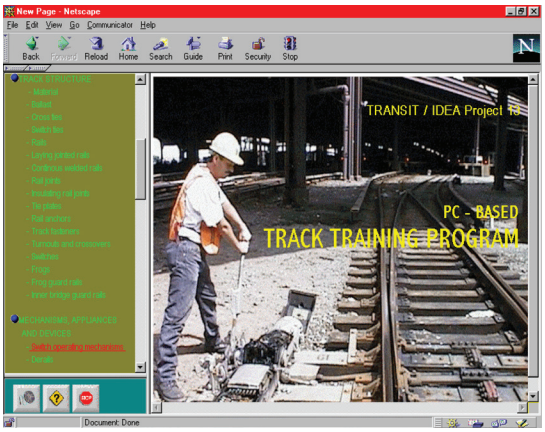


**Figure 1**

*Maintenance home page on the Internet.*

# Instant Rent-a-Car Technology Applied to Transit Station Car Practice
# Transit IDEA Project 14

John Chisholm
(formerly with C.F. International)

This IDEA project employed ITS technology for short-term rentals of electric or compact vehicles to and from transit stations for increasing transit ridership. As illustrated below, the Instant Rent-a-Car (IRAC) fleet management technology uses radio communications between the rental vehicle and a central processor to trace the status of a fleet vehicle. Rental transactions are possible by personal computer reservation or through a "walk-in" process. The user can then drive the vehicle and leave it parked on the street when finished. After the user exits the vehicle, the door is locked and a message is sent to the central processor containing billing data, rental availability, and other fleet management information, which may be used by other potential vehicle renters.

The project focused on integrating IRAC into transit practice by feeding rail rapid transit stations. The IDEA project included a limited-scale operational pilot test in the spring of 1997 using up to 10 IRAC electric vehicles feeding a Bay Area Rapid Transit (BART) station to confirm predicted usage and ridership projections and patterns. Preliminary projections show that in a transit operation such as BART, ridership can be significantly increased with IRAC use by increasing the ridership on currently underused trains. IRACs are also applicable to express buses and car pools and could provide a new market for the auto rental industry.

A large-scale operational test and evaluation using IRAC-configured vehicles was done as a follow-up after this Transit IDEA project to establish the viability for wide implementation of IRAC technology. BART subsequently conducted a large-scale demonstration of a similar system. This provided information that was useful in subsequent implementation of car-sharing systems such as ZipCar, many of which serve transit stations.

The project cost was shared between the Transit IDEA and ITS IDEA programs, under ITS IDEA Projects 3 and 48, and Transit IDEA Project 14.

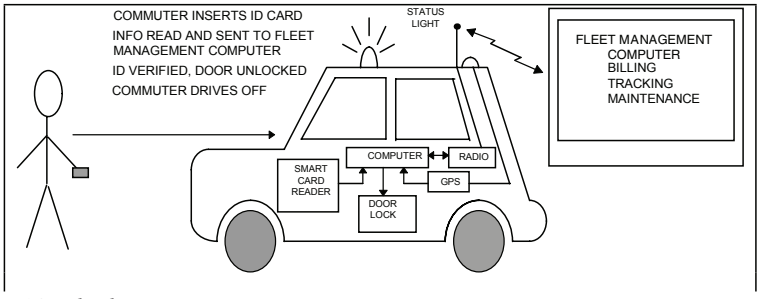


**Figure 1**

*IRAC fleet management technology.*

# Internet Information Sharing for Transit Maintenance Transit IDEA Project 15

Victor Kiernan
Kiernan Transit Associates

Transit maintenance data and information may be shared by public and private ground transportation agencies through the Internet. By sharing this information, cost savings are achieved in joint purchases, trading spare parts, and disseminating information related to transit maintenance, safety, and contracts. This IDEA project supported the Internet transit-maintenance information study in cooperation with major public transit agencies in the San Francisco Bay area. The study results show that transit agencies could achieve time and cost savings through Internet sharing of maintenance information.

The transit information maintenance system communicates through the World Wide Web. Some of the potential benefits of the IDEA project for transit maintenance include

- Reducing the costs of purchase ordering by an estimated 80 percent by using electronic ordering rather than the current paper-based systems.
- Transmitting competitive bidding and pricing on requests for spare parts among participating vendors and agencies.
- Increasing supplier discounts for coordinated joint spare-part purchases.
- Reducing inventory costs due to just-in-time ordering by sharing of the estimated more than $400 million in reserve spare parts currently held in transit agency warehouses.
- Facilitating sales of surplus parts through a single announcement capability on the Web site.
- Optimizing periods between routine maintenance by the comparison of maintenance information between agencies that specifies tasks, work performance, and personnel requirements.
- Sharing maintenance and life expectancy records of parts, which results in more dependable and efficiently run systems for improved safety and convenience for passengers.

Using the Internet for sharing information provides the potential for reducing parts inventory costs of transit systems. Two journal articles by the California Transit Association in its *Transit California* magazine describe the possible benefits of a compendium of transit maintenance information. Following this Transit IDEA project, a large-scale demonstration project of a similar system started in 2000 under a demonstration project funded by the Federal Transit Administration to the Metropolitan Atlanta Rapid Transit Authority.

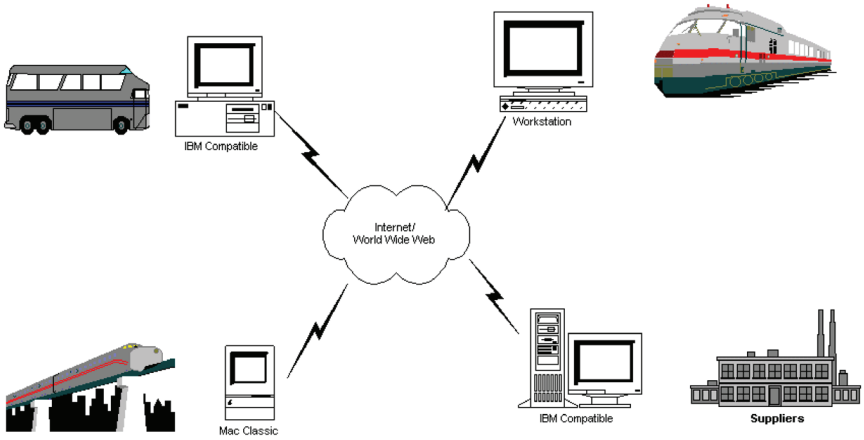


**Figure 1**

*Information through the Internet.*

# Transit Restraint System for Wheelchair Users Transit IDEA Project 16

Steven Reger
The Cleveland Clinic Foundation, Cleveland, Ohio

## IDEA Concept and Product

This project developed several restraint design concepts and tested one that brings the anchor location into proximity with the wheelchair seat. The unique design of this restraint system eliminated the disadvantages of the existing seat belt systems anchored on the vehicle floor and routed around the pelvis of the person seated in the wheelchair. The prototype was designed to offer an easier and faster operation, often eliminating the need for assistance by the bus operator. When the restraint is not in use, the adjustable rails are rotated into a stored position clear of interference with passenger seating and ambulation. The lap belt is also stored on a small retracting spool to remain clean when not in use.

## Project Results

Traveler protection during transit and vehicle impact is the primary objective of occupant restraint design, including occupant restraints of wheelchair-using travelers in transit vehicles. The objective of this project was to develop and evaluate new occupant restraint design concepts with focus on minimizing the efforts to operate the system while maintaining the crash protection of the wheelchair-using traveler.

The investigation started with the formation of the design criteria based on multiple inputs from a resource panel of experts, wheelchair users, transit administrators, vehicle operators, human factors testing of wheelchair-using travelers, and an experienced public transit vehicle designer.

A survey was developed and disseminated to administrators at 12 transit authorities throughout the country and vehicle operators involved with transportation of wheelchair users. Overall, the survey indicated conflicting information on priorities of safety, lack of use of lap and shoulder belts, fastening time between fixed route and paratransit application, and the need for alternatives to the existing occupant restraint designs. New design criteria were indicated for restraints to be used independently and rapidly by many wheelchair users with reduction of stop dwell time and driver involvement.

The human factors testing established anthropometric envelopes of a wheelchair occupant's seated posture, reach, hand strength, and functional ability to position the wheelchair.

The design criteria from all these inputs were finalized and tabulated. The criteria established specifications for activation time, user independence, durability, component locations, operating hand function requirement, body size accommodations, and crash safety in terms of load and deflection parameters.

Using the design criteria, three conceptual models of wheelchair occupant restraint systems were developed and investigated. The early concepts of stanchion-mount and wall-mount

designs were evaluated but not implemented because of obtrusive bulkiness for the first and incompatibility with vehicle structural design for the second. In previous sled impact testing (30 mph, 20-g and 5-g lateral impact) the stanchion-mount design performed well and appeared to be superior to the 3-point belt restraints.

The final panel-mount design was developed and refined, and a full-scale prototype was built for limited user tests and strength evaluation. The concept is illustrated in Figure 1. To minimize costs and to enhance commercial appeal, an effort was made for a simple design with off-the-shelf components and cost-effective tolerances.

### Field testing

The prototype was built and installed in a 44-foot bus in service at the Greater Cleveland Regional Transit Authority that was driven to wheelchair users for a hands-on trial (Figure 2). The limited field trial in the nonmoving vehicle by experienced wheelchair travelers pointed out a general acceptance of the principles of the prototype design, a dissatisfaction with the current lap-belt system, and a need for further improvements in slimmer design and in the operation of the panel-mounted restraint design.

### Pull testing

The final evaluation of the prototype restraint system was a static pull test to determine compliance with the Federal Motor Vehicle Safety Standard (FMVSS)-210 for seat belt anchorage. This test was performed at the NASA-John H. Glenn Research Center in Cleveland, Ohio. The test results indicated the ability of the restraint prototype to carry nearly half of the 5,000 lbs of target load, displacement, and duration. Failure of the body block in the prototype restraint system occurred at approximately 2,200 lbs in this test. The early failure did not occur in the design concept but was due to faulty welding and the incorrect accommodation of the belt anchor to the commercial wheelchair.

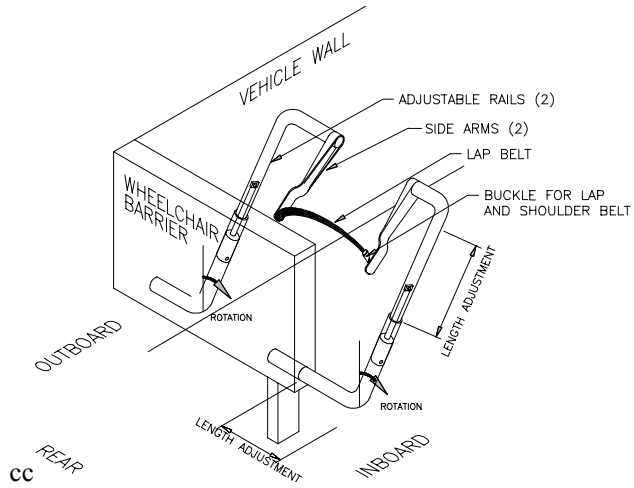


**Figure 1**

*Panel-mount design for wheelchair occupant restraint system.*

**Figure 2**

*Side view of the prototype restraint.*

## Product Payoff Potential

This project conducted surveys of transit administrators and fixed route and paratransit operators, which indicated conflicting understanding of crash safety and belt restraint use. This information reinforces the need for an educational effort to inform providers of the importance of properly positioned lap and shoulder belts for wheelchair traveler crash safety. The project has also shown why it is important to reduce operator assistance and enhance rapid user application of restraint systems, which would reduce bus stop dwell time and improve operational efficiency.

# Operational Evaluation of Automated Rail Wheel-Gauge Inspection System Transit IDEA Project 17

Zahid Mian
International Electronic Machines Corporation

This IDEA project demonstrated a low-cost prototype of an automated rail wheel-gauge inspection concept that had originally been developed under Transit IDEA Project 3. The rail wheel gauge uses a series of laser scanners and cameras mounted at trackside along with a series of ultrasonic sensors. These scan an entire cross-section of the wheel.

The measurement output is a digitized profile of the wheel that is processed by geometric algorithm software. A set of standard wheel measurement data compatible with existing measurements is derived from the digitized profile. Additional computations are incorporated into the algorithm to check for such critical specifications as wheel cracks, flange angle, wheel diameter, hollow tread, and so forth.

Transit operators and railroads often use time-consuming manual procedures to inspect and maintain rail wheels. Existing handheld measurement instruments lead to inefficient and nonuniform inspection operations.

The product provides a complete profile of a rail wheel and inspects the wheel and flange wear. The advanced wheel inspection method is particularly attractive to rail operations where issues of wheel/rail interaction are crucial to overall performance and safety.

A conference convened during the Transit IDEA project confirmed that the automatic wheel-inspection system could meet rail transit requirements. The system was also field tested at the Amtrak Albany-Rensselaer Yard. IEM developed a booklet on wheel inspection stations.

Subsequently, the investigator received a contract from the New York State Energy Research and Development Authority (NYSERDA) for approximately $500,000 to expand and continue the work. Additional field tests revealed certain potential limitations of the original system. A redesign involved added cameras and a faster and more reliable wheel detection and capture system (the detection and capture subsystem never failed to detect and trigger capture of a wheel in many months of trials). The refined system also has no special rail segments or footings for installation and a fully 3-D laser imaging-based measuring system. The current system operates at higher speeds than the prior system, has the potential to measure wheels on trains moving at normal full-transit speed, and determines all measurements by more accurate and robust means than used in the original design. A diagram of the current system layout is shown in Figure 1. A patent for the system was issued in October 2002 and additional patents on other aspects of the system were issued in July 2004 and August 2011.

Several transit and railway companies and organizations in the United States, including Miami-Dade County Transit and others in countries ranging from China to Brazil have made inquiries to the investigator about obtaining these systems for commercial use. The investigator has prepared technical specifications and overviews of the systems' requirements, installation, and use for prospective customers. CSX Corporation signed a contract for the purchase and installation of one of IEM's in-ground, rail-based wheel inspection systems. The full system installation was completed in October 2006. IEM demonstrated the operating system to interested transit customers. Figure 2 shows one view of the installed system at CSX Transportation's Selkirk, New York, "hump yard." The system became fully operational in early 2007 and has accurately measured many tens of thousands of wheels as verified by multiple tests. CSX also purchased four additional systems. New Jersey Transit (NJ Transit) has purchased this system to inspect wheels on rail transit vehicles.

As part of a consortium for Australian rail transit projects, IEM built and installed a rail-based wheel inspection system for the Sydney City/Rail transit system in 2009 and 2010. The system was built in the U.S. by IEM and was exported and installed in Sydney, Australia by employees of IEM, who traveled from the U.S., and who will also provide maintenance for the system.This has resulted in jobs for U.S. workers.

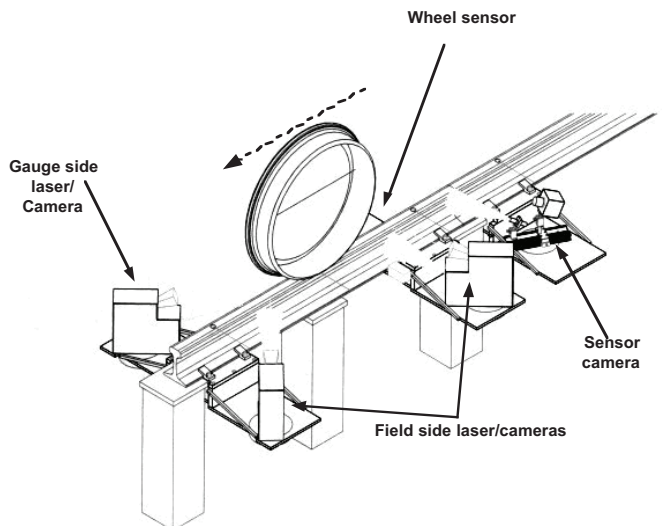


**Figure 1**

*Rail-based wheel inspection system.*

**Figure 2**

*Installed system at CSX yard in Selkirk, New York.*

# Innovative Payment Options for Independent Transportation for the Elderly Transit IDEA Project 18

Katherine Freund
Independent Transportation Network

## IDEA Concept and Product

This project pilot tested two innovative payment operations for independent transportation for the elderly—adult child payment plans and merchant participation. It also investigated the use of geographic information system (GIS) technology for community-based transportation for seniors.

A previous Transit IDEA Project, *Independent Transportation Network: Alternative Transportation for the Elderly*[2] (Transit IDEA Project 9), developed and tested the independent transportation network and showed that seniors were willing to use a transportation service that models the comfort and convenience of the private automobile and included shared rides. (Freund, McKnight, 1997) This Transit IDEA Project 18 examined several innovative sources of revenue and the application of information system technology.

Transit IDEA Project 18 investigated innovative payment methods by looking outside the traditional public funding sources to private resources in the community. This project demonstrated that businesses and adult children are willing to participate in the cost of transportation for seniors.

Adult children whose parents use the transportation service and members of the business community whose customers and patients use the service were identified as groups who might be willing to help pay for rides. Geographic Information System (GIS) technology was selected as the information system application most likely to contribute to the efficiency of the service.

Research was conducted at the Independent Transportation Network (ITN) in Portland, Maine. ITN uses automobiles and both paid and volunteer drivers to provide service seven days a week. Seniors who use the service become members of the nonprofit organization and open prepaid accounts which are debited to pay for their rides. No money changes hands in the vehicles; rather, members receive monthly statements, similar to a telephone bill, detailing their rides and charges.

## Project Results

A. *Innovative Payment Operations for Adult Children*
A catalogue that combined gifts and transportation certificates was tested with seniors and their adult children. The response rate from the target market, adult children of seniors, was approximately 10 percent. By comparison, the typical response rate of companies in the catalogue industry is only two percent. Most of the gift certificates purchased, however, were for transportation only, not transportation combined with a gift. This meant that the only

opportunity to raise revenue was from fees charged for the certificates, a practice that was unpopular with consumers. The willingness of adult children and families to participate in the ITN senior transit service was then tested as a membership campaign, expanding the membership concept from the senior customers to families and the population as a whole. The membership program produced revenue immediately, with membership dues from adult children and siblings ranging from $35 to $1,000. Gift certificates have been retained in the transit program as conveniences for customer service. Adult children liked them as a feature of the service and showed their appreciation for the ITN through contributions and membership dues. Likewise, credit cards as a payment method did not increase adult child participation in the program, but they did provide a good customer service.

B. *Innovative Merchant Program*

Merchant participation was tested with the Ride & Shop program. A control group and an experimental group tested the program for six months, collecting stickers from thirteen area merchants. The results indicated the Ride & Shop program was effective in increasing rides to participating stores. Each sticker collected was worth $1.50, with $1 going to the riding seniors, as an incentive to patronize that store, and $.50 going to the ITN to help cover the deficit incurred with every ride. The administrative cost of the Ride & Shop program exceeded the economic benefit until the program became "stickerless" as an electronic transfer of funds from the merchant's account to the accounts for the seniors and the ITN. Like the membership campaign described above, the electronic Ride & Shop program that was developed in this project was implemented at the ITN in Portland, Maine, after the project was completed.

C. *Information System Technology*

A GIS program was designed to create shared rides among community-dwelling seniors by using windows of availability and by dispatching volunteer drivers. Available commercial GIS software applications for transit were found to be inappropriate and unaffordable for small community volunteer transit services that need to capture the detail necessary to properly dispatch volunteer drivers and their vehicles. Focus groups and a survey of seniors using the ITN service indicated that 80 percent of seniors were willing to share rides in automobiles with other seniors in the service. A GIS software application that uses Transit IDEA research results was built with other resources. The program dispatches to both paid and volunteer drivers, creates shared rides as a consumer choice, incorporates revenue and data collection for the innovative payment operations (Ride & Shop, Healthy Miles, and Ride Services), and maintains a database for membership.

By demonstrating two innovative payment options through adult children of seniors and businesses in the community and by using a GIS to create shared rides and efficiently dispatch volunteers, this project provides information on innovative payment methods for transportation services for elderly people.

More than $1 million in follow-on funding was obtained and used for post-IDEA research and development. ITNAmerica is a national organization that was created to spport deployment of this kind of service. Some of the methods developed in this project and Transit IDEA Project 9 were subsequently used in more than two dozen other cities and metropolitan areas, including Los Angeles, California; Orlando, Florida; and Lexington, Kentucky.

# Field Testing and Evaluation of the Transit Integrated Monitoring System (TIMS) Transit IDEA Project 19

Manuel D. Rossetti
University of Arkansas, Fayetteville, Arkansas

## IDEA Concept And Product

Transit IDEA Project 10 addressed the need for improved methods of data collection concerning transit users and vehicles by developing a prototype radio frequency identification (RF/ID) tag that acts as a bus pass. Passengers carrying the cards can be *uniquely* identified and tracked throughout the transit system. This Phase II demonstration project, Transit IDEA Project 19, improved on the prototype by field testing an integrated automatic passenger counting (APC) system and automatic vehicle location (AVL) system based on GPS and RF/ID smart cards.

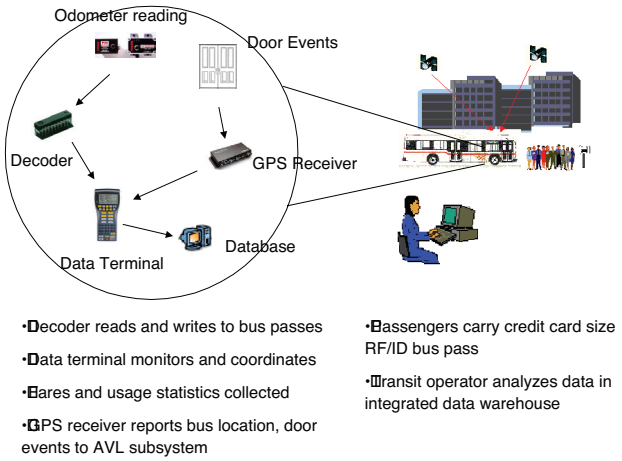


**Figure 1**

*System concept diagram.*

## Project Results

During the Transit IDEA Project 10, a prototype based entirely on RF/ID tagging technology was developed and tested on a University of Virginia bus route using student volunteers. In addition to providing tags to bus passengers, RF/ID tags were embedded at bus stops along a route to track the movement of buses. Preliminary data were collected in near real-time. The read rate of the embedded tags was less than 50 percent. The data captured included passenger and bus stop identifiers and event times (arrival and departure times of buses and boarding/alighting times of transit users). From these data, information such as origin-destination pairs, passenger transit times, and schedule adherence were derived. The data were organized into a database and example summary reports were formulated. Passenger acceptance of smart cards and tracking was analyzed via surveys.

The results of the Transit IDEA 10 project indicated the potential of using radio frequency identification to integrate APC and AVL systems. The Transit 19 Phase II demonstration examined the integration of APC/AVL and other monitoring functions in the form of a Transit Integrated Monitoring System (TIMS). Objectives for Phase II included developing a demonstration system that (1) improved the hardware components of the Transit 10 prototypes, (2) enhanced the software architecture and software subsystems, and (3) enabled a better understanding of the operational performance of TIMS under transit conditions. A route within the Charlottesville Transit System served as the demonstration's case study.

The hardware system was redesigned to utilize global positioning technology as the primary bus stop identification mechanism. In addition, the system concept was changed to allow fare collection on a portable data terminal mounted within the vehicle. The results include an object-oriented software architecture of the information content for the system, a set of use cases for the system, a design specification for the database, a design specification for the user interface, and the hardware requirements and specifications. The system was tested during a field trial of two weeks. The results of the testing yielded a 96.5 percent read reliability rate for the cards. In addition, if the cards are used as proximity devices, a 100 percent rate was achieved. The final product associated with this project is the completed design and specifications of TIMS using the software industry standard Unified Modeling Language, the integrated hardware and software, and a demonstrated system. The final report for the Transit IDEA project was completed.

## Product Payoff Potential

The primary benefit of this project is the design of an integrated system that replaces the functionality of disjointed passenger counting, vehicle location, and fare collection systems at approximately the same cost. In addition, because the system can record boarding passengers' fares automatically without the passenger having to remove the fare card from their purse or wallet, time can be saved.

For this demonstration, APC integration was achieved through the use of smart cards based on radio frequency technology; however, the hardware and software design specifications *do not* depend on the use of radio frequency based smart cards. The potential benefit of this project to practice depends on the acceptance of smart cards by the general population within the United States. Integrated systems such as TIMS can take advantage of the growing use of smart cards.

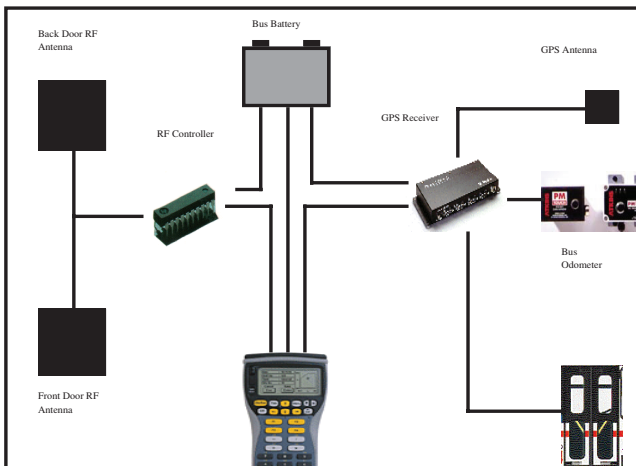


**Figure 2**

*Hardware connections.*

## Product Transfer

The steps taken to facilitate product transfer include:

1. *Partnerships with industry:* The project was a joint effort between academic researchers and a smart card company, Axcess Inc.
2. *Partnerships with transit providers:* Transit IDEA Project 10 was implemented on the University of Virginia transit system. Transit IDEA Project 19 was implemented on the Charlottesville Transit System.
3. *Monitoring by a Transit Users Forum:* The forum consisted of researchers and practitioners associated with the Virginia Department of Transportation, Charlottesville Transit System, and the Richmond Transit Authority.
4. *Publications:* Two journal articles and a conference paper.

Additional plans by the investigator as a follow-up to this project include:

- Seeking additional financing to enhance the system to include real-time DGPS, GIS, and Web-based interfaces.

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# Noncontact Sensor for Passenger Counting and Classification Transit IDEA Project 20

Gene Greneker
Greneker and Associates Inc., Powder Springs, Georgia

## IDEA Concept and Product

A transit passenger counting system was developed to provide counts of multiple passengers entering rail rapid transit vehicles through a wide-stream door. The direction of travel of each passenger can also be determined. This prototype system is called the Cyclops Passenger counter and was originally developed under Transit IDEA Project 5. In addition, an experimental method was tested to determine if individual passengers can be tracked to determine origin and destination stations.

Three elements currently comprise the experimental Cyclops system: (1) a radar system, (2) a television camera, and (3) a wireless data link that transmits both radar and television images to an associated data recording system (not shown). The radar system was tested to determine if it could serve as a low-cost sensor/counter capable of detecting a passenger entering the radar beam and determine if the detection is an entry or exit event. The television camera system was used for counting passengers and identifying the stop where a passenger boards and exits. In final form, a microprocessor controller could process the radar and television camera system data and provide that information as output to the transit vehicle's database, on-board recording and collection system, or radio-linked data collection system.

## Project Results

This project was conducted in two stages. The first stage tested the performance of the Cyclops experimental passenger counting system employing radar and television sensors and a wireless data transmission system. These tests were conducted in the laboratory to demonstrate the feasibility of using each type of sensor to count passengers entering and exiting a simulated wide-stream door located in the laboratory. Each of the two sensor systems (radar and television) was designed to sense passenger presence data independently.

During the second stage of research, radar and television image data were first collected from an operating out-of-service rail transit vehicle to determine if there are vibrational or electromagnetic interference issues that must be addressed and solved. This was followed by full-scale testing of the system on Metropolitan Atlanta Rapid Transit Authority (MARTA) rail rapid transit cars during revenue service. Counting multiple passengers simultaneously entering the wide stream door abreast of each other, shoulder to shoulder, is a challenge for the current radar system design. The Cyclops passenger counter system would need further development to overcome that obstacle before it could provide passenger counts on transit vehicles with wide-stream doors.

## Summary of Testing Program

The data produced during testing were used to determine the vibration environment as well as the electromagnetic environment found on a moving rail transit vehicle. Following static testing, operational problem areas were identified and these problems were addressed before tests were conducted on a rail transit vehicle in revenue service.

Processing algorithms were developed in the laboratory after the recorded data were analyzed. The processing system provides the total number of entry and exit events through a wide-stream door at each stop with a time tag.

## Product Payoff Potential

The system, when fully developed, may offer transit systems an efficient method of obtaining ridership counts.

## Product Transfer

A final report on the Transit IDEA project has been completed. If the passenger counting system can be further developed to overcome the obstacle of multiple passengers simultaneously entering wide stream doors, a commercial prototype system could be developed. This system could be provided to firms in the passenger-counter industry for the purpose of testing to industry standards. Problem areas will need to be corrected during further development. The system design could then be licensed to the passenger counter industry for manufacture and sales to the transit industry.


**Figure 1**

*Passenger Counter being mounted on MARTA rail rapid transit vehicle.*

# Smart Parking Lot with Just-in-Time Bus Service Transit IDEA Project 21

Chris A. Bell
Oregon State University

## IDEA Concept and Product

This project was aimed at developing and trial testing an adaptive software system and scheduling algorithm for a "smart" parking lot with just-in-time shuttle bus service to improve parking efficiency in large parking lots at intermodal and transit terminals. Based on the results, prototype input-output hardware and software systems were designed to prepare for deployment trials in a large parking lot at Portland International Airport (PDX).

Demonstration tests were performed at the PDX airport parking lot. The deployment testing process will be supported through external cooperative funding.

## Project Results

The project involved four stages of research. The first stage involved collection of information on parking issues in large intermodal parking lots and the development of an appropriate system configuration for operating the "just-in-time" parking process. A beta version of the smart parking simulation software was developed and preliminary results for a hypothetical parking lot were evaluated and found satisfactory to proceed to simulation of the more complex situation of a real parking lot. A panel of regional experts convened to discuss Stage 1 results and evaluate project plans and endorsed the development of the simulation to apply to the Economy parking lot at PDX airport.

Following refinement of the simulation, verification tests were performed in Stage 2 using the PDX parking lot configuration. The simulation has a dumb and a smart mode, enabling comparison of operating characteristics before and after implementation of the smart system.

Stage 3 involved additional refinement of the simulator based on data collected at the PDX Economy parking lot. Various operating characteristics were evaluated, and, based on the results, the system was improved. Criteria for designing input-output hardware and software were developed by applying the results of the simulation. The regional panel of experts was convened again to discuss proposed improvements and advise on plans for the fourth and final stage.

Stage 4 completed the design of an automated parking system to prepare for a pilot system on the PDX parking lot.

## Project Payoff

The market potential and benefits for this concept are significant. The concept relates to parking information systems and will improve efficiency of parking at any parking terminal (with an input routine to define the lot characteristics). Time savings can lead to cost savings. In addition to the application in public transportation practice, there are significant applications in the private sector, where parking lots for large industrial campuses deal with several thousand users on a daily basis.

## Product Transfer

The project was undertaken with the collaboration of the parking contractor at the PDX airport. The Port of Portland is the airport owner and was also represented on the regional panel of experts, together with TriMet, the local transit agency in Portland, Oregon. A successful demonstration was performed at PDX with external funding, following completion of the Transit IDEA project. The final report for this project was completed.

This approach has subsequently been implemented at parking facilities at a few airports. This would have applications for parking facilities for other airports or transit terminals or other large parking facilities.

# Sleeved Column System for Crashworthiness of Light Rail Vehicles Transit IDEA Project 22

Ronald A. Mayville
(formerly with Arthur D. Little Inc., Cambridge, Massachusetts)

## IDEA Concept and Product

The concept and product that was tested is a novel, low-cost, lightweight replaceable energy absorption system that can be incorporated into modern rail transit vehicles to provide substantial protection in collisions with other trains and with road vehicles at grade crossings. The system is based on the sleeved column technology, in which one or more small-diameter steel core rods carry load and compress and efficiently absorb energy within a sleeve made of mild steel or other material. The sleeve prevents buckling of the relatively slender core and can be an existing structural member in the rail vehicle underframe.

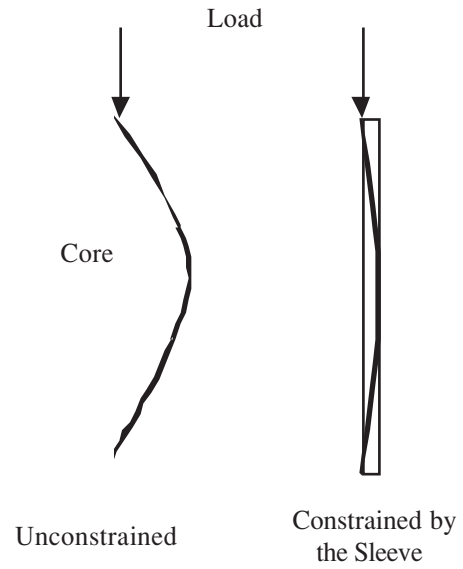



**Figure 1**

*Sleeved column concept.*

## Project Results

A detailed design of a sleeved-column energy absorber was developed and fabricated for dynamic testing. The sleeve is a rectangular, hollow, mild steel member with a length of nearly 8 ft. Rectangular structural members are more commonly used in rail vehicle construction than shapes with circular cross sections. A single core element was fabricated from a solid, high-strength, low-alloy steel piece.

Tests indicated that the design crush load is reached at the first stage of crush and then increases by a factor of two for the second stage crush, resulting in a desirable stepped load-crush response distributing energy absorption to other vehicles. Tests were performed and results reviewed by the project panel.

## Product Transfer

While the primary objective of this project was to demonstrate the applicability of the sleeved-column technology to rail transit vehicles, the investigators also explored the incorporation of the system into light rail vehicles through a collaborative effort with a manufacturer of transit vehicles for U.S. service.

This project included generation of a structural layout of the new energy-absorbing elements in a representative light rail vehicle underframe and analytical evaluation of the performance of this system. This engineering work is available for potential use. The final report for this project was completed. It includes information needed by practitioners in the rail vehicle industry to design sleeved column energy absorbers.

# Optimizing Travel Paths for People with Disabilities Transit IDEA Project 23

W. Davis van Bakergem
(formerly with Washington University, St. Louis, Missouri)

This IDEA project developed a method for people with various types of disabilities to review barriers to travel before embarking on a transit trip, so they can plan their paths to more easily reach destinations surrounding transit stations.

The research analyzed typical travel barriers for the disabled around transit access points. A database of physical landscapes and barriers was developed and a prototype transit-accessibility mapping system was demonstrated. The model is based on Metrolink light rail transit stops in the St. Louis, Missouri, region. The scope of this project was reduced to accommodate the FY'98 Transit IDEA funding shortfall. The investigators only conducted Stage 1 of this project.

# Intelligent Rail Lubrication System Transit IDEA Project 24

Sudir Kumar
Tranergy Corporation

This project designed, built, and demonstrated an automated, computer-controlled onboard intelligent system for applying new environmentally safe and consumable lubricants for rail systems. The lubricant applied to the rail will reduce friction between the wheel and rail and is expected to provide significant benefits in maintenance, safety, and overall economic efficiency. A schematic diagram of the rail lubrication system for railroads is illustrated below.

Progressive development of a rail lubrication system for U.S. railroads and transit systems indicates potential benefits including reduction in wheel wear, rail wear, and track maintenance costs. The scope of the Transit IDEA project was reduced to accommodate the FY'98 Transit IDEA funding shortfall. A final report was prepared for this Transit IDEA project.

Tranergy continued the work on the system at its own costs after discontinuation of funding. In September 2000, a new joint venture called "Friction Management Services, LLC" was formed by Tranergy and Timken, a major international corporation. This joint venture has been continuing the work on the system and has installed many systems on locomotives of four Class I railroads in the United States and Canada for checking performance improvements on trains in revenue service.

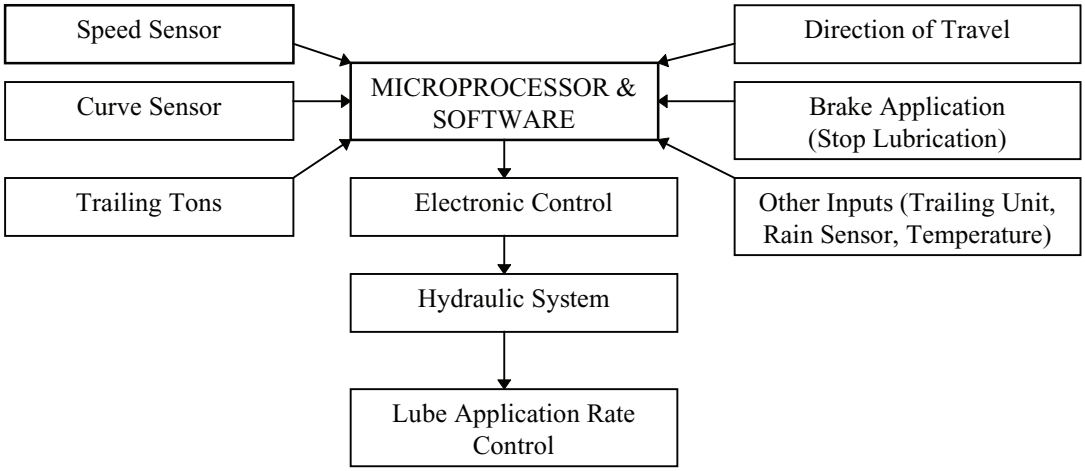



**Figure 1**

*Schematic diagram of rail lubrication system.*

# Designing Transit Services for the Mode-Choice Market Transit IDEA Project 26

Alan Hoffman
The Mission Group, San Diego, California

## IDEA Concept and Product

The project was aimed at developing new tools for market-focused transit planning to compete for riders who have a choice of modes. The approach, named "Stage III" to distinguish it from current mode-centered planning, directly builds on the two variables of great importance in designing competitive transit services: time and modal utility. The project had planned to address the first variable through the elaboration of a new measure of regional mobility, the Mobility Index, which measures and maps automotive and transit mobility based on trip times to demand generators. The second variable was addressed by focus group research aimed at solving the problem of market positioning for transit services.

## Investigation

The project was planned to involve three stages of research. The first stage focused on the development of the Mobility Index and a set of associated maps for the San Diego metropolitan region. Each Transportation Analysis Zone (TAZ) in the region was scored for its absolute (average time required to reach all regional demand generators, weighted by demand) and relative mobility (average time required to reach those demand generators actually demanded by the target TAZ) for both automobile and transit modes. These maps and measures were produced for both a baseline case and for one or more alternative transit strategy cases. The research was tied closely to the strategic planning effort being undertaken by the San Diego Metropolitan Transit Development Board (MTDB).

The second stage focused on the question of designing transit services aimed at the mode choice, or discretionary, market. A limitation of some transit system design has been the gap between what is designed, named, depicted, and promoted, and what key segments of the choice market would most respond to. The literature on service-sector industries suggests an approach to product and service design based on careful market segmentation, intelligent market positioning, and careful attention to the design of the customer experience at every stage in the "service encounter." The focus group research attempted to identify the "bellwether" segment(s) of the choice market and explore those elements that are crucial to designing and then positioning new transit services aimed at achieving significant penetration of the choice market.

In the third stage of this project, the investigators had planned to prepare a document summarizing the results of the project: *The Market Intelligence Report on Positioning Transit Services for the Mode Choice Market*, a document setting out a set of recommended strategies for agencies seeking to design and position transit services targeted at the mode choice market. However, the investigators did not carry out the third stage of this project.

| | Stage III |
|---|---|
| Description | Transit services are designed and developed to compete effectively for riders with modal options and to maximize regional mobility. |
| Challenge | Effectiveness will depend on degree to which transit planning can begin with market needs and work backwards from these. |

**Figure 1**

*Stage III transit planning.*

# Scratchitti Removal by Controlled Fire Polishing Transit IDEA Project 28

Shane Y. Hong
(formerly with Columbia University, New York City, New York)

## IDEA Concept and Product

This project addressed the problem of vandalism on rail transit car windows. A type of graffiti vandalism that has emerged and prevails is the scratching or etching of polycarbonate and glass windows in subway cars, called "scratchitti." Unlike paint graffiti, the scratches cannot be removed or covered, and they cause permanent damage.

New York City Transit supported this project from the time it was proposed and has collaborated in providing samples of scratched glass subway windows to Columbia University to test and characterize.

To address the problem, this project used an innovative approach—controlled fire polishing, which incorporates a technique of localized softening and surface tension. Intensive heat is positioned near to the scratch marks on the glass panel. The heat melts a thin layer of glass into liquid, changing the glass's viscosity to a formable state. The glass is melted to a level close to

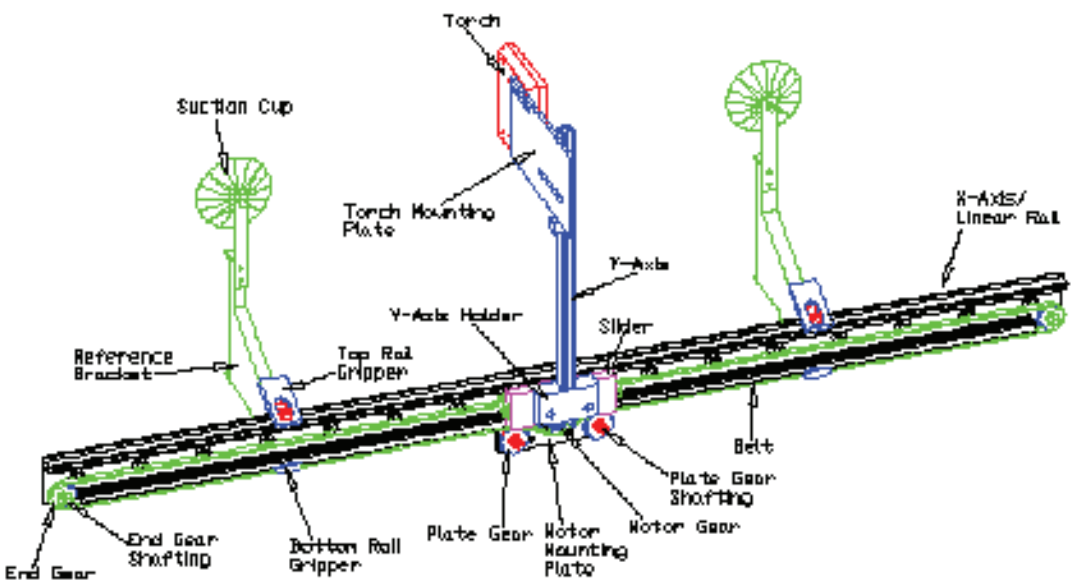



**Figure 1**

*A rail attached to the window holds a motor driving an arm that would sweep a flame across the window. When the glass cools, it is scratch free.*

the depth of the scratch, and allowed to cool down naturally. During the cooling process, the surface tension of the melted glass evens out the scratching indent. After cooling and without grinding or polishing, the glass is as even and smooth as it was originally. The glass remains solid and structurally sound during this operation to prevent any distortion of the glass panel. This process can flatten and smooth the surface and restore its optical transparency in an environmentally safe manner. It can significantly reduce costs compared with replacing subway car windows.

## Project Results

This Transit IDEA project has successfully demonstrated the feasibility of this innovative process in the laboratory. Investigators at Columbia University surveyed and characterized the scratchitti, investigated the glass or polycarbonate properties, designed the heat source, ran a heat transfer analysis and temperature computer simulation, and designed and built a motor-driven prototype tool for removing scratchitti for initial tests. The project has demonstrated the feasibility of the proposed system and collected the necessary data and parameters for controlling the process.

To facilitate the smooth operation, a uniform, linear, narrow, and high-temperature flame served as the heat source and provided a cost-effective tool for fire polishing. This was achieved through three iterations of nozzle development. The machine investigators designed and built *Scratchitti Buster*, a motor-driven slider controlled by a computer to move the nozzle at a constant speed during the polishing process. Light and portable, this machine has suction cups to cling to the glass panel for positioning. It uses the glass surface as reference by a pair of brackets so that the nozzle will keep a constant distance while moving. The brackets are adjustable to fit the machine with different sizes of windows. The oxy-fuel used can be acetylene-oxygen for high-speed fire polishing or propane-oxygen for convenient and easy operation.

Analytical and numerical heat transfer simulations of the flame and glass pane interaction yielded satisfactory operational parameters for the desirable steady-state temperature distribution. The control parameters included the flow rates of the fuel and oxygen and their mixing ratio, and the flame travel speed and distance from glass surface. The desirable temperature distribution enabled the glass surface to re-flow and remove etches, while preventing glass distortion and cracking. Experimental testing of the fire-polishing process was performed, and the feasibility of the process was demonstrated by glass samples that recovered from heavy scratches to a smooth, clear, and transparent state. The ranges of optimum operating parameters for high polishing quality have been identified through a range of testing conditions.

## Project Payoff Potential

This project addressed the pressing scratchitti vandalism issue faced by rail transit agencies operating subways. Unlike paint or ink graffiti, the glass etchings cause permanent damage. Scratchitti is prevalent on many subway car windows of New York City's subway lines. Because replacing the damaged window is so time consuming and costly, transit agencies have not been able to replace all of the damaged windows. Currently, New York City Transit (NYCT) replaces glass only when it becomes so scratched it cannot be seen through, or when it has obscenities or racial slurs etched into it. In 1997, NYCT replaced approximately 62,000 pieces of damaged subway window glass for a material and labor cost of $2.6 million. NYCT has estimated that, in order to run a scratch-free subway rail car fleet, they would have to spend $60 to $70 million per year in window replacement and labor costs.

## Product Transfer

A process demonstration was performed at Columbia University for representatives from New York City Transit who have supported this project from its beginning and have provided assistance to the researchers. The results from this Transit IDEA project have successfully demonstrated the feasibility of this innovative process in the laboratory. The final report for this Transit IDEA project has been completed.

The information from this project could serve as a basis for product development and design in commercialization stages. It could move into development of an operational instrument. Following this project, the investigators propose to develop a well-controlled operational instrument or tool for removing graffiti from subway car glass windows, based on the results of this project, if they can find financing. A private company obtained a license for the technology from Columbia University. A follow-on effort has been pursued with private resources to deal with automating this graffiti removal system.

**Figures 2 and 3**

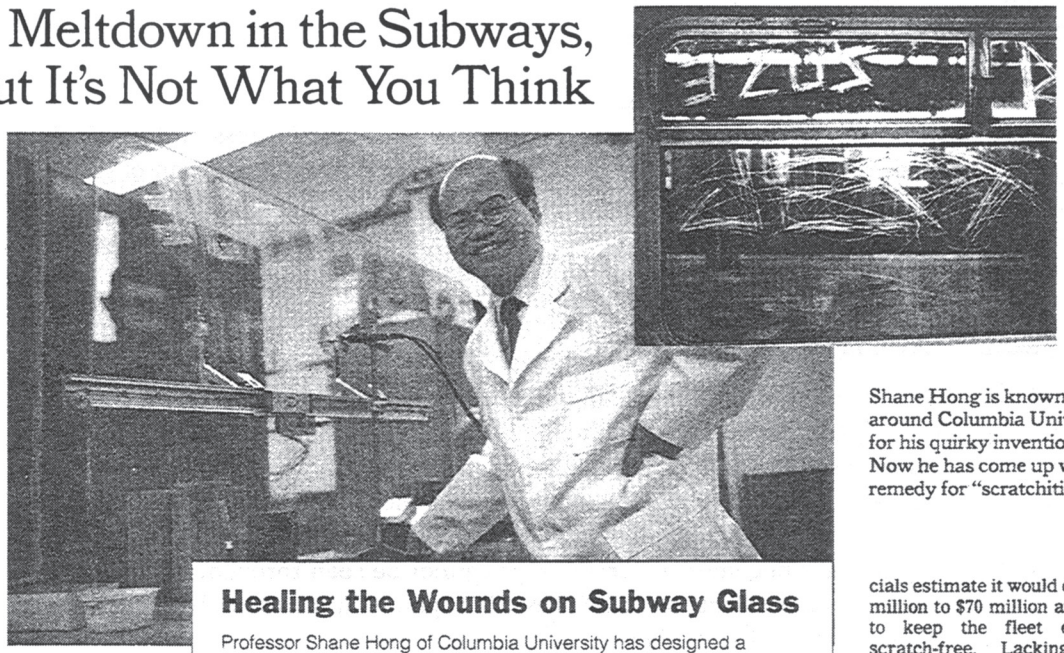
*Scratchitti on the rail car windows in the New York City subway.*

THE NEW YORK TIMES, SUNDAY, APRIL 16, 2000

# Neighborhood Report

NEW YORK UP CLOSE

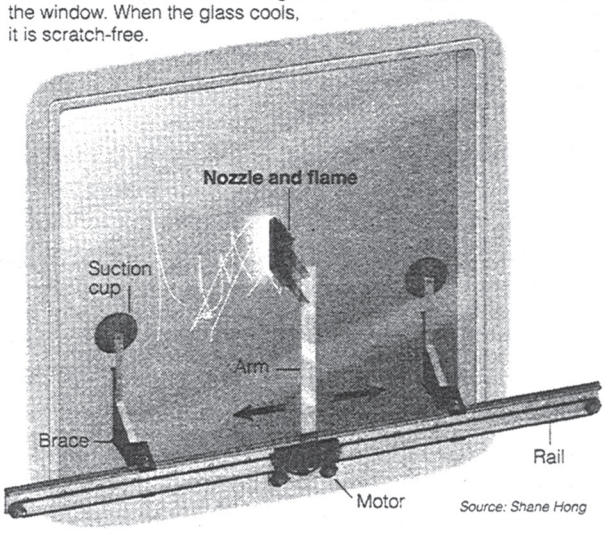
## A Meltdown in the Subways, But It's Not What You Think



Shane Hong is known around Columbia University for his quirky inventions. Now he has come up with a remedy for "scratchiti."

### Healing the Wounds on Subway Glass

Professor Shane Hong of Columbia University has designed a machine to erase scratches on subway windows. A rail attached to the window holds a motor driving an arm that sweeps a flame across the window. When the glass cools, it is scratch-free.




Source: Shane Hong

A decade ago, New York subway riders often had to squint through windows covered with painted graffiti to see a station. Today, the graffiti is gone, but many windows are still obscured, with deep, ugly scratches known as scratchiti.

But a Columbia University professor thinks he has found a way to attack the scratchiti scourge. The professor, Shane Hong, has designed what he calls a scratchiti-buster, a device that applies a flame to melt the window surface just enough so scratches dissolve and the glass regains its smoothness as it cools.

In the prototype, which is in production, the small propane flame would be controlled by a mechanized arm that would attach to a subway car window. An operator would not have to control the flame, but would move the arm, weighing less than 10 pounds, from one window to the next.

Mr. Hong, who teaches mechanical engineering and is known around campus for his quirky inventions, said he came up with the idea during a subway ride several years ago. Last year, he approached the Metropolitan Transportation Authority with his plan.

M.T.A. officials say they hope Mr. Hong's device will be a money-saving improvement over the only current remedy — replacing scarred windows. The agency spends $3 million a year on replacements, and officials estimate it would cost $60 million to $70 million annually to keep the fleet entirely scratch-free. Lacking that kind of money, or even a budget for research, they helped Mr. Hong get a $135,000 grant from the National Research Council to build a prototype.

A graduate student and several undergraduates are helping him design the motor and arm, taking into account the varying dimensions of subway car styles. The team is also figuring out how hot and how large the flame must be to lightly melt — but not shatter — the bulletproof glass.

Through the testing, Mr. Hong said, he remains focused on his goal: clear subway windows. "Some people think that professors in a place like Columbia should only study theory," he said with a grin, "but I think making people's lives better, even just a little, is the way to go."

Transit officials say that scratchiti first appeared in 1994, the year after a well-publicized crackdown eliminated most spray-painted graffiti from the subway's 5,792 subway cars.

"We've tried a lot of things, but nothing has worked so far," said the M.T.A.'s senior director of facilities, planning and car appearance, Carol Florio. "We're just hoping that Professor Hong is holding the golden key."

*HANNAH FAIRFIELD*

# Fare Machine Tactile/Audio Instruction System Transit IDEA Project 29

George Leonard
SEB Associates (formerly KRW Incorporated), Woodbridge, Virginia

## IDEA Concept and Product

The project addressed the difficulties that people with vision impairments encounter when they try to use most existing transit fare and ticket vending machines. The complex fare structures and operating mechanisms on many transit fare machines make it difficult to design and fabricate raised letter and Braille operating instructions that are independently usable by persons with vision impairments. Working collectively with the Tri-County Commuter Rail Authority (Tri-Rail) and the National Federation of the Blind (NFB), an audio device has been developed that can be programmed and installed on existing equipment to assist people with vision impairments to use these complex fare machines.

## Project Results

The project consisted of three stages. Stage 1 documented the design and procurement process that was used to develop the tactile/visual instruction face plate for the existing Tri-Rail ticket vending machines. Extensive one-on-one testing with individuals who are blind or have vision impairments was undertaken to determine the usability of the existing tactile/visual instructions. During stage 2, the audio system, consisting primarily of a microprocessor, power supply, speaker, and response button, was designed and tailored to fit within the existing ticket vending machine cabinet. Audio instructions were composed and programmed to provide a question and response dialogue to make the ticket vending machine independently usable by persons with vision impairments. Initial responses from individuals with a broad range of vision impairments who were involved with the testing were very positive and provided insights on how the original design could be further improved before conducting additional testing to "fine tune" the text for the audio instructions. Stage 3 consisted of a three-month trial period where usability, reliability, maintainability, and overall patron acceptance was monitored. The results of the stage 3 testing of the equipment provided valuable insights into factors that must be considered to ensure that the equipment will be reliable and continue to function effectively in a range of environments.

## Product Payoff Potential

The project demonstrated conclusively that the fabrication and installation of an audio instruction system, supplemented by a tactile instruction system, can greatly improve the usability of fare vending equipment by individuals with vision impairments. The project provides a blueprint for replication of these efforts. The project generated a user guide with two reports that will be useful to the transit industry. The first report documents a step-by-step process illustrating how to design and procure usable tactile/visual instructional face plates for complex ticket vending machines. The second contains instructions on how to design, fabricate, and install a supplemental audio system on existing ticket vending machines and how to

program concise, to-the-point audio instructions to effectively supplement the tactile/visual instructions. These products will show transit agencies how to make existing ticket vending machines independently usable by persons with vision impairments.

## Product Transfer

The project was undertaken with the full collaboration and participation of the Tri-County Commuter Rail Authority and the National Federation of the Blind. The research has had successful results, in that patron acceptance has been positive and Tri-Rail took steps, even before the project was completed, to expand the use of the devices to more of its commuter rail stations. The original project plan called for four audio instruction devices to be installed and tested at four Tri-Rail stations. Tri-Rail, with assistance from the National Federation of the Blind, purchased six more devices which were installed at four additional commuter rail stations during the stage 3 evaluation period. There was positive feedback from the disability community. Elements of the audio instruction system, including the design and installation of tactile pathways and the creation of audio instructions keyed to the tactile pathways, have since been used on Maryland Transit Administration's fare vending machines on their light rail transit system and Metro Subway transit system in Baltimore.

The project produced a final report, which documents the three stages of this project and the results of the project. A user guide provides step-by-step instructions describing how to design, fabricate, and install the necessary hardware and how to compose and program effective audio instructions to implement tactile and audio instructions that make existing fare vending equipment usable for persons with vision impairments.


**Figure 1**

*Face of the Tri-Rail fare vending machine showing the large green audio response button and speaker grille unit installed on the right side of the face plate, just below the credit card insert slot.*

**Figure 2**

*Audio system hardware components, including, left to right, power surge protector, audio response button, and speaker grille, microprocessor cabinet, speaker, and audio amplifier/controller.*

# A Tool for Evaluating and Optimizing Bus Stop Location Decisions Transit IDEA Project 31

Peter G. Furth
Northeastern University, Boston, Massachusetts

## IDEA Concept and Product

This project developed a tool for evaluating and optimizing bus stop locations. In evaluation mode, it will determine the impacts of a proposed change in bus stop locations, adding or removing a stop. In optimization mode, it will select the optimum stop locations from a set of candidate locations (generally, all the intersections along the route).

Users of this prototype software will be able to specify the relative importance of walk distance, riding time, and operating cost. The tool will be realistic in accounting for transfer demand and demand arising along side streets that is more like point demand than like continuous demand. It will account for roadway and traffic parameters that affect stopping delays (grade, cruise speed, traffic control). While this project addressed urban bus routes in general, attention was paid to a planned bus rapid transit application and to a light rail transit case study.

Changing stop spacing has three predictable, quantifiable impacts: it affects walk access distance, riding time for through-riders, and operating cost. While the mathematical relationship of these impacts to stop spacing was published 20 years ago, this knowledge has not been translated into practice because the mathematics was expressed in terms of data inputs that were not generally available. The concept in this project is to develop a software tool that will calculate the impacts of changing stop spacing, using generally available data—on/off counts and geographic data such as road maps and assessor's maps.

There is a general awareness that part of what detracts from bus transit's attractiveness is the frequency of stops. Urban bus routes in the United States typically have stops about 200 meters apart (8 stops per mile), compared with 320 or 400 meters in Europe (5 or 4 stops per mile).

## Project Results

A mathematical model was developed for creating the demand distribution along a route from on-off counts and map data. This model results in a set of continuous and point demands that permit accurate estimation of access walk distance. Mathematical models were also developed for impact evaluation for a set of proposed stops and for optimization, using dynamic programming to find the set of stops with least overall societal cost. Recent refinements have included rider shed line formulas that differ depending on whether one is boarding or alighting, consistent with user travel time optimization, impact of grade and traffic control on delay impacts, and adjustments for evaluating and optimizing sections of a route instead of an entire route.

The first generation models have been programmed in Visual Basic in a Microsoft Excel environment and tested on an MBTA bus route in Boston for a single period and direction. The results show that the method is practical—it yields practical results using readily available inputs. Just as importantly, they show that improved decisions about stop location can yield significant benefits. In the example, the optimization recommended 19 stops on a route that now has 37 stops, changing the average stop spacing from 202 meters to 404 meters. While reducing the number of stops increases average walk access time by 0.6 minutes, it decreases average passenger ride time by 1.8 minutes and decreases one-way running time by 4.2 minutes—enough to save a bus without changing service frequency. This also reduces operating costs.

Figure 1 shows a comparison between existing stop locations and those recommended in our first generation study for MBTA bus Route 39. It also compares existing and optimal stop density along the route. It emphasizes the fact that the tool being developed recommends not only the spacing between stops, but their actual locations as well.

## Completed Investigation

A second generation evaluation and optimization tool has been programmed using the C++ programming language. It includes several enhancements based on input from transit planners and from lessons learned in applying the method to different test sites. The investigators also plan to develop GIS modules to automatically generate geographic inputs from assessors' maps.

The second generation tools were applied to transit routes at two transit agencies: a bus route of the Capital District Transportation Authority (Albany, NY) and a light rail transit of the Massachusetts Bay Transportation Authority in Boston. Feedback during the application stage was used to refine the tools to reflect available inputs and desired outputs.

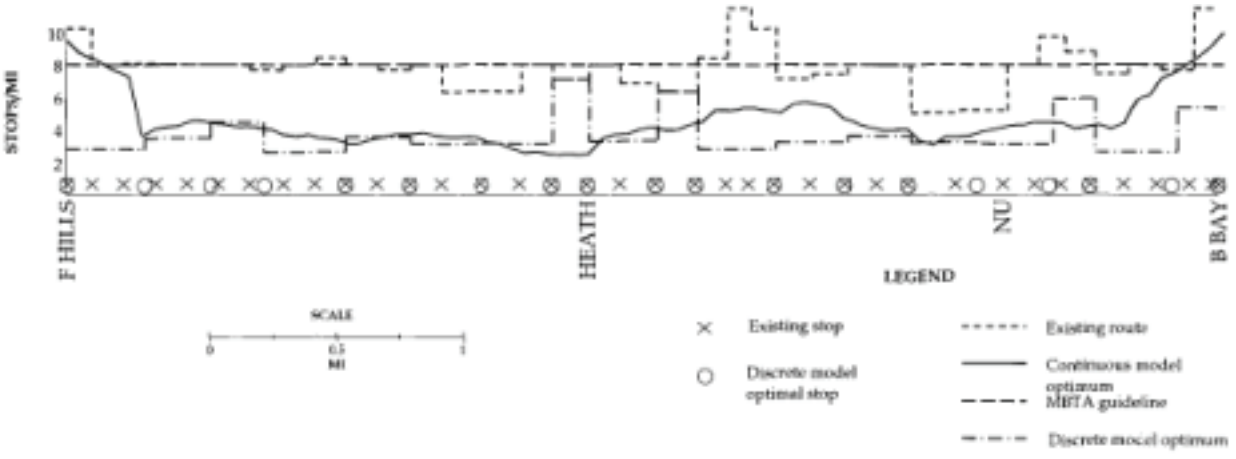



**Figure 1**

*Comparison of existing and optimal stop locations and stop densities, MBTA Route 39.*

## Product Payoff Potential

The tool, when fully developed, could offer transit agencies an automated and accurate method of evaluating bus stop location decisions and rationalizing stop locations. It could be an important tool for Bus Rapid Transit route development, as well as for improving the efficiency of urban bus routes. By providing the technical support needed to justify stop rationalization, it can lead to making transit faster and more cost efficient and attracting greater ridership.

# Simulation and Animation Model for Planning and Designing Transit Terminals Transit IDEA Project 32

Prianka N. Seneviratne
TransAn LLC, Silver Spring, Maryland

## IDEA Concept and Product

This project developed a simulation and animation model of traffic flow in bus transit terminals. The model is designed to assist transit facility planners and engineers in testing alternative strategies to improve the efficiency of bus flow, increase capacity, and minimize delays and vehicle emissions in bus transit terminals. The objective of the project was to develop and demonstrate this computerized planning and design tool for increasing the efficiency of vehicular flow in bus transit terminals.

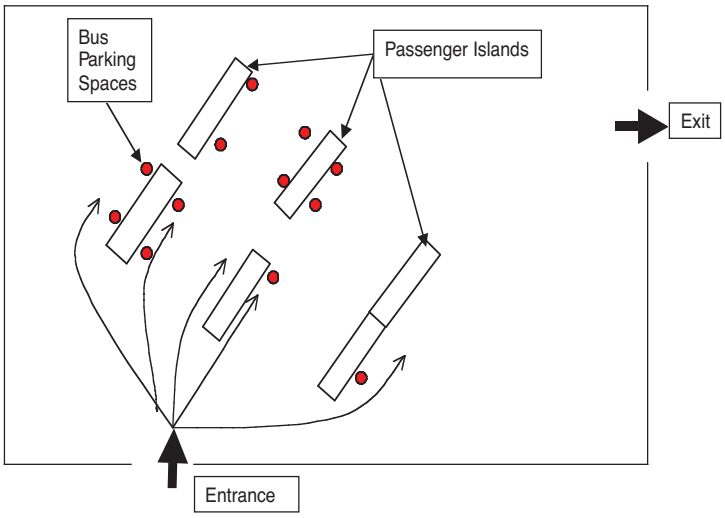



**Figure 1**

*Transit terminal application.*

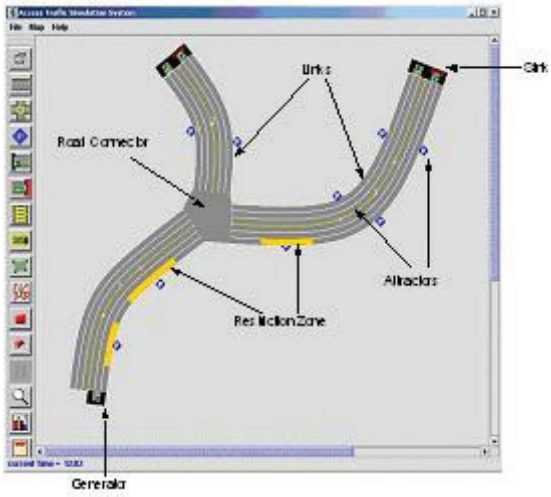



**Figure 2**

*Computer screen of model.*

## Completed Investigation

The investigators (a) developed routines and logic to describe bus vehicle and pedestrian (object) movement; and (b) designed a user-interface for data input and output including background for animation (i.e., layout and editing features). In particular, the elements involving random variables such as vehicle arrival rates, dwell times, and pedestrian/passenger flow, that lead to nonrecurrent congestion were analyzed and defined in relation to the modules they fall into within the overall model. The investigators also incorporated high-performance graphics capabilities to the 2-D simulation and developed predefined 3-D views.

Tests were performed to determine the robustness and validity of the individual modules of the model. The first module, the graphics module, was tested to determine the flexibility of importing and editing site configurations, particularly with regard to changing dimensions and characteristics such as angles of bus bays and no-parking zones. The second module, the traffic/pedestrian flow module, was tested for the accuracy of event generation rates as well as for logic governing object movement. Typical Washington Metropolitan Area Transit Authority (WMATA) transit terminal operations at the Silver Spring Metrorail station bus loading area were used to test the ability of the model to simulate and animate the conditions. An expert review panel, including consultants and WMATA staff, reviewed and commented on the work and the applicability of the model.

WMATA and its planning consultants provided the necessary data and graphical backgrounds for the animation. A literature review of recent advances in traffic and pedestrian simulation principles and technologies was also conducted.

## Product Payoff Potential

The tool developed in this project will permit pre- and post-implementation testing of traffic management strategies and layouts for bus transit terminals. It will allow a planner to review the impact of a strategy both visually (queuing, etc.) as well as statistically (average delays, volumes, etc.). Moreover, it will permit plans for new transit terminal facilities to consider traffic/demand conditions.

## Product Transfer

The model was made available to WMATA for use in planning and designing future facilities. A final report and a user guide detail the project activities, test design, and results.

# Community Design of Light Rail Transit-Oriented Development Transit IDEA Project 33

Ted Grossardt and Keiron Bailey
University of Kentucky

## IDEA Concept And Product

This project was aimed at enhancing community involvement in the design of proposed light rail transit-oriented development. A combination of an advanced decision technique and virtual reality computer visualization were tested. This process is designed to enhance public input and cooperation in the planning process, and to provide recommendations for transit agencies, planners, and architects. The process was tested in Louisville, Kentucky, in cooperation with the local transit agency, Transit Authority of River City (TARC).

## Completed Investigation

The research team devised a novel visual assessment methodology termed Casewise Visual Evaluation (CAVE). This process uses a fuzzy set-theory based modeling system. When there are many design parameters, the CAVE process translates community preference for complete designs into preference for each of the elements in that design. Preferred combinations of elements can then be determined. There are many design elements in each scenario, such as building type, open space type, height, density, and so on.

Once the significant design elements are identified and a highly preferred combination is determined using CAVE, virtual reality visualizations are used to display design options and assess community reaction to them.

## Project Results

A Structured Public Involvement protocol was used to gather community input. An iterative series of focus group meetings were organized in partnership with the local transit agency, TARC. Community feedback on the desired features of the development was gathered, and the forthcoming CAVE process was explained.

An electronic scoring system was then used to assess preference for transit-oriented developments (TODs) in other cities, using photographs. This allowed for fair, free, and anonymous evaluation by the community, using a 1 to 10 point preference scale.

The community's response to these pictures was then used as input to CAVE. To code the photos in terms of inputs useful to professionals, architectural experts were consulted and a design vocabulary was defined. The architects described the TOD images in useful and familiar terms. Using these as input parameters, with public preference as the output, the modeling process was started and a knowledge base was built. This modeled how community preference responded to varying height, density, typology, and open-space type.

The information was used by the design team to determine which combinations of elements were preferred by the residents. In collaboration with architectural experts, the output of the knowledge base provided guidance for design types. These designs were modeled as scenarios in the virtual reality visualization model.

The CAVE methodology has been demonstrated and provided clear design guidance for experts. Moreover, feedback from community participants has been positive. Comments included an expressed appreciation of the power devolved to the focus group in terms of determining which aspects are preferred. Residents have also commented on the importance of increasing participation at the focus group meetings so that more of their neighbors can participate in the design process. This desire of residents to involve others is a positive indicator.


**Figure 1**

*Screenshot showing an example of a virtual reality visualization.*

## Project Payoff Potential

By providing an efficient, organized public involvement process using decision modeling and visualization, the public's preferences are translated into specific design recommendations quickly and easily. Because the public feels greater ownership of the design product, as evidenced by feedback comments, there is less resistance and more enthusiasm for participation and implementation. These qualitative improvements translate into fewer problems for transit agencies charged with such development. More effective public involvement also leads to a valuable improvement in the local culture of citizen participation for future projects.

## Product Transfer

The lessons learned during the project are included in a final report for this project. The research team has submitted several papers on the results of this project to research journals, and presented the research at the Community Design Symposium at Harvard University.

The protocol developed in the project is being used by Arizona DOT and by the Kentucky Transportation Cabinet. The investigators on this project at the University of Kentucky are supporting public involvement processes a number of different areas, using methods developed in this project.

# Innovative Bioterrorism Detection Technology for Transit Security Transit IDEA Project 35

Douglas B. Rivers
Science Application International Corp.

## IDEA Concept and Product

This project investigated the detection and identification of potential biological warfare agents in both a benign laboratory environment and a simulated subway situation, using an integrated approach involving proprietary laser technology. The objective of this project was to demonstrate that biological agents can be quickly detected and characterized in a transit environment. This would have the potential to improve security in subway systems and give an early warning to transit officials so that they could take appropriate actions quickly and effectively.

## Completed Investigation

The investigators integrated the laser technology into a demonstration system to test the principle of biological agent detection and characterization. The system was first set up and tested in a benign laboratory environment to demonstrate the ability to detect and differentiate the samples.

The investigators procured typical subway particulate matter from a New York subway station characteristic of what would be expected in an operational transit subway station environment. They tested the ability of the system to detect and distinguish biological contaminants in the presence of field particulate matter from subway stations.

## Project Results

Laboratory setup for this investigation has been completed and the investigators have received certification from the government to work with dead target organisms. A literature review of available biological agent detection technologies has also been completed.

The biological material used in the tests has been detected and researchers have been able to separate the target agent from the particulate matter collected in the subway system. Detection sensitivity limits and identification time were evaluated. The tests will allow the investigators to assess this approach for transit applications.

## Project Payoff Potential

If proven successful in a transit environment, this technology has potential to detect biological threat attacks in real time, to alert appropriate officials to the nature of a specific attack, and to identify the biological agents. Beyond specific applications to subway systems, there is potential to translate the developments designed specifically for subway transit security into other possible transit applications.

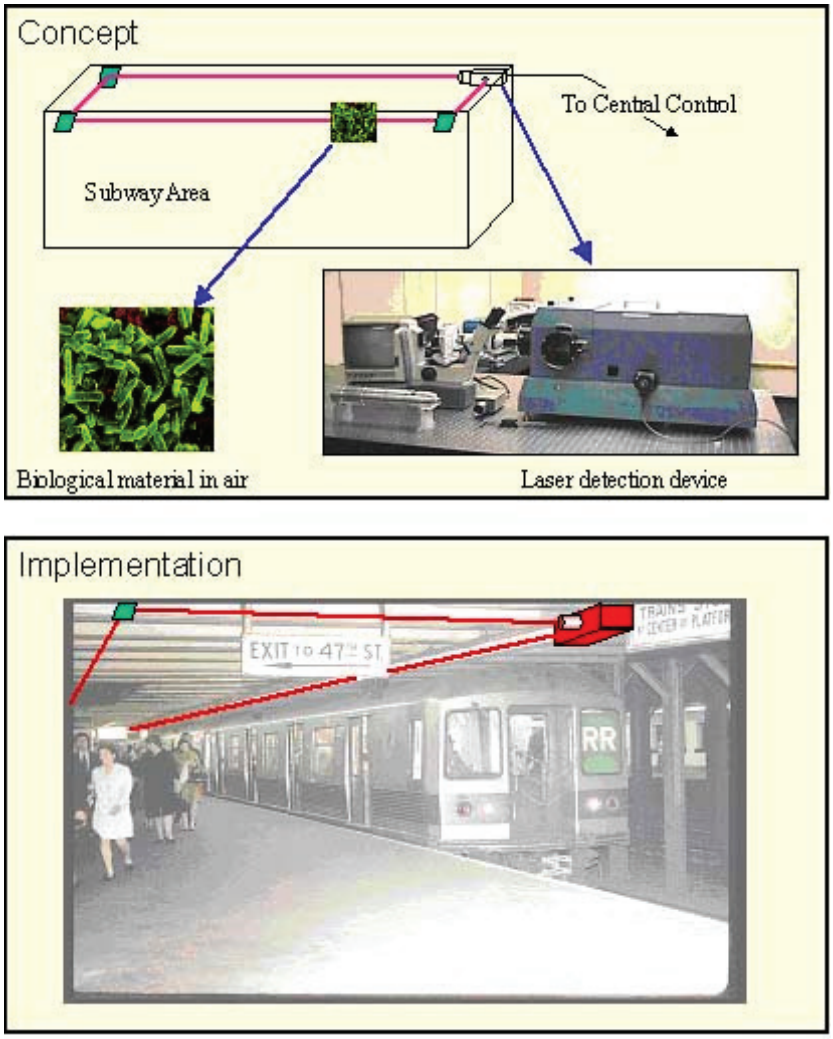



**Figure 1**

*Laser technology detection device concept and transit station application.*

## Product Transfer

New York City Transit (NYCT) participated in the project by assisting the investigators in obtaining sample particulate matter from a typical subway station and by reviewing and commenting on the technical progress of the system. A final report describes the project activities, test design, and results.

# Cleaning Device for Electrified Third Rail Insulators Transit IDEA Project 36

Arun Vohra, Consulting Engineer

## IDEA Concept and Product

This project developed and tested prototype devices and methods to clean electrified third rail insulators for rail rapid transit systems. Dirt and grime can short circuit the insulator and cause arcing, burning, and smoke, which can cause the rail system to be shut down. The insulators are extremely difficult to clean because the third rail carries very high voltage, and the third rail cover and tunnel walls limit access to the insulators. Figures 1 and 2 show examples of these problems on different transit systems. This project included development, proof of concept, and prototype testing of the cleaning devices to address the problems.

The prototype device was developed and attached to a service vehicle and tested on the Washington Metropolitan Area Transit Authority (WMATA) Metrorail system and the Maryland Transit Administration (MTA), Baltimore rail rapid transit facilities. The following transit agencies participated in this project by providing staff review and guidance: the San Francisco Bay Area Rapid Transit District (BART), Chicago Transit Authority (CTA), New York City Transit (NYCT), Metropolitan Atlanta Rapid Transit Authority (MARTA), Southeastern Pennsylvania Transportation Authority (SEPTA), and the Massachusetts Bay Transportation Authority (MBTA). These agencies have also indicated a need for a third rail insulator cleaning device.

DIRTY INSULATOR AT WMATA 8/16/2001

**Figure 1**

*Example of a dirty insulator.*

BURNT INSULATOR AT MARTA

**Figure 2**

*Example of a burnt insulator for an underrunning third rail.*

Dirty insulators are among the most frequent causes of downtime in many rail rapid transit systems around the country. Aging infrastructure and insulators of different sizes, shapes, and materials pose challenges. The insulator cleaning devices have the potential to improve the safety and security of rail transit systems and enhance public perception and confidence in the security of these transit systems.

Rail rapid transit systems use power supplied by a third rail that sits on insulators, which are typically spaced about 10 feet apart. Most rail rapid transit systems have an overrunning electrical collector shoe above the third rail. Carbon dust from carbon brushes on the traction motor, rust particles, dirt, and grime can short circuit the insulator, cause smoke, and set wood ties on fire, which can shut down train operation. If the insulator is made of fiberglass, it can burn. Porcelain insulators can become red hot and melt. When a porcelain insulator flashes over, it can explode and the resulting plasma ball can have a temperature of up to 5000 °F and can vaporize a concrete tie and rebar. Because of environmental considerations, chemical cleaning agents are generally not allowed. Stray currents, caused by partially shorted insulators, can corrode gas and water mains in the tunnels.

Rail rapid transit systems routinely replace thousands of burnt-out insulators every year at considerable cost. Cleaning insulators is especially difficult and costly inside tunnels where there is no rain to wash away dust and nowhere for combustible debris and smoke to go. In one agency, about 4,000 insulators failed per year inside tunnels and about 100 insulators failed in outside tunnels. Tunnels often have water drips creating lime deposits and higher humidity. This condition speeds up rusting and corrosion of metal bases, caps, and retaining rings on insulators and accelerates failure.

**Figure 3**

*Prototype insulator cleaning device in action.*

## Project Results

This Transit IDEA project has developed and successfully demonstrated a prototype cleaning device. Bench tests were conducted to evaluate the potential performance of several insulator surface cleaning technologies: (1) pneumatic polishing with rice husks with high silica content, (2) mechanical cleaning with powered rotating brushes, and (3) pressure washing with high temperature tap and deionized water. Pressure washing with hot tap water was the most appropriate cleaning tool.

A U-shaped cleaning station with four spray nozzles was attached via primary and secondary arms to a service vehicle. Electric power must be shut off before this device can be used.

The cleaning system was developed into a prototype that was mounted on a service vehicle driven on the tracks, and tested and evaluated at MTA in Baltimore and WMATA in Washington, D.C., rail rapid transit facilities. BART, CTA, NYCT, MARTA, SEPTA, and MBTA participated in this project and provided guidance to the principal investigator. The final report included information so that other rail rapid transit agencies can consider using this device for cleaning their third rail insulators

## Project Payoff Potential

The cleaning device could offer rail rapid transit agencies an effective method to efficiently and cost-effectively clean dirty insulators in place, improving the safety and reliability of those transit systems.

## Product Transfer

The prototype insulator cleaning device was tested on the WMATA Metrorail and the MTA, Baltimore rail rapid transit systems. The results were included in a final report for this project and will be disseminated by the principal investigator via papers presented at symposia, professional meetings, and TRB and APTA conferences. The results of this project were presented at the APTA Rail Conference in June 2006. The participation of the eight transit agencies identified above will make the results useful to transit systems with different kinds of third rail insulators.

Building on this project, a follow-on Phase 2 project, to develop a higher-speed operational cleaning device, was conducted. That Phase 2 project is Transit IDEA Project 47. The principal investigator has shown the insulator cleaning devices to transit agencies and equipment manufacturers.

# Bandwidth Expansion and Real-Time Surveillance for Security on Transit Buses
# Transit IDEA Project 37

Yang Cai
Carnegie Mellon University, Pittsburgh, Pennsylvania

## IDEA Concept

The investigators have developed a real-time video surveillance technology for enhanced security on transit buses. The system uses digital cameras on buses and adds a broad-bandwidth wireless network modem and unique software to expand the bandwidth for the wireless transmission of streaming digital video. The broad bandwidth wireless real-time video surveillance system includes remote viewing, monitoring, and alerting functions at a transit central control room. Advanced data transmission and compression technologies have been used to extend the data bandwidth constraint.

Wireless networks extend the coverage of broadband services and provide ubiquitous network access to mobile devices. There are, however, many technical challenges to overcome before the vision of broad bandwidth networking can be realized. Video over wireless networks presents additional challenges due to the limited bandwidth available, the higher loss rates of signal strength, and the temporary periods of disconnectivity from the network. In order to make video streams feasible on mobile devices, new methods of wireless data transfer have to be designed.

This project was carried out by Carnegie Mellon University, with participation by the Port Authority of Allegheny County in Pittsburgh.

## Results

Investigators have experimented with two wireless network infrastructures for mobile video streaming, including a Hot-Spot network that transmits video over existing 802.11b wireless hubs. The advantage of this method is that it would not need extra network facilities. Investigators have also experimented with the ad hoc network for video streaming that allows a network of mobile devices to communicate without centralized control. The mobile devices would dynamically detect and adapt routes to the other hosts in the ad hoc network. The advantage of this approach is that it would provide more flexible infrastructure for video streaming. Field tests and analysis show that the system design is feasible and economical. The prototype system can transfer the digital video at a resolution of 640 × 480 at a speed of more than one frame per second (fps). Based on existing wireless hotspots in an urban area, the prototype system can transfer video to a server on the Internet. Users can view the video on a computer with a web browser. Experiments also show that at the speed of 1 fps, the wireless network used less than 25 percent of connection capacity. The speed and format of video are compatible with what the Port Authority is using.

## Product Payoff Potential

The real-time surveillance system will be able to enhance the security and safety of transit systems, especially in emergencies. The security and safety authorities could assess and respond to a situation instantly rather than wait until after it has happened. Also, *automated face recognition* systems could be considered as an option so that suspects could be tracked and reported in real-time. In addition, the potential for detecting *unusual situations,* such as medical emergencies or vandalism, could benefit transit agencies during their daily operations.

## Product Transfer

The Port Authority of Allegheny County in Pittsburgh participated in this project by reviewing the development and proof of the concept and by participating in the technical development and testing. A final report was prepared by the investigators at Carnegie Mellon University, documenting the results of this project. Bombardier has contributed funds for adapting the technology for transit systems.

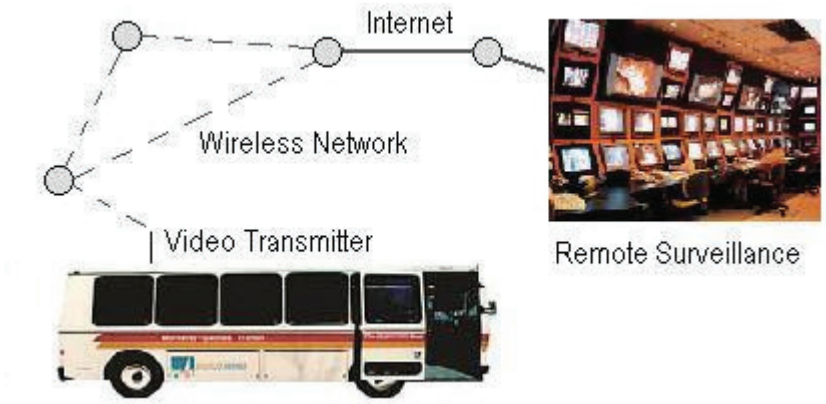



**Figure 1**

*Illustration of the general concept.*

# Assessment of Rear-Facing Wheelchair Accommodation on Bus Rapid Transit Vehicles Transit IDEA Project 38

Katharine Hunter-Zaworski, Ph.D., P.E.
Oregon State University

## IDEA Concept

This project investigated the physical response of occupied wheelchairs and the acceptance of wheelchair users of rear-facing containment on Bus Rapid Transit (BRT) vehicles. The concept is that wheelchairs can be safely transported using passive securement rather than active securement such as the belt systems currently in use by most transit agencies. The passive securement is accomplished by positioning wheelchairs in a location where their movement is constrained by the walls of a compartment.

This system was demonstrated and tested on transit buses of the Lane Transit District (LTD) located in Eugene, Oregon and at BC Transit in Victoria, British Columbia, Canada. In establishing the Expert Review Panel for this project, the investigators learned of an opportunity for research collaboration with BC Transit in Victoria. Additional data were collected on BC Transit buses that have rear-facing securement. The data collection in Victoria used the same protocols as those used in Eugene. The project determined that this type of rear facing wheelchair accommodation provides acceptable levels of comfort and safety for people in wheelchairs.

## Completed Investigation

The project was done in three stages. Stage 1 included the field test preparation, the final approval, and permits for the field tests. Stage 2 included the tasks that are related to the field tests and analysis of the results. Stage 3 of the project included documentation of project activities, dissemination of results, technical papers, and the final report. This task also included the plan for transfer of the project results to practice.

## Product Payoff Potential

It is anticipated that the results of this project will have a major impact on wheelchair accommodation on transit vehicles by providing more options for interior design of BRT vehicles in particular and of new transit vehicles in general. Finally, in the long run, it is anticipated that securement of wheelchairs on mass transit vehicles may become a nonissue for both the wheelchair users and the vehicle operators. This project provided information that could be useful in future review of the existing ADA requirements for bus rapid transit vehicles.

The principal result of the project determined the adequacy of rear-facing compartment securement systems. Specifically, the project determined that this type of passive securement will provide acceptable levels of comfort and safety for users of wheelchairs. In addition, the project resulted in knowledge of transit vehicle operating dynamics, the effect of those dynamics on passengers using wheelchairs, and detailed information that would justify less restrictive requirements for wheelchair accommodation on large transit vehicles.

## Product Transfer

A number of transit agencies and federal agencies, such as the U.S. Department of Transportation, the U.S. Department of Justice, and the U.S. Access Board will benefit from the results of this research. The results of this research provide information that could be useful in future review of the requirements of the ADA concerning wheelchair orientation and securement for BRT vehicles. In addition, the U.S. transit industry as a whole will benefit from development of new approaches for wheelchair accommodation that promote the safety and dignity of travel for persons with disabilities and decrease dwell time at stations and bus stops.

As a follow-on to this Transit IDEA project, the research team at Oregon State University has actively assisted Lane Transit District (LTD) in Eugene, Oregon, with additional technical development of rear facing securement technology for the new BRT vehicle procurement. LTD and Greater Cleveland Regional Transit Authority have purchased new buses that include rear-facing wheelchair securement positions, based on the results of this Transit IDEA project, in addition to front-facing securement. The first of these new buses at LTD entered service beginning in January 2007. Follow-on development activities on rear-facing securement have been conducted as a result of the testing activities that were done in this Transit IDEA project. Transit IDEA Project 57 will build on the results of this completed project. Additionally, the results of this project were the basis for a paper presented at the APTA Bus and Paratransit Conference in May 2006, which encouraged other transit agencies to seriously consider rear-facing wheelchair securement when purchasing new buses.

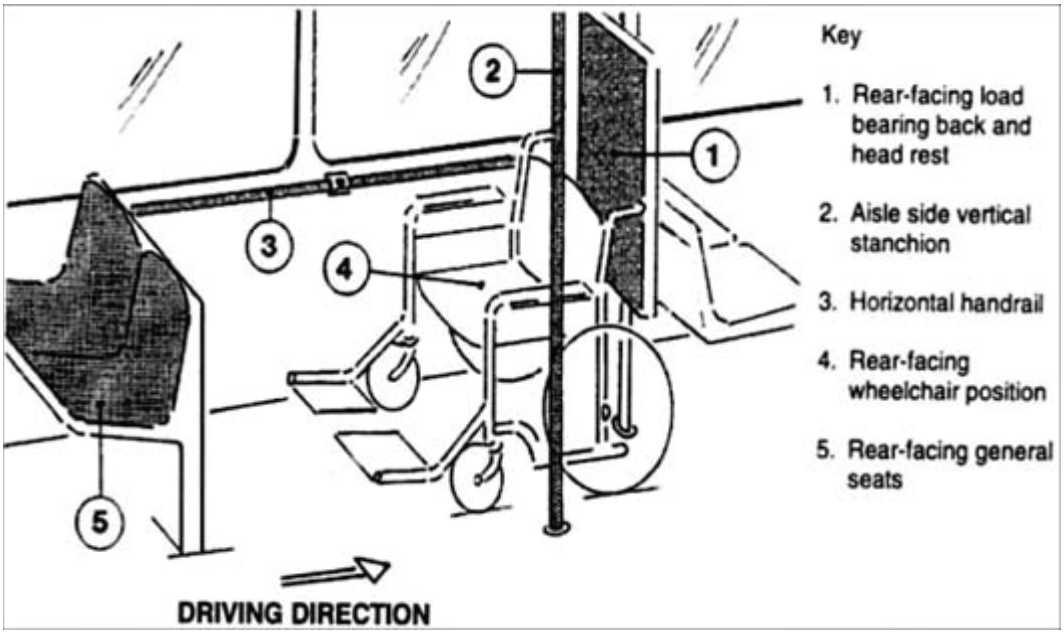



**Figure 1**

*Sketch courtesy of Uwe Rutenberg.*

# Dynamic Timetable Generator from Schedule Data Transit IDEA Project 39

Paula Okunieff
Consensus Systems Technologies (formerly Systems & Solutions, Inc.)
Boston, Massachusetts

## IDEA Concept and Product

The Dynamic Timetable Generator project developed a tool that enables transit agencies to dynamically generate timetables for customer Web access directly from "raw" schedule data. In general, transit agencies encounter problems in exchanging key data between applications. Updating schedules and timetables is of particular concern since they change frequently due to service demand, detours, and special events. Transit agencies expend significant staff time and resources in making minor changes to their Web sites or reformatting timetables due to these changes. Technologies such as Web sites, kiosks, and Internet-enabled cell phones support the rapid dissemination of timetable updates. However, tools for efficiently organizing, translating, and laying out the data to populate these media are needed.

New technologies enable the development of a tool that dynamically loads timetable data from a batch file or from a database, translates the data to a standard content and format, and then presents the information to the public in specified languages and in a variety of accessible display formats. Using new industry standards and off-the-shelf tools, the investigators built a general purpose "Dynamic Timetable Generator" tool that will automate the exchange of timetable information. An important aspect of the approach uses information technology (IT) standards to provide a solution that is applicable to a wide range of agencies. This project developed the tool based on IT standards, eXtensible Markup Language (XML), eXtensible Stylesheet Language and Transformation (XSLT), and Transit Communications Interface Profile (TCIP). This project used and supported the work by the American Public Transportation Association (APTA) on the TCIP standards. This project was the first application test of the standard. The investigators on this project coordinated closely with APTA's Working Groups and consultants.

Tri-Met (Portland, Oregon), New York State DOT with Suffolk County Transit, and the Regional Transportation Authority (RTA) in Chicago participated in this project and tested the application.

## Completed Investigation

A brief review of various types of timetable data and configurations was undertaken to ensure that the results of this project are applicable to other transit agencies, including large, medium, and small, urban, rural and suburban. The overall requirements to meet an accepted timetable model were explored, including internal data, policy, and style requirements associated with each of the represented transity agency participants. Further, the approach considered legacy and current technologies to ensure interoperability with existing investments. These requirements were incorporated into the product architecture. An input interface was developed as part of this project and supported customization of the product display.

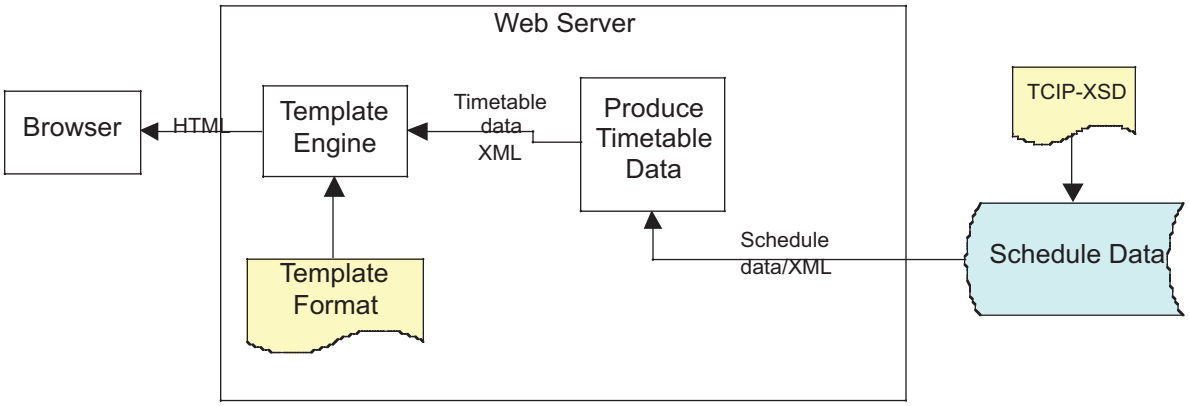



**Figure 1**

*Conceptual architecture for dynamic timetable generator.*

The first stage of the project (Requirements Analysis), identified the functional and interface requirements and access methods for translating and presenting the timetables. In this stage, the investigators employed a UseCase Approach to develop the concept of operations, functional requirements, as well as TCIP XML message requirements.

In the second stage (Proof of Concept) a prototype was developed in which the transit agencies supplied their data. Tools and documentation for installation, user guidance, and the software were developed.

The third stage (Production Application) included deployment of the application at Tri-Met. In this stage, a module was reviewed, improved, branded by Tri-Met, and implemented to translate data to TCIP directly from their back-office database.

The software architecture is illustrated in Figure 1.

## Product Payoff Potential

This project will provide key benefits to transit agencies as well as the public. For transit agencies, the results of this project will increase the ability to exchange schedule data and support more effective use of transit resources to deliver timely information. Also, the tool will facilitate the acquisition of automated tools by transit agencies that do not currently deploy Web-based information. For the public, the results will provide riders and potential riders with more timely, accurate, and accessible information. The tool may even serve to standardize timetable formats by using the FTA Transit Web recommended template to present schedule information to the public, which benefits riders as they travel regionally, using different service providers.

By using the transit industry data interface standard, TCIP, which was under development by APTA and their consultants, the project team demonstrated how TCIP may be implemented in different operating environments.

## Product Transfer

As part of the project, the project team and its transit agency partners tested the working product. The choice to include three transit agencies, providing data sets from four service providers, was to ensure that the concept was transferable to a range of transit agencies that offer different service types and retain various levels of technical expertise. All three transit agencies provided data and technical oversight as part of the project.

A number of the participating transit agencies plan to use the tool to manage regional timetable displays. For example, NYS DOT will include the Dynamic Timetable Generator in their Transit Schedule Data Exchange Architecture to provide timetables for transit operators in the downstate New York region. The tool was highlighted in the Federal Transit Administration report, *Advanced Public Transportation Systems: The State of the Art, Update 2006* (FTA-NJ-26-7062-06-01). The participating transit agencies' use of the project results shows a high level of interest in the new transit Dynamic Timetable Generator.

TriMet and New York State DOT developed tools and methods adapted from this project's application to automate the generation of timetables from raw schedule data and provision to a web page display. The *Timetable Publisher,* which was adapted by TriMet from the method applied in this project, was the subject of a Webinar put on by U.S. DOT in May 2008.

The tool is available as "open-source" software (www.timetablepublisher.org) (subject to open-source licensing restrictions).

# Counterterrorism Chemical Detector for Rail Transit Systems Transit IDEA Project 40

Joseph J. Bango
Connecticut Analytical Corporation

## IDEA Concept

This project investigated the feasibility of a novel aerosol air collector and a chemical detector for subway cars and in subway stations. This research investigated an advanced sensor technology to rapidly collect and detect the release of toxic polar chemical species. Such polar molecules include the nerve agents, phosgene, chlorine, and nitrates indicative of explosive agents, to name a few. Dr. John Fenn of Virginia Commonwealth University conceived the aerosol collector concept. He is the 2002 Nobel Prize for Chemistry winner and a consultant on this Transit IDEA project. New York City Transit (NYCT) participated in this project.

### The Transit System Chemical Detection Challenge

The most significant challenge for the successful integration of advanced sensor technologies into a subway system is the need to sample, concentrate, and analyze the local atmospheric conditions in real time. Most available field-portable sensing technologies provide detection thresholds that are not ideal for the highly dynamic conditions in a transit system itself. Furthermore, due to atmospheric dilution of chemical and biological signatures, point detection systems are often inadequate without significant sampling and pre-concentration in the local environment. Typically, air circulators entrain large volumes of air, which is then filtered and sampled before being analyzed for the presence of contaminants. However, the air samplers and pre-concentrators developed to date are very bulky and power consuming for use in an economical and small system.

The air sampling or entrainment of chemical particles using the electrospray ionization (ESI) technology is based on research by Dr. John Fenn. The ESI sampler offers a unique and unprecedented combination of performance parameters including low power, lightweight and high sampling efficiency over an enormous range of particle sizes from molecules to microscale particulates. It is believed that a suitable sensor suite for chemical agents may include specialized molecularly imprinted polymers (MIPs) and/or surface acoustic wave devices (SAWs) combined with the aerosol collector. It is expected that this would be capable of detection needed for trace chemical species such Sarin, VX, other nerve agents, and various explosives.


**Possible sensor placement locations to be considered may include interior of transit vehicles, different areas of the subway station and associated air handling system.**

**Figure 1**

## Investigation

This project included the following objectives:

- Identify and prioritize chemical agents that could be threats to subway systems;
- Identify mechanisms for delivering selected threats to rolling stock, stations, tunnels, passenger entry and exit points, ventilation points, etc.;
- Define initial ESI collector-detector system parameters using estimates of the threat, delivery mechanisms, airflow patterns, telemetry, and transmission information;
- Design a proof-of-concept demonstrator ESI collector-detector system;
- Perform laboratory controlled tests of the ESI proof-of-concept design;
- Identify design changes subsequent to initial testing; and
- Prepare and deliver a report of the results.

The project analytically verified the principals of operation and performance.

## Product Payoff Potential

If a reliable chemical detector could be deployed on transit rolling stock and in subway transit stations it could assist in mitigating the effects of a terrorist release of chemical agents. Detection of dipicolinic acid from Anthrax using MIPs has been successfully demonstrated by colleagues at Virginia Commonwealth University under U.S. Army funding support, and is planned to be combined with the electrospray collector technology.

## Product Transfer

The investigators have transitioned other applied research into manufactured products in ambient gas monitors for industrial and medical applications.

# Track Geometry/Design Testing for Transit Applications Transit IDEA Project 41

Miles H. Letts
Trak-Tech Corporation, Fairfax, Virginia

## IDEA Concept and Product

This project developed and tested a concept to determine actual track geometry alignment and cross level in sharp curves and turnouts in rail transit systems. The improved track geometry testing system would utilize the current track design or a "best fit" track design as a baseline for testing rail rapid transit and light rail transit track.

This concept would provide transit systems the ability to accurately identify track geometry defects based on their track design, thereby reducing maintenance time and cost. Transit agencies could also benefit by utilizing the "best fit" track design data generated by the track geometry system as an alternative to improve their current track design.

Track classification standards in sharp level curves and turnouts cannot be defined using the industry's current geometry testing methods. Therefore, during an automated track geometry test, this type of track is not properly classified, and required maintenance may be ill-defined and possibly overlooked. When using conventional methods of track geometry testing, the track design criteria are not considered. Automated track geometry tests using original design criteria or calculated "best fit" designs would provide accurate results for evaluating track alignment deviations. Evaluating current track conditions and managing these conditions on rail rapid transit and light rail transit systems could be greatly improved if this concept is proven and implemented. Time and costs currently incurred by transit systems in evaluating and managing their track could be significantly reduced. This would improve the efficiency of the track evaluation and of tamper maintenance, which would enable the transit agency to focus its time and efforts on actual track problems, contributing to improved track safety.

## Planned Investigation

The Massachusetts Bay Transportation Authority (MBTA) and the Washington Metropolitan Area Transit Authority (WMATA) have participated in this project, including field testing on their tracks. The investigator established agreements with the participating transit systems to utilize geometry data gathered on their respective systems. A software routine was developed to scan the geometry track data and determine the location of curve points. Curve data were selected from the database using the curve point identification procedure developed in the previous software routine. Semi-automated curve designs were developed from the manual curve designs. The curve design model was tested.

## Project Results

The project has been successful in defining a continuous analytical function of the "desired curve" that can be made to best fit the measured track geometry curve and serve as a model for track alignment and crosslevel corrections. It has been shown that the desired track is not always a theoretical mathematical model but is rather more complex. The effort has developed a method whereby a digital foot-by-foot description of the regular safe accepted track configuration can be computer generated from automated track geometry measurement data.

The process finds the exact position of curve points for the curve model. During the automated search for a solution, the half throws are minimized to within expressed limits. The process therefore provides valid track geometry exceptions as well as tamper input data for correcting the exceptions.

The project results include finding solutions for all 16 curves on a section of track. The tools developed for solving these curves prove that the basic model and concepts for automating the solutions are valid. Design engineers can do the selection and application of these tools manually, or they can be automatically applied in standard sequences as manual applications become routine. To date, two fully automated sequences have been found very useful and further extension of the automation is anticipated based on the elementary tools provided to date.

One challenge remaining to be solved is the synchronization of curve design data with each future geometry test. In theory, the model and the measurements must be located to the nearest foot. In practice, it has been shown that some curve point locations may shift with the seasons. Fortunately, curves in tunnels and complex trackwork do not move and can be used for automatic location detection.

Avenues of further investigation could include (a) making seasonal models of the track design to accommodate seasonal changes in the acceptable track configurations, (b) comparing the model curve points with the original design charts, and (c) proving in practice that the tamper data provided can be synchronized to eliminate the exceptions.

## Product Payoff Potential

The method used in this project has been to model the existing track construction as the accepted design and to calculate the deviations from that design and restore the track to its accepted condition with automatic equipment. This is the process used to eliminate false exceptions in geometry reports and to generate valid input data for tamping and lining machinery. Fully implemented, the process can provide automatic location detection of track geometry measurements to the nearest foot. This method would improve the efficiency of rail transit track evaluation and of tamper maintenance.

# Detection of Radioactivity in Transit Stations Transit IDEA Project 42

Eric P Rubenstein, Ph.D.
Advanced Fuel Research, Inc.

## IDEA Concept and Product

This project developed and tested prototype devices and methods to detect and identify radioactive material carried into rail rapid transit systems. A prerequisite for the early response and interdiction of such material is the detection and tracking of its location. This project included development, laboratory proof of concept, and prototype testing of the radiation detection system to address this problem. The prototype system was tested in a Metrorail station of the Washington Metropolitan Area Transit Authority (WMATA).

This project developed hardware and software technology to implement radiation monitoring in transit stations. The system makes use of existing security video cameras already installed in many rail transit stations to detect and identify the nature of both ambient radioactivity levels and nearby radioactive materials, for example, radiological dispersal devices or "dirty bombs." The radiological materials that terrorists might use in the construction of a dirty bomb emit energetic particles that could be detected by the Radiation Event Detection System: Tracking and Recognition (REDSTAR™) system. To identify and distinguish the dirty bomb signature, multiple detectors would be networked into local and remote computers. The actual detection of radiological sources would be performed by REDSTAR software optimized for detecting the artifacts created by energetic particles hitting the detectors. This inexpensive combination, REDSTAR™ and existing security cameras, could be rapidly deployed.

Transit IDEA Project 54, a Phase 2 project, built on the results of the previously completed Transit IDEA Project 42, and installed, tested, and evaluated a prototype system using security cameras in a Metrorail transit station of WMATA. This project was successfully completed.

## Project Results

Laboratory tests were conducted to evaluate the sensitivity of the hardware detection technologies. The investigators performed tests using three different radioactive sources. The energetic gamma rays emitted by the sources are very penetrating. The laboratory tests demonstrate that the REDSTAR detection system is sensitive to the smallest radioactive source used. Since a detectable amount of gamma rays can pierce significant amounts of lead shielding, it is very unlikely that pedestrians could carry enough shielding to prevent the detection of a significant source.

The REDSTAR™ detectors and software system collect data in the rail rapid transit stations, process that data, and provide any potential alert information to the security personnel in the operations control center. Existing digital security cameras are used to minimize system cost. The prototype was tested in Transit IDEA Project 54 to verify the laboratory detections and to validate estimates of sensitivity.

**Figure 1**

*WMATA Metrorail system in Washington, D.C.*

## Completed Investigation

The hardware and software development and subsequent integration into a prototype were performed first in the contractor's laboratory. In that setting, the sensitivity of the system was measured. Using that data, the investigators made extrapolations to estimate the probable efficacy once deployed in transit stations. Tests were performed in a rail rapid transit station of the WMATA Metrorail system, in Washington, D.C. Additional testing was performed at Memorial Sloan-Kettering Cancer Center using their calibrated radiation sources.

## Product Payoff Potential

The early detection of radiological materials has the potential to save lives by alerting security personnel to the presence of such material. By providing this information to a transit control center and law-enforcement authorities, a dirty bomb could be detected.

## Product Transfer

Use of existing security cameras in rail transit stations and network infrastructure would make it relatively low cost to implement the system.

# Cleaning and Recoating Electrified Third Rail Cover Boards Transit IDEA Project 44

Arun Vohra
Consulting Engineer, Bethesda, Maryland

## IDEA Concept and Product

This project developed and tested a prototype device to clean and recoat the cover boards on electrified third rails for rail rapid transit systems. The ultraviolet action of the sun on the fiberglass reinforced plastic cover board degrades the protective gel coat and then delaminates the glass fibers.

The weakened cover boards sometimes flutter excessively from the draft caused by trains and from high winds. The holes in the cover board for the retaining pins enlarge and the pins can slip out. The cover board can drop on the third rail. The contact shoes, which slide on top of the third rail and provide power to the traction motors, break off when they hit the dropped cover board. Traction power is lost and the rail system shuts down. The high voltage and access restrictions to cover boards make them difficult to clean and recoat.

**Figure 1**

*Example of a weakened cover board with mold and fungi on it in Miami, Florida, in December 2003.*

Rail rapid transit systems often need to replace third rail cover boards at considerable cost. One agency is replacing all their cover boards that are only 20 years old, at a cost of several million dollars.

The prototype device developed in this project was tested on the Miami-Dade Transit (MDT), the Bay Area Rapid Transit District (BART), and Metropolitan Atlanta Rapid Transit Authority (MARTA) rail rapid transit systems, with the participation of those transit agencies. Other rail rapid transit systems, including the Washington Metropolitan Area Transit Authority (WMATA) Metrorail system, the Maryland Transit Administration (MTA) Baltimore rail rapid transit system, and the Los Angeles County Metropolitan Transit Authority (LACMTA) have also indicated a need for a cover board cleaning and recoating system, and have participated in reviewing the work in this project. The cover board cleaning and recoating system will improve the safety and reliability of rail transit systems and will enhance public perception and confidence in the security of rail transit systems.

Transit IDEA Project 59, a Phase 2 project, built on the results of the previously completed Transit IDEA Project 44, and fabricated, tested, and evaluated a higher speed prototype system to recoat the cover boards on electrified third rails. This prototype system was tested at Miami-Dade Transit in this Phase 2 project.

## Completed Investigation

The completed Transit IDEA projects developed and successfully demonstrated a prototype two-component recoating system.

A two-component, spray-applied recoating system was developed into a prototype that was mounted on a service vehicle driven on the tracks and tested and evaluated at the MARTA, Miami MDT, and BART rail rapid transit systems, with the participation of those transit agencies. WMATA, MTA Baltimore, and LACMTA also participated in this project and provided guidance to the principal investigator.

## Product Payoff Potential

The recoating system could offer rail rapid transit agencies a tool that would restore third rail cover boards in place in an efficient and cost-effective manner and improve the safety and reliability of those transit systems.

## Product Transfer

The prototype third rail cover board recoating system was tested on the MARTA, Miami MDT, and BART rail rapid transit systems. The results, which are included in a final report for this project, have been disseminated by the Principal Investigator via papers presented at APTA rail conferences and other professional meetings.

# Chemical and Biological Decontamination System for Rail Transit Facilities
# Transit IDEA Project 45

Christos Athanassiu
Foster-Miller Inc., Waltham, Massachusetts

## IDEA Concept and Product

This project explored a concept for a rapidly deployable decontamination system to restore rail transit facilities in the event of a chemical or biological agent release in a rail transit subway station. The system, as conceptually depicted in Figure 1, is conceived to utilize the existing rail transit system tracks to deliver an automated car using a unique decontamination system and expandable booms to reach various inaccessible areas in the station.

The heart of the system is the electrostatically charged aerosol decontamination (ECAD) capability conceived by Foster-Miller. Although this core technology has been demonstrated in a number of other applications, none has been as large, as complex, or as challenging as a rail transit station.

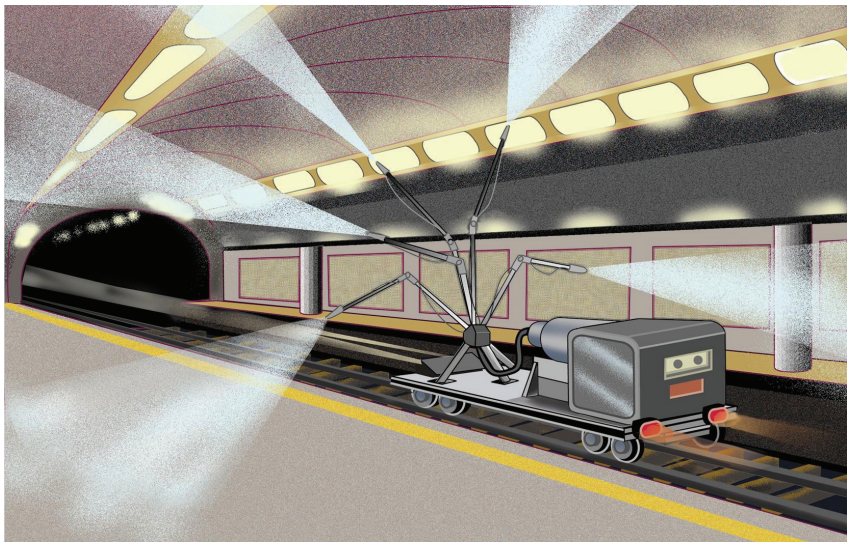


**Figure 1**

*Conceptual system for transit station decontamination.*

The basic concept is similar to one used for cleaning subway facilities today, but differs in configuration of the automated car and the unique decontamination delivery system. The car will carry the ECAD system that Foster-Miller first developed for the Army's Chemical Demilitarization program.

The ECAD nozzles incorporated into the system both aerosolize and charge liquid droplets produced from any stored aqueous solution. The effect of this aerosolization and charging is a fine mist that is attracted to all surfaces, providing a coating of disinfectant on even hard-to-get-at locations. In concert with the nozzles, the automated car is expected to be equipped with the necessary compressor, reagent storage, power conversion and related equipment. Also, as depicted in Figure 1, the system is envisioned to have extendable booms capable of being expanded and moved to deliver the reagent to remote, difficult-to-reach locations within the transit facility.

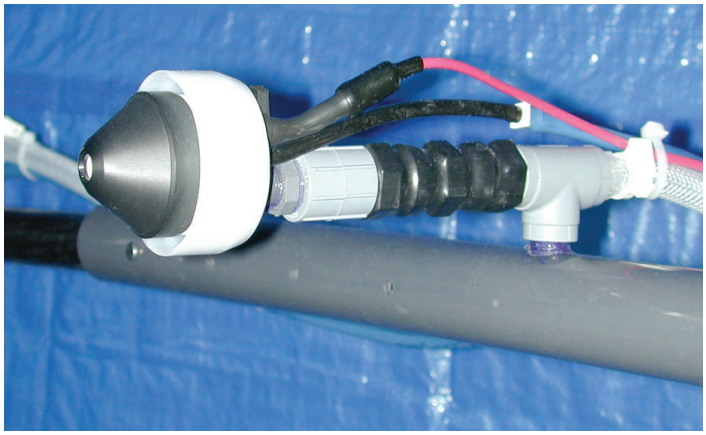


**Figure 2**

*ECAD nozzle.*

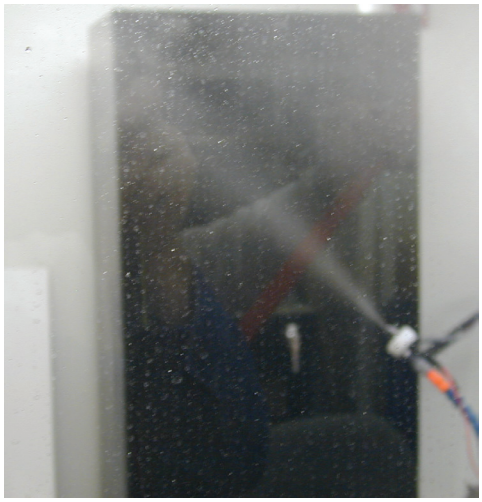


**Figure 3**

*ECAD spray.*

## Completed Investigation

This project investigated the use of electrostatically charged aerosol decontamination (ECAD) to restore rail transit facilities in the event of a chemical or biological release. The application of this approach to a large, complex facility, such as a rail transit station and subway tunnel, presents a challenge to both the delivery system and the decontamination agent. This project addressed the critical initial stage development and validation of an automated delivery system (ECADS) in providing effective decontamination coverage in subway stations. Foster-Miller Inc. developed the requirements for a large-scale, automated system to provide subway station and subway tunnel decontamination, developed a concept model to meet those requirements, and conducted static tests at a selected Metrorail station to determine ECADS nozzle effectiveness in the transit facility environment and to identify performance enhancements. The Washington Metropolitan Area Transit Authority (WMATA) participated in this project by assisting in developing the requirements (needs statements) for such a system for Metrorail stations, provided technical guidance, and participated in the prototype testing in their transit system.

In addition to the delivery capability, another key element of the "system" is the decontaminant itself. Foster-Miller has utilized a number of "decontaminants" with the ECAD capability, including bleach-based reagents for chemical decontamination and unique biocides. Foster-Miller also looked into the use of other reagents to find the decontaminate that is effective against a variety of chemical and biological agents.

## Product Payoff Potential

The sarin gas attack in the Tokyo subway system and the SARS infections in Toronto are ready reminders of the potential for transit system disruption. Although small portable decontamination units are available for use in transit rail car and transit bus disinfection, no such approach to deal with the complexities and size of transit subway stations and tunnels is currently available. Applying a capability first developed for the military to decontaminate a facility after a chemical or biological agent release will not only be effective in dealing with the contaminant, but will quickly restore service and rider confidence. Also important is the deterrent effect of having such a system available for quick restoration.

## Product Transfer

This project evaluated the concept of a track-mounted decontamination capability that could be readily deployed in the event of a chemical or biological agent release. Follow-on work would be needed to develop a prototype system. The participation of WMATA in this project and the stated interest in the ECADS capability for transit decontamination and disinfection applications by other transit agencies could aid in further development of this system.

# Cleaning Device for Electrified Third Rail Insulators—Phase 2 Transit IDEA Project 47

Arun Vohra, P.E.
Consulting Engineer

## IDEA Concept and Product

Building on the successfully completed Transit IDEA Project 36, Cleaning Device for Electrified Third Rail Insulators, this project developed and tested a higher speed automated device to clean electrified third rail insulators for rail rapid transit systems, as shown in Figure 1.

Transit IDEA Project 36 developed and tested an innovative prototype device with individual flat jet spray nozzles. The unique design of this device allows insulators to be cleaned all the way around, eliminating the problem of not being able to clean the back of the insulator with a hand held pressure washing gun. The prototype was designed to offer an easier and more efficient way to clean insulators.

This Phase 2 project included testing of a higher speed prototype cleaning device on the tracks of the Metropolitan Atlanta Rapid Transit Authority (MARTA), San Francisco Bay Area Rapid Transit District (BART), Washington Metropolitan Area Transit Authority (WMATA), and New York City Transit (NYCT). Other transit agencies that participated in this project are Maryland Transit Administration (MTA) in Baltimore, Chicago Transit Authority (CTA), and Southeastern Pennsylvania Transportation Authority (SEPTA).

Dirt and grime can short circuit the insulator and cause arcing, burning, and smoke, which can cause the rail system to be shut down. The insulators are extremely difficult to clean because the third rail carries very high voltage, and the third rail cover and tunnel walls limit access to the insulators. Dirty insulators are a frequent cause of downtime in many rail rapid transit systems around the country. Aging infrastructure, different sizes and shapes and materials of insulators pose challenges.

## Completed Investigation

A higher speed cleaning device was designed, fabricated, and tested. Stronger hinges and linkages were developed for the positioning arm to make it stronger than the initial prototype in Project 36. This device used spinning round jet nozzles.

The higher speed cleaning device was mounted on a service vehicle driven on the tracks, and tested and evaluated at MARTA, BART, WMATA, and NYCT rail rapid transit facilities. MTA in Baltimore, CTA, and SEPTA participated in reviewing the work of this project and provided guidance to the principal investigator.

**Figure 1**

*Advanced automated cleaner at BART.*

## Project Payoff Potential

The cleaning devices could offer rail rapid transit agencies a tool that would clean insulators in place in an efficient and cost-effective manner and improve the safety and reliability of those transit systems. A faster cleaning device would increase insulator life, reduce unplanned downtime, improve the safety and reliability of rail rapid transit systems, and enhance public perception and confidence in the security of these transit systems.

## Product Transfer

The higher speed insulator cleaning device was tested and evaluated on the MARTA, BART, and WMATA rail rapid transit facilities. The results are included in a final report for this project, and have been disseminated by the principal investigator via papers presented at professional meetings and APTA conferences. The participation of the seven transit agencies identified above make the results useful to transit systems with different kinds of third rail insulators.

U.S. and international patent applications have been filed by Arun Vohra for this device and process. Following this project, the principal investigator has shown the insulator cleaning devices to transit agencies and equipment manufacturers for potential commercialization.

Following these two successful Transit IDEA projects, a follow-on project was funded by the Federal Transit Administration through the U.S. DOT Small Business Innovative Research Program (SBIR). That SBIR Phase I project report, titled "High Speed, Low Water Consumption Insulator Cleaner," has been completed. An SBIR Phase II contract was awarded.

The Principal Investigator also received follow-on funding from the New York State Energy Research and Development Authority (NYSERDA). That report titled "Reducing Electric Losses from Rail Transit Insulators" estimated that the annual cost of dirty insulators that leak electricity at New York City Transit (NYCT) is nearly $2 million per year.

# SmartSander Enhancement for Commuter Rail Transit IDEA Project 49

Graham Curtis
Principal Investigator, DeltaRail Group Limited, Derby, England

Don Minini
Local Liaison, Cos Cob, Connecticut

## IDEA Concept and Product

This project tested the effectiveness of an automated, intelligent sanding system in a US commuter rail environment. For a trial in the United States, the investigator conducted a test using a SmartSander installation on a Metro-North commuter rail car.

A system with a multi-step or a proportional sand control operation would give more precise management, providing the maximum available railhead adhesion level. Low wheel-rail adhesion continues to be a major issue for many commuter rail operating agencies, particularly during the fall season when many leaves fall on the tracks. The inability to brake effectively in low adhesion conditions has important safety implications and has performance and cost impacts.

Although large strides have been made in the development of better wheel-slide protection systems, these systems can only optimize the prevailing wheel-rail adhesion that is present. What is needed is a means of improving adhesion consistently. This has been provided by reworking the SmartSander system for the U.S. commuter rail industry.

## Completed Investigation

This project was carried out in partnership with Metro-North Commuter Railroad personnel. Using the manufacturer's drawings and visits to examples of the commuter rail cab cars in the United States, a design was proposed and developed and a prototype was manufactured.

Working with the Metro-North Commuter Railroad, DeltaRail Group supplied a complete installation kit for a Metro-North Commuter Railroad Shoreliner cab car. The pilot design was installed on a sample commuter rail car.

## Product Payoff Potential

The significant advantage of the SmartSander over regular sanding systems is the ability to deliver sand safely in every brake step. Not only does this significantly improve conditions for the trains that it is fitted to, but also that much more of the commuter rail system receives regular small applications of sand. This improves conditions for all rail cars that use the route. SmartSander is designed to reduce delays to service, reduce unplanned passing of signals, and increase wheel life by reducing the frequency of wheel truings and reducing the amount of material removed during each wheel truing.

Potential benefits for commuter rail:

- Improved safety and stopping during low adhesion rail conditions,
- Reduced wheel truing cost overall by reducing wheel defects due to slide events with a target of allowing four re-turns being made over a wheel's life rather than three,
- Reduced sand consumption, and
- Improved commuter rail passenger environment due to minimizing noise caused by defective wheels.

The increased adhesion provided by SmartSander operating at all levels of brake demand meant a typical train operator in the UK benefited from significantly reduced wheel damage.

## Product Transfer

Following a successful test with Metro-North Commuter Railroad, the results have been included in the final report for this project and the results will be reported in papers presented to the commuter rail industry by the principal investigator.

# Developing Regional Mobility Management Centers Transit IDEA Project 50

Jon E. Burkhardt
Senior Study Director, Westat, Rockville, Maryland

This project identified methods of integrating transportation to different services—which are currently provided by different operators—by organizing, coordinating, scheduling, and dispatching transportation resources through regional brokerage mobility management centers. The focus was on how to integrate the information and capabilities of multiple software applications for scheduling and dispatching paratransit services so that they can transfer information seamlessly to each other.

This effort included support from public and specialized transportation providers in Florida (VOTRAN serving the Daytona Beach area), Massachusetts (Montachusett Regional Transit Authority), New Jersey (Meadowlink Commuter Services), North Carolina (Macon Area Transit Services), and Virginia (EZ Ride in Prince William County, and Mountain Empire Older Citizens, Inc. serving southwest Virginia).

The final report for this project includes recommendations and benefits regarding coordinated transportation brokerage services, and recommendations for development of data interchange protocols and software.

# Travel Assistance Device (TAD) to Help Transit Riders Transit IDEA Project 52

Philip L. Winters
Transportation Demand Management Program Director
Center for Urban Transportation Research
University of South Florida
Tampa, Florida

## IDEA Concept and Product

This project developed a Travel Assistance Device (TAD) for transit riders with cognitive disabilities through the creation of an intelligent software system that integrates cell phones with transit agencies' automated vehicle location (AVL) systems. This project built on the initial TAD work funded through the National Center for Transit Research at the University of South Florida (USF) by the Florida Department of Transportation and U.S. Department of Transportation.

The TAD prototype software application was developed at USF and was tested with the participation of the Hillsborough Area Regional Transit (HART) Authority, which serves the Tampa area. TAD uses multimedia cell phones with built-in global positioning systems (GPS) to overcome the challenges facing new transit riders, especially those who are cognitively disabled. The TAD provides many services to the user, including ringing, vibrating, or playing a message as a reminder when the rider is approaching their stop. This tracking system can also monitor their travel behavior in real-time and notify the travel instructor or guardian if the rider deviates from the expected route.

This project enhanced the TAD by providing a link to HART's real-time AVL data. This data can be used to provide services including (1) delivering information to the rider via their mobile phone while they are waiting at the bus stop and while they are riding on the bus, (2) notifying riders when their specific bus has arrived, (3) providing the rider with identifying information so that they board the correct bus if multiple buses are present, and (4) alerting the rider and officials if the rider boards the incorrect bus.

## Completed Investigation

Software for GPS-enabled cell phones and an intelligent server system was developed to link the existing TAD system with the AVL system of HART. Open standards such as XML Web services were utilized to provide a high level of interoperability with outside organizations' information technology (IT) infrastructures. The Internet was used to transfer XML-formatted data to and from the transit agency so that AVL information is accessible to any authorized user with an internet connection. This flexibility also extends to the mobile phone. As a result, real-time "push" information delivery systems that are based on real-time transit data are made possible.

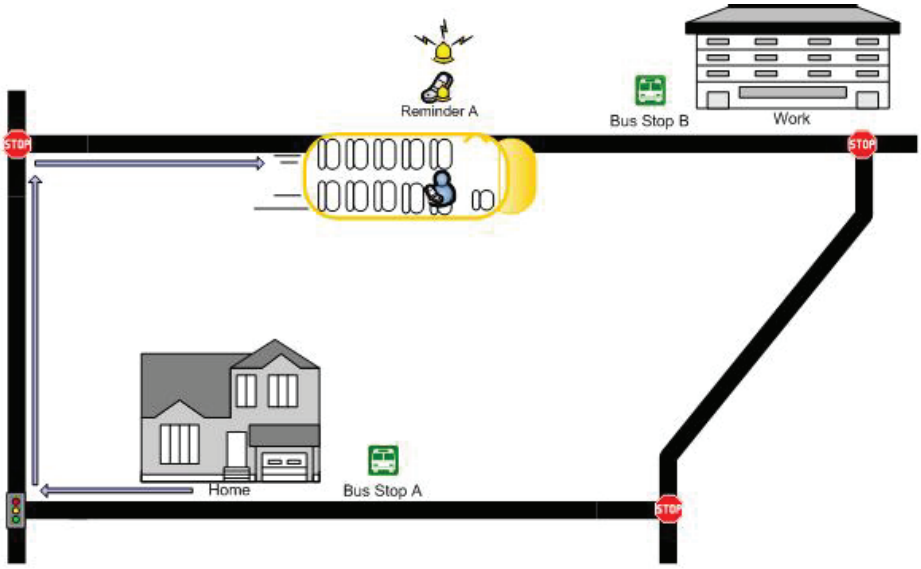



**Figure 1**

*TAD application on GPS-enabled mobile phone alerts transit riders when they are about to reach their stop.*

## Project Payoff Potential

The TAD software system aids new transit riders by overcoming traditional barriers such as learning where and when to request a stop. Also, the TAD could help transit agencies reduce costs by shifting able cognitively impaired riders from paratransit to fixed route transit, while increasing the rider's independence and monitoring their safety. The integration of the TAD and AVL systems will also serve as a model to other transit agencies for making internal AVL information accessible to outside agencies using standardized methods such as XML Web services. Such integration will support innovation in transit information distribution through personalized channels such as mobile phones and will also promote the use of accessible AVL data in other external systems with no additional cost to the transit agency.

## Product Transfer

Implementation of the TAD technology will be relatively low cost for transit agencies. The basic system uses consumer-owned cell phones. The TAD phone software could be distributed electronically over the cellular network to the clients, with little deployment cost. HART's participation assures that the TAD system will be relevant to real-world transit operations. As transit agencies add or update AVL systems and electronic records of transit routes, the standardized communication model based on XML Web services could enable the integration of TAD into transit systems' daily operations, as well as provide this information to the public. USF has been issued patents for the technology that supports the TAD, and USF's Division of Patents and Licensing (DPL) provides support through negotiation of license agreements. USF will disseminate information about the TAD system through presentations at national conferences.

Following this Transit IDEA project, USF received follow-on funds for TAD demonstrations in four other cities. They deployed TAD to four additional transit agencies in Florida. These deployment tests demonstrated that the TAD application performs successfully in additional cities. Also, an independent human behavior analysis study of TAD provided supporting evidence that TAD has a positive effect on the ability of individuals with cognitive disabilities to travel independently using public transportation. In 2010, USF negotiated a license of TAD to a Florida company, DAJUTA, LLC, that is handling the operation and support for deployment of the TAD system and training travel instructors to use TAD. To that end, the company has hired workers to deploy TAD to other transit agencies, and they have worked with a number of transit agencies.

# Ultraviolet Germicidal Irradiation for Transit Buses Transit IDEA Project 53

Lee Huston, President
JKA Company, Venice, Florida

## IDEA Concept and Product

This project incorporated ultraviolet germicidal irradiation (UVGI) into transit bus air conditioning systems. UVGI was tested for its ability to provide protection against harmful virus, bacteria, mold, and airborne pathogens for passengers riding on and employees working on transit buses. In addition, this project evaluated reduced maintenance costs on bus air conditioning systems by use of UVGI.

This project included testing and evaluation of UVGI systems on transit buses. Testing was done in cooperation with Houston Metro in Texas. Tests performed on the buses showed 95 to 99 percent reductions of virus, bacteria, mold, and fungi. In addition, laboratory virus testing was conducted to simulate bus conditions. Additional tests evaluated coil cleaning effectiveness, airflow improvement, temperature improvements, fuel savings, and reduced maintenance costs.

## Completed Investigation

Prototype UVGI systems were designed and installed on the transit buses selected for testing. Three different models of buses required different mounting configurations and lamp sizes. The project tested and demonstrated the ability to use UVGI on different types of transit buses.

Buses were inspected and information relating to the test parameters was recorded. At the end of the test period, the information was compiled and evaluated by Biological Consulting Services Inc. and the investigators in cooperation with Houston Metro.

## Project Payoff Potential

UVGI can help provide protection for passengers and transit employees against bioterrorism agents and common harmful pathogens like flu, viruses, mold, and bacteria on transit buses. UVGI can provide increased safety for mechanics while maintaining the bus air conditioning system. Maintenance savings of reduced fuel, increased component life, and less labor to maintain the air conditioning system were also found in the testing and evaluation.

The evaluation showed significant reductions of mold, bacteria, fungi, and harmful virus within the bus, which affect passengers, drivers, and employees. It also showed saving in maintenance costs with these systems.

## Product Transfer

After testing at Houston Metro, the results were evaluated and included in a final report for this project. The principal investigator has disseminated the findings via professional meetings and conferences. The application of UVGI for transit vehicles is patented.

The principal investigator has presented results of this project to individual transit agencies. Based on the successful results of this project, many transit agencies have purchased these systems and installed them in transit bus air conditioning systems, including transit agencies in Forth Worth, West Palm Beach, Fort Lauderdale, Tampa, and Jacksonville. The Chicago Transit Authority (CTA) has written the UVGI system into their specifications for purchasing new articulated transit buses. Dallas Area Rapid Transit (DART) has written it into their specifications for purchasing new transit buses, many of which were scheduled to be delivered in 2012. Some transit agencies are also considering installing the UVGI system in rail transit cars.

# Warning Device for Rail Transit Personnel for Approaching Trains
# Transit IDEA Project 55

Peter M. Bartek
Director of Technology, ProTran1, LLC, Ledgewood, New Jersey

## IDEA Concept and Product

This Transit IDEA project developed and tested a device to warn rail transit personnel of approaching trains.

The devices to detect and alert transit track workers of approaching trains have been designed to help prevent accidents by giving rail transit personnel advance warning of approaching trains. The devices have been designed to enhance the safety of track workers. A personal arm band alert device to directly alert track work crews and a supervisory flagger alert device have been developed.

The two types of warning devices are the Portable Train Detector and Warning unit with wireless safety LED lights and horns, as shown in Figure 1, and the Train-Mounted Device that is installed in an operator's cab, as shown in Figure 2. These two complementary devices would detect an approaching train and then immediately send a protected signal to turn on a set of wireless safety lights and horns (set in the work zone) and to personal arm band devices to be worn by track workers, flaggers, and trackwalkers. The Greater Cleveland Regional Transit Authority (GCRTA), the Massachusetts Bay Transportation Authority (MBTA) in Boston, and the Maryland Transit Administration (MTA) in Baltimore have participated with their staff and equipment in testing on their transit facilities as part of this project.

## Completed Investigation

This project included development and prototype testing. Key elements of the investigation found reliable technologies available and adapted and incorporated them into the system.

Testing was done at various locations that included different types of curves, tunnels, and obstructions, as further discussed on the following pages.

## Project Payoff Potential

Federal Transit Administration (FTA) and Federal Railroad Administration (FRA) data from between October 2005 and April 2008 show a significant increase in the number of rail transit worker fatalities and a significant increase in injuries. In 2008, there were an additional eight track worker fatalities in the United States.

**Figure 1**

*A portable warning unit with lights and horns and a train detector installed on the tracks.*


**Figure 2**

*Train-Mounted Device installed in a train operator's cab.*

These devices have been designed to enhance the safety of transit track workers. Such technology can give track workers an early warning of oncoming trains.

Following the development and testing of these devices, other applications have emerged, such as restricted speed location warnings, train reverse direction warnings, and advance warning for transit police and emergency responders.

## Project Results

The development and prototype testing of the devices to warn transit track workers was done at a number of locations at different transit agencies. Site testing was performed at a Greater Cleveland Regional Transit Authority (GCRTA) blind curve, Southeastern Pennsylvania Transportation Authority (SEPTA) 36th Street double "S" curve, and on the Massachusetts Bay Transportation Authority (MBTA) Red line and Green line. The prototype tests demonstrated that the devices to warn rail transit personnel of approaching trains worked effectively.

## Product Transfer

A number of transit agencies have subsequently implemented technology that was developed in this Transit IDEA project, including the Chicago Transit Authority (CTA), Los Angeles County Metropolitan Transportation Authority (LACMTA), Southeastern Pennsylvania Transportation Authority (SEPTA), Santa Clara Valley Transit Authority (VTA), Sound Transit serving the Seattle area, GCRTA serving the Cleveland area, the MBTA in Boston, and the MTA in Baltimore on their Metro Subway rail rapid transit line and their light rail transit system.

Other transit agencies that have purchased warning devices using the technology that was developed in this Transit IDEA project include the Metropolitan Atlanta Rapid Transit Authority (MARTA), Charlotte Area Transit System (CATS), and Toronto Transit Commission. In addition, railways from other countries that have purchased the devices for implementation include an Australian railway, Queensland Rail, and a Russian railway, and those devices are being manufactured in the U.S for export to those countries.

The National Transportation Safety Board (NTSB) recommended use of appropriate track-worker alert technology in their January 2008 report on how to prevent future track-worker fatalities on rail transit systems. NTSB staff demonstrated technology that was developed and tested in this Transit IDEA project at their public board meeting when they released their report in January 2008 (NTSB Report R-08-04).

# Detection of Explosives and Weapons in Transit Systems Transit IDEA Project 56

Kirill Mostov
Systems Micro Technology Inc., Berkeley, CA

## IDEA Concept and Product

Transportation systems are very vulnerable to terrorist threats. The tragic attacks in Madrid, London, and Mumbai brought the horror of this vulnerability home.

This project will develop and test a small-size, low-cost, extremely low-power, safe for humans, radio locator (radar) with detection capability for identification of explosives and weapons [such as improvised explosive devices (IEDs)] in transit systems.

## Planned Investigation

In this project, a prototype IED detection device was developed and incorporated into a San Francisco Bay Area Rapid Transit (BART) station in a non-revenue environment for testing. Intensive laboratory tests were performed to analyze the prototype "sensor return" to detect explosive compounds, components, and liquids of a typical IED.

Future deployment of the IED detection system would be completely unobtrusive and unseen in the rail transit system. The detection device is very small and can work through barriers, lending itself to very simple infrastructure integration. This approach would not require any changes to the currently utilized infrastructure.

Given the high volume use of the rail transit systems, the False Alarm Rate (FAR) must be very low. Thousands of users may pass through each section of the transit system each day. The company will work toward reducing FAR by utilizing proprietary signal processing techniques, including pattern-recognition, probabilistic reasoning, and other algorithms.

## Project Payoff Potential

The early detection of explosives and other weapons in rail transit systems has the potential to save lives by alerting security personnel to the presence of such threats. With this information, transit control centers and law enforcement authorities could detect and apprehend a potential terrorist bomber. Lives could be saved and damage to the rail transit system could be avoided, ensuring the continuing operation of the system.

## Product Transfer

The IED detection devices to be tested in this project could be deployed in transit stations, in rail transit cars, and/or as handheld units with transit police officers. When the IED detection device is used in a fixed, mounted position in transit stations, it would scan customers for explosives and other weapons and automatically alert the station agents as well as the police.

In the case of a handheld operation, the device would be used by law enforcement officers in apprehending suspected threats and in identifying hidden threats on passengers.

The proposed system, KIED, will be optimized to detect guns and improvised explosives; that is, suicide bomber vests. We will demonstrate the principle feasibility of detection of various liquids, such as flammable liquids and/or liquid explosives. The proposed device also has the capability to measure the psychophysical parameters (stress level) of the suspected terrorist remotely in order to increase the confidence of detection. KIED can operate through opaque obstructions; for example, through brick and concrete walls. The range of confident detection is 7 to 10 meters. The system works up to and beyond 50 meters with degraded capability. Power consumption and weight-dimensional characteristics of the device are less than that of a notebook computer (laptop PC). Owing to the estimated low cost of the future production (~ $1,000) the device can be widely deployed in order to improve security in rail rapid transit systems, and as portable devices (a handheld-camera-like device). The device is based on SMT's proprietary, breakthrough know-how of polarizing radiolocation and analysis of the spectrum of fluctuations of the effective surface of the observable object in comparison with the stored database of radio images for IEDs and weapons (i.e., guns). BART has agreed to participate in this project by testing the detection system on BART fare gates in non-revenue operation.

# Independent Wheelchair Securement Transit IDEA Project 57

Joseph R. Zaworski, P.E., Ph.D.
Oregon State University, Corvallis, Oregon

## IDEA Concept and Product

This project developed and tested a rear-facing wheelchair containment system for transit buses. It included a prototype device to allow users of wheelchairs to safely and independently use rear-facing containment on large buses, in lieu of the current standard four-point tie-down wheelchair securement system.

The device developed in this project includes a backrest and a movable aisle-side containment structure. The operation would begin with the user backing into the securement space until the rear of the chair is in contact with the backrest. Activation of the aisle-side device would then provide the second side of containment; the bus wall would act as the third side.

Results of the previous Transit IDEA Project 38 showed that rear-facing wheelchair containment is feasible and desirable for bus transit operations. It provides an appropriate level of safety, allows wheelchair passengers full independence in riding the bus, and reduces the time required for bus driver assistance, which then substantially reduces in-vehicle dwell time. The current limitation is the absence of a good means for aisle-side containment. One alternative in use is a fixed stanchion, as shown in Figure 1. However, this stanchion severely limits wheelchair maneuvering space, and it requires that the passenger has the ability to hold the stanchion. The other alternative does without aisle-side containment. This necessarily limits the use of the rear-facing option to those passengers in stable power chairs or to passengers able to securely hold on to a wall-side handhold.

The device developed was a rear-facing containment system designed for retrofit to existing buses. It provides both a rear backrest and an automated aisle-side armrest to prevent excessive movement of a wheelchair into the aisle, as recommended in the previous Transit IDEA project 38. A concept sketch is shown in Figure 2. When not in use, this structure is stowed to allow maximum space for maneuvering into and out of the wheelchair station.

**Figure 1**

*An aisle-side stanchion provides containment, but limits maneuvering space.*

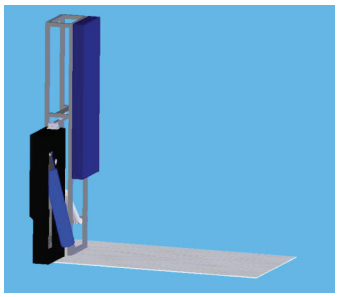


**Figure 2**

*A concept for an aisle-side armrest that is stored in the frame of the backrest until deployed. In this figure, the armrest is at the start of the deployment cycle.*

## Completed Investigation

This project developed a rear-facing wheelchair containment system for buses and included design, construction, laboratory testing, and refinements, followed by in-vehicle testing of a final prototype. This project included regular reviews by collaborators, including Lane Transit District (LTD) of Eugene, Oregon. LTD is an early implementer of Bus Rapid Transit (BRT) and has a fixed stanchion rear-facing wheelchair securement position on each of its new BRT vehicles, in addition to a front-facing wheelchair securement position.

Specific activities that were conducted for this project included the following: the use of a formal process for design, solid model development, and virtual testing along with finite element analysis for strength, construction of a prototype for testing, laboratory testing for strength, cyclic testing for durability, construction of a final prototype that incorporates identified improvements, and in-vehicle testing with regular wheelchair passengers of LTD.

## Product Payoff Potential

It is anticipated that the results of this project will have a major positive impact on the transit industry's approach to wheelchair securement. The use of independent rear-facing containment will reduce the time and the operator assistance that are currently required when a wheelchair user rides a bus. This project provides information that transit agencies need to provide effective rear-facing containment. It also provides data that could be useful in future consideration of an appropriate revision to the existing Americans with Disabilities Act (ADA) Accessibility Guidelines on rear-facing wheelchair containment for buses. Specifically, this project determined where aisle-side containment surfaces should be centered, what shape they should be, and how big they should be. It also determined the magnitude of the forces that aisle-side containment must withstand. This project also demonstrated a solution to meet those requirements.

## Product Transfer

The knowledge that was gained about independent wheelchair securement as a result of this project will be disseminated by the principal investigator through publication in appropriate journals, presentations at transportation conferences, and in meetings of the American National Standards Institute (ANSI) Committee on Wheelchairs and Transportation. Also, the final design of a movable aisle-side containment system will be made available to interested manufacturers.

# Google Transit Data Tool for Small Transit Agencies Transit IDEA Project 58

Prescott Sherrod
President, PEMCCO, Inc.
Virginia Beach, Virginia

## IDEA Concept and Product

This project developed a tool that allows small transit agencies to enter, export, and host the transit data needed to participate in Google Transit. While mid- to large-size transit agencies often have the resources to provide Google Transit data feeds in accordance with the Google Transit Feed Specification (GTFS), many small transit agencies do not have the required resources to enter, export, and host the required transit data feed or do not have their data in the required format.

The Transit Data Feeder (TDF) tool developed is available in the form of a Web-based application and released under an open source software license making the tool open and transferable. TDF can be found on the internet at the following location: http://datafeeder.trilliumtransit.com/transitdatafeeder.

TDF can be available in two configurations. Transit agencies can choose which configuration best fits their needs and circumstances: (1) hosted configuration, which minimizes the equipment requirements for the transit agency user to a personal computer with Internet access; and (2) local Web application installation by the transit agency user. This Web application can be downloaded from the project Web site. The Web application architecture is innovative as it is platform-independent (MS Windows, Linux, or others), as well as independent of which database management system (SQL Server, MySQL, or others) is used. In this configuration option, hosting of GTFS data feeds would be provided by the transit agency.

## Completed Investigation

This project included Web application pilot implementation and transit agency application testing during the beta test phase of the project. Once the software design was verified and validated and the coding was completed, the code was validated with test cases from a function and systems test scenario. After testing was determined to be successful and complete, a selected transit agency entered the project beta test Pilot Program. During the Pilot Program the TDF application was hosted on a team member's Website for the participating agency's use. The TDF application enabled the transit agency to process their real transit data creating the required GTFS data feed for publishing their transit information on Google Transit. The TDF application is now available for others to use on another organization's server for hosting or for an agency to download and use internally.

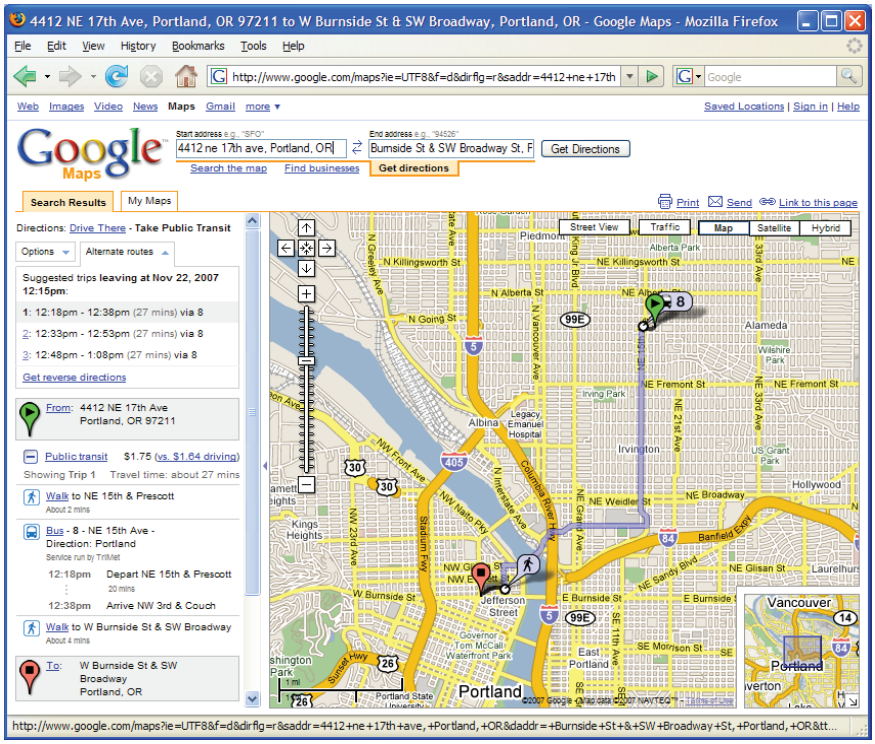



**Figure 1**

*Example of a route identified on the http://www.google.com/transit site*

## Project Payoff Potential

Small transit agencies in particular can benefit from this TDF tool, although other transit agencies can also use it. TDF enables the entry, export, and hosting of the transit data needed to participate in Google Transit in either of two alternative configurations commensurate with small transit agency circumstances and resources.

Even though Google does not charge transit agencies for the Google Transit Web-based trip planner (http://www.google.com/transit) (see Figure 1), there is effort and cost for transit agencies to provide GTFS data feeds to Google. The TDF web-based application has resulted in the expected reduced cost and effort for providing GTFS data feeds.

## Product Transfer

An interested transit agency can use the TDF application through an agreement with a hosting organization, or with the capability to host it themselves, and a personal computer with Internet access. The relevant transit data will be entered and managed by the transit agency user with the Web-based interface. In a final step, the export and hosting of the transit data in accordance with the GTFS allows Google to publish the transit data for use in Google Transit.

With this package, a small transit agency has everything to make their schedule and route information available on Google Transit, Google Maps, and Google Earth. If other online mapping organizations decide to include transit information in their products, it would be possible for them to use the GTFS data feed.

# TCIP Traveler Information Pilot Transit IDEA Project 60

Robert G Ayers, P.E.
President, Ayers Electronic Systems, LLC
Richmond, Virginia

## IDEA Concept and Product

This project installed and field tested a TCIP-based passenger information and vehicle tracking system. This project included testing of the system at LYNX, the transit agency in Orlando, Florida, and demonstrated TCIP interfaces in a transit agency environment.

Transit Communications Interface Profiles (TCIP) is an APTA standard that provides a means to define and implement interfaces for data exchange among transit business systems. The TCIP standard was released by APTA in August 2006.

This project converted proprietary vehicle tracking data to TCIP, merged the tracking data from a bus being tracked with a TCIP-based AVL solution, and used the data from both sources to provide information to passengers via an electronic sign installed at the LYNX central station. The sign receives bus location information for display to passengers via a TCIP interface.

## Completed Investigation

TCIP interface and application software, developed by Ayers Electronic Systems LLC (aE), was ported to appropriate rugged hardware and installed into the LYNX operating environment. The installed system was successfully tested and evaluated to verify its operation and effectiveness in a transit environment.

A rugged computer was installed on one bus, and other LYNX buses were tracked using translated data from the existing AVL system. A rugged sign was installed at the LYNX central station to convey arriving bus information to passengers. A server was installed in the dispatcher area, and the subsystems were interconnected using the Internet, a commercial wireless data provider, and local networks.

## Project Payoff Potential

The use of TCIP is expected to reduce life-cycle costs to transit agencies that implement intelligent transportation systems technologies, to facilitate increased integration of transit information systems leading to greater operating synergies and efficiency, and to increase the degree of control that transit agencies are able to exercise over the integration of their information systems.

This project demonstrated TCIP interfaces to perform real-time interactions between business systems in the transit environment.

## Product Transfer

After the system was installed at LYNX, it was evaluated. The final report for this project includes information so that other transit agencies can consider using this technology. The results will also be disseminated by the Principal Investigator via papers presented at professional meetings and conferences of transit organizations and associations.

Following this project, aE plans to further develop the technology used in this project and to offer to install the resulting products for a fee to transit agencies. Since TCIP is an open standard, other suppliers will also be able to offer compatible products and systems based on this technology.

# Flexible Carpooling to Transit Stations Transit IDEA Project 61

Paul Minett
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Auckland, New Zealand

## IDEA Concept and Product

This project investigated and defined a flexible carpooling service to increase the amount of carpooling to transit stations. Increases in carpooling to transit stations could increase transit ridership and improve the effectiveness of investments in parking at transit stations.

Parking at transit stations often has a high capital cost and limited opportunity for expansion because of the high value of the land around many transit stations. Transit ridership is often constrained by the amount of parking at transit stations.

Traditional carpooling involves pre-arrangement and commitment to being in a particular regular carpool at a particular time. Flexible carpooling to and from transit stations was investigated to see if it could address some of the limits of traditional carpooling to transit stations.

The flexible carpooling approach operates in a similar way as the casual carpools (San Francisco, CA) and slug-lines (Washington, DC/Northern Virginia, and Houston, TX). These operate like a 'taxi stand for carpoolers', with lines of people or lines of cars, and the front people getting into the front cars to go to a predetermined destination. There is no pre-commitment, and each day each participant can decide to ride, drive, or not show up, without having to inform the rest of the participants. The flexible carpooling approach analyzed in this project would create a more formal system (than the casual carpooling examples), with membership, pre-screening, and tracking technology, while retaining the characteristic of no pre-arrangement.

## Completed Investigation

To increase the utilization of parking at a given transit station, it is necessary to first understand the usage of that parking. This project included:

- surveying travel patterns of users of selected parking facilities at transit stations owned or operated by Seattle area transit agencies, including Sound Transit, King County Metro Transit, and Washington State Department of Transportation;
- surveying the conditions in potential flexible carpooling origin areas;
- choosing the optimum route for a field operating trial based on the surveys;
- defining a prototype flexible carpooling service; and
- specifying a future proposed field operating trial, including budget estimates.

This project included selecting up to five Seattle area parking facilities at transit stations and surveying in which the origin area and occupancy rates of arriving vehicles were recorded and analysed for origin grouping potential (OGP).

Origin areas with high OGP were evaluated for their potential for flexible carpool formation to either reduce the number of vehicles from that origin area, increase the number of transit riders from that origin area, or both. This effort included outreach to local officials in the origin areas to determine their interest in supporting possible future implementation of a flexible carpool pick-up point within their community, including identifying appropriate pick-up locations.

The project selected the most promising of the routes, considering the estimated number of carpools for further development. A draft specification prepared by the principal investigator was adapted for the route and conditions, including technology enhancements.

The project defined a future proposed field operating trial to test the adapted specification, including a detailed budget for the trial. A future proposed field operating trial is not funded and would need sponsorship and financing.

## Project Payoff Potential

The flexible carpooling system could enable ridership growth without associated investments in parking at transit stations. The method of analysis developed and tested in the project will help transit agencies to analyze the use of their own facilities to identify origin areas with high OGP as a first step in using flexible carpooling to increase ridership. Flexible carpooling to transit stations could reduce average VMT of transit patrons arriving at transit stations, thereby reducing fuel use, emissions, and traffic in the vicinity of the transit stations.

## Product Transfer

After the analysis was performed on Seattle area parking at transit stations, the results were evaluated and included in a final report for this project. Results will be disseminated by the principal investigator via papers presented at professional meetings and conferences. The participation of the transit agencies identified above will make the results useful to transit agencies. A possible future field operating trial based on the findings could demonstrate how the service would work to potential users.

# Development of Maintenance Training Module for Bus Transit Technicians Transit IDEA Project 62

Robert Mann
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Queensland, Australia

## IDEA Concept and Product

This project developed and tested an electrical/electronics training module for bus maintenance technicians, to be delivered online. CDX Global adapted and modified its current multimedia content, which targets automotive technicians, specifically for transit bus maintenance technicians.

This project provides a model for the application of web-based training and testing for both entry-level and experienced bus maintenance technicians in modern electrical/electronic systems in transit buses. This will be particularly valuable for transit agencies that do not have the resources to deliver such training. The focus on electrical/electronic subjects addresses an area of rapid technological change where significant training is required by new entrants and also by practicing technicians in transit agencies.

## Completed Investigation

The curriculum that was developed focused on current and emerging technologies, including content on hybrid engine technologies used by transit agencies. CDX expanded the series of tasks associated with these new technologies that transit technicians need to understand to keep modern fleets operating efficiently. For example, general principles and procedures to safely service battery systems for hybrid electrical buses were one of the key topics for this module. The same overall approach will be applied to other alternative fuel technologies. CDX worked with the Francis Tuttle Technology Center in Oklahoma City and Rio Hondo Community College, of Whittier, California, which has a heavy vehicle training facility.

Investigators at CDX have consulted extensively with transit agency training managers regarding the content of this module. Transit trainers have emphasized the importance of electrical/electronics training to keep fleets operating effectively, especially as buses become more sophisticated electronically in alternative fuel engine systems.

Once the content was developed, this electrical module was pilot tested at transit agencies, including the Santa Clara Valley Transportation Authority, the Chicago Transit Authority, and Golden Gate Bridge Transportation District.

## Product Payoff Potential

Bus maintenance workers will have the opportunity to log on to the web-based training module to work their way through the content. Convenience and low cost are the goals in this type of delivery system, which has particular appeal to transit agencies that value training but operate under tight training budgets. This training could also be a key component of the Automotive Service Excellence (ASE) testing requirements for the bus maintenance electrical/electronics certification.

## Product Transfer

The intention of CDX is to deliver the training module to other transit agencies via the internet, in cooperation with the American Public Transportation Association (APTA), through a dedicated CDX web portal.

# Improving Bus Transit On-Time Performance through the Use of AVL Data
# Transit IDEA Project 63

Jack M. Reilly, Ph.D.
Pascal Systems, Inc.
Latham, New York

The purpose of this project was to develop a set of desktop tools to analyze archived fixed-route transit automatic vehicle location (AVL) data for the purpose of measuring on-time performance and developing schedule times (running times) between timepoints. The tools were developed using data from the Capital District Transportation Authority (CDTA) in Albany, New York. The project was also intended to determine if the system developed could be exported to other transit agencies with a different AVL system than that used by CDTA.

Through consultation with staff of the CDTA, a set of requirements were developed for the system, including the reports to be produced, formats, and user interfaces. A prototype system was developed, which included a number of reports on on-time performance and running times both from originating terminals, as well as intermediate timepoints on a route. Further, a set of tools was prepared that assessed the layover time at the end of scheduled transit trips. The prototype was developed using CDTA data, and revisions were made based on comments from the CDTA staff and those of the Project Review Panel. In addition, the software was applied to data from the Ann Arbor Transportation Authority and the Lehigh and Northampton Transportation Authority in Allentown, Pennsylvania.

It was determined that archived transit AVL data could be used to provide reasonable results in running times. While it is theoretically possible to reduce the peak fleet requirement by reducing running times, the project did not experience this. This is likely due to the fact that the system was applied to smaller transit agencies that have few buses to begin with on the routes they operate. The tools developed could improve the on-time performance of transit systems or determine the upper bound on on-time percentage given underlying variability in the transit travel times resulting from factors outside of the control of transit operators such as vehicle traffic.

The procedure for the determination of appropriate running times consisted of two analyses: terminal to terminal times and times between intermediate timepoints. Suggested terminal to terminal times were established by finding the time necessary to assure that the subsequent trip on a vehicle assignment could depart on time with a certain probability such as 95%. Suggested intermediate timepoint times were established by determining the specific time that would maximize the number of bus trips that would depart from timepoints between one minute early and five minutes late.

A few statistical tools to transit AVL data were applied to make the determination of appropriate running times, but also make the system accessible to transit schedulers through the development of a simple user interface.

The application of these tools to the transit systems in Ann Arbor and Allentown demonstrated that the system could be exported to develop appropriate running times on data from different AVL products. This would require some reformatting of data from these AVL systems.

This work demonstrated proof-of-concept that AVL data can be used to improve the on-time performance of transit systems through changes in running times. Further, it has been shown that this set of analysis tools can be used on data sets from a number of different vendors of AVL systems.

The OTP reports are useful in identifying "hot spots" for further investigation. The system developed here can provide a number of tools to identify the reasons for substandard on-time performance. These include an assessment of on-time performance at terminal departures and assessment of the amount of layover time of scheduled buses.

While the primary objective of optimizing running times is to improve the quality of service to customers, it is possible that shorter running times may reduce operating costs. This would occur if running times were reduced and the number of vehicles required to maintain service frequency were also diminished. Opportunities to reduce vehicle requirements were not observed, primarily because the number of vehicles assigned to the routes was small, with the maximum being about 10 vehicles.

It was concluded that making reasonable inferences on running time is very data intensive, and implementing new schedules involves considerable staff time to develop and requires adaptation by customers. As a result, running times are not updated very frequently.

AVL data can also enable diagnosis of schedule reliability (consistent arrivals at stops on the same scheduled trip across successive days.); there was some reporting on this. However, there is limited data on appropriate management actions to control poor reliability. This might be a fruitful area of future research. However, from a customer point of view, this might be secondary to improving the basic level of on-time performance.

Scheduling has some elements of art as well as science. For example, the transition between peak hour running time and off-peak running time sometimes requires a gradual change in order to avoid long gaps in the headway of waiting customers.

Although the tool can be used for optimization, it also has utility as a diagnostic tool to identify the routes, route segments, and time periods that have the largest departure from technically optimal running times.

There are at least two pathways for implementing the results of this project. The first would be to work with current AVL system vendors to integrate this software into their project offering as a value-added service. This would enable some differentiation of their project from their competitors. A second channel would be to promote this product directly to transit systems that have AVL systems either when they are implementing new or replacement AVL systems.

The investigator is planning to demonstrate this product at the annual meeting of the New York Public Transit Association in the fall of 2014. Further, the investigator has a number of current and previous clients in the passenger transportation industry that would be targeted for presentations in coming months.

# A Context Aware Transit Navigator Transit IDEA Project 65

Jakob Eriksson, Ph.D.
University of Illinois at Chicago
Chicago, Illinois

## IDEA Concept and Product

This project developed and tested a system for context aware, real-time transit navigation support using smart phones. The system combines the convenience of existing online transit trip planners with the up-to-date accuracy of real-time transit tracking from multiple transit operators in a region.

The end-user device is a GPS-enabled smart phone. Based on a selected trip origin and destination, the transit navigation system provides the user with a real-time updated, optimal route for the intended itinerary, requiring minimal manual input. It is intended that by enabling efficient, up-to-date, and real-time transit navigation support, the system will improve the experience of current transit riders and encourage infrequent riders to increase their use of public transit options.

Transit tracking and schedule data were obtained from the Chicago Transit Authority (CTA) and Pace Suburban Bus service. These agencies will provide the data and technical guidance in this project.

## Completed Investigation

The completed navigation system supports unified real-time transit navigation, including walking, biking, or handicapped access, across all three Chicago transit agencies: CTA buses and subway trains, Pace suburban buses, and Metra commuter rail. The back-end is built as a generic routing service, which can be used by any number of client applications. On the client side, an iPhone application has been created, with an attractive user interface and a wide selection of convenient features. The iPhone application has been published on the iTunes App store for public download. The app is downloaded by approximately 2,000–3,000 users per month, and has received more than 1,000 reviews, many of which are very positive.

The next immediate step is to identify a feasible business plan for the continued funding and commercialization of the service.

The server back-end part of the work is and will continue to be available for open-source download at https://github.com/jeriksson/graphserver. Depending on how future commercialization efforts develop, the client side app may also be released under an open-source license in coming years.

## Project Payoff Potential

The transit navigation software developed in this project is expected to improve on the reliability of schedule-based transit trip planning services, particularly where published schedules do not always correspond to the actual arrival and trip times of the transit vehicles. Uncertainty of wait times and travel times is one of several factors influencing travel decisions, and this system is intended to help reduce the uncertainty.

## Product Transfer

This project will result in advances in transit navigation research, as well as a major software product. The results will be disseminated through conferences and journals by the Principal Investigator, and the software for a Chicago-based test will be made available to transit agencies and other interested parties through free downloads. An open source license will be made available, enabling other cities and transit agencies to deploy the software to support their own transit services.

# Advanced Wayside Energy Storage Systems for Rail Transit Transit IDEA Project 66

Colette Lamontagne
Navigant Consulting, Inc.
Burlington, Massachusetts

## IDEA Contract and Product

This project explored the use of advanced wayside energy storage systems (WESS) in light rail transit and heavy rail rapid transit systems to reduce electricity costs and accrue other benefits to transit systems.

## Completed Investigation

Operational costs to the transit agency were documented, including peak load reduction, voltage support, and regenerative braking improvements. By considering the full range of stakeholders, this project identified sustainability improvements and revenue streams resulting from WESS. In addition, it performed basic cost analyses for a wide range of WESS technologies and capabilities as well as expected changes in technology and price.

Part of this project identified and aggregated complementary WESS benefits and associated equipment costs into financial value propositions. For instance, energy storage devices could help transit operators in their efforts to meet their renewable energy goals, reduce greenhouse gas emissions, and increase reliability of their systems. A combination of distributed WESS devices of different sizes and types will be considered.

Through cost-benefit analyses, simulation, and case studies, this project explored the full range of value propositions associated with WESS. The project investigators coordinated this project with the American Public Transportation Association (APTA)/Electric Power Research Institute (EPRI) Energy Storage Research Consortium and built on their work in this area.

Case studies were carried out in cooperation with the participating transit agencies: Greater Cleveland Regional Transit Authority (GCRTA) and Denver Regional Transportation District (RTD). These two transit agencies are located in states with renewable portfolio standards. They also present key similarities and differences that enabled a diverse set of WESS value propositions to be explored in different transit environments.

## Project Payoff Potential

Potential benefits to transit agencies could involve maintaining train performance and responding to electric service interruptions.

## Product Transfer

This project was closely coordinated with the Energy Storage Research Consortium, a joint APTA-EPRI sponsored initiative designed to accelerate the understanding, coordination, and application of energy storage technologies for transit systems. The Consortium provides an information clearinghouse for trackside energy storage information. Consortium members represent transit operators, utilities, public agencies, and suppliers who form partnerships to evaluate energy storage opportunities for public transit systems.

# Diesel-Electric Locomotive Energy Recovery and Conversion Transit IDEA Project 67

Dr. Claudio Filippone
ThermaDynamics Rail LLC

Waste heat energy recovery technologies, implemented as retrofit or at the engine manufacturer level, can reduce locomotive fuel consumption and pollutant emissions while increasing locomotive efficiency. ThermaDynamics Rail LLC (TDR) has developed waste energy recovery technologies for minimally invasive retrofitting applications.

Baseline data collected from literature and from measurements of selected locomotives equipped with a widely utilized type of engine were analyzed with respect to technical and economic performance of a waste heat recovery technology developed by TDR. The collected data involved identification of key exhaust gas parameters including overall dimensions of the exhaust stack, manifolds, temperature, and velocity of the exhaust gases sampled at given locations of the hydraulic exhaust gas piping system. Data analysis also included Particulate Matter emissions and fuel consumption rates. Additional information addressing locomotive duty cycles focused on line-haul and commuter rail operations was also utilized for the purposes of estimating economic performance of TDR waste heat recovery technologies when utilized to retrofit selected locomotive engines.

A thermodynamic model to represent the thermal-hydraulic behavior of TDR waste heat recovery and conversion components was optimized using the commercially available software Engineering Equation Solver (EES). Under a set of simplifying assumptions, the overall performance of the TDR model was investigated for locomotives operating at different notch settings. When analyzing a locomotive engine producing relatively low temperature exhaust gases, a Rankine-based power cycle, executed under TDR waste heat recovery components configuration, can achieve a total energy recovery of approximately13% at Notch 3 to 17% at Notch 8 of the total waste heat energy otherwise vented to atmosphere. The recovered energy may then be directly converted into pollutant-free propulsion or electric power, thereby reducing fuel consumption and exhaust gas emissions. Accordingly, under industry accepted assumptions of locomotive usage and duty cycles, when the waste heat recovery operated under TDR modeling is retrofitted with engines producing averaged exhaust gas temperatures, the yearly fuel savings can be significant. Retrofitting TDR waste heat recovery components with locomotive engines characterized by higher temperature exhaust gases can result in even higher yearly savings while further reducing pollutant emissions.

The effects of assumptions utilized to simplify a bottom-cycle Rankine model were analyzed by varying the efficiencies of the pump, turbine, and alternator. As expected, turbine and alternator efficiencies were found to induce considerable effects on the model performance. Additionally, the effect of pressure ratio between the high- and low-pressure thermodynamic state of the working fluid was also assessed, thus providing results indicating how pressure in the waste heat recovery Rankine cycle may be optimized to increase efficiency at low notch settings.

Two different approaches were considered for achieving waste heat energy recovery when locomotives are operated at idle and low notch settings. One approach involved lowering the Rankine cycle operating pressure. The second approach involved utilization of an organic working fluid such as R134a. In both cases very modest power recovery could possibly be obtained at idle and low notch settings.

A "first generation," low-cost, locomotive-burner simulator was developed to validate computer model results. The simulator was developed to generate exhaust gases with characteristics comparable to those emitted by locomotive engines. As the locomotive-burner simulator was tested it became apparent that the dimensional constraints imposed by the locomotive exhaust gas manifolds induced a combustion chamber hydraulic diameter too small for complete combustion of the fuel. As a result, the locomotive-burner simulator did not perform as expected. A redesigned combustion chamber is required. Computer models were then tested against a limited set of data obtained from a GE-Dash-9 locomotive retrofitted with two high-pressure heat exchangers (HiPHEXs). With this limited data set and under model assumptions the HiPHEX effectiveness tends to decrease for increasing notch numbers. In fact, as the total mass of exhaust gases flowing through the two heat exchangers increases beyond a certain threshold, the total surface area of only two HiPHEXs becomes insufficient to effectively transfer energy from the exhaust gases to the working fluid, thus extrapolation of data becomes increasingly inaccurate with increasing notch numbers.

Overall, the analyses based on limited actual locative test data show that the basic HiPHEX design performs reasonably well at all notch numbers (~50%) with attractive economic and pollutant reduction benefits. However, additional experimental measurements are necessary to further validate the results and aid the design toward HiPHEX configurations with higher effectiveness (i.e., extending heat exchangers surface area within the constraints of executing non-invasive locomotive retrofitting).

# Light Rail Transit/Street Grade Crossing Safety System Transit IDEA Project 68

Carl E. Conti
SIL4 Systems Inc.
Pittsburgh, Pennsylvania

SIL4 Systems Inc. developed and tested an intelligent Light Rail Transit/Street Grade Safety System that can be used by light rail transit systems.

The concept investigated and developed in this project is active, adaptive, alert, and improves recording of crossing incidents for the approaching light rail vehicle (LRV), its operator, and the pedestrian, motorist, and/or worker at the crossing. An outline of the system features and impacts are listed here:

| *FEATURE* | *IMPACT* |
|---|---|
| 1. Active system—Alerts operator | Improved alertness/response time of operator |
| 2. Active system—Alerts trespasser/worker | Improved alertness/response of person at risk |
| 3. Improved alertness/response time | Actively alerts operator and pedestrian/motorist |
| 4. Active system—Applies brakes | Actively alerts operator then applies brakes |
| 5. Adaptive—works only when train approaches | Avoids false triggers |
| 6. Comprehensive record | Records events on the train and in the crossing |
| 7. Adaptable/portable | Can be set up in temporary work areas |

Features 1, 2, 3, 4, and 5 are implemented and achieved by the system such that it can activate the crossing light/alarm from the vehicle given the preset "time to crossing" programmed to 20 seconds. At this point, the HRC package can then communicate to surface traffic controllers or gate mechanisms, or additional surface traffic lights or alarms via WiFi or cellular networks or relay logic interface.

The crossing alarm sequence is activated by any of the following (or any logical combination of these) inputs:

a. Automatic activation via LRV based on LRV "distance to crossing" arrival threshold (expressed in feet or meters)
b. Automatic activation via LRV based on LRV "time to crossing" arrival threshold (expressed in feet or meters)
c. "Motion within crossing" per camera image detection versus a static image
d. "Occupancy within crossing" per camera image detection versus an empty crossing
e. Manual activation via train operator touch-screen button
f. Automatic activation via LRV after cab alarm times out due to no braking command from operator as measured by Master Controller position monitor
g. Automatic activation via LRV after cab alarm times out due to no braking response of vehicle as measured by on-board accelerometer

Feature 6, a comprehensive record, is achieved via our on-board Data Logger/Event Recorder along with a NVR video record.

Feature 7, the HRC package being compact, low profile and under 10 lb. can easily be mounted on a battery/work area lighting cart for temporary work area applications. Since it has on-board GPS, it can report its location wherever it is set up.

Here are some possible applications of the system and various features and technology:

- Positive Train Control (PTC)/Positive Separation (PTS)
- Advanced Warning for Railroad Delays (AWARD)
- Second Train Coming (STC) Detection
- Four Quadrant Gate System with Obstacle Detection
- Intelligent Grade Crossing

# Predictive Failure Mode Characterization System for Rail Transit Car Equipment
# Transit IDEA Project 69

Withdrawn

# Effortless Passenger Identification System Transit IDEA Project 70

Del Peterson
North Dakota State University
Fargo, North Dakota

The objective of this project was to evaluate the technical, operational, and economic feasibility of using medium-range radio frequency identification (RFID) technology to track four main tasks including field testing, controlled testing, consumer acceptance, and both operational and economic feasibility.

Detailed passenger ridership data can improve the efficiency and effectiveness of transit planning, operations, and reporting. The RFID tags used by an EPIS system can be read at longer distances than contactless or proximity cards currently used in the industry. This characteristic allows passengers to be identified and counted as they board and alight vehicles without requiring them to physically present their card within a short distance of an on-vehicle reader.

The medium-range reader used during field testing at North Dakota State University (NDSU) successfully recorded riders boarding the bus almost 90% of the time. The RFID tags used at NDSU were attached to the outside of student backpacks allowing for little interference between the card and the reader. Controlled testing results indicated that the reader received a valid signal from the RFID card if it was in plain sight and there was no interference present. When riders boarded the bus with the card either in their pockets or against their cell phones, the read quality dropped dramatically. However, read quality was very good when the RFID card was attached to a metal wheelchair.

The consumer acceptance task evaluated the RFID perceptions of college students, people with physical and mental disabilities, and parents of school-aged children. Overall, all three groups believed that RFID technology has merit with respect to bus transportation. Many respondents felt that an RFID card kept in a wallet or pocket would be more efficient for the riders and system as a whole. Students largely agreed that they would like to see RFID implemented at their college or university, replacing the use of their current student ID cards. Also, most felt that using RFID technology would reduce boarding times and keep the buses running on schedule, which is a main benefit when implementing an RFID system. However, the main obstacles and resolutions for successful implementation are the issues of multiple reads occurring when riders get too close to the antennas, and the current inability to create a system where the cards are read successfully through clothing and when interference is present from other items such as cell phones. Measures that could be taken to resolve these issues may include more advanced RFID readers and tags that employ technologies limiting interference from clothing and electronic devices.

The economic feasibility of EPIS was evaluated by conducting a thorough cost-benefit analysis simulating different agency and ridership scenarios. The analysis identified the economic

impacts of EPIS on the agency, riders, contracting agencies, and other external stakeholders. The economic impacts in this analysis were quantified by identifying explicit and implicit costs and benefits over the life cycle of the investment. Measures including net present value (NPV), cost-benefit ratio (CBR), and internal rate of return (IRR) were calculated for each alternative to determine the economic feasibility of EPIS for different agencies and ridership scenarios. The analysis showed that with proper ridership numbers and varying percentages of non-student riders, EPIS technology can provide an economic benefit to transit agencies.

Controlled testing of the equipment indicated that when interference was present, from clothing, cell phones, etc., card read quality dropped considerably. Because of this, field testing at NDSU was conducted with students attaching RFID cards to the outside of their book bags to minimize interference between the cards and the reader. Also, Zonar Systems has discontinued selling and supporting its medium-range readers because of their inefficiencies in tracking elementary aged children riding school buses. Therefore, in order for transit agencies to implement an effective EPIS system utilizing medium-range RFID readers and cards, current technology must be improved upon to address both read quality and interference issues that deem the system insufficient in its current form.

# Transit Information Access for Persons with Visual or Cognitive Impairments
# Transit IDEA Project 71

Roberto Manduchi
University of California, Santa Cruz

## IDEA Concept and Product

This project has developed a system to ensure that all passengers, including passengers with visual or cognitive impairments, are able to access relevant transit information. These passengers face information access challenges when using public transportation. For example, they may have difficulties understanding which bus has just arrived at a bus stop and at which stop they should dismount. ADA-mandated acoustic and visual informational systems are ineffective in situations with loud background noise or for people with a hearing or attention deficit. With our system, passengers will be able to access personalized, real-time transit information through their cell phone. This information is provided by Wi-Fi access points (AP) that are placed at bus stations and on buses. APs transmit information that is already currently posted (in printed form or through audible and textual displays), but cannot be easily accessed by persons who have sensory or cognitive impairments. Customers can receive information in a customizable format; for example, they can check the list of bus lines through a certain stop, request to be notified ahead of time when the bus is approaching a desired stop, and ask for the same information to be repeated multiple times, in case they are unsure or become anxious during travel.

## Completed Investigation

Our project has explored a novel approach to real-time, customizable, multi-modal, travel-related information access. Information is pushed to one own's smartphone from Wi-Fi APs. In our system, APs are placed both at bus stops and within buses. These APs are programmed to communicate with the user's smartphone through Wi-Fi, providing information that is then presented to the user in accessible form. In our prototype implementation, Wi-Fi APs are embodied in TP-LINK systems, running different types of server software, depending on whether the AP is placed at a bus stop or inside a bus. The APs communicate with a client application implemented in a Nexus 7 tablet, operated by the user.

For our user studies, we instrumented three bus stops and one bus in the UC Santa Cruz campus. Four blind participants tested the system during February and March of 2015 (see Figure 1). Each participant underwent the full procedure described above twice, operating the Nexus 7 tablet and interacting with the system. The principal investigator and a graduate student supervised all user studies and took accurate notes (including video recordings) of the whole procedure. In addition, each participant completed a semi-structured interview at the end of the study, which highlighted relevant accessibility issues with the current public transit system, recurring problems experienced by blind travelers, and perceived benefits and shortcoming of the proposed new technology.

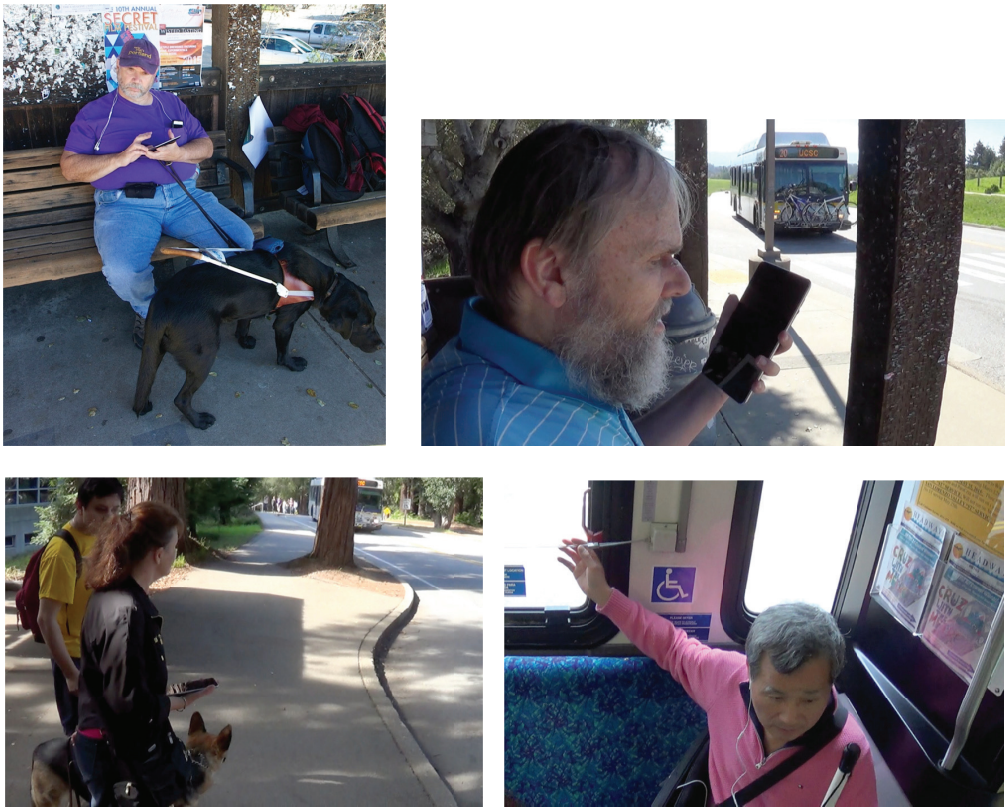



**Figure 1**

*Blind participants during user studies.*

## Product Payoff Potential

By providing personalized transit information to each user, regardless of possible sensorial or cognitive impairments, this system has the potential to increase ridership by large segments of the community who are currently unable or unwilling to travel independently. Some of these individuals currently prefer to resort to paratransit, rather than taking a bus, resulting in unnecessary high costs for the transit agencies. The proposed system encourages and facilitates independent use of public transportation, resulting in increased revenues for public transportation entities.

## Product Transfer

During the course of this project, we have collaborated with the Transportation & Parking Services (TAPS) group that operates shuttle buses at the University of California, Santa Cruz campus. TAPS has been very supportive of this work and facilitated project tests by allowing deployment of APs at bus stops and inside their shuttle busses. We plan to approach local transit entities [in particular, the Santa Cruz Metro, Santa Clara Valley Transportation Authority (VTA), and San Francisco Municipal Transportation Agency (MUNI)] to conduct larger scale experiments, and to explore the interest of these entities in adopting this system for improved transit access. In addition, we plan to approach companies such as NextBus, which provide real-time information about bus arrivals, to investigate whether our accessible technology could be integrated in their online system.

# Handheld Wheel Flaw Detection Device: Noncontact Electronic Wheel Gauge Transit IDEA Project 72

Zack Mian
International Electronic Machines Corporation
Troy, New York

As current-art solutions to complete wheel measurement and maintenance have proven inadequate, International Electronic Machines (IEM) has developed a prototype handheld, self-contained Noncontact Electronic Wheel Gauge (NEWG), deriving from IEM's prior work with both handheld wheel gauges and noncontact metrology.

The Stage 2 work has shown that the NEWG is completely feasible, and with recent contacts it has been demonstrated to be of relevant interest to the transit industry. Although a final prototype is still in development, all of the key technological aspects—specific camera selections, mounting, laser selection, calibration, image acquisition and processing, actual measurement, and interface/data presentation—have been directly addressed and tested.

IEM has identified three specific, related areas that will require additional research work to address: reflective glare in images, proper calibration and imaging precision, and the accuracy of diameter measurement in specific areas. The basic principles and overall performance of the NEWG have been demonstrated; however, in these specific areas there are key elements, especially in the imaging analysis using the particular stereo-equivalent pairs of images, which are innovative and unique and require further investigation and refinement to reach the specified levels of performance.

The development of the NEWG is therefore a success and IEM believes that finalizing a production design and moving forward to marketing and distribution is the obvious next step. It should also be noted that the basic technology of the NEWG is capable of performing accurate measurements of multiple other targets and objects including rail.

# Innovative Operating Strategies for Paratransit Services Transit Idea Project 73

Luca Quadrifoglio, Ph.D.
Texas A&M Transportation Institute, College Station, Texas

Paratransit services are a large industry providing transportation services for disabled and elderly customers across the country. Demand for these services has been continuously growing since the Americans with Disabilities Act (ADA) was implemented in 1990 and there are no signs indicating a reversal of this trend. More than 30 million paratransit trips are requested yearly from the U.S. population. As these services are very costly and mandated by law, transit agencies work to deliver an adequate level of service in a cost-effective manner and are always looking at ways to improve their performance and reduce their operating costs. However, the current operating policy adopted by most transit agencies is inefficient. When an independently managed zoning operating strategy is adopted, cross-zonal customers need to be dropped off outside their pick-up zone; the service provider's vehicle will bring the customers to their destination, but is not allowed to pick up customers outside of its own service zone. This zoning strategy prohibits potential ridesharing and increases the empty trip miles driven, eventually increasing the costs of these services considerably, as cross-zonal customers can be as high as 30% of the daily demand, for example, in Los Angeles County. Furthermore, customers having pick-up and drop-off locations in different zones are required to rely on two different providers for their round-trip, with potentially different booking rules, and therefore they might experience a reduced level of service.

To address this issue, this project explored innovative strategies for operating ADA paratransit services. Since an inefficiency of the paratransit services can be attributed to the large number of empty trip miles driven while serving cross-zonal customers, the goal of this research was to quantify the potential benefits of enabling service providers to serve both trips of cross-zonal customers in need of round-trip rides. The primary anticipated benefits due to the implementation of this innovative operating practice would be a significant reduction of the empty trip miles driven (and their associated costs) and an improvement of the level of service provided to customers. This research explored whether allowing the innovative proposed strategy could benefit the overall operations and to what extent, by investigating both static and dynamic scheduling scenarios:

- Static: advance requests are generally scheduled the night before the day of operations. The new proposed strategies were implemented to test the difference of the static solutions.
- Dynamic: a portion of the demand may occur dynamically during the day of operations (according to the data currently in our possession, it is approximately 15-20% of the total demand).

This project had two stages. In the first stage, three new policies were proposed allowing providers to serve a given zone to pick up out-of-zone passengers that are in need of their return trip to this zone. Among these new polices, two base the customer assignment decisions on the relative distance between pick-up and drop-off locations. The research team developed new algorithms that incorporate the proposed strategies into the scheduling and developed simulation models that replicate the paratransit operations. The static and dynamic models were developed and validated using simulated schematic cases.

The second stage of the project evaluated the effects of implementing the proposed operation strategies using a simulation platform we developed and the real demand data we collected from Houston, Los Angeles, and Boston. Simulations were first performed assuming Manhattan distances and then using real network distances calculated with ArcGIS geocoding and network analyst software to carefully replicate real operations. Simulation results showed that, without sacrificing customers' level of service, the best policy can significantly reduce the inefficient empty trip miles by up to 23%. As a result, an agency can save up to 6.6% assigned vehicles, lower the total mileage by 9%, and improve the passenger trips per revenue hour by 7.8%, indicating a significant saving in operation cost and improvement in productivity while maintaining a reasonable level of service quality.

The implementation of our operation strategies will have these noticeable benefits:

- Maintain a zoning structure for easier overall management and better reliability (higher percentage of on-time performance), as already preferred by many agencies.
- Reduce the empty trip miles to lower operating costs.
- Improve the passenger trips per revenue hour, which is a productivity indicator frequently referred to by transit agencies.
- Allow cross-zonal customers to book both legs of their round-trip ride with the same provider, for an improved level of service.

The simulation model developed can serve as a powerful and effective platform to test and evaluate different paratransit operation policies.

# Apparatus for Gap Management Transit IDEA Project 74

Thomas O. Boucher
Rutgers University

## IDEA Concept and Product

The purpose of this project was to design, build, and test an apparatus that can provide safe passage for passengers over the gap between a high level platform and a commuter train. It applies to commuter trains that use a trap door to accommodate both high level platform and ground level traffic.The proposed apparatus will dynamically bridge the gap and provide three functions: (1) easy access for mobility-impaired passengers, (2) protection against slip and fall injuries for all passengers, and (3) automatic data logging of actual gap widths to alert maintenance personnel of track movement or other anomalies in accordance with the Federal Railroad Administration's (FRA) approach to managing gap safety.

The product replaces the existing trap door currently used aboard commuter trains by a new trapdoor of the same footprint, but with an integrated moving slide that automatically covers the gap when passengers are entering and exiting the train. The unit incorporates a motor drive that is compatible with the railcar power supply, contact sensors to ensure safe operation, and a magnetic pulse sensor mounted on a rotary actuator for measuring the length of the extension before contact with the platform, thus measuring the gap width. This innovation provides unique features that are not currently available on commuter trains. The current apparatus design can be used to retrofit existing railcars and the design concept can be integrated into the design of new vehicles.

## Completed Investigation

Several steps were taken to develop this IDEA product. A laboratory version of the apparatus was modified so that it could be installed on a railcar. With the collaboration of New Jersey Transit (NJ Transit), the modified laboratory unit was successfully demonstrated on an Arrow III railcar for deployment and retraction of the device. Testing was done at the NJ Transit Maintenance Yard in Kearny, New Jersey. Subsequently, the electronic controller of the laboratory version of the apparatus was redesigned such that it integrates the operation of the movable plate with the opening and closing of the railcar door.

The laboratory prototype served as a model for demonstrating proof of concept. The laboratory prototype construction was not optimal for a final design because it was narrower than desirable for wheelchair passage, was much heavier than the conventional trap door currently used aboard commuter trains, and the use of standard off-the-shelf components in its construction did not provide optimal strength and rigidity requirements. An improved unit of lighter weight, wider bridge area for a wheelchair, and more durable mechanical components that could be fabricated from metal parts was designed and built.

Figures 1 through 3 show the testing in the NJ Transit Maintenance facility of the apparatus built to the final design specifications. In Figure 1, the apparatus is in the retracted position as it would be before the railcar has entered a train station. When docked in a train station and

while the train door is still closed, the control system commands the bridge to extend until it reaches the platform or until it reaches its maximum extension (Figure 2). Sensors on the front of the bridge stop the forward movement if the platform is reached. If a passenger on the platform should place a body part between the platform and the extending bridge, the bridge will also cease forward movement. The device has been designed to be safe for use by the traveling public. Note that in Figure 2 that the train door is still closed until the bridge has completed its full extension. Finally, in Figure 3, the door is opened and passengers are allowed to traverse the gap over the bridge plate. After passenger traffic has ceased, the control system reverses the sequence, closing the door first and then retracting the bridge plate to the position shown in Figure 1. The apparatus is equipped with a sensor that can monitor forward movement of the bridge and measure the actual gap width between the train and the platform.

The project testing of the apparatus was done in the NJ Transit Maintenance Yard and in the Automation Laboratory of the Industrial & Systems Engineering Department at Rutgers University. Testing aboard the Arrow III train proved that the unit performs as designed in terms of fitting on the equipment and integrating the control of the unit with the opening and closing of the passenger doors. The unit is designed to handle loading of 800 lbs. with minimal deflection. It has undergone accelerated life testing in the Automation Laboratory at Rutgers University in order to test the motor and drive system as well as the consistent deployment and retraction

**Figure 1**

*Innovative trap door in retracted position.*

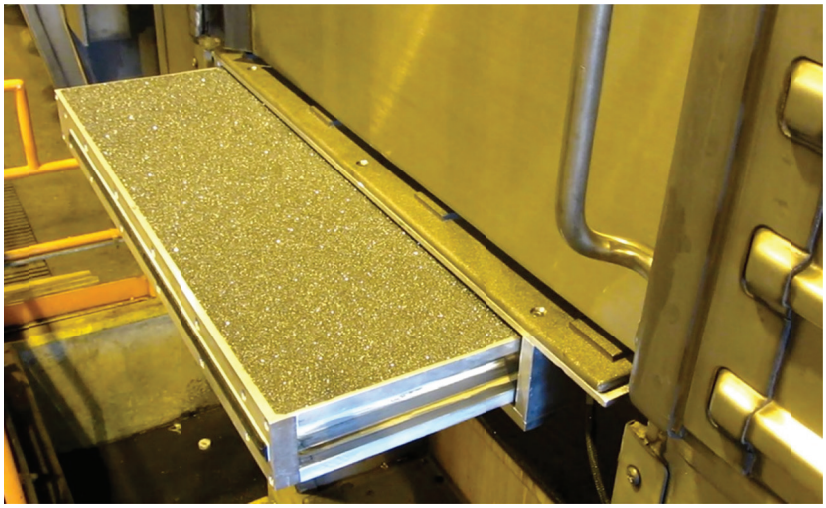


**Figure 2**

*Innovative trap door being deployed before passenger movement is allowed.*

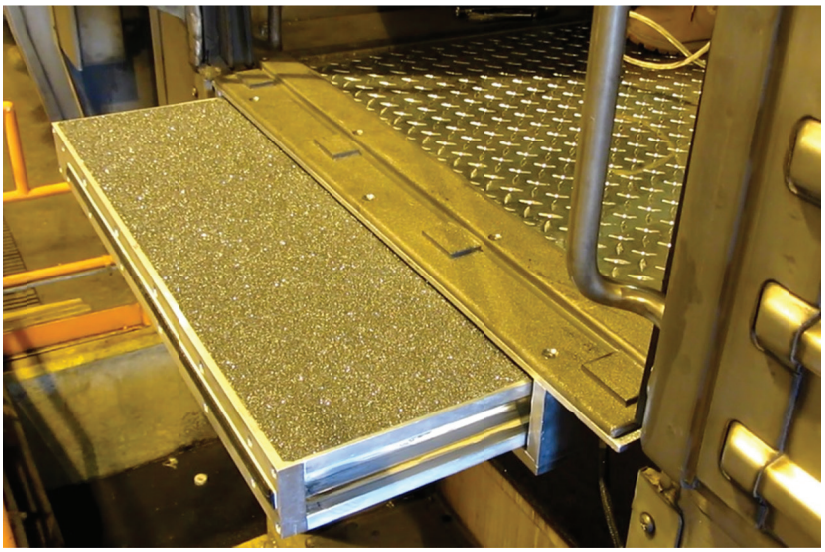


**Figure 3**

*Innovative trap door in deployed position with passenger movement allowed.*

of the bridge plate. Accelerated testing equivalent to two months of regular use on a train was done. During this testing there were no mechanical malfunctions of the unit or of the electronic control system. The testing demonstrated that this unit could perform effectively in actual use.

## Project Payoff Potential

The apparatus addresses the convenience and safety of travel to the public. In addition to providing safe passage across a potential hazard, it also makes it easier for any passenger moving baggage on wheels to exit and enter the train. Passengers commuting to and from work, and to and from airports, are often moving luggage on wheels. This apparatus will make it easier for them to move these items across train gaps. Gap-related injuries are also regularly reported, particularly for children and older adults. This apparatus should reduce these incidents considerably, if not entirely. Finally, the FRA's "approach to managing gap safety" recommends, for monitoring purposes, regular manual measurements of the gaps at each station. The apparatus has a built-in measurement sensor and can provide these data in real time, thus eliminating the cost of manual data collection.

## Product Transfer

The engineering of this product is now complete. Rutgers University has applied for a patent on this innovation and the patent application is published and available in the public domain. The next step in technology transfer is deployment of the current unit on a train in order to observe its actual use in place, and particularly to observe the reaction and behavior of the traveling public to it. The unit was purposefully designed such that it could be installed on a single door of a commuter railcar and operated under the supervision of a conductor. Field trials in which the traveling public is involved are an important next step in product transfer. In our opinion, it is important that a railcar equipment builder be involved with the transit agency so that lessons learned from field trials can be integrated into a commercial version of the product. Engineering drawings and other technical information is available for transfer to any vendor who enters an agreement to license the technology from Rutgers University.

# Transit Trip Planning Web Application
# Transit IDEA Project 75

Thomas Adler
Resource Systems Group, Inc.
White River Junction, VT

## IDEA Concept and Product

After years of decline, intercity bus service has increased by more than 50% over the past six years. There are now more than 100 intercity bus carriers providing that service in the U.S. However, there is no single place that travelers can go to determine which of these bus services best matches their travel needs, let alone how they compare with, or can connect with, AMTRAK rail services.

The overall purpose of this project is to provide the traveling public with door-to-door trip planning options for using public transportation modes for longer distance intercity travel integrated with local transit. The work builds on a prior project that was funded by the I-95 Corridor Coalition to build a proof-of-concept system for a region including Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, and New York. The project team developed a web-based system for that region that was very well-received and more than accomplished its original "proof-of-concept" objective. The goals of this Transit IDEA project were to (1) develop a fully scalable and flexible version of the system and (2) address the key institutional issue of how to cost-effectively assemble reliable schedule data that underlie this system.

The key accomplishments toward the project's two primary project goals included re-implementation of the system in fully scalable, cloud-based open source software. The algorithms were improved to support full schedule details and the interface was optimized to support mobile devices.

The resulting product is unique in several respects. First, it is the only existing intercity trip planner that provides detailed schedule information on all available passenger bus and rail services. The planner provides door-to-door travel information, including local transit connections where available. The trip planner uses a sophisticated algorithm to identify all "good" itineraries from the millions of possible alternatives that exist even in limited regions such as the Northeast U.S. And, the information is presented in a form that allows travelers to sort and filter their alternatives in ways similar to those used in air travel itinerary planners.

Currently, individuals who are planning to make an intercity rail or bus trip have only limited access to information about available services. They can access individual carriers' websites or printed schedules or they can use one of the online bus ticketing services that represent a small subset of the existing intercity bus carriers. However, the full set of available rail and bus options is quite large and diverse and very likely many "good" options are not identified by

potential bus or rail travelers. The trip planner developed in this project will provide a single point of access to the full array of available options for a given trip origin and destination. Making this information readily available will inform travelers about public transport options that they might otherwise not consider and remove a barrier that prevents some travelers from considering alternatives to driving a car for intercity trips. This will provide additional mobility and stimulate bus and rail ridership, improving the overall efficiency of intercity travel.

The trip planner software implementation is complete and there is a link to a partner's data that will provide access to continuously updated schedule data. RSG expects to complete the data work necessary to show national service coverage and to deploy a public-facing site in 2015.

The trip planner has already been used to support a study of the service provided by intercity buses on National Highway System airport connectors. In addition, RSG has been awarded two projects to develop schedule data to support bus ridership estimation for U.S.DOT/FHWA and for the Northeast Corridor Commission. These projects both include support for the development and updating of bus trip schedules to complement the Russell's Guide data. The Review Panel and others who were consulted as part of this work suggested that there is significant public interest in the provision of an integrated bus/rail trip planner. The project team will continue to pursue public funding for work related to the trip planner, but is concurrently developing private-sector interests in this product.

# RideScout
# Transit IDEA Project 76

RideScout
Austin, Texas

## IDEA Concept and Product

RideScout is a mobile application that aggregates information for travelers on all types of ground transportation ride options—public, private, and social—around a user in real time. The RideScout aggregation systems searches nearby buses, trains, subways, taxis, sedan services, bikeshare services, carsharing, and carpooling programs and displays the results on one simple interface. A social layer, with user-created groups, Google, Twitter, and Facebook integration, allows for group trip planning and ridesharing. A rider can sort his/her ride results by cost or time preferences, to compare options in real time. Users can book, pay, and rate the ride within the application. Finally, an integrated carbon footprint gamification feature will show users the environmental impact of their transportation decisions. This project will further develop, test, and launch the RideScout mobile application and evaluate usage results and patterns.

## Project Results

During Stage I of the IDEA project, RideScout completed the development of Version 1.1 of RideScout's mobile application. From the backend perspective, RideScout successfully learned how to best integrate different ride providers such as public transit options, taxi providers, and Car2Go. The UI (User Interface)/UX (User Experience) also experienced significant improvements based on usability testing results and customer feedback.

Over Stage II of the project, RideScout executed a successful launch in Austin, Texas. Traction with iPhone users and demand in Austin was proven as RideScout's cumulative downloads (6,000 downloads from March–November 2013), week-to-week downloads, and active users maintained positive growth trends. After traction was demonstrated with iPhone users and a successful Austin launch, the project developed an Android platform, as well as launching in Washington, D.C. The Washington, D.C., rollout was also a success, and proved that the application could successfully be replicated in additional cities. After the launch in Washington D.C., and Austin, RideScout had surpassed 25,000 cumulative downloads by March 2014.

## Product Payoff Potential

**1) Increased Transit Usage:**
RideScout will give smartphone users real-time information (where available, schedules otherwise) on transit options around them. When riders can access route, time, and cost information from a single application, the likelihood of finding and utilizing public transit alternatives may increase. What differentiates RideScout from other transit-focused applications is that it integrates multiple modes of transportation.

**2) Improved Operating Efficiencies:**
The RideScout application is being developed to capture information that may be valuable to transportation entities. From rides booked through the application, it will be possible to gain insight into volume and patterns of transportation usage, peak and off-peak traffic "hot spots," commuter habits, preferred modes of transportation, true origin and destination information, etc. This information can help inform a variety of transit entity decisions improve transit-operating efficiencies through more effective allocation of resources.

## Product Transfer

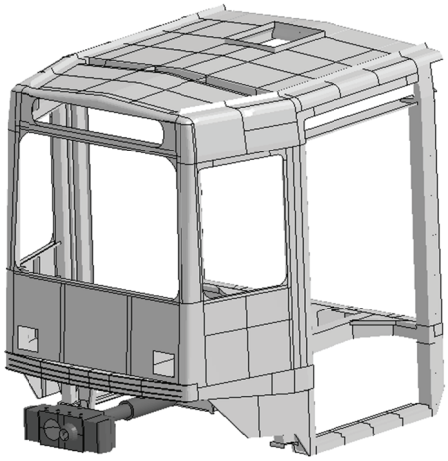
In April 2014, RideScout expanded into the San Francisco Bay area. Soon after, RideScout hosted launch events, press events, and social strategies to launch and gain users in Boston, Chicago, and New York, in addition to that already established the Austin and Washington, D.C. optimized markets. On July 9, RideScout then commenced a major update to the application by launching in 69 different major markets throughout the country in the "Summer of 69" campaign. RideScout integrated 300+ transit providers across the country by importing data from the General Transit Feed Specification (GTFS) exchange and utilizing data already available through partners. RideScout choose these 69 cities after performing an analysis on what options were currently available in each city through RideScout. Each city that had four or more unique transportation options became "live" during the launch of the "Summer of 69" campaign. This campaign allowed RideScout to bring together 337 transportation services, enabling 186 million people to search for rides, discover more options, and explore dozens of cities.

# Development of a Prototype Retrofit Bumper for Improved Light Rail Vehicle (LRV) Safety Transit IDEA Project 77

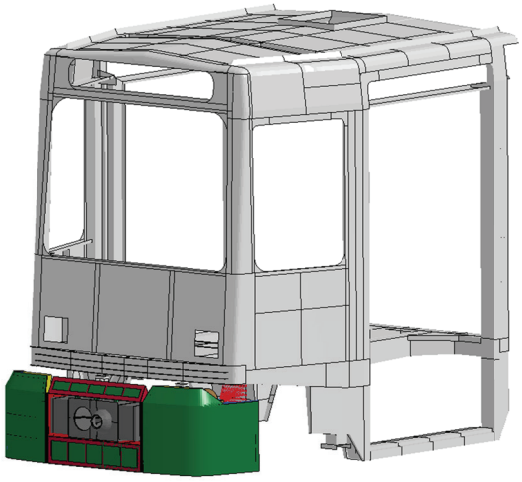
Steven Kirkpatrick and Robert MacNeill
Applied Research Associates
Southwest Division, Silicon Valley Office
Los Altos, California

## IDEA Concept and Product

The purpose of this program was to expand on previous research by adapting a conceptual light rail vehicle (LRV) retrofit bumper design onto a particular car. The work was performed by Applied Research Associates (ARA), in partnership with a car manufacturer, Siemens Industry (Siemens), and with the LRV operator Sacramento Regional Transit (RT), that is interested in implementing the system. Sacramento RT's CAF LRV was considered for the bumper retrofit under this program.

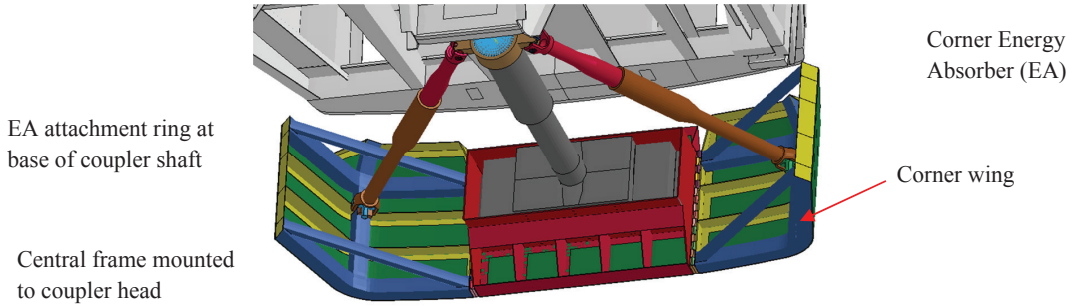


*Current configuration of LRV end structure with an exposed coupler and underframe.*



*LRV with adapted coupler-mounted crashworthy bumper design.*

In this project a novel coupler mounted, segmented bumper design with different energy-absorbing characteristics for frontal and corner impacts was developed. The segmented bumper is designed to actuate at much lower forces in corner collisions with automobiles. The bumper design also includes an improved geometric profile, making the front end less aggressive to automobiles and pedestrians. The retrofit bumper concept addressed by this project incorporates ASME RT-1 safety standard compliant LRV end design features, with respect to the protection of street vehicles. The bumper design includes a full-width, smooth end enclosure with low ground clearance and is designed for optimized crash compatibility with road vehicles. By improving the collision compatibility, the bumper also reduces the LRV derailment potential in these impacts. The ability to retrofit the bumper onto existing LRV designs is also a key innovative feature of the bumper system.




*Bumper structure and coupler integration (view from below looking forward).*

## Completed Investigation

This program involved several steps to advance the LRV bumper development. The bumper concept was adapted to the CAF LRV geometry. Detailed finite element models were developed and crashworthiness analyses were performed to evaluate the system's effectiveness at reducing struck vehicle occupant injuries. The analysis indicates remarkable injury reduction potential with the bumper system. For example, the probability of serious injury was reduced by 66% with the bumper. An overall improvement in serious pelvic injury probability of 25% was demonstrated. Average serious thoracic trauma probability was dramatically reduced by 91%. Research plans for ongoing development including prototype bumper construction, testing, and implementation were also generated.

## Project Payoff Potential

The purpose of the bumper system is to improve LRV crash safety and safety improvements that directly translate to cost savings through reduced injury liability for LRV operators and municipalities. Further cost reductions would be realized from shorter disruptions in service and reduced LRV vehicle repair costs. Looking at past data, improving the RT fleet with this technology would result in annual savings of approximately $2 to 3 million, most of which would be from reduced litigation and liability costs. The safety improvements to LRV systems will also improve public perceptions of the transit operations. Increased overall safety will reduce incidents and associated damaging media coverage, which would improve public relations for transportation agencies.

## Product Transfer

The bumper design was developed as a retrofit for the currently in-service Sacramento RT CAF car. The project is a collaborative effort, with ARA and Siemens performing the design and analysis work and Sacramento RT providing system and vehicle access for design and testing, as well as helping to define system requirements. Sacramento RT is interested in the implementation of these bumpers into its system for improved safety. With some additional effort, the bumper retrofit could also be adapted to its similarly configured Siemens cars. In its current configuration, all RT LRVs have an open underframe front end, which would greatly benefit from this bumper system.

After demonstrating the performance of the LRV bumper system through implementation on the RT CAF cars, the larger goal is to spread the technology to other LRV fleets through retrofit and incorporation onto future LRV designs. There are more than 1,000 LRV cars in North America that share right-of-way with other road traffic that could all benefit from this technology. The long-term goal is to pursue these and other markets worldwide.

# Rail Neutral Temperature Monitoring for Rail Transit Transit IDEA Project 78

Peter Bartek
Protran Technology, Newton, New Jersey

## IDEA Concept and Product

Thermal loads develop in rail due to daily heat/cooling cycles. Extreme fluctuations in rail temperature can cause buckling and breaks and lead to derailments if undetected.

Current outdated procedures for many transit agencies is to implement speed restrictions once the ambient temperature reaches a certain level (which varies depending on geography). Speed restrictions slow trains down, which causes delays and reduction in on-time performance.

This Transit IDEA project has developed and tested a network of remote sensors installed on the web of continuous welded rail to monitor and log the stresses of the rail to detect the daily heat/cooling cycles and detect rail buckling and breaking before they occur.

Two main components that make up the system: a sensor unit, and a collector unit. The sensor unit continuously monitors rail temperature, rail neutral temperature (RNT), and rail forces for hazardous rail conditions. When detected, rail failures trigger an alert system that sends an emergency text and/or e-mail. The information collected also populates a database that offers a simple web-accessible user interface that can be used for data analysis and presentation. Each collector unit can receive data from up to 13 individual sensor units and transmit the data to the web-accessible database.

## Completed Investigation

This project included development and prototype testing. Key elements of the investigation found the most reliable technologies available and incorporated them into the system.

Testing was done at two main types of track that included curves and track abutments.

## Product Payoff Potential

In these times of dwindling resources, the system can be used to prioritize maintenance and establish the performance trends of different track structures

The system developed under this Transit IDEA project offers four principal functions: (1) continuous monitoring for broken or buckled rail, (2) advance emergency notification to the railroad including train operator, (3) web-accessible GIS user interface, and (4) assistance in rail de-stressing operations.

**Figure 1**

*Sensor unit installed on the web of continuous welded rail.*


**Figure 2**

*Emergency notification to train operator of broken rail ahead in real time.*

## Project Results

The development and prototype testing of the sensor unit and a collector unit was done at Maryland Transit Administration. The prototype tests demonstrated that the devices monitor and log the stresses of the rail and the daily heat/cooling cycles. The system was able to detect rail buckling and breaking before they occurred and effectively sent in real time an advance emergency notification to the railroad, including train operator.

## Product Transfer

Following this project, the Washington Metropolitan Area Transit Authority has purchased the system developed in this project for subsequent pilot testing and evaluation under their operating conditions on their transit facilities.

# Implementation of Smart Card AFC Standards for Small Transit Agencies
# Transit IDEA Project 79

Walter E. Allen, President & CEO
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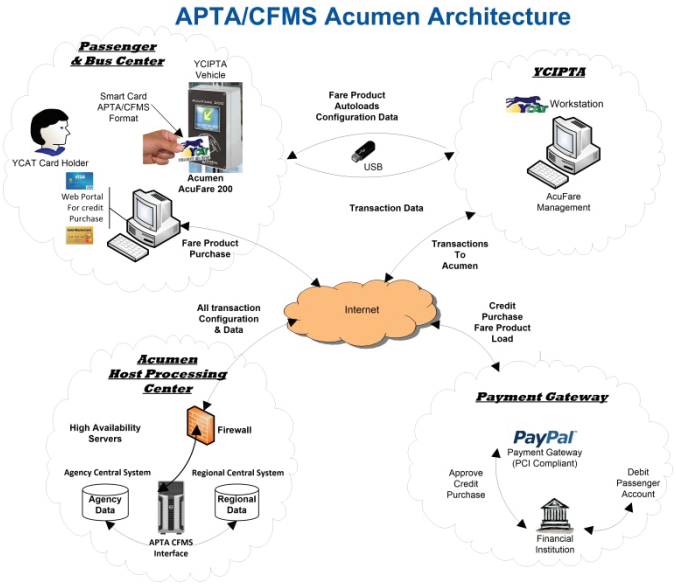
## IDEA Concept and Product

While many of the nation's large transit agencies have adopted electronic automatic fare collection (AFC) and smart card systems, small and rural agencies remain tied to obsolete manual, cash-based fare collection. Implementation of smart card AFC technology in small and rural transit agencies offers the promise of increased passenger convenience, added passenger satisfaction, and improved agency efficiency. For agencies, it improves passenger flow and bus stop data. However, small agencies cannot afford expensive proprietary smart card solutions typically offered by the major system suppliers. Deployment of the APTA Contactless Fare Media System (CFMS) Standard eliminates the proprietary solution, ultimately lowering the cost of implementation. Acumen chose the Yuma County Intergovernmental Public Transportation Authority (YCIPTA) existing proprietary YCAT smart card system to implement CFMS. YCIPTA operates 18 buses on 11 fixed routes throughout southwestern Yuma County cities, Indian reservations, and California's Imperial County. In addition to converting to the CFMS format, Acumen implemented the added benefit for passengers to purchase and load fare products using an Internet credit card payment processor. The project culminated in a 90-day pilot operation successfully demonstrating the feasibility and operability of the APTA CFMS at a small agency.

## Completed Investigation

Implementation of the APTA CFMS required restructuring the YCAT smart card data to the CFMS data structure. Since the YCIPTA system is in operation and will remain so after the project, the smart cards with the CFMS format co-existed with the existing cards during and after the project. The transition from the existing proprietary smart card data format to the new CFMS smart card data format was transparent to the YCAT cardholders. On passenger use, the card data structure was seamless to the passenger and to YCIPTA. The new data structure includes all data fields required by the CFMS and necessary for the YCAT existing operation and business rules. Both existing cards and readers were modified.

Acumen also implemented the APTA CFMS Regional Central System (RCS) and Agency Central System (ACS) to comply fully with the standard. Since a "region" does not really exist for YCIPTA, Acumen combined the ACS functions and the RCS functions into the single host computer system. Prior to the 90-day pilot operation, Acumen and YCIPTA transferred the smart card processing from the YCIPTA computer to the Acumen data center. During pilot operation, Acumen operated the system, gathered data, and hosted the website to the credit card payment gateway. YCIPTA had complete access to smart card and passenger flow data through the Acumen data center. Upon completion of the Project, YCIPTA may choose to retain the new system features.




*Acumen Architecture for YCIPTA*

## Project Payoff Potential

There are more than 1,300 small and rural agencies in the United States. Acumen is evaluating additional agency candidates that can benefit from the CFMS smart card system. The features implemented at YCIPTA can be implemented at other small and rural agencies. Frequently, payment card systems require extensive security procedures for implementation. The project demonstrated online fare product purchases at a low operating cost and without complex security requirements.

Acumen is currently working to list the system modules on a General Services Administration schedule, so that small agencies can select the units desired at the lowest manufacturer's price.

## Product Transfer

As with any undertaking there are lessons learned, both positive and negative, that can be applied to improve the implementation efficiency and the results for a similar undertaking. These and other lessons are documented in the final TRB report:

- Some passengers lack credit cards
- Some passengers are averse to technology
- Conflicting standards
- Inefficient XML data communications
- Lack of passenger awareness
- Underestimated technical challenges
- Unneeded standard features
- Dual data structure challenges
- Large data structure timing
- Missing data features

The project demonstrated the viability of the CFMS on a small agency. However, small agencies have limited technical resources and are most focused on operation rather than maintenance or the training of passengers on system features and usage.

For payment credit cards, the project demonstrated the ability to purchase fare value, rides, and passes with credit cards on the Internet at a reasonable cost without highly complex security requirements.

The original Acumen system design employed a wired data retrieval system from the card readers via a USB thumb drive. During this project, it became evident that the method is a less desirable alternative and should be replaced with a wireless method. Acumen already has conceptualized a wireless option enhancement. This feature will be offered to future agencies using the Acumen system.

Acumen documented CFMS inefficiencies, inconsistencies, limitations, and features unnecessary for small agencies. If requested, Acumen can assist APTA in the resolution of these items. Among these items are the inefficient XML data communications format, requirement for a Regional Computer system, inconsistencies among CFMS Parts II and III and completion of CFMS Part IV for security. With regard to security, Acumen has chosen to review the OSPT Alliance CiPurse specification that is proposed for adoption by APTA for card security. The CiPurse is promoted as a security standard that is highly flexible for both smart cards and mobile devices in AFC systems. If the CiPurse meets its functionality promises, Acumen may consider its usage for future implementation.

# Enhancing Safety and Security of Transit Systems Using Computer Vision
# Transit IDEA Project 80

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## IDEA Concept and Product

Detecting distraction and fatigue in drivers of mass transportation and commercial vehicles is important for preventing accidents and improving their driving performance. To this day there is no available fatigue monitoring system that is reliable, easy to use, and inexpensive. The Rutgers team has recently developed a novel computer vision-based technology based on a single camera and an off-the-shelf computer that uses deformable model technology to track the geometry of any person's face and his/her expressions, and measure slow eyelid closure (PERCLOS), which is directly related to fatigue. The system is nonintrusive and can work with both visible and infrared light regardless of the driver's vehicle background (which changes over time during driving due to lighting and other factors). What makes our system reliable is that its tracks the whole face, including large variations of the facial pose and can reliably detect the eyes and the eyelids. Our system is also potentially cost-effective since it is based on an off-the-shelf computer and a single camera. The technology success motives us to develop a real-time driver's behavior monitoring system to enhance the safety and security of driving in commercial vehicles.

## Project Results (or Planned Investigation)

This project provides automobile drivers the ability to detect distractions and fatigue during driving in order to prevent accidents. The system is based on a single camera aimed at the driver's face and provides a warning signal when the driver is distracted or fatigued. The Rutgers team has developed the system and tested the method and has advanced it to a prototype for use on vehicles and future commercialization. The testing took place on buses at Southern Pennsylvania Transportation Authority (SEPTA) and on a bus simulator at MTA (NYC). Rutgers team conducted the research and development in order to achieve the goals listed below:

1. Develop a prototype of driver facial monitoring system via porting the software onto a portable processor to create a hardware system.
2. Perform initial prototype testing using existing or acquired videos to test the accuracy of the tracking ability of the prototype with a variety of facial features, including glasses, different skin tones, facial hair; with different levels of illumination; and with various degrees of facial movement.
3. Conduct public beta testing of prototype on buses at SEPTA and MTA to evaluate the accuracy in terms of: (a) validity—that the system accurately measures what it is supposed to measure, and (b) sensitivity—that the system picks up distraction and fatigue with minimal false positives and negatives.

All the above goals were achieved.

## Product Payoff Potential

The Rutgers team assessed the ability of the drivers to use the system and the cost of implementation. Generally, use of the driver monitoring system has the potential to contribute to safer commercial vehicles, safer highways and improved transport of cargo. The system has the ability to recognize fatigue and distracted driving, resulting in a safer driving by automatically alerting the driver. It can also be used in other very important applications such as drunk driver detection, and driver recognition since it tracks the whole face and it is easy to spot abnormal facial behavior and identity in a personalized way. Regarding of the cost of the product, the driver monitoring system is based on an off-the-shelf single camera and computer; it is very easy to deploy; and is economically and easy to commercially install on vehicles, if mass-produced.

## Product Transfer

The results of the pilot investigation conducted by the Rutgers team has open the way for future development of the driving monitoring system and the creation of a commercial product capable of detecting distraction, fatigue and driver identity, coupled with GPS, other vehicle data, and other vehicle cameras. The Rutgers team future goal is to actively pursue several avenues such as market and integrated in vehicle products to ensure the use and commercial success of the fatigue/distraction system that will result in safer highways and reduction in accidents and loss of lives.

# Advanced Locomotive Exhaust Gas Simulator to Fine-Tune Energy Recovery and Conversion Systems Transit IDEA Project 81

Dr. Claudio Filippine
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## IDEA Concept and Product

Internal combustion engines typically convert one-third of fuel potential into useful power (i.e., propulsion), while the remaining two-thirds is lost as heat energy rejected to the environment. ThermaDynamics Rail (TDR) harnesses wasted heat energy from internal combustion engines and converts it into conditioned power in the form of electric or mechanical energy. TDR's technology is based on the conversion of "heat-to-power" through optimized thermodynamic power cycles. Accordingly, a working fluid (e.g., water or an organic fluid) is pressurized and flows through a High-Pressure Heat Exchanger (HiPHEX) that is positioned in the exhaust gas piping system of the internal combustion engine. The HiPHEXs are scalable, non-invasive heat exchangers designed to reliably operate when exposed to streams of high-temperature exhaust gases. Exhaust gases transfer thermal energy to the working fluid, which becomes superheated prior to expanding through a turbine coupled to an electric generator. Finally, a power conversion unit regulates the electricity produced by the thermodynamic power cycle for distribution to various electrical loads, thereby providing pollutant-free augmented propulsion (mechanical) power or electric power while reducing fuel consumption and pollutant emissions.

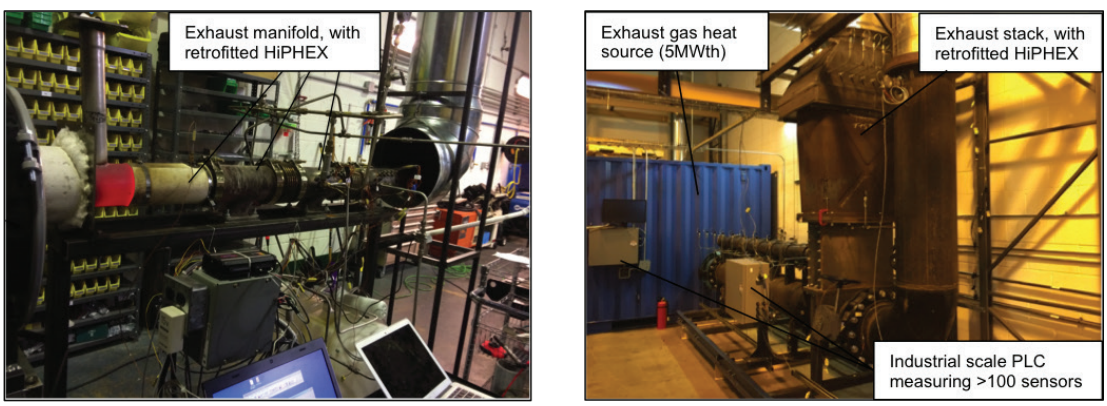
## Completed Investigation

The investigation conducted under Transit IDEA Project 81 expands on the findings obtained in the technical and economic performance analysis of a waste heat-to-power system, applied to internal combustion engines equipping locomotives, executed under Transit IDEA Project 67. The analysis conducted under Transit IDEA Project 67 showed that capturing and converting locomotive engine waste heat into useful energy results in up to 17.5% in fuel savings. In addition to the economic benefits represented by heat-to-power systems, pollutant and greenhouse gases (GHG) emissions are proportionally reduced while lowering thermal pollution. Transit IDEA Project 67 focused on preliminary testing of TDR technologies and opened the way to technology optimization activities aimed at increasing the amount of energy recovered through the non-invasive retrofit of locomotive engines. To further validate and optimize TDR heat-to-power technologies, Transit IDEA Project 81 was dedicated to the customization of an advanced locomotive exhaust gas simulator to enable low-cost prolonged testing of locomotive-scale waste heat recovery components.

Stage I tasks included the design, assembly, and testing of an Expanded Combustion Chamber utilized to support full-scale HiPHEXs testing through the locomotive-scale simulator. This Stage also included tasks dedicated to the optimization of thermodynamic codes to estimate waste heat recovery performance under various locomotive engine duty cycles.

Stage II included the customization and testing of a locomotive-scale simulator to produce exhaust gases equivalent to those generated by locomotives at all power settings. The locomotive simulator allowed full-scale testing of the HiPHEX as if they were retrofitted with actual locomotive engines. This Stage was also dedicated to the optimization of the HiPHEXs configured for locomotive stack retrofitting to maximize power output while complying with "zero-invasiveness" requirements.

Stage II test results showed that large portions of thermal energy (heat) from the exhaust gases can be recovered with negligible effects on the performance of the locomotive's engine, and confirmed that a waste heat recovery system optimized for locomotive retrofitting can reliably reduce fuel consumption, pollutants, GHG, particulate matter (PM) emissions. and thermal pollution.




*(Left) Expanded combustion chamber fitted to locomotive exhaust manifold for HiPHEX optimization. (Right) Locomotive scale (MW) exhaust gas simulator for testing and optimization of TDR waste heat-to-power technologies.*

## Product Payoff Potential

TDR technologies convert waste thermal energy into zero-emission conditioned electricity to support different applications via non-invasive and reversible retrofitting. In the locomotive industry, TDR technologies represent a cost-effective alternative to locomotive replacement by providing a reliable solution for the reduction of pollutant and GHG emissions at an OEM level, while reducing fuel consumption and operational expenses. Through TDR products, railroad companies can retrofit locomotive fleets or integrate the technology on new locomotives and obtain:

- Lower fuel consumption costs. Project results showed annual fuel savings per locomotive of $84k at 2016 averaged diesel fuel price and $142k at 2014 averaged diesel fuel price.
- Lower pollutant, GHG, and PM emissions, thus meeting increasingly stringent EPA requirements for new and old locomotives.
- Lower thermal pollution as the exhaust gases are cooled down prior to venting to atmosphere.
- Enable continued usage of aging locomotive fleets for which railroad companies have well-established locomotive shops and supply chain.

## Product Transfer

The customized locomotive exhaust gas simulator enables accurate testing and optimization of locomotive-scale, specially customized, waste heat-to-power components designed to non-invasively retrofit locomotive engines. Upon successful completion of testing, TDR plans to enter into production and commercialization of waste heat recovery technologies. In addition to funding for Transit IDEA Project 81 through the National Academy of Sciences, TDR was awarded grants from the Federal Railroad Administration (FRA), and secured funding from private investors. In parallel with testing and optimization activities, TDR developed business and technical relationships with the Transportation Technology Center, Inc. (TTCI), executed testing and failure mode safety analyses, and cooperated with Class I railroad companies to validate waste heat recovery components on operational locomotives. All of these activities support TDR transition of waste heat recovery technologies into products to reduce pollutants, GHG, and PM emissions, while decreasing locomotive operational costs and thermal pollution.

# Active Safety-Collision Warning Pilot in Washington State Transit IDEA Project 82

Jerry Spears
Washington State Transit Insurance Pool, Olympia, WA

## IDEA Concept and Product

The Washington State Transit Insurance Pool (WSTIP) provides risk management services to 25 public transportation providers in the state of Washington. It has been monitoring transit industry claims for 28 years, insures 5,000 vehicles, and handles about 1,000 claims per year. WSTIP is acutely aware of the magnitude of the problem of bus collisions and the ensuing losses they create. The IDEA grant and insurance company contributions funded this project to install Rosco Mobileye Shield+ collision avoidance warning systems (CAWS) on 35 buses at seven WSTIP member agencies and three additional buses at King County Metro in Seattle. The project included a comprehensive examination of the total costs of the most severe and costly types of collisions, frontal collisions and collisions with pedestrians and cyclists, the potential for collision avoidance technology to reduce the frequency and severity of these types of collisions, and reduce the associated casualty and liability expenses.

## Completed Investigation

A three-month data collection and reporting period was run from April 1, 2016 through June 30, 2016. During that period, WSTIP and KC Metro Transit buses equipped with CAWS logged 352,129 miles and 23,798 operating hours. Video recording captured approximately 10,000 events spanning 16,600 hours and required 19 terabytes (Tb) of storage.

The team analyzed 13 years of claims data provided by WSTIP and developed an analysis framework to classify claims according to the magnitude of loss and the relevant explanatory factors. Of a total $53.1 million in claims for fixed-route buses, $18.3 million (35%) were attributable to preventable vehicular collisions, and $16.0 million (30%) were attributable to preventable pedestrian/bicyclist collisions. These numbers established an upper bound for the potential cost savings.

The most significant measure of acceptance of CAWS by the transit industry is expected to be the degree to which CAWS will reduce collisions and claims. We were able to run a controlled experiment to estimate potential reductions in collisions and claims. CAWS on Spokane Transit buses were set up to collect and transmit data via telematics only and did not issue warnings to drivers. This was called operating in "stealth mode." Buses operating with systems in stealth mode served as a baseline, or control group, to help determine if CAWS resulted in changes in driver performance over time. It was hypothesized that as drivers gain experience with the Shield+ equipped buses, they may be better able to anticipate adverse driving conditions, which would be reflected in fewer events per miles logged.


**Figure 1**

*CAWS installation underway at C-TRAN in Vancouver,Washington, on one of 38 pilot buses.*

**Figure 2**

*Pedestrian collision warning indicator on center of windshield illuminates during test.*

## Product Payoff Potential

For each warning type, there were fewer warnings per 1000 miles for the active fleet compared with the control group. Although data was not linked to individual drivers, it appears that drivers of buses in the active fleet triggered fewer warnings than those who drove buses in "stealth mode." Buses with active CAWS experienced 71.55% fewer forward collision warnings per 1000 miles and 43.32% fewer pedestrian collision warnings per 1000 miles. These rates were applied to the historic costs for claims described above. The net result was an estimated reduction in vehicular claims of $13.1 million and a reduction in pedestrian claims of $6.9 million. The total reduction of $20.0 million amounted to an estimated 58.5% potential reduction in claims due to collisions for all buses insured by WSTIP.

The upper and lower bounds for annual claims reduction per bus were estimated at $2,514 and $1,471 respectively for an annual average of 1,058 buses insured by WSTIP. Annual benefits were estimated by subtracting the cost of the CAWS (estimated at $7,375) from the claims reductions for service periods ranging from 5 to 14 years. Upper bound annual net benefits from collision claims reduction for all WSTIP members were estimated to start at $1,099,262 in Year 5 and increase to $2,102,473 in Year 14. For the lower bound, benefits were estimated to be negative by $4,232 in Year 5, but become positive in Year 6 and increase to $998,979 by Year 14.

## Product Transfer

Early findings from this pilot led one of the study participants, Pierce Transit, to obtain a $1.66 million research and development grant from the Federal Transit Administration (FTA) to equip all 176 of its 40-foot transit buses with CAWS and to run extended testing and data collection. Starting in 2018, Pierce plans to conduct a full-year of testing, data collection, analysis, and evaluation during an estimated 4.4 million miles of revenue service. Pierce Transit also will test using the CAWS to trigger autonomous emergency braking (AEB).

# Track Circuit Monitoring Tool Standardization and Deployment at Chicago Transit Authority Transit IDEA Project 83

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## IDEA Concept and Product

In 2014 the American Public Transportation Association (APTA) initiated a program to evaluate and develop a software-based Audio Frequency Track Circuit maintenance tool for the purpose of developing an industry wide APTA recommended practice. This program was linked to an NTSB recommendation and is intended to provide a guideline to a commonly accepted industry approach for a Secondary Train Monitoring System with the capability to identify and alert abnormal operation of track circuits. The Track Circuit Monitoring system (TCM) serves as a non-vital track circuit integrity monitoring system to alert and announce potential safety critical failure conditions of track circuits as well as serving as an important maintenance support tool and early warning system for equipment degradation.

The TCM tool—if included in daily maintenance planning—increases the reliability of track circuits by continuously monitoring and evaluating occupancy indications for integrity and plausibility and is qualifying its condition as normal, irregular, failure, or potentially critical condition. It provides appropriate alerts and notifications for follow on actions to inspect and maintain track circuits to a state of good repair.

The purpose of this program is to enable the TCM tool to become a standardized and independent subsystem and to provide proof of concept by deploying it at the Chicago Blue Line (Forrest Park to O'Hare Airport) for the Chicago Transit Authority. The success of this project will substantiate the value it can provide to the operations and maintenance department of transit agencies and to demonstrate the potential for improved systems oversight that enhances safety and reliability in vital applications of train detection systems.

The TCM tool helps in identifying and communicating the risk for track circuit failure. It alerts operations, maintenance, and engineering organizations to a potential threat in the shortest possible time.

## Project Results

In most cases the TCM system will be operating in online mode (24/7) as an extension to the agency's existing central control system (CCS). TCM processes the same (raw) field information that the CCS does, however, using a unique algorithm. In this online operating mode, the TCM tool provides real-time alerts for track circuits showing abnormal behavior.

It has been found that applying TCM in stages provides multiple benefits —beginning at allowing the agencies the opportunity to customize the tool to the agency's specific needs, followed by working out inconsistencies and errors in the agency's track network database, as well as to realize an early benefit by identifying misbehaving track circuits in offline mode based on

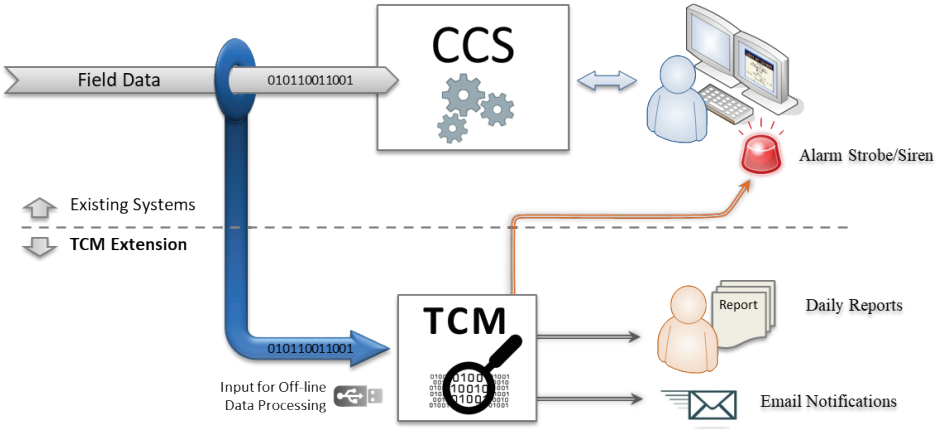


**Figure 1**

*TCM integration approach.*

historical data. This initial off-line operating mode does not require a live-link to an existing CCS (illustrated in Figure 1 by the blue data link) but would instead only requires off-line data import via e.g., a USB-Drive.

Gaining these early benefits of TCM can be accomplished by the following 3-stage integration approach:

Stage 1: Tool parameterization and track network database development. This stage allows for initial offline Track Circuit event data analysis and provides already valuable information to wayside signaling staff.

Stage 2: Continued data vetting and train/vehicle performance parameter entries for enhanced TCM integrity evaluation.

Stage 3: Final configuration and integration into existing infrastructure for online operation based on live data processing and integrity evaluation including real-time alert functionality if a safety critical condition has been identified.

The implementation and deployment of TCM at CTA has been completed and operates since July 2017 in Stage 3 online mode with 24/7 live data exchange between CTA's existing CCS (QuicTrak) and TCM.

## Product Payoff Potential

The use of track circuits in the transit and railroad industry remains wide spread. The TCM Tool offers innovative algorithms and concepts to uncover critical problems in train occupancy detection and initiate adequate announcements (i.e. notification, warnings, alarms) as well as initiate inspection, equipment failure diagnostics, timely maintenance, and improved maintenance management.

TCM offers valuable information for signal system maintenance and operations managers alike. For maintenance managers, it provides an insight into track circuit related reoccurring operations reliability problems as well as potentially serious problems, thereby assisting in prioritizing of actions related to track circuit incidents. This capability is a significant improvement over existing conventional methods for determining the effective use of limited maintenances resources.

For the operations department it provides the ability to quickly and efficiently identify and evaluate track circuit locations where potentially serious anomalies may be happening, thus resulting in timely response before potentially critical conditions can impact revenue service. These features are major assets for a Transit organization, striving to continuously improving their commitment to safe revenue operation.

Benefits of the TCM Tool include:

- Improved timely reaction to potentially safety critical conditions and serious incidents
- Daily reports on irregularities and anomalies
- Maintenance prioritization for faster response to reoccurring problems
- Early detection of track circuit malfunction or deterioration
- Improved asset reliability and subsequently more reliable service
- Extended useful lifetime of assets

Besides the performance and integrity monitoring of track circuits the TCM Tool is able to provide indications for circuits that were out of tolerance, with loose or broken terminations, or otherwise in need of adjustment and/or repair. TCM has proven to be a valuable tool in identifying the following problem areas:

- Parasitic oscillation
- Circuits out of adjustment
- Corrugated rail
- Damaged bonds
- Broken rail clamps
- Loose connectors
- Short circuits protected by loss of shunt (LOS) timer
- Traction power imbalance
- Dissimilar rail
- Rusty rail or autumn leaves

Figure 2 illustrates the trend in alarm occurrences after implementation of the TCM tool. Improvements—i.e., reduction in alarms—directly related to improvement in maintenance actions and subsequently, resulting in increased reliability of equipment and passenger service. The number of alarm events continuously fell from a high of almost 300 per day to about 10 per day over the period July 2010 to July 2011.

## Product Transfer

Transit agencies are the target audience and the TCM tool is gaining visibility by participation of the TCM team in transit industry forums such as APTA Recommended Practice Meetings, Signaling Standards Meetings, APTA Annual Rail Conferences, APTA Webinars, and transit

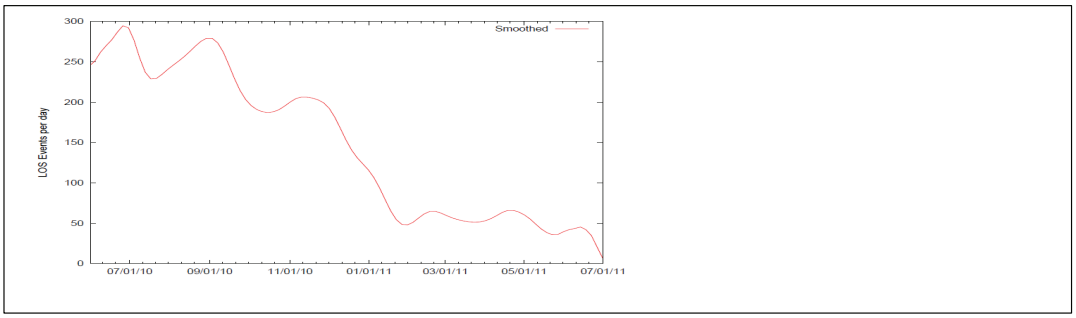


**Figure 2**

*Trends in alarm occurrence.*

industry conventions and exhibitions. These forums allow for creating awareness of LOS and false track circuit occupancies (FTO) risks and enable discussions about identification and mitigation approaches to this matter. Recent meetings have led to discussions with BART for considering a TCM deployment at BART's new CBTC designs as secondary train movement monitoring system. Other transit agencies included in these forums are MARTA, MBTA,LAMTA, SORTA, SEPTA, CTA/METRA, Miami Dade, TU, TriMET, NCTD, SCRRA, and others.

The long-term goal is to institutionalize a "continued improvement and feedback loop" for the benefit of all participating agencies, providing the option to upgrade previous installations with new functionality and features. For this purpose, a website is being developed that provides TCM relevant information and articles such as TCM concepts and systems requirements, software download sites, systems references, FAQ, etc.

As part of this, it is the goal to create a self-sustaining environment for TCM tool know-how, allowing for continued tool improvements, best practice advise for tool implementation, tool support (now and in the future). To this end, an initial TCM User Group has been created which is expected to further evolve, consisting of experts in software and wayside signaling technologies. User Group members stem from involved transit agencies (WMATA, CTA, MARTA), Rail IT, and APTA.

# Development of a Mass-Based Automated Passenger Counter
# Transit IDEA Project 84

Will Northrop
University of Minnesota, Minneapolis

## IDEA Concept and Product

The goal of this project was to develop and refine a low-cost automated passenger counter (APC) technology with improved accuracy and lower cost than currently available systems. The concept was to use data collected from pressure sensors connected to the vehicle air suspension system and advanced algorithms to determine changes in vehicle mass during stops that correlate to passenger boarding and alighting events.

## Project Results

This project developed an inexpensive passenger counting system that allowed simple integration with existing vehicle information systems. The APC relates bus mass to pressure in the air spring suspension system and then correlates passenger boarding and alighting. A microcontroller installed on the bus conducted calculations that the stop event. A feed-forward neural network and convolutional neural network algorithm were used to analyze the shape of the signal and predict boarding and alighting at each stop. Built completely using commercially available, open-source software and hardware, this new system was cost-effective, easy to set up, and could be integrated into existing transit agency databases.

During the project, the system was installed on four in-use transit buses around the Twin Cities Metro area. The machine learning algorithms had 91% accuracy for training data sets. However, testing with the trained algorithms showed that the mass-based APC was 61% and 38% accurate in recording boarding and alighting events, respectively. An illustration of the passenger count for this route is given in Figure 1. Although the algorithms had poor accuracy for alighting events specifically, the system was able to accurately estimate the mass of the bus at each stop. As the project progressed, new, vision-based APC systems were brought to the market by other manufacturers. Based on the testing data collected in this project, the developed APC could not compete with the accuracy obtained by these new systems. Future work will look to use the mass-based system to augment existing infrared-based systems to improve their accuracy to new passenger counting standards.

In an extension of this IDEA project, the University of Minnesota team used bus instantaneous mass recorded by the developed system to estimate the effect of passenger loading on fuel economy and bus energy consumption. A simulation study was done by using multiple days of second-by-second bus mass and speed with hybrid and conventional buses to show the effects of passenger loading on the fuel consumption of each technology. The results showed that fuel consumption in hybrid buses is less affected by passenger mass since the additional mass increases the available energy from regenerative braking. Future work in this extended research area will look to better predict the driving range of all-electric transit buses by measuring instantaneous bus mass.

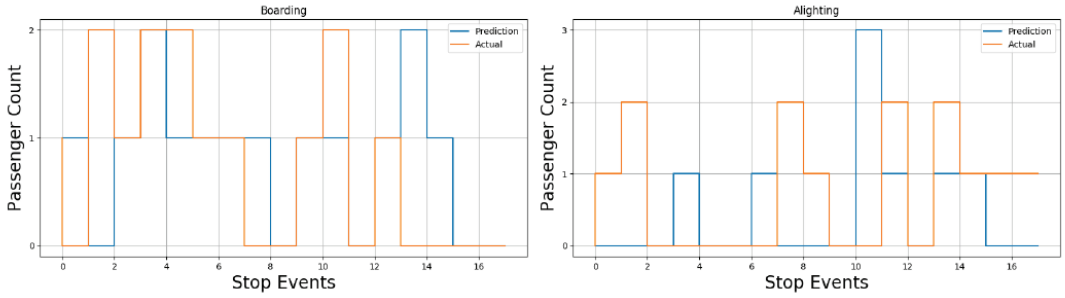


**Figure 1**

*Boarding and alighting predictions during testing of the mass-based automated passenger counting system on 1 day on one route.*

## Product Payoff Potential

Transit authorities use APC data to collect data for service and operations planning and for reporting to the National Transit Database. Transit authorities are highly motivated to accurately measure passenger count from at least 10% of their fleets at the lowest possible cost. In a recent survey, median capital cost of available APC systems was $6,638 among the 26 agencies responding. In 2011, there were 66,506 buses available for peak service within the United States. If the bus fleet were to be turned over every 12 years, an APC cost savings per unit of $1,000 would save roughly $5.5 million per year, assuming all buses are equipped with an APC. The mass-based APC system is targeted to have an installed cost of less than half of existing systems, as the hardware required is much less expensive. Further benefits of the mass-based APC system include providing additional data to transit authorities like overall vehicle mass for bus route allocation optimization based on fuel economy and distribution of passengers on the bus for deciding how to configure future buses added to the fleet.

In an alternative use case, the mass-based sensing system could be used within an energy management system (EMS) of fully electrified transit buses. Uncertain electric range of battery electric buses is one factor restricting their greater market presence. Based on the results of the modeling study completed in this project, passenger mass can influence the energy used by electric buses and therefore affect their driving range. Advanced connected EMS systems under development by the project team can use mass as an input to models that predict electric bus range and require on-route charging energy.

## Product Transfer

To commercialize the mass-based APC approach that has been developed, the research team has a business plan for the technology and is open to industry partners interested in providing large-scale adoption. A published U.S. patent application on the algorithms for mass-based passenger counting was filed through the University of Minnesota's Office of Technology and Commercialization to protect the intellectual property (US20170057316A1).

# Location Aware Networks Optimizing Use of Transit Systems by Blind Travelers Transit IDEA Project 85

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## IDEA Concept and Product

LookingBus is a connected vehicle technology that helps riders with disabilities use public transit. By utilizing smart location aware sensors and Internet of Things (IoT), LookingBus provides drivers with notifications of riders with disabilities at their upcoming stops and when the riders need to get off the bus (Figure 1). This ensures that drivers can assist riders while boarding and departing. People with disabilities, such as visual impairments, depend on public transit for engaging in daily life and social activities. However, they often face challenges with (1) finding the correct bus stop; (2) determining which bus to board, especially at busy bus stops when multiple buses approach; (3) boarding the correct bus before the bus leaves the stop; and (4) departing the bus at the right bus stop. The LookingBus system includes location aware sensors that are placed on bus stops and work in synchrony with mobile apps. The system alerts drivers about the presence of riders with disabilities at their upcoming stops, as well as when they need to get off the bus. As a Vehicle to Infrastructure system, LookingBus developed proprietary hardware and a slew of software applications, including driver apps, rider apps, and a dispatch center. By means of technology that allows the drivers to be prepared for and aware of the needs of the riders, LookingBus is looking out for every rider and addresses all these challenges.

**Figure 1**

*LookingBus in action.*

## Project Results

Previous pilot testing was conducted in collaboration with the Suburban Mobility Authority for Regional Transportation (SMART, in Detroit, Michigan) and is now in deployment at Capital Area Transportation Authority (CATA) on their entire bus fleet.

Pilot testing of LookingBus produced valuable findings that were used to improve the technology. Volunteer riders suggested audible directions, use of vibration, and reminders for the mobile app. Drivers provided ideas about visual, timing, and audible aspects for the notifications and feedback on the positioning of the driver unit to minimize distractions. Operations personnel suggested hardware design that included water resistance, robustness, and communication capabilities. The company aims to make LookingBus a flagship solution for cities and transit agencies, which they will be proud to highlight in their annual reports and display as a success in the adoption of advanced technologies that underpin the cities of the future.

During the pilots, LookingBus sensors were tested in the field to evaluate their durability in variable Michigan weather. A pole-mountable casing was also developed to provide waterproof housing for the sensors, as well as allow mounting them on bus stops in positions that facilitate strong and reliable wireless communication. Testing showed that, in addition to hot summer temperatures, the sensors performed well even in the coldest weather and exhibited a resistance to notable fluctuations in temperatures. With the information gained from pilot testing, LookingBus is continuing to refine the sensors to ensure their continued success and accuracy.

In addition, the technology provides reservation reliability, weather accountability, a user-friendly app, driver UI, failproof system, and reliability. The user is able to make a trip reservation within a flexible time range while using the LookingBus rider app, which is simple and easy to learn. With cases of extreme weather, including rain, cold, heat, or snow, LookingBus guides riders to shelters and notifies the driver of their location. The driver UI is designed so that it is simple to use without creating distractions for driving and rider safety. Obvious visual indicators are used to provide clear notifications to drivers and to eliminate any confusion related to alerts. The driver terminal used to provide information to the bus driver is completely independent from other bus systems, which is an advantage as it will not experience failure if other bus systems were to experience technical issues.

The LookingBus technology is proprietary, patented, and on the cutting edge, adding to the "wow" factor among users and customers. This is a system that bus agencies will be proud to display when they highlight their interest in adapting smart technologies of the future that are designed to improve the accessibility of public transportation of all riders, especially those with disabilities.

## Product Payoff Potential

LookingBus generates value for several parties, beyond just bus agencies as the customers that pay for the service. Drivers and riders, both vital champions (benefiters and influencers), also gain value through the integration of the technology. Value propositions for bus agencies are numerous, ranging from cost savings of shifting riders from paratransit to fixed route and improving perception of the company from their user base. From a cost perspective, paratransit accounts for 4.2% of the total rides and 20.6% of the total costs for bus agencies. LookingBus provides a solution that can reduce paratransit rides by providing riders with disabilities a technology that improves their independence and safety while riding fixed-route buses. For

each ride shifted from paratransit to fixed route, a transit company could save $20 making a return on investment feasible and realistic. LookingBus enhances fixed-route transit for ADA riders, which will improve the perception and image of transit agencies. Many ADA riders have expressed concerns with their paratransit experiences and desire improvements that would make fixed-route services more accessible. Transit agencies are required by law to provide accessible transportation to ADA riders. The LookingBus system is a solution for improving the transportation service offered to these ADA riders by transit agencies.

From the user perspective, feedback was positive and indicated that LookingBus provided value beyond available technologies such as common GPS devices and other smartphone applications. LookingBus also provided an additional sense of security due in part to the knowledge that drivers expect riders that may need assistance waiting at the coming stop. Specifically focusing on expenses, ADA riders spend $2.20 per ride on paratransit and ride for free on fixed-route buses. As such, there is a monetary incentive for ADA riders in using fixed-route buses enhanced by LookingBus technology, as well as the potential to improve customer perception of transit agencies. Furthermore, since bus agencies will bear the cost of the LookingBus service, users will be able to access the mobile app and service for free, so they will not have to dedicate any of their savings from fixed-route use on access to the LookingBus technology.

## Product Transfer

LookingBus is ready for implementation in additional cities and looking to expand for more user experience. The company hopes to have more developments and collaborations with bus agencies in addition to the pilot with CATA in Michigan. LookingBus addresses the challenges that people with disabilities face while riding public transportation. This product will enhance experiences for people with disabilities, especially those with visual impairments, who are limited in their ability to ride public transportation. Through implementation of smart bus stops, as well as user and driver applications, LookingBus enables people with visual impairments to use public transit services that are reliable, safe, and more independent. LookingBus is hoping to have more developments and collaborations with bus agencies in addition to the pilot with CATA in Michigan.

# Advanced Neutral Temperature Estimation Using Solitary Waves (ANTEUSW) Transit IDEA Project 86

Piervincenzo Rizzo
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Pittsburgh, Pennsylvania

## IDEA Concept and Product

Continuous welded rails (CWRs) are track segments welded together. With respect to joint rails, CWRs are stronger and smoother, require less maintenance, and can be traveled at higher speeds. When anchored, a CWR is pre-tensioned to counteract the thermal expansion occurring in warm days. Typical pre-tension is such that the rail neutral temperature (RNT), i.e., the temperature at which the longitudinal force is zero, is between 90°F and 110°F. The pre-tension force cannot be higher because material contraction in winter may break the rail. Over the years the RNT decreases to an unknown value usually comprised between 50°F and 70°F, increasing the risk of extreme thermal compression in summer when the temperature of the rail exceeds the ambient temperature by 30°F or more. Such extreme compression raises the possibility of thermal buckling, a structural problem that may cause derailments. To prevent derailments rail operators need to estimate the temperature at which the rail reaches its Euler (buckling) stress. This is achieved by estimating the RNT, by measuring the rail stress at any given temperature. Ideally, this should be done with an accurate nondestructive evaluation (NDE) method that can be used anytime, anywhere and with minimum traffic disruption. This Type 1 project investigates a new NDE method to determine axial stress and then infer RNT in CWRs. The method relies on the propagation of solitary waves within granular chains in contact with the rail to be inspected. The hypothesis is that the stress in the rail influences the characteristics of the waves propagating within the chains.

## Project Results

We used the plug-and-play transducer (PaPT) that was found to be most appropriate for field testing during Stage 1 of the project to test a thick beam and a short rail segment. The PaPT is shown in Figure 1 and it is able to trigger, sustain, and sense solitary waves. The transducers

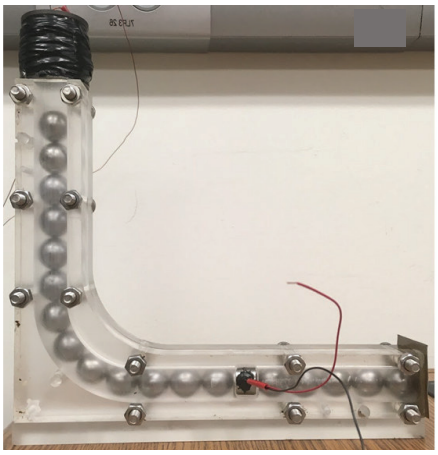

**Figure 1**

*Photo of the plug-and-play transducer used in the experiments.*

consists of four parts: (1) a certain number of spheres (beads) in contact with each other and forming a chain; (2) a frame holding the chain; (3) an actuation system able to trigger one solitary pulse; and (4) a sensing system able to measure the waves propagating within the chain. The transducer is designed to be connected to a data acquisition system to control the trigger and to digitize the sensed signal for post-processing analysis. The beam was subjected to thermal stress across tension-compression load. The rail was subjected to mechanical compression. The experimental results were compared to the results of a finite element method developed also during this project.

The main conclusions of the first part of the study are that the L-shaped PaPT are more practical and efficient because they can be easily placed in contact with the web of the rail to be tested. The electromagnet-based actuator is smaller and lighter and can be easily mounted above the chain of particles with respect to the shaker. However, the latter provides more repeatable results although the advantage is not significantly much better.

A photo of the experimental setup relative to the rail segment is shown in Figure 2a whereas the numerical results relative to a straight rail 3600 mm long is presented in Figure 2b. The latter displays one of the features of the solitary waves as a function of the rail stress. The figure demonstrates that some features of the solitary waves are affected by the stress present in the rail. In the future the model can be adapted to any rail of any profile, steel type, and length to predict the variability of the solitary waves due to longitudinal stress in the track.

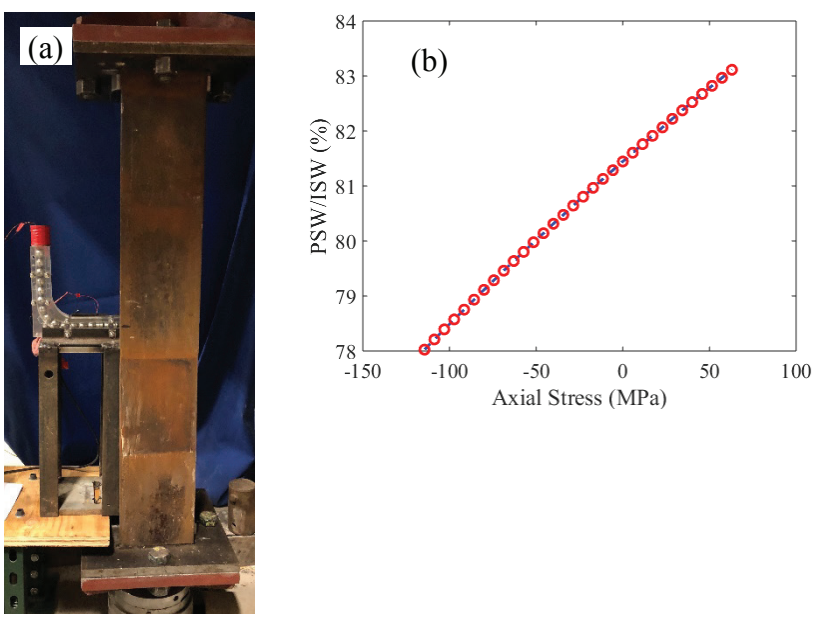


**Figure 2**

*(a) Photo of a 0.9 m rail under mechanical compression and inspected with a PaPT. (b) Numerical results relative to a 3.6 m long straight rail. The amount (in %) of the wave reflected at the chain-rail interface with respect to the incident wave is plotted as a function of the longitudinal stress.*

## Product Payoff Potential

The rail network is one of the backbones of the U.S. economy. The Federal Railroad Administration (FRA) estimates that the growth of the U.S. population will increase the tonnage moved by the freight system by 22% within 2035. These come at a time when climate change does not show any reversing trend and therefore more extreme temperatures are expected in the years to come. The "physiological" reduction of the RNT combined with climate change and the increase in passenger and freight tonnage, escalates the risk of thermal buckling in rails. As such the first and foremost impact for practice of this project is the prevention of derailments. Second, the project addresses the long-standing challenge of measuring nondestructively and reliably stress and RNT. Third, the project contributes to the advancement of engineering in the areas of dynamics, wave propagation, and transportation because we study the effects of stress on the propagation of SWs. Fourth, we create a new NDE method in rail transportation.

## Product Transfer

This is a Type 1 project. Owing to the planned scope of work, there will not be the participation of any transit agency or any rail owner. Nonetheless the vision about the transition into practice is clear. The successful completion of this project will secure: (1) the proof that ANTEUSW works in rails; (2) the submission of a provisional patent; and (3) the ground to discuss with the FRA and private sectors about testing ANTEUSW in the field.

# Development of pathNav: A Pedestrian Navigation Tool that Utilizes Smart Data for Improved Accessibility and Walkability Transit IDEA Project 87

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## IDEA Concept and Product

The goal of this project was to develop pathNav, a pedestrian navigation tool that utilizes a connected network of sidewalk and pathway data. pathNav implements our published route accessibility index (RAI) that considers the quality of the pathway as determined by data collected through our pathMet device and/or reported through our free pathVu Navigation mobile app. The pathNav web interface allows pedestrians to search for the most accessible routes to their destination based on their customized profile and comfort settings. After completion of the tool, we conducted a survey with 20 participants of varying abilities to understand product performance and areas for improvement. Overall, participants liked the functionality of the app but desired some design improvements, such as a legend, to make the map more understandable.

## Project Results

pathVu has successfully developed a tool that routes pedestrians along the sidewalk/crosswalk network based on the user's comfort settings and quality of the pathway. This method of routing users is based on the RAI of each pathway segment and considers the types of routes users wish to travel. The data were collected through various tools that pathVu has developed. The primary tool used in data collection was pathMet. pathMet is a manually propelled stroller-type device that collects high resolution pathway data about tripping hazards, roughness, running slope, cross slope, GPS, and imagery. We also utilized our pathVu Navigation app, in which pedestrians can submit reports about pathway conditions.

pathVu worked with Fine Humans, LLC, a Pittsburgh small business, in order to design the web interface. The pathNav web app has the following nine features:

1. **Map view:** A map on the home screen showing color-coded sidewalk quality.
2. **User accounts:** Custom accounts with saved user settings.
3. **Step-by-step navigation using pathway/sidewalk network and route quality:** Routes that utilize RAI and user account settings.
4. **Preview mode:** Preview a destination to see the surrounding pathway conditions.
5. **Comfortability settings and alert settings:** Users specify the conditions most important.
6. **Preset profiles:** Blind, sighted, and walking; wheelchair user; and cane/walker user presets.
7. **Crowdsourced reports:** View crowdsourced hazard reports from the pathVu Navigation app.
8. **Recent paths:** Shows recent destinations searched.
9. **Favorites:** Create a list of your favorite destinations for quick access.

After completion of the pathNav web app, a survey of 20 participants was conducted. Participants expressed the following as top suggestions and areas for improvement: (1) add a legend to improve the usability of the map, (2) improve usability for people with visual impairments or additional testing with a screen reader, (3) include additional details regarding the *X* number of hazards that have been reported, and (4) include the distance between navigation steps. These suggestions provide a list of the next development features to be implemented in pathNav.

## Product Payoff Potential

Although all of the benefits of pathNav were not fully measured as part of this project, five possible payoffs of the system include

Payoff 1: Increased safety and reduced trip and fall injuries.
Payoff 2: Reduced social isolation of people with disabilities and older adults.
Payoff 3: Increased public transit ridership.
Payoff 4: Reduced pathway-related lawsuit costs.
Payoff 5: pathNav is a commercially successful product.

Use of pathNav will make pedestrians aware of the most accessible routes. By taking safer routes, there will be a decrease in pedestrian-related trip and fall injuries, especially for older adults and people with disabilities, thus reducing lawsuits against cities. We believe that pathNav will reduce social isolation of people with disabilities and increase transit ridership. pathNav will become a commercially successful product that will one day be available in every major city.

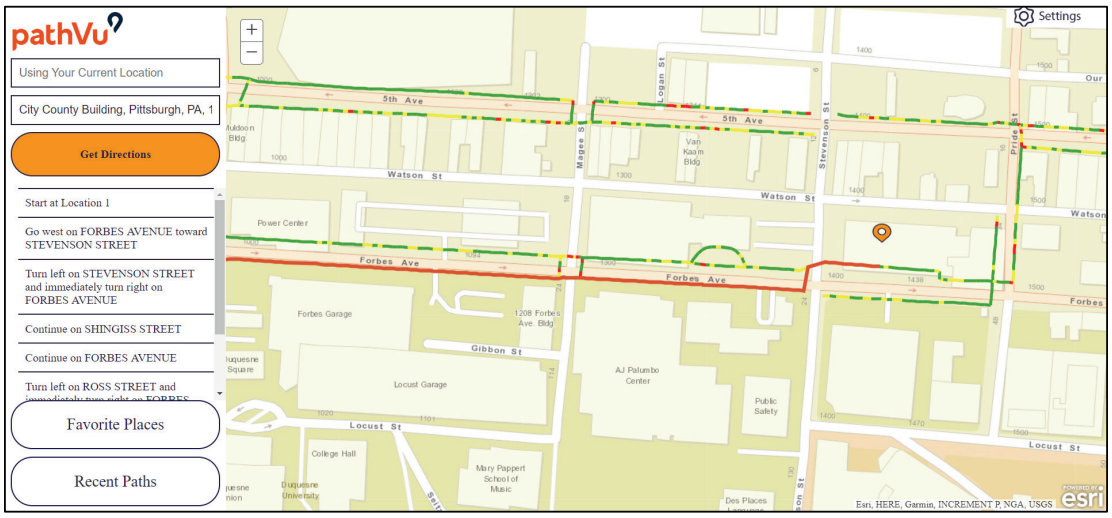


**Figure 1**

*URL to access the web app is https://pathvudata.com/pathvu/navigation/index10.php.*

## Product Transfer

pathVu (see Figure 1 above) has begun implementing pathNav in Pittsburgh as the first metropolitan area with pedestrian navigation. We have started with the two major business districts in the city, Downtown and Oakland. Moving forward, we will continue to implement pathNav in other densely populated neighborhoods (e.g., Shadyside, East Liberty, and Squirrel Hill). In order to market pathNav, we will work with organizations such as Visit Pittsburgh, Cultural Trust, and Oakland Transportation Management Association (OTMA).

After the successful completion of a pilot in Pittsburgh, pathVu plans to launch pathNav in one or two additional cities. We plan to launch in cities where we already have data or upcoming projects. We have completed projects in cities such as Louisville, Kentucky (1,800 miles); Boston, Massachusetts (70 miles); and Washington, D.C. (66 miles). Upon implementation of pathNav in these additional cities, pathVu will begin launching in other U.S. cities.

One of the values of pathVu is that local residents can collect data with the pathVu app for free, which is then used in pathNav. Although pathVu recommends use of its pathMet device, app data are a suitable source of data for pathNav pedestrian navigation. We will work with national organizations such as America Walks, with whom we have previously partnered, to reach transportation organizations around the country focused on improving walkability and accessibility.

# Evaluation of an Automatic, Individual Computer-Based Operator Education and Training Program Transit IDEA Project 88

Matthew Camden
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## IDEA Concept and Product

One proven method to reduce risky driving behaviors is combining onboard safety monitoring (OSM) systems. However, OSM systems alone are insufficient to significantly reduce risky driving behaviors in the long term. Instead, lasting behavioral change requires combining operator coaching with the data from OSM systems.

To address this challenge, RMJ Technologies developed Predictive Coach, a first-of-its kind software that uses OSM data to monitor operator behavior and automatically assign relevant, individualized online operator training as needed. Predictive Coach incorporates a three-step process, as shown in Figure 1. Although the use of OSM systems and operator training is not innovative per se, the targeted training delivery, tailored training content, and automatic training tracking and documentation are innovative concepts.


**Figure 1**

*Overview of the Predictive Coach program.*

## Project Results

This project is a concept exploration designed to evaluate the ability of Predictive Coach's innovative driver training delivery method to reduce risky driving behavior. Results showed that bus drivers had 7,267 risky driving events over the 34 weeks, including 0 hard acceleration events, 39 hard braking events, 5,786 hard cornering events, and 1,442 excessive speeding events while operating the buses. Figure 2 shows the weekly average rate of bus operators' risky driving events per 1,000 miles.

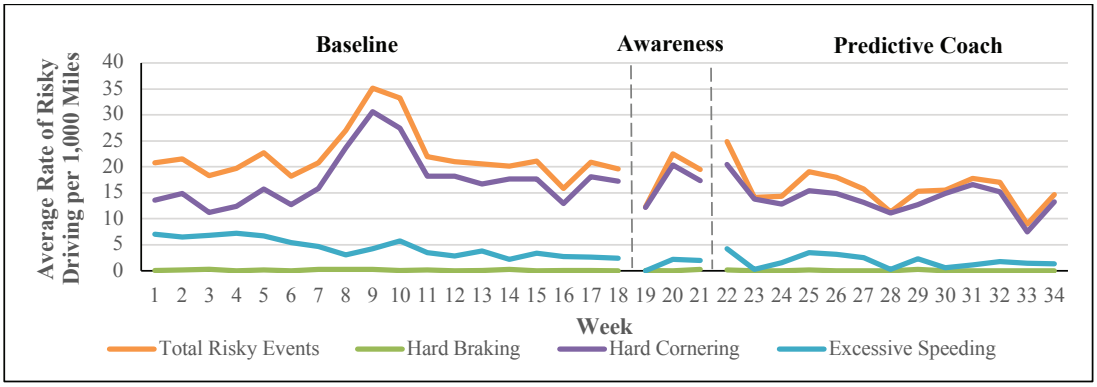


**Figure 2**

*Average rate of risky driving events per 1,000 miles per week across all bus drivers.*

Table 1 shows that the rates of overall risky behavior, excessive speeding, and hard cornering were found to be significantly lower during the Predictive Coach phase compared with the Baseline Phase.

**Table 1**

**Results comparing specific risky driving behavior rates in each study phase for bus drivers.**

| Risky Driving Type | Comparison | Relative Risk Estimate | Adj CI | *df* | *t*-value | *p*-value |
|---|---|---|---|---|---|---|
| Overall | Predictive Coach vs. Baseline | 0.6940* | (0.6527, 0.7568) | 578 | –9.37 | <.0001 |
| Excessive Speeding | Predictive Coach vs. Baseline | 0.3662* | (0.3002, 0.4469) | 578 | –9.91 | <.0001 |
| Hard Cornering | Predictive Coach vs. Baseline | 0.8104* | (0.7478, 0.8783) | 578 | –5.14 | <.0001 |

* Denotes statistically significant result at alpha = 0.05.

## Product Payoff Potential

Results from this study showed that the Predictive Coach program was associated with a reduction in bus drivers' risky driving behaviors, including a 63% reducing in excessive speeding events. It offers fleets an objective method of identifying drivers in need of training, offers targeted training courses based on individual driving habits, and does all of this automatically without the need for fleet intervention. Additionally, the results showed that the Predictive Coach program provides a complimentary system to video-telematics OSM systems to help fleets further reduce risky driving.

## Product Transfer

The innovative training concept offered by Predictive Coach was built to be open to the various types of hardware and software used by transportation fleets. Predictive Coach currently works with Geotab, an inexpensive, popular, and powerful open source OSM service provider. However, Predictive Coach can be easily integrated for use in any user interface from an OSM system provider. Based on the results of this project, RMJ Technologies will accelerate their efforts to incorporate the training offered through Predictive Coach into other telematics systems. Furthermore, Predictive Coach will focus on developing their own basic user interface and software gateway in 2021. By developing a customized Predictive Coach user interface, an end user of any telematics provider will be able to connect with Predictive Coach and directly access the Predictive Coach user interface. Finally, RMJ Technologies is exploring the possibility of developing more specialized and thorough transit-specific training. This would help the Predictive Coach platform gain additional traction in the transit industry in the hopes of reducing fleet risk and improving safe driving.

# Dynamic Vehicle to Infrastructure TCIP Communications Laboratory Proof of Concept Transit IDEA Project 89

Marilyn Fortin
Ayers Electronic Systems, LLC
North Chesterfield, Virginia

## IDEA Concept and Product

Transit agencies within the United States use four primary communications mechanisms to dispatch, monitor, and manage the operations of their mobile assets: private radio systems, Wi-Fi communications, cellular communications, and track circuits and signaling. Most data communications in the transit industry today are still based on vendor proprietary communications protocols and messaging. This limits agency choices when procuring new systems and often leads to agencies experiencing vendor lock-in, where an incumbent vendor has significant control over the agency's ability to procure new systems. TCIP has been used to standardize communications in several agencies and, in each case, TCIP-based communications have been successful in meeting project requirements.

This project brought together the capabilities of two long-running industry and government initiatives to bring benefits to the transportation industry: Dedicated Short Range Communications (DSRC) and Transit Communications Interface Profiles (TCIP). TCIP is an American Public Transportation Association (APTA) standard that defines standard mechanisms that are tailorable for exchanging information among transit components and business systems in the areas of Onboard Systems, Control Center (Vehicle/Center Communications), Fare Collection, Scheduling, Transit Signal Priority, Geographical Information, Common Public Transport, Passenger Information, Demand Response Service (Paratransit), Light Rail Operations, and Incident Management. DSRC is a standard for short range data communications between vehicles (V2V) and between vehicles and the roadside infrastructure (V2I). DSRC has been under development by the U.S. Department of Transportation since the 1990s. In 1999, the FCC allocated 75 MHz of spectrum for DSRC in the 5.9 GHz band. The allocation was adjusted in 2004 and 2006 and was "refreshed" in 2016. Numerous field tests have been conducted with DSRC, but most have involved passenger cars.

## Project Results

With the completion of function, stress, and soak testing, the research team determined that there were some technical items that needed to be addressed for the Dynamic Vehicle to Infrastructure (DV2I) system to become a viable commercial product. Optimization of message rates is the key technical item to be addressed, along with some system enhancements suggested by the Ayers Electronic Systems team. Overall, the DV2I system functions as intended, but at a lower than expected throughput. With additional investigation and field testing, the system has the potential for becoming a viable commercial product.

## Product Payoff Potential

The successful integration of DSRC, Wi-Fi, and cellular communications to transmit TCIP data has the potential to open the door to a number of benefits to transit agencies in future production projects, including

- Availability of en route high-capacity communications with transit vehicles with a cost-effective means to update schedules and GIS information.
- Reduction of cellular costs by rerouting cellular traffic over DSRC where it is available.
- Improvement of tracking and monitoring system performance in agencies with private radio systems by sending large messages over DSRC rather than over private radio systems.
- Reduction of cellular dependence during major incidents by allowing intermittent communications with enroute vehicles, even if cellular communications are unavailable.
- Expectation that in the future, new road vehicles will be delivered with DSRC radio systems as standard equipment to facilitate the operation of such vehicles in the V2V and V2I environments. This project will demonstrate the feasibility of using these new radio systems to facilitate transit operations.

## Product Transfer

This project demonstrated the viability of using DSRC to convey standardized TCIP information between control centers and en route vehicles. With further investigation into the message speeds, DSRC could be installed at multiple stations and a back-office system for a transit agency. Vehicles passing or stopping at the stations will communicate with the office systems via DSRC roadside units at those locations. Since DSRC will not be available along the vehicle's entire route, cellular communications will be used to "fill in" communications at other locations. This system, as shown in Figure 1, will provide transit agencies with a vendor-independent solution for low-cost data transmission. As a follow-on project, the research team plans to add a functionality that will wrap non-TCIP messages such that the system will be vendor agnostic, allowing an agency to add this communications system to an existing system.

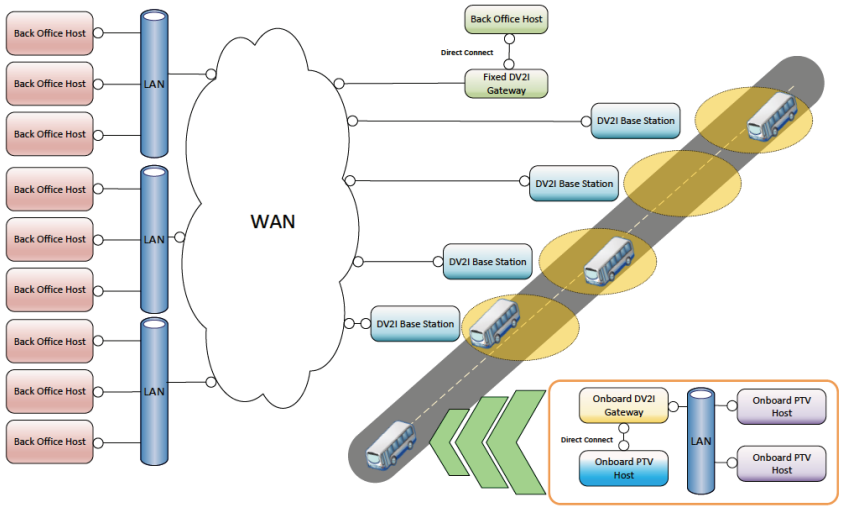


**Figure 1**

*Dynamic Vehicle to Infrastructure Operating Environment system.*

# sUAS-based GeoINTEL for CR Parking in Rural and Suburban Areas
# Transit IDEA Project 90

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## IDEA Concept and Product

Commuter rail services bring travelers from the rural and suburban fringes to the inner neighborhoods and central business districts of many large metropolitan areas in the United States. The isolated nature of these rural and suburban commuter rail (CR) parking lots makes it difficult and expensive to secure and safely operate these transit assets. Further, as the more than two dozen commuter rail systems in the U.S. try to avoid cash payments for fares and parking fees, they must embrace consumer friendly options and mobile phone-based payment systems that are not standardized and not easily integrated into large databases for "big data" analysis. This situation makes the validation of commuter rail parking payments difficult and increases the potential for systemic fraud and abuse. Using autonomous flight modes, small unmanned aircraft systems (sUAS) can provide high resolution imagery that can document each individual vehicle parked in a specific parking space at a specific date and time (Figure 1). The speed at which this data can be collected is at least four times faster than current methods, thereby providing four times the data using the same human resources (the remote pilot).

The purpose of this study is to develop and field test a prototype of sUAS and geospatial intelligence (GeoINTEL) analytics in a "living lab" to enhance the safety, security, and parking revenue validation at small urban and rural commuter rail parking areas. A critical objective of this research is to use commercially available, off-the-shelf (COTS) products and services that meet the budgetary constraints of rural and suburban transit systems within existing transit technical staff resources.

**Figure 1**

*An oblique photograph from a DJI Phantom 4 drone, observing the MBTA commuter rail parking, residence hall parking, and a University Parking garage using a "perch and stare" mode from a launch/landing zone on the edge of the Bridgewater State University East university campus. (Source of Photo: Lawrence J. Harman)*

## Project Results

Using a combination of three emerging technologies: (1) sUAS for remote sensing, (2) aerial imagery analytics, and (3) Edge of the Cloud computing based on a state-of-the-art communications infrastructure, the researchers developed a prototype approach to transit safety and security in a suburban Boston, Massachusetts, setting. The project addressed the issues of real-time transmission of drone imagery to local police in suburban areas, counting parked cars using 2-D orthomosaics from drone imagery (without recording personally identifiable information, and creating solutions that are faster, cheaper and better than current transit industry approaches.

The Transit IDEA project demonstrated that the required infrastructure can be built and operated at the urban–rural fringe of a major metropolitan area using a university transit system and a regional commuter rail service as a living lab prototype. This prototype can be implemented locally and nationally using the U.S. Department of Transportation's systems engineering approach that was modified by this research project. Based on interviews with transit managers, police, and trade representatives; the safety and security services that these technologies deliver is needed immediately to secure our transit systems and make their operations safer.

## Product Payoff Potential

- Federal and state agencies have continued to support research efforts at state universities and their cooperating transit partners to apply innovative technology to improve transit safety and security.
- Local and regional transit agencies in Massachusetts, as partners in supporting Bridgewater State University's "LivingLab," are poised to implement the results of this demonstration using Bridgewater State University's communications infrastructure backbone that currently exists from Bridgewater to Boston's Internet Hub.

## Product Transfer

In addition to the TCRP Project T-90 Oversight Committee, the project benefited from a technical oversight committee from the University's information network technology division, the Bridgewater State University Transit Service, the University Police traffic operations and tactical response divisions, and the regional transit managers affected (e.g., Brockton Area Transit and the Massachusetts Bay Transportation Authority). A potential field operational test site, the Montachusett Regional Transit Authority (MART) was represented on the TCRP IDEA T-90 Project Oversight Committee. As a part of project outreach, the principals participated in related national and international transportation research meetings and presented project findings.

# Augmented Reality Train Dispatcher User Interface Transit IDEA Project 92

Carl Stanton
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## IDEA Concept and Product

This proof-of-concept project was aimed at determining the viability of leveraging the emerging technology, augmented reality (AR), as a new user interface for train dispatching. The tool would allow users to view the track layout; train information; train movements; schedule adherence; and information about trains, services, and stations. The product was built by combining an off-the- shelf, open-source train-dispatching simulator (NDP Systems' TS2) as its back-end, and 360 World's Clairity mixed reality platform (shown in Figure 1) to create the AR displays. The Microsoft HoloLens Augmented Realty Headset was used to run the AR user displays. Ross & Baruzzini | MACRO contracted with 360 World to leverage their Clairity AR interface, which is already in use at airport control centers. 360 World adapted the Clairity Interface for rail. NDP Systems was contracted to modify their TS2 simulator to work as the back-end for Clairity.

Dispatchers and control center staff from Utah Transit Authority (UTA) and Metro Atlanta Rapid Transit Authority (MARTA) agreed to be partners on the project and provided staff time to determine the requirements for the proof-of-concept product as well as to perform user testing and feedback on the outcome.


**Figure 1**

*Example of the HoloRail interface.*

The success of the proof of concept was evaluated based on the following criteria: the ability to

- Display track layout and trains in 3-D;
- View information about trains, services, equipment, and stations;
- Monitor on-time performance;
- Route trains; and
- Leverage gesture and voice inputs.

## Project Results

Ross & Baruzzini | MACRO completed the final report for this project in June 2021. The user research consisted of on-site meetings with agency staff and Ross & Baruzzini | MACRO. NDP Systems updated their train-dispatching simulator to act as the back-end server for the Clairity.

After the agency research, Ross & Baruzzini | MACRO worked with UTA and MARTA to finalize requirements for the user interface. Development on the user interface took place from June to December 2019.

Ross & Baruzzini | MACRO created simulations of sections of UTA and MARTA's service areas that are used by the TS2 simulator for internal testing, as well as testing with UTA and MARTA.

### Agency Testing

Agency testing with UTA took place in February 2020 and with MARTA in September 2020. Ten dispatchers from UTA and MARTA participated in on-site testing lead by Ross & Baruzzini | MACRO. This testing consisted of an interface tutorial, a guided tour of the HoloRail platform, structured testing, and unstructured testing. At the conclusion of the testing, each dispatcher completed a feedback survey. Full results of the user testing are provided in the final report for this project. The URL for the report is provided below.

### Virtual Testing with MARTA

Due to COVID-19 preventing on-site user testing, Ross & Baruzzini |MACRO developed a plan to conduct the user testing virtually. Ross & Baruzzini shipped all the equipment necessary to conduct the user testing to MARTA, and Ross & Baruzzini conducted the same testing that was planned in person through videoconferencing, with the assistance of MARTA personnel.

## Product Payoff Potential

Based on initial project research and feedback from the user testing with MARTA and UTA dispatchers, the following potential payoffs were identified:

- Headsets can replace multi-monitor displays and video walls, which significantly changes the space requirements and design of control rooms.
- Headsets create the potential for dispatchers to be mobile or easily change locations if necessary.
- Individual customization of information layouts, including overview displays.

On the basis of the results of user testing, Ross & Baruzzini concluded that while there are barriers to current implementation of AR, it is a viable technology for future control centers. AR technology is rapidly advancing, which will eliminate the hardware barriers to implementing AR in the future. AR in the control center could also result in significant costs savings for agencies.

The final report outlines the lessons learned throughout the process and is available on the TRB website to any public transit agency interested in learning more about, or experimenting with, this technology. See https://onlinepubs.trb.org/onlinepubs/IDEA/FinalReports/Transit/Transit92.pdf.

## Product Transfer

This project tested the viability of using AR for train dispatching and sparking additional innovation and discussion within the industry. There is no intent to turn this proof of concept into a commercial product. This proof of concept is for research and education purposes.

# An Open Platform for Transit Agencies to Improve the Quality of Their Real-Time Data Transit IDEA Project 93

Drew Dara-Abrams
Interline Technologies LLC, Alameda, California

## IDEA Concept and Product

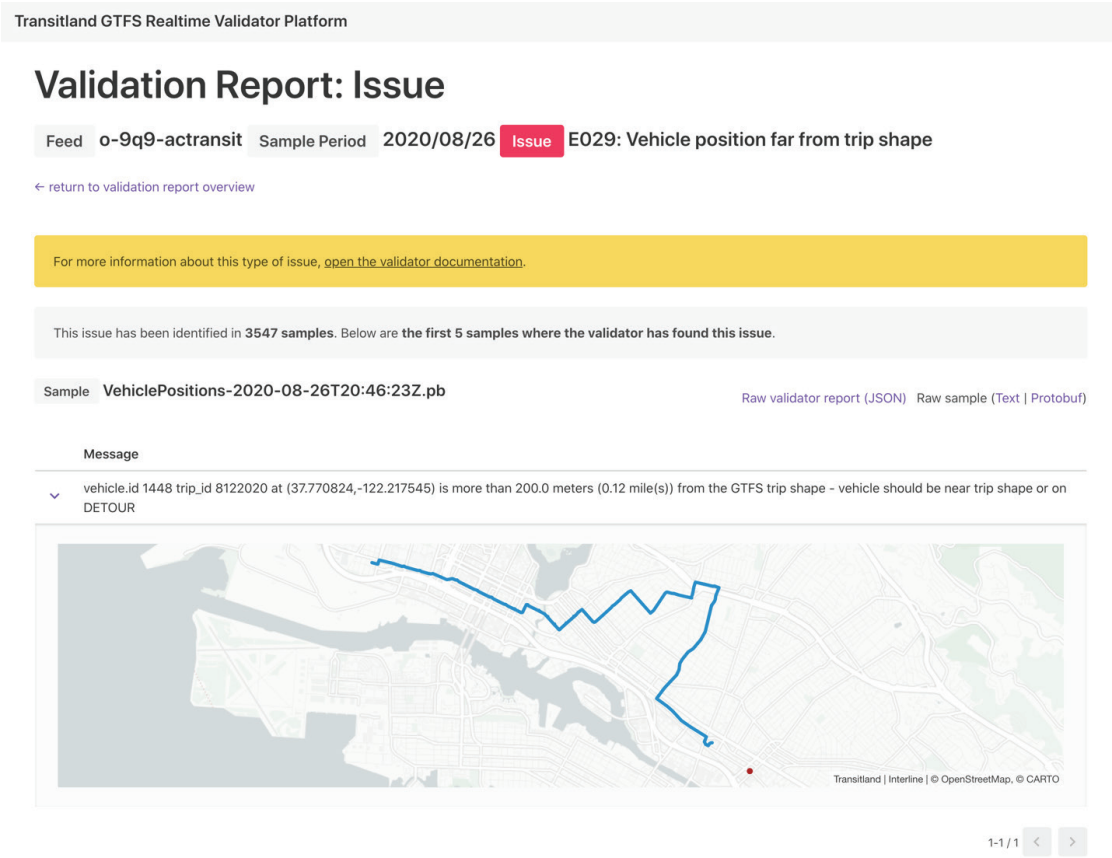
Real-time transit information has many benefits to transit riders and agencies, including shorter perceived and actual wait times, a more welcoming experience for new riders, an increased feeling of safety, and increased ridership. Real-time transit data are, in comparison with many other potential operational or capital improvements to bus or rail service, an affordable means of increasing ridership. In the last few years, a real-time complement to the General Transit Feed Specification (GTFS) format, GTFS Realtime (https://developers.google.com/transit/gtfs-realtime/) has emerged. Despite its promise, adoption of GTFS Realtime by transit agencies has been hampered by a lack of clear documentation and readily available validation tools.

In this project, Interline Technologies LLC and the Center for Urban Transportation Research (CUTR) created a prototype platform that makes GTFS Realtime validation tools readily available to, potentially, all transit agencies in North America. The two organizations built upon two open-source projects: the GTFS Realtime validator prototype (https://github.com/CUTR-at-USF/gtfs-realtime-validator) and Transitland (https://transit.land), an open transit data platform. This project applied the open-source and open-data community models to the challenges of creating and improving GTFS Realtime data.

## Project Results

### Stage 1: Build and Test GTFS Realtime Data Platform

The research team combined the Transitland open data platform, the GTFS Realtime Validator, and a list of 162 GTFS Realtime feeds (provided by a partner organization). The combined platform collected GTFS Realtime data from a specified feed, ran the validator process, and produced a report on any detected errors. Below is an example screenshot of the validator platform that shows contextual information from both a GTFS Realtime feed and its associated static GTFS feed. The E029 error indicates that a vehicle position is too far from its associated trip shape. The map shows the bus position as a red dot and its scheduled route shape alignment in blue. This error will degrade maps and arrival-time predictions presented to riders.




## Stage 2: Testing with Transit Agency Staff

The project team tested the platform by preparing quality reports for seven public-transit agencies and reviewing the results in the platform user interface with agency staff members over video calls. These agencies represented a diverse range of rider population sizes, staff skill levels, and locations (urban and rural). In these user-testing sessions, the project team collected information from agency staff about how GTFS and GTFS Realtime data are created at each agency, any known issues, and any open goals. After being given a tour through the platform and its interface, agency staff reviewed the reports for their own GTFS Realtime feeds. Agency staff were asked to provide input on both the specific quality checks and the overall presentation and approach used by the platform.

All agencies found the experience of exploring the warnings and errors useful, to the point that most of the sessions ran long. Each of these video calls turned into miniature consulting sessions, with the conversations between agency staff and the research team often ranging from specific GTFS Realtime data fields to system-level architecture concerns. On the one hand, this showed the power of the platform to surface useful information for such wide-ranging investigations. Agency staff reported that some of this information was available through other sources but not aggregated in one place, while other information was previously unknown. On the other hand, these consultations showed how unique each GTFS Realtime system is and how wide a range of information and functionality is necessary for the platform to serve all agencies' potential needs.

## Product Payoff Potential

By combining the open-source components of a GTFS Realtime validator with a catalog of GTFS Realtime feeds, hosted on Transitland's cloud servers, this project has made the process of validating real-time data simple and accessible to agency staff from any computer with a web browser. As a result, GTFS Realtime data will improve in quality and availability. Transit riders will have a better experience (which has been linked to higher ridership), agency staff will provide better service with less effort and cost, and system vendors will provide higher quality products.

## Product Transfer

To bring the capabilities of this GTFS Realtime validator platform to a wider range of transit agencies on an ongoing basis, the research team:

- Enabled the Transitland platform to accept submissions of new GTFS and GTFS Realtime feeds by agency staff.
- Distilled the results of our user-testing process into a subset of the most important GTFS Realtime errors and warnings. The T-93 Final Report includes a table explaining how each of these data issues may affect the rider experience (https://onlinepubs.trb.org/onlinepubs/IDEA/FinalReports/Transit/Transit93.pdf).
- The research team is using this smaller list to focus on follow-up work and has shared the list with other organizations concerned with GTFS Realtime data quality (such as the California Department of Transportation [Caltrans]).
- Presented project results to a wide range of venues, including the APTA Research and Technology Committee and the following TRB committees: AP075 Light Rail Transit, AEP35 Effects of Information and Communication Technologies (ICT) on Travel Choices, AP090 Transit Data, and AED30 Information Systems and Technology.
- Published an accessible summary of project results in *TR News*. See D. Dara-Abrams, March-April 2021, *Open Platform for Real-Time Transit Data: Helping Agencies Provide Better Rider Information*, pp. 10-13.
- Is currently exploring sponsorship for follow-up work and opportunities for cross-organizational collaboration.

# Evaluation of Transit Vehicle Brake Inspection Through Ultrasonic Emissions Analysis Transit IDEA Project 94

Brian Hearing
BrakeAudit LLC, Bethesda, Maryland

## IDEA Concept and Product

Despite advances in transit vehicle safety technology, vehicle brakes remain a common cause of accidents, injuries, road calls, and mechanical breakdowns. In the United States there are over 480,000 truck and bus crashes annually, with almost 30% of them involving brake failure as a factor. Every year about 15% of all commercial vehicles, including buses, are placed out of service after inspections because of brake-related violations. Brake-related road calls and unplanned maintenance in transit agencies can exceed several per day. In 2010, Washington Metropolitan Area Transit Authority averaged 3 brake-related road calls per day; in 2005, Miami-Dade averaged 2 brake-related road calls per day; and in 2013, Montgomery County (Maryland) averaged over 1.5 brake-related mechanical failures every week.

Transit vehicle brakes require invasive and time-consuming manual inspection in order to reliably detect issues. This is because many critical components face each other with only millimeter-sized gaps, requiring disassembly for visual inspection. Because of this, vehicle brakes are usually not disassembled and fully inspected more than twice a year, long enough for problems to occur without notice between inspections. Existing alternatives to visual inspection methods are available but have limitations such as performance-based brake testers (expensive and time- consuming) and infrared imaging (expensive and limited effectiveness). Development of a non-invasive method for detecting brake problems that does not require disassembly could save commercial vehicle fleets significant resources and improve roadway safety by facilitating brake maintenance.

This project proposes a new approach for improving transit safety by analyzing ultrasonic sounds emitted by the brakes to detect problems. Vehicle brakes emit ultrasonic energy (acoustic frequencies above what humans can hear) as part of the friction process; the spectra of these sounds are highly dependent on the mechanical condition of the brake and can be used to detect specific types of problems.

Ultrasonic-based brake monitoring systems consist of non-invasive sensors placed roadside near exits of transit vehicle facilities. The sensors can be automated to provide daily analysis of brakes for every vehicle and issue alerts if problems are detected. The data can be used to optimize maintenance schedules based on the conditions of the brakes.

## Project Results

Almost 10,000 ultrasonic recordings of 160 different vehicles were made over a period of 9 months. Maintenance records concerning brake work were also collected. It was found that changes occur in the acoustic emissions as the brake ages and becomes more worn. Characteristics such as spectral complexity, frequency, and amplitude were examined as potential indicators of brake condition. It was found that average frequency centroids increase as the brake ages, as shown in Figure 1, but there is substantial variance in the data. The use of this information as a predictive maintenance indicator was explored and the trade-off between additional inspections caused by false alarms versus reduction in time a vehicle could develop a brake issue before detection was quantified. While the trade-off will differ for each transit agency a typical example would be to decrease the time a brake problem could go undetected by 50% for a 20% increase in additional inspections.

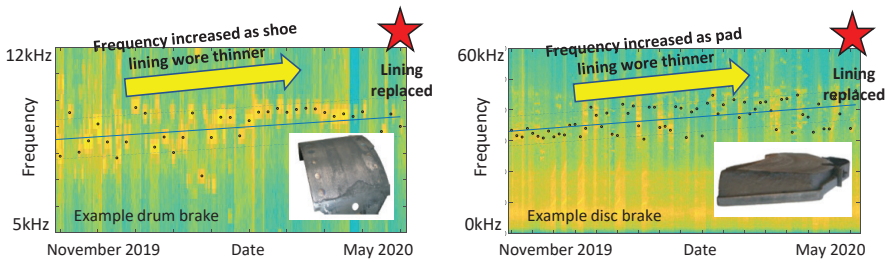



**Figure 1**

*Frequencies of braking resonances increase as brakes wear thinner.*

## Product Payoff Potential

Advanced warning of brake problems can lead to benefits in increased transit safety and operating efficiencies. Transit safety will be improved through fewer accidents and injuries due to brake failures. The ultrasonic-based system issues alerts if critical safety conditions are detected; the bus can be inspected and brake issues will be caught before the typical periodic maintenance schedule. Operating efficiencies will be improved through fewer road calls, mechanical breakdowns, and unplanned maintenance. The ultrasonic-based system provides updates of brake conditions, which can help optimize maintenance schedules.

## Product Transfer

Non-contact ultrasonic sensors are commercially available as a low-cost and non-invasive tool that can be purchased directly by transit agencies and installed roadside near exits of maintenance facilities. Reports and alerts are issued to maintenance personnel via cloud and email or via an interface directly to existing maintenance management systems. The potential transit customer base includes public transit agencies and private transit companies; the transit bus market size in the United States consists of 600,000 private transit buses, over 400,000 public buses, and 6,000 federal government buses. This market is growing at an annual rate of 7.7%. Additionally, development of the technology could lead to vehicle-mounted sensors that could capture data during operation and provide real-time feedback.

# SECTION 2
# ACTIVE IDEA PROJECTS

This section reports progress on all TCRP-IDEA projects that were active during the 2020 program year.

# Comprehensive Wayfinding for All (CWall) Transit IDEA Project 91

Michael J. Walk
Texas A&M Transportation Institute, Austin, Texas

## IDEA Concept and Product

Although public transit is a vital transportation option for people with visual and mobility impairments, public transit is not always easy to use or fully accessible. Transit information (e.g., maps, schedules, and real-time displays) often requires sight, and pedestrian pathways to transit stops may be missing or damaged. Although several app-based transit navigation options exist, to date, there is no app that combines transit and accessible pedestrian pathway navigation into a single solution. The Texas A&M Transportation Institute's (TTI's) project will develop and test a prototype CWall smartphone application (app) that will provide accessible transit and pedestrian trip plans with step-by-step navigation assistance during an entire transit trip. Although CWall's intended audience is users with visual and mobility impairments, the app will also benefit users without disabilities by reducing the learning curve of taking transit and making the sidewalk and transit network easier to understand and use.

Figure 1 illustrates an example use case.

The app will be built on open and scalable technologies, integrating pedestrian pathway data from OpenStreetMap, transit data in the general transit feed specification (static and real time), and Bluetooth low-energy beacons installed at transit stops (Figure 2).

TTI is leading the project in partnership with the Capital Metropolitan Transportation Authority in Austin, Texas (Capital Metro) and The Taskar Center for Accessible Technology (TCAT) housed by the Paul G. Allen School of Computer Science at the University of Washington.

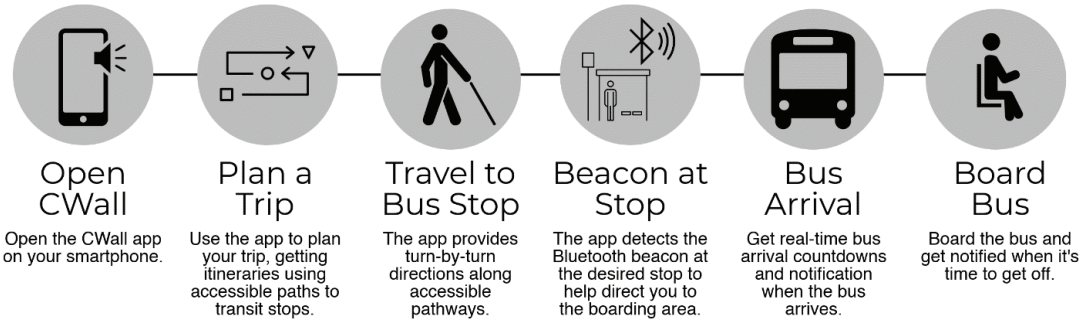



**Figure 1**

*Example of CWall use case.*

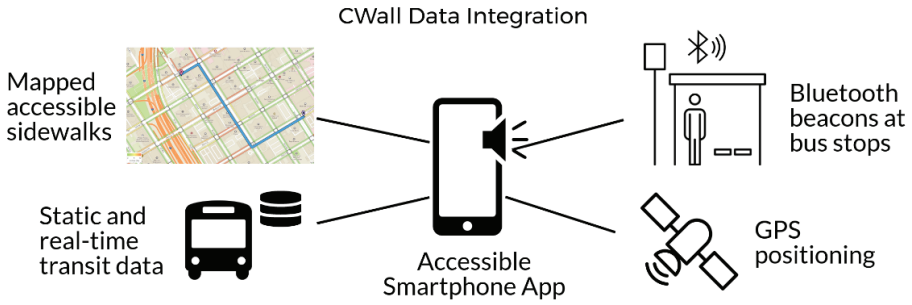



**Figure 2**
*CWall data integration model.*

## Project Results

The research team established a participatory design team comprising people with visual and mobility impairments for stakeholder involvement. The research team has completed and validated an inventory of the pedestrian network in the Downtown pilot zone and in the Tech Ridge Park & Ride pilot zone, including sidewalks, street crossings, and curb ramps. Pedestrian network data are uploaded to OpenStreetMap.

Also, Capital Metro procured enough Bluetooth low-energy (BLE) beacons to install in both pilot zones. Capital Metro installed BLE beacons on select bus stops in the Downtown pilot zone for preliminary and internal app testing.

In the area of CWall alpha app design and testing, the research team has configured server systems to manage user profiles and preferences and to provide a set of pedestrian-plus-transit trip itineraries upon request using the open-source routing engine, Navitia.io. Due to some development challenges, the team is exploring additional options for the app development and user interface to streamline the development process and make the best use of project resources.

## Product Payoff Potential

The CWall application has several potential benefits for users and transit agencies.

### Benefits for Users

For many transit riders, especially those with mobility limitations and visual impairments, CWall will help make fixed-route transit easier to use. As fixed-route transit becomes easier to use, users will have improved mobility and freedom by using fixed-route transit more often—all while decreasing the overall personal cost of traveling by avoiding expensive Americans with Disabilities Act (ADA) paratransit, transportation network companies, or taxis.

### Benefits for Transit Agencies

CWall will benefit transit agencies by helping shift passengers with disabilities onto fixed-route transit. Because ADA paratransit is 7-to-10 times more expensive per passenger trip than fixed-route transit, any shift in passenger travel from paratransit to fixed-route transit helps transit agencies control and potentially reduce operating and capital costs associated with operating paratransit service. Also, the CWall application will be built using relatively inexpensive and scalable technology and open data sets.

## Product Transfer

TTI is partnering with Capital Metro for the development and pilot testing of the CWall app. Capital Metro's passengers and other local users will help test the CWall app, and Capital Metro is supporting the installation of the Bluetooth beacons, the mapping of pedestrian pathways in pilot areas, and testing the app's accessibility. The app will be developed using open and standard data sets. The app's final code will be available for open use by transit agencies, and the final report will include documentation to help transit agencies replicate the app within their local contexts.

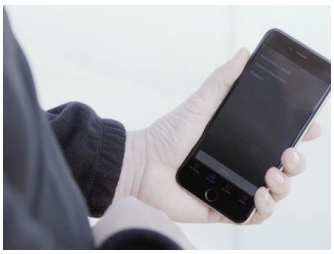
# Connected and Automated Parking Feasibility Pilot: Improving First and Last Mile Commuter Mobility, Safety, and Transit Revenue
# Transit IDEA Project 95

Mike Helta
Maryland Department of Transportation/Maryland Transit Administration, Baltimore, Maryland

## IDEA Concept and Product

The concept of the Connected and Automated Parking Feasibility Pilot at MARC Dorsey Station in Maryland is to test connected and automated vehicles (CAVs) through a mobile application enabling passengers to autonomously park and hail passenger vehicles. Overall, the idea is to determine/ask the question whether improving the efficiency of commuters' first and last mile experience by allowing their vehicle to self-park and hail, are commuters more likely to consistently take commuter rail? STEER Tech, the Maryland DOT MTA's project partner, developed a mobile application that allows users to self-park and/or hail their vehicle to autonomously drive to them in a designated area. The cars are retrofitted with necessary sensors and connect with the vehicle's actuators (brake, accelerator, and steering) to allow for autonomous driving (Figure 1).

(1) Send the Car

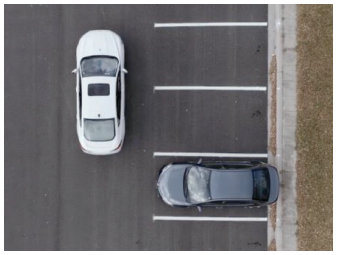


Passengers exit vehicle and engage STEER app to self-park vehicle

(2) AV-mode Launches

Upon exiting vehicle, car will self-drive into a designated parking spot

(3) Fetch Car



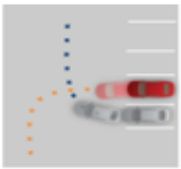
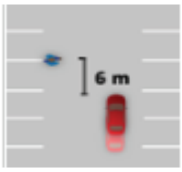
During departure, car is summoned via mobile app for passenger pick-up

**Figure 1**

*STEER Tech product overview.*

## Project Results

The project has two distinct phases: Phase I includes cordoned off automated valet parking (AVP) testing in a designated area, where members of the public cannot access the deployment site. Phase II integrates the STEER Tech vehicles within a publicly accessible MARC Commuter Rail station parking lot. The first segment of Phase II includes off-peak testing (10:00 a.m. to 3:30 p.m.) when fewer commuters are using the parking lot. The first segment lasts for 4 weeks and was interrupted in March of 2020 due to the onset of the COVID-19 pandemic. Testing resumed after an 8-month layoff. The second segment of Phase II was 4 weeks of peak traffic (7:00 a.m. to 9:30 a.m. and 4:00 p.m. to 5:30 p.m.) and was completed in March of 2021. The following table shows two sample test scenarios explored during Phase II. Final analysis and documentation are under way.

| | |
|---|---|
|  | STEER car auto-summons left.<br>Human-driven car (forward-facing) pulls out in the opposite direction. |
|  | Pedestrian crosses STEER car's path 6 meters ahead from STEER's driver's side. |

Concerning project results, the team implemented and tested a total of 210 unique scenarios, with a total of 2,775 test runs encapsulating 165 hours of test time over the course of the program. Of the 2,775 test runs, there were 1,312 full valets, 810 full summons, and the remainder were a combination of point-to- point and fast in/out scenarios. A *full valet* is defined as the car autonomously starting at the drop-off zone, driving, and completing a parking maneuver. A *full summon* is defined as the car starting in the spot which it parked, driving to the user location, and "picking up" the user. There were few operational challenges, with only 3% of test trips having disengagements. Surveys were also taken to gauge customer acceptance and opinion, with some key results being that 42% of riders do not feel safe in a parking lot where they park far away, but 75% of those people said a technology like this would make them feel safer. 23% of those surveyed said they would be more likely to take transit if they did not have to deal with the hassle of parking.

## Project Payoff Potential

The worldwide connected car market is projected to grow from $59.70 billion in 2021 to $191.83 billion in 2028 at a compound annual growth rate of 18.1%, assuming a return to pre-pandemic levels, once the pandemic is over[1]. The Connected and Automated Parking Feasibility Pilot will determine if Maryland DOT MTA and other transit systems are prepared for this emerging technology. AVP technology is most promising in its potential for increasing parking lot and garage capacities. Studies show that AVP parks cars closer together (since drivers are not needed to open and close doors), allowing for as much as a 20% increase in the number of vehicles that can be accommodated in the same space[2]. Furthermore, the convenience of AVP will positively affect commuter behavior and increase ridership if the former parking pain point is eliminated.

[1] *Transportation & Logistics/Connected Car Market,* Fortune Business Insight, 2020.
[2] Nourinejad, M., et al. *Designing Parking Facilities for Autonomous Vehicles.* Transportation Research Part B: Vol. 109, March 2018.

## Product Transfer

Maryland DOT MTA and STEER Tech, which is the partnership team for the project, are taking the following steps to successfully transfer lessons learned to transit agency partners:

1. The team will be providing a summary of insights from in-person and online surveys conducted during the testing phases gauging passenger awareness, education, and acceptance of automated vehicle technologies. This summary will identify knowledge gaps and determine when and where and how project information can be successfully implemented.
2. The team will be collecting both qualitative and quantitative data to produce insightful lessons learned and develop best practices to decrease risks and minimize the learning curve associated with CAV deployments for partner transit agencies.

# Multi-stage Planning for Electrifying Transit Bus System with Multi-format Charging Facilities Transit IDEA Project 96

Yu Zhang
University of South Florida, Tampa, Florida

## IDEA Concept and Product

The electrification of transport plays a critical role in reducing the footprint of greenhouse gas (GHG) emissions. Cities across the world increasingly consider electric bus (e-bus) as a way to reduce local air pollution. Charging facilities are important and organic components of an e-bus system. Currently, there are four ways to charge an e-bus: plug-in charging station; high-tension overhead cable; solar charging board; and dynamic wireless charging facility (DWCF). If only plug-in charging is implemented, e-buses need to carry a large battery, and back-up buses are necessary to replace the service bus, running the risk of the state of charge (SOC) being below the minimum level required to complete a round of service. The consequences are extra capital for back-up bus acquisition, low utilization of bus hours, and excessive energy consumption for carrying a heavy battery during bus operation.

As shown in Figure 1, along with the plug-in charging facility in the base stations, the DWCF can serve as a complementary charging facility to ensure continuous operations of an e-bus by maintaining the level of the SOC of the battery during bus motion. It can also help downsize battery packs, which could be a significant percentage of bus weight and reduce the space of e-buses for carrying passengers. Proper battery size is dependent on the transit network structure, operation dynamics, and the location of the plug-in and wireless charging facilities and vice versa. In addition, the battery lifetime is impacted by charging frequency and the depth of discharge. Therefore, how to combine these two charging modes and determine locations of DWCF and on-board battery size to provide feasible, reliable, and cost-effective e-bus operations is a critical problem to solve.

This study aims to provide a decision support tool to public transit authorities for facilitating the process of electrifying buses. Specifically, given the periodical budget and transit network characteristics, this tool would provide outcomes at different stages, including (1) which routes the acquired e-buses should serve; (2) where to deploy the two different charging facilities; and (3) what should be the right size of onboard battery for a specific route.

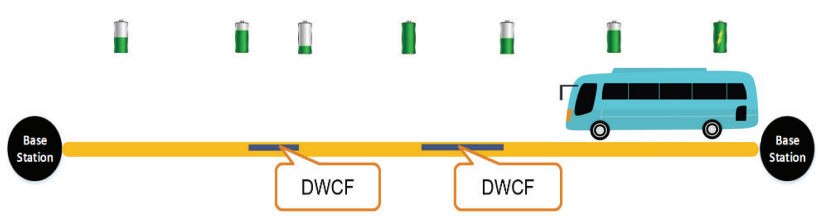



**Figure 1**

*Illustration of battery energy levels during bus operations with DWCF.*

## Project Results

The research team has finished the literature review, data collection, and mathematical model and solution algorithm development. To be specific, the key pros and cons of four typical charging facilities were reviewed. The transit network data from Hillsborough Area Regional Transit (HART) were collected and analyzed. The research team also discussed with representatives of local transit authorities the factors that they consider while embracing e-buses. In addition, cost parameters of on-board battery, charging facilities, construction, and so forth were determined based on the literature review and meetings with transit authorities.

The research team also modeled full electrification, partial electrification with route selection, and dynamic planning of electrification of transit networks. The mathematical models optimize two objectives: capital investment of DWCF and cost-of-energy consumptions carrying heavy battery packs. These models are formulated as bi-objective mixed integer programs. The weight sum method and genetic algorithms are developed to solve small-sized transit networks with exact solutions and sub-optimal solutions for large-scale transit networks. The modeling and solution algorithms were applied for the case study of HART transit networks.

In addition, a decision support tool was designed for transit authorities based on the research outcomes of this project, with graphic user interface and modeling and solution algorithm in the back. Coded in Python, this decision support tool allows users to vary parameters of the modeling, for example, how many routes to electrify in each stage; cost parameters of installing DWCF; charging rate of DWCF; price of electricity; and so forth. The tool allows users to obtain the optimized multiple objectives under different settings. The tool also allows users to visualize the optimized locations of DWCF on the study transit networks.

## Product Payoff Potential

The tool developed is named "Multi-stage Planning for Electrifying Transit Bus Systems with Multi-format Charging Facilities (ETBS-MPMC)". The tool provides decision support to transit authorities while electrifying bus fleet, aiming to minimize capital investment and long-term energy consumption while avoiding operation interruptions. From the perspective of transit authorities, the developed tool can help them improve their key performance indicators (e.g., ridership productivity, efficiency, quality of service, on-time performance, and finance). From the perspective of passengers, they will benefit from the continuous operations of bus services ensured by the decision support tool and enjoy the quiet and environmentally friendly service that an e-bus system will bring to them. From a socio-economic benefit perspective, different from plug-in charging stations that require large spaces, wireless charging uses existing roadways and does not require extra urban space, which is extremely desirable for cities with limited land resources.

## Product Transfer

The research team is working closely with two local transit authorities: HART and the Pinellas Suncoast Transit Authority. Representatives from both transit authorities are participating in periodical project meetings and serve on the expert review panel. The feedback and comments from the transit authorities and other stakeholders have been incorporated into the development of mathematical modeling, the solution algorithms, and the ETBS-MPMC tool. The research team will disseminate the outcomes of this research project via conference presentations and journal papers and work with the TRB IDEA program to promote the decision support tool to transit authorities.

# An Open Platform to Attract, Organize, and Coordinate Volunteers for Rural and Small Urban Transit Agencies Transit IDEA Project 97

V. Dimitra Pyrialakou
West Wirginia University, Morgantown, West Virginia

Leily Farrokhvar
California State University-Northridge, Northridge, California

## IDEA Concept and Product

One of the most critical challenges facing rural and small urban transit agencies in the United States today is the scarcity of available funds. Although volunteers can help transit agencies reduce operational costs, the barriers to volunteerism, such as difficulties attracting and coordinating volunteers and addressing liability issues, inhibit the widespread use of volunteers by transit agencies.

This project aims to provide a decision support system that transit agencies can use to organize and coordinate volunteers in providing transportation services to customers. The system under development is based on a two-sided application platform (volunteer side and transit agency side), a database that stores all task and volunteer information, and an optimization matching engine that matches tasks with volunteers. The team will develop the system, test it, and advance it to a prototype support platform for application and potential commercialization. The project will be performed in two contingent stages: Stage 1 (*define and undertake essential research studies*) and Stage 2 (*case study and decision support tool kit design*). The testing is scheduled to take place in Monongalia County, West Virginia, partnering with Mountain Line Transit Authority during Stage 2 of the project. Figure 1 presents a conceptualization of the platform.


**Figure 1**

*Platform design conceptualization.*

## Project Results

In Stage 1, the basic platform was designed. The platform design involved two distinct components: *The design of the platform interface* and *the design of the optimization engine.* Design criteria for both components were developed based on best practices and a literature review focusing on transportation volunteering programs and transportation volunteering coordination practices. Furthermore, the platform underwent initial testing using simulated data to assess the solution quality and evaluate the logical assignment of tasks based on the volunteer preferences and transit agency needs and the solution time required. Stage 2 of the work plan (estimated to begin in August 2021) involves the stakeholders' evaluation of the platform, the refinement of the platform based on stakeholders' feedback, and 6 months of beta testing and the beta testing evaluation,along with further feature refinements.

## Product Payoff Potential

The platform has the potential to help transit agencies with recruiting volunteers by providing an easy, straightforward way for volunteers to assess volunteering opportunities, sign up, schedule activities around their availability, track service hours, and, if applicable, get compensated for their efforts. In addition, because the platform will be a cloud-based web application, it is expected that the platform will facilitate an expansion of the potential demographic pool of volunteers and allow transit agencies to attract and incorporate more volunteers from younger generations.

The platform is also expected to improve the allocation of resources, facilitate cost reductions, and increase the efficiency and effectiveness of transit operations. Although current transportation volunteering is mainly focused on volunteer driving, this platform will allow the matching of volunteers with a variety of transit agency needs in addition to driving needs. This feature will allow the minimization of potential costs and help transit agencies provide more personalized services to meet the mobility needs of their customers. Furthermore, the platform will help transit agencies assign volunteers to specific shifts and coordinate them and facilitate the driving assignments for volunteer drivers. Current practices require a transit employee to communicate and coordinate with the volunteer, allocate tasks, and so forth. Therefore, using this platform will ensure the maximization of efficiency and the best allocation of resources.

## Product Transfer

This project will be a proof of concept. To ensure that this innovative platform will be used in practice, the project team will follow a four-part approach. First, the team has partnered with Mountain Line Transit Authority, a local leader in transit operations, for the development and pilot testing of this platform. Second, the team has been engaging and will continue to engage key stakeholders and interested parties throughout the project. As part of the project, the team will also collect input from key stakeholders and other interested parties in the state to evaluate and refine the platform and maximize its usefulness and ease of use, as well as the potential for widespread adoption of the platform in the state of West Virginia. Third, the team will disseminate the project results using our local network of stakeholders and through national research and practice conferences. Finally, the team will seek funding for the full development and testing of the platform (i.e., generalization and scaling of the concept product produced from this project).

# Safety Assessment of the Interaction Between Autonomous Bus Shuttle and Vulnerable Road Users Transit IDEA Project 98

Sungmoon Jung
Florida State University, Tallahassee, Florida

## IDEA Concept and Product

As the use of low-speed automated vehicles (LSAVs) continues to increase, there is a need for investigating the safety of vulnerable road users (VRUs) such as pedestrians and bicyclists. There has been a growing body of research to improve the understanding of LSAV-VRU interactions, such as detection and recognition of road user behavior or intention and proper communication methods. However, these technologies are still in their early stages, and measures must be taken to address the issues that arise from the new unsafe situations caused by vehicle or road user errors. This research aims to evaluate the LSAV operational design domain regarding pedestrians for transit agencies by using a combination of close-track tests (conducted by our industry partner), simulations, and field data analysis. The results will identify potential high-risk scenarios quantitatively and qualitatively and provide recommendations for mitigations.

## Project Results

A total of 21 tests related to pedestrians and cyclists were conducted by our industry partner, the Jacksonville Transportation Authority, and the vehicle performance and behaviors were evaluated in different scenarios (Table 1).

**Table 1**

Summary of close-track tests conducted by Jacksonville Transportation Authority.

| Number of Tests | Test Name | Test Goal |
|---|---|---|
| 12 | Pedestrian Detection | Evaluate the vehicle's performance when it encounters the stationary and moving pedestrian test for different pedestrian positions. |
| 6 | Vehicle Response to Cyclists | Evaluate the vehicle detection and maneuverability when facing cyclists at two different positions. |
| 3 | Rain Test | Ensure that the LSAV performs without a problem. |

Due to the weather conditions in Florida, the heavy rain test was also conducted to ensure that vehicles would perform without a problem. For the tested vehicles, since the autonomous sensor stacks (Perrone Robotics) and the vehicles (GreenPower Motor Company) were manufactured separately by two companies, extra procedures were required to prepare the vehicles to operate in a driverless mode. The vehicle test data was then used to improve the accuracy of our vehicle model simulation developed in PC-Crash and MATLAB software. The movement of pedestrian was modeled using the Social Force Model to obtain a more realistic behavior of pedestrian motion.

The primary field data analysis using the Federal Transit crash data has been conducted to extract contextual information regarding pedestrian-related crashes. The results indicate that the highest pedestrian fatal crashes (29% and 23% of total fatal pedestrian crashes) occur at revenue facilities and right-of-way roads. This information will be used to build the simulation scenarios and to quantify the crash and injury risk in the next phase.

To provide a better understanding of transit properties and evaluate safety, a system approach framework for a qualitative LSAV-VRU safety analysis has been developed and presented in Figure 1. The system theoretic process analysis (STPA) was used to define each component and its interactions.

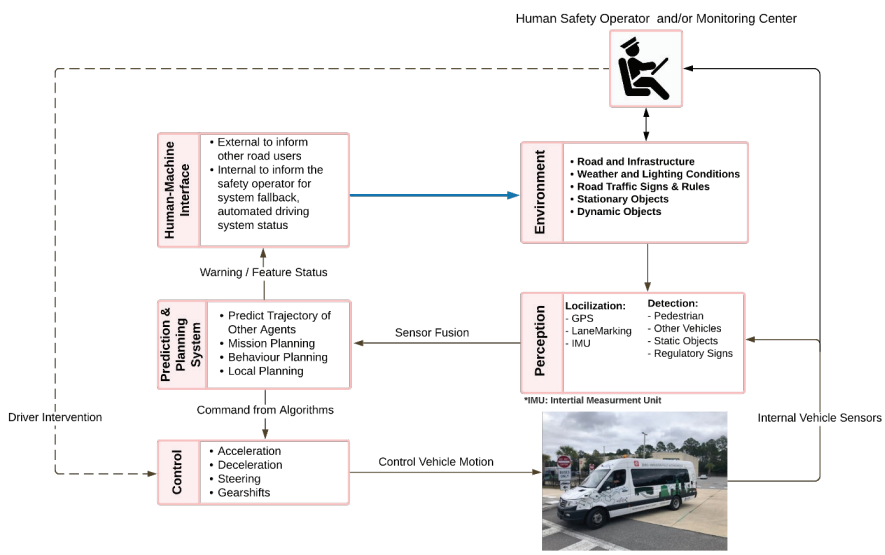



**Figure 1**

*Automated shuttle bus block diagram for safety analysis that is based on STPA.*

## Product Payoff Potential

The success of the LSAV implementation and its social acceptance highly depend on how safety issues are addressed. It is vital for transportation professionals, manufacturers, and policymakers to consider effective safety measures at different stages of development, demonstration, and deployment of this new technology. This project provides a quantitative and qualitative risk assessment of LSAV-VRU interactions and identifies proper mitigation and recommendations to support the safe operation of LSAVs.

## Product Transfer

This collaborative effort between the university and the Jacksonville Transportation Authority will explore the LSAV-VRU safety considerations through research and practical application in a controlled environment and through information sharing. In addition, given that public awareness and acceptance regarding LSAVs is a vital key for transit agencies, the results of this project can be transferred to stakeholders (e.g., manufacturers, transit agencies, and the public). Although this is a multifaceted task that requires efforts from developers, regulators, and the public, this research will provide basic information about the safety of LSAV-VRU interactions, which will inform consumers/road users to have appropriate expectations of this technology.

# Bike Love
# Transit IDEA Project 99

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## IDEA Concept and Product

Palo Alto Transportation Management Association (PATMA) is developing a first-in-the-world "Bike Love" pilot with software partner ByCycling, featuring six unique aspects:

1. PATMA will provide daily incentives for verifiable active mode first-mile commute trips to transit, up to $600 per year per commuter.
2. Geofenced location tracking will confirm bike, e-bike, e-scooter, and e-skateboard trips. Areas surrounding 32 Caltrans commuter rail stations will be geofenced to confirm first-mile trips.
3. Within 60 seconds, incentive dollars may be redeemed at local merchants via "reloadable" Apple Wallet/Google Wallet e-debit cards.
4. By restricting transaction authorization to local merchants, program funds are recycled back into the local economy, multiplying program impact.
5. A novel incentive structure featuring higher daily incentives in the first few weeks and during foul weather.
6. Persuasive marketing utilizing door-to-door, in-person outreach to 800 businesses encompassing technology, light office, government, and service workers.

Bike Love scales to other cities and major employer commute programs, increasing transit ridership at no cost to transit operators.

Bike Love addresses public transit's decades-old FIRST MILE Problem as expressed by our transit operator partner letters:

- "VTA supports active modes and recognizes the importance of bicycles as a way to extend the reach of transit. One of the greatest challenges we face as a transit operator is the low density of our suburban county and long distances to transit stops."
- "Caltrans encourages passengers to use sustainable transportation modes, including bicycling, to get to and from stations."
- "Commute.org's strategic plan includes a task to 'encourage more San Mateo County commuters to use bicycling as an alternative to driving alone for both first/last mile commutes as well as full-length commutes.'"

## Project Results

Software development is progressing toward feature-complete. Fifteen software builds have been tested, generating 43 enhancement requests and bug reports.

PATMA researched Fintech advances, meeting with Virtual Incentives, Marqeta, Brex, Mastercard, VISA, Apple Pay, Square, Toast, Clover, Blackhawk Networks, and three local merchants (Zareen's Restaurant, Coupa Cafe, and Palo Alto Bicycles). Previously, our Fintech solution was restricted to merchants using a single point-of-sale (POS) vendor, requiring negotiation with each local merchant for intrusive Application Programming Interface (API) access to the merchant's financial system. We discovered an improved technology using reloadable mobile wallet e-debit cards that eliminate merchant negotiation. PATMA has adjusted our software plan to adopt this improved technology and expects this Fintech API to become available in fall 2021.

PATMA grew our set of research partners to twenty, including the Transportation Research Board; American Public Transit Association; public transit operators (Caltrans, Valley Transportation Authority [VTA], LA Metro, City of Palo Alto, Commute.org, and Austin Capital Metro Transit); Bay Area MTC; Caltrans's secure bike storage vendors (BikeHub, E-Lock, and BikeLink); City of Menlo Park; City of Redwood City; a bike shop (Palo Alto Bicycles), regional planning advocates (Silicon Valley Leadership Group), Fintech industry leaders (Virtual Incentives, Marqeta, and Sutton Bank); Silicon Valley Bike Coalition; and ALTRANS TMA Inc.

PATMA developed an 80-second video explaining app installation, program onboarding, adding an e-debit card to the mobile wallet, automated and geofenced trip logging to collect credits, and reward redemption at a merchant's POS terminal.

## Product Payoff Potential

In the project's upcoming second phase, the aspiration is to grow active users by fifteen per month for 8 months. This will result in 120 active users at project completion, taking 2,400 Bike Love qualifying trips in the last month, generated at no cost to public transit agencies.

PATMA is committed to Bike Love and has long-term funding in place. PATMA's GIS analysis supports the potential for Bike Love to scale. 80% of PATMA's target commuters live within 3 miles of Caltrans, VTA LRT + Caltrans, El Camino Real bus, or Dumbarton Express bus. This analysis indicates the tremendous potential for mode shift to transit.

Recent local infrastructure improvements support increased bike adoption: the Peninsula Bikeway, slow streets, and two new Highway 101 bike bridges.

## Product Transfer

ByCycling's platform is built to scale to other locations, and ByCycling can also upsell its product to individual employers. PATMA expects to see first-mile and active mode incentives to expand beyond the relatively small set of U.S. incentives providers: (Atlanta's Cash for Commuters; Yolo County T.R.I.P.; Seattle Children's Hospital; the Gates Foundation; Sony; Ecology Action; Oregon Health & Science University; Stanford University Clean Air Cash (temporarily suspended); Tesla Motors; and Google). PATMA expects that one additional software vendor (GetMiles, RideAmigos with Strava, Dero Zap, Agile Mile, or Velocia) will adopt e-debit card Fintech commute rewards by the end of 2022.

Project partners have expressed interest in scaling Bike Love, such as:

- VTA will analyze Bike Love to "see if it can be replicated in other locations."
- The City of Menlo Park will analyze the "potential to scale Bike Love."

Our Austin and Los Angeles partners provide augmented potential to scale beyond the Bay Area.

Bay Area Metropolitan Transportation Commission's regional planning states, "When it comes to achieving mode shift, strategies that prioritized active transportation saw the most pronounced shifts in the regional model. Given the low cost relative to other investments studied, the benefit-cost ratio is greater than one, and the equity scores suggested that lower-income individuals received a larger share of accessibility benefits than higher-income individuals."

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