The Exploratory Advanced Research Program

EXPLORATORY ADVANCED RESEARCH

# Technological Innovations in Transportation for People with Disabilities

WORKSHOP SUMMARY REPORT • February 23, 2011

U.S. Department of Transportation
Federal Highway Administration

## Foreword

To examine technological innovations in accessible transportation and better understand the requirements of pedestrians and travelers with visual impairment or other disabilities, the Federal Highway Administration's Office of Research, Development, and Technology and, specifically, leaders from the Office of Operations Research and Development and the Exploratory Advanced Research Program, convened a 1-day workshop to explore this area. In February 2011, a panel of speakers made up of disability experts, academia professionals, transportation industry experts, and other professionals were brought together to discuss applications of technology, identify knowledge gaps and opportunities, and highlight barriers to implementation.

Through the distribution of this summary report to the workshop participants and the broader highway and disability communities, we aim to encourage further discussion regarding the development of technological applications for pedestrians and travelers with disabilities. These discussions could also lead to the identification of future research needs and opportunities to enhance the transportation accessibility for all Americans.

Michael F. Trentacoste
*Associate Administrator for Research, Development, and Technology*
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<tr><td colspan="6">16 Abstract<br>The report summarizes a workshop held February 23, 2011 to examine technological innovations in accessible transportation and better understand the requirements of pedestrians and travelers with visual impairment or other disabilities.<br><br>Part One focuses on the following presentations: Triggering a Virtuous Circle of Self-Sustaining Accessibility and Transportation; Environmental Awareness for People with Visual Impairments—Gaps, Challenges, and Opportunities; Getting There if You are Blind: Synergistic Convergence of Technologies to Improve Wayfinding; Using Robotics and Artificial Intelligence to Improve Mobility and Navigation of People with Special Needs; Opportunities and Innovations in ITS and Mobile Technology for Accessible Transportation; Making Technology Universally Accessible for all Users, Including Those with Sensory and Cognitive Impairments.<br><br>Part Two of the report summarizes the group breakout discussions.</td></tr>
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# Executive Summary

The Technological Innovations in Transportation for People With Disabilities workshop began with an introduction from U.S. Department of Transportation representatives and a brief background to the workshop. A panel of six speakers then presented on technological advancements, existing and developing tools, methods, and concepts related to vision-impaired pedestrians and other disabilities.

David Lewis, Senior Vice President at Henningson, Durham & Richardson (HDR), Inc. began the speaker presentations by highlighting the ongoing struggle to understand the relationship between public policy regarding technology, and the penetration and commercial realization of design and technology solutions that improve the lives and wellbeing of people with disabilities. Gil Lutz, Chief Pioneering Officer at Sendero Group, then provided an overview of what he regards as the most sophisticated consumer Global Positioning System (GPS) on the market. The Sendero system fills a gap in the market for accessible, talking, GPS navigation.

Following this, Bill Crandall, a scientist at Smith-Kettlewell Eye Institute, focused on overcoming barriers faced by people with visual impairments as they travel around on a day-to-day basis. Tools discussed included tactile print maps, GPS, geographic information systems, and remote infrared audible signs (RIAS). Next to speak was David Bruemmer, Vice President at 5D Robotics. He offered insight into the role of service robots in the total global robotics market. The market is expected to progress rapidly in the coming years, so it is important to find the right task allocation for robots to meet specific requirements.

Larry Head, Department Head of Systems and Industrial Engineering at the University of Arizona, then demonstrated the benefits of a connected environment, explaining the benefits offered to all road users, from emergency vehicles approaching an intersection to pedestrians waiting at a crosswalk. The final presentation came from Katharine Hunter-Zaworski of the National Center for Accessible Transportation at Oregon State University. Hunter-Zaworski presented on making technology universally accessible to all users. The urban-rural accessibility divide was highlighted, as well as many of the new technologies aimed at improving access for all, including handheld devices, video phones, and accessible information systems.

The remainder of the 1-day workshop included small breakout group discussions on four topics, all offering a foundation to be developed into something that empowers people with disabilities: Intelligent Transportation Systems (ITS), wireless technologies, and mobile computing; robotics, artificial intelligence, and object detection; navigation, wayfinding, orientation, and guidance; and universal design and accessible transportation.

Some of the issues related to ITS, wireless technologies, and mobile computing were identified as a hierarchical series of basic travel needs to be met, from the ability to receive information on a mobile device to sharing real-time transit information over a network. The proliferation of smart phones points to many future applications for such devices, although affordability and overall cost to access this technology need to be kept in mind.

Discussion of robotics, artificial intelligence, and object detection covered some of the many problems facing a visually-impaired traveler on a daily basis; from identifying departure information and purchasing a fare to boarding the correct vehicle and disembarking at the correct stop. Instead of basic close-range object detection, of greater importance is finding ways to improve overall spatial awareness and implement assistive technology while minimizing costs.

Discussion of navigation, wayfinding, orientation, and guidance highlighted the need to consider a multimodal journey when attempting to implement wayfinding technology for visually-impaired travelers. Wayfinding information by transportation facilities is inconsistent. There is an opportunity to improve access for all and offer technology to improve the confidence of travelers with disabilities.

When examining issues pertaining to universal design and accessible transportation, there is a need to remove unexpected obstacles between different jurisdictions to make getting around as seamless and barrier-free as possible. A level playing field is needed, with cross-disability support provided in multiple formats. Other topics discussed included outreach to investors to secure funding for adoption of new technology, standards for infrastructure, and compiling a detailed understanding of the transportation problems that people face.

General discussion at the end of the workshop was designed to identify a few good ideas that could be taken to the next level. To begin, it was suggested that the EAR Program develop foundation research that could eventually lead to improvements and enhancements to existing infrastructure. The importance of sharing information between interested parties was also considered key to moving forward.

There is a need to pay attention to policy, rules, and regulations. There have been many cases of a new technology that would be of great benefit to many people being held up because of regulations, so there may be a need to amend rules to ensure that there is a clear path for new assistive technologies and markets to thrive.

Finally, many new technologies could offer a different way to carry out a task, but to make a case for investors, the true benefits need to be accurately measured. Quantitative and qualitative assessments of the potential impact of a new technology on the end user should be identified. Given that travelers with disabilities have wide variation of wants and needs, the target population should be involved at all stages.

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# Introduction

Technological advancements could help to empower people with disabilities by addressing their mobility needs, but the benefits of such advancement have not yet reached this segment of the traveling public. There is a need to explore the suite of new technologies, such as wireless, dedicated short range communication (DSRC), global positioning systems (GPS), object detection, and robotics to find methods, tools, or devices that offer persons with different impairments accessible transportation to meet their individual needs.

The Federal Highway Administration's (FHWA) Office of Operations Research and Development (R&D) with the Exploratory Advanced Research (EAR) Program, intends to examine current and future advancements in Intelligent Transportation Systems (ITS) and other technologies to improve accessible transportation for people with vision impairment and other disabilities. It also aims to identify opportunities and share knowledge and experience on how different technologies could be integrated to assist people with disabilities to be more mobile and independent.

On February 23, 2011, at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, VA, the EAR Program convened a 1-day workshop on Technological Innovations in Transportation for People with Disabilities. The objectives of the workshop were to identify areas of focus where research could lead to radical new approaches in personal mobility, and assess technological viability and capabilities.

Attendees were welcomed by U.S. Department of Transportation (USDOT) representatives, who presented background information. Michael Trentacoste, Associate Administrator for Research, Development, and Technology (RD&T) at FHWA and Director of TFHRC, provided an overview of FHWA's involvement in transportation accessibility and the importance of improving highway facilities for all users. Joe Peters, Director, Office of Operations R&D at FHWA, outlined the importance of raising awareness of people with disabilities and addressing individual user requirements, and David Kuehn, EAR Program Manager at FHWA, offered insight into the application of long-term research to provide travelers with greater safety, mobility, and access.

Richard Devylder, Senior Advisor on Accessible Transportation at USDOT, presented his thoughts on technology solutions to mainstream accessible transportation and ensure that functional needs are being met. Finally, Mohammed Yousuf, Office of Operations R&D at FHWA, provided insight into the importance of technological innovations in transportation for people with disabilities and addressed the suite of new and emerging technologies now available.

The presentations that followed, by six experts in this area, covered existing and developing tools, methods, technological advancements, and concepts with potential for improving mobility and wayfinding for travelers with disabilities. Following these presentations, the participants discussed applications to wayfinding and guidance for travelers and identified gaps, opportunities, and barriers to implementation.

Part One

# Speaker Presentations

# 1. Triggering a Virtuous Circle of Self-Sustaining Accessibility and Transportation

**David Lewis,** *Senior Vice President, Henningson, Durham & Richardson (HDR), Inc.*

## Myth vs. Reality

The relationships between technology research and development and between market penetration and diffusion was the focus of this presentation. It has been a struggle to understand the relationship between public policy regarding technology and the penetration and commercial realization of design and technology solutions that improve the lives and well-being of people with disabilities. There is a small-market myth that the target population, those with disabilities, is too small to drive a market for technological innovation; however, the reality is different, and shows that markets can be triggered and become self-sustaining.

## Countering the Myth

There are two steps to countering the small-market myth. The first step is public policy "nudging" driven by a recognition of the true benefits. Markets can be very shortsighted and often neither consumers nor suppliers recognize the full value of something without a public policy nudge. The second step is using policy to encourage a sufficient amount of capital investment to trigger a self-sustaining market for accessibility. It is crucial to understand the fundamentally important role of capital in triggering self-sustaining markets.

Policy is all about creating the initial recognition. Using nutrition as an example, a regulatory shove would be to take a soda machine out and put in an orange juice dispenser; however, a public policy nudge would be to put the orange juice dispenser next to the soda machine and provide education and training to influence the choice. Before finding that self-sustaining reality, there has to be a public policy realization of what is going on. That depends on the value proposition for the technologies and instruments of change.

## Making a Business Case

User benefits are the beginning of making a business case, but understanding the use-related benefits to people with disabilities is only the beginning. There are also other benefits that can be valued, including time savings, improved safety, and improved quality of time spent. Then there are comfort and convenience benefits, including two benefits which are now being recognized and valued: reduced stigmatic harm and reduced humiliation. Use-related benefits matter and can be extended to people without disabilities as well.

To make a cost-benefit case in anticipation of what a market will value, the value of the benefits to people with disabilities must be recognized. Additionally, there are other non-use-related benefits to consider. People are willing to pay taxes for many things that are not used. An example of this is saving an endangered species in the wilderness. People are willing to pay tax dollars and higher prices for something they will not use; they pay for the option value and existence value.

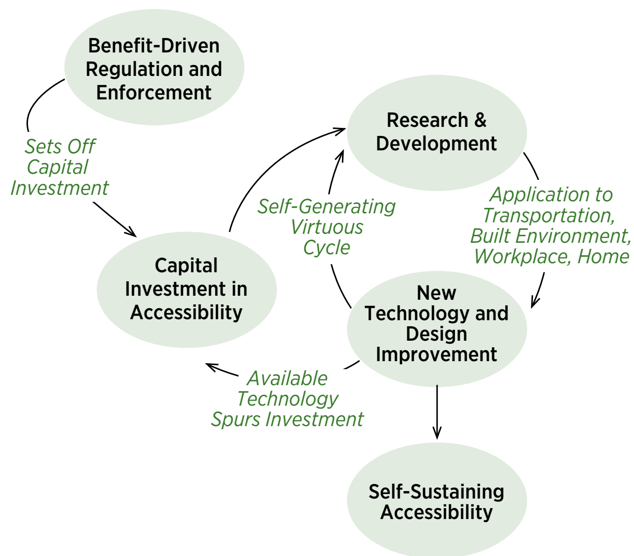
To reliably and accurately monetize the benefits, it is necessary to challenge and review using properly vetted empirical evidence, evaluations, and analytics. It is also important to engage in evaluation and analysis with real people. Checks and balances are the key, but they only work if there is a foundation of decent empirical evidence.

## Cost-Benefit Analysis

Using an example of an accessible automatic ticket machine at an airport, and looking at the user benefits of people with disabilities, in terms of time savings alone, there is a value of about $330 per 100 uses. If you include time saved, comfort, and avoided stigmatic harm of having to go up to a counter for assistance, the value goes up to over $700 per 100 uses.[1] The cost-benefit analysis from a regulator point of view cannot be justified unless you take all these other benefits into account.

## Development Process

The first step is to identify technologies and design improvements for the purpose of R&D that, on a broadly defined basis, have a value proposition that says the benefits exceed the cost. The next step, looking at the effect of capital investment in society today, is to search for things that consumers value and are willing to pay something for. One example is washing machine manufacturers, who compete on price but also quality and functionality of the product. New technology is frequently introduced and creates a demand. Technology becomes embedded, and then new technology continually emerges as part of a self-generating circle.




**A self-generating virtuous circle.**
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## Conclusions

To achieve economically sustainable accessibility, a virtuous circle of self-sustaining investment in accessible technology and design needs to be triggered. To trigger a virtuous circle, there needs to be sufficient capital investment and R&D in accessibility. To ensure sufficient capital investment, there needs to be a strong regulatory nudge. Finally, to ensure a sufficiently strong and appropriate regulatory nudge, all benefits need to be quantified—not just the obvious ones.

1 "Countering the Economic Threat to Sustainable Accessibility," David Lewis, S. Ling Suen, Daphne Federing, Institute of Transport Studies, Monash University, Australia, 2010.

# 2. Environmental Awareness for People With Visual Impairments—Gaps, Challenges, and Opportunities

**Gil Lutz,** *Chief Pioneering Officer, Sendero Group*

## GPS Assistive Technology

As original GPS navigation systems emerged onto the market, companies were not making them adaptable with screen readers or even magnification. Sendero was formed to develop an accessible talking GPS unit and offer that positioning functionality to those with impairments.

## The System

The Sendero GPS allows a visually impaired user to look up an address in the database and acquire familiarity with a new area before arrival. Sendero purchases every point of interest (POI) database available, so it is possible to look up restaurants, hotels, and many other locations using the system. Obtaining POI databases is crucial to presenting as much information as possible to users so they can clearly place their location in relation to what surrounds them. A social community built around the system encourages users to actively share routes and create their own POIs. These contributions are compiled once a month, and there are now approximately 5,000 user-generated POIs available. The maps are updated once a year, using Tele Atlas and Navtec data, and error reporting is encouraged throughout the year.

**The Sendero GPS system.**


The goal is to develop voice software similar to that seen on the IBM machine "Watson" (as featured on Jeopardy), where it would be possible to get directions from voice input alone—for many people, typing is not an option and they are unable to use Braille.

## Mapping Features

It is possible to learn and retrace a route even if away from the street system. For example, a user can be guided along a trail or across a campus once, and from then on they will have specific directions instructing them to turn left or right at a certain distance. The turning increments can even be customized as compass degrees, or a clock face, according to user preference.

## Conclusions

Although the system represents a new wayfinding frontier for many people, there are several known shortcomings at this time. For example, it does not currently feature grade or slope information. Another issue is where to cross a street—usually this is done at a stop sign or traffic light, but Sendero does not have access to a database with that information. These data are out there however, and could ultimately be converted and uploaded. Navigating roundabouts is also a challenge.

# 3. Getting There If You Are Blind: Synergistic Convergence of Technologies to Improve Wayfinding

**Bill Crandall,** *Scientist, Smith-Kettlewell Eye Institute*

## Overcoming Barriers

There are several systems designed to help overcome the barriers faced by people with visual impairments in getting around in day-to-day life. Examples include large tactile print maps, accessible GPS and geographic information systems (GIS), variable message signs, remote infrared audible signs (RIAS), real-time passenger information systems, vehicle "destination" and "next stop" signs, accessible ticket machines, and detectable warning surfaces.

One example of a barrier faced is when construction blocks a pedestrian right-of-way and forces a change of direction for a traveler—it is important to know what to do at that point and a speaking sign would aid someone with visual impairment in this situation.

## Trip Chain

During a typical trip, a person with a visual impairment faces a number of challenges. A trip can be considered a chain of activities, and any broken link in the chain can significantly delay a trip. Delays can bring about frustration and prevent a traveler from attempting the trip a second time.

When faced with an unfamiliar trip on a public transit system, the chain can be seen as the following sequence of events: travelers must arrive at the beginning of their journey and identify that they are at the correct place; they must locate a fare machine and pay; they need to find the correct location for boarding the vehicle in a station; once underway, they need to identify the correct stop; and finally they need to exit the vehicle and the transit system. Each step is made difficult for travelers with visual impairment because of a lack of accessible communication.

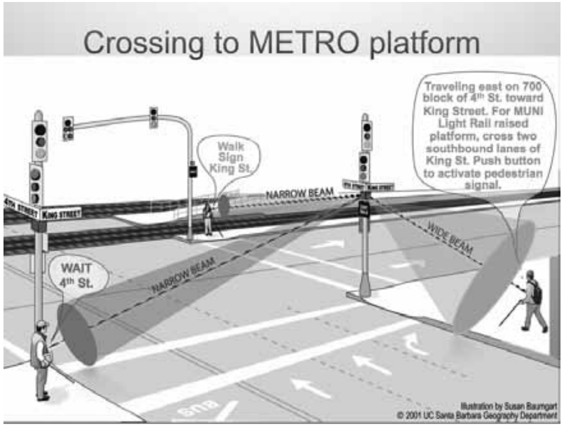



RIAS being used to locate information booth.

## Mapping Clarity

Maps are useful tools for travel planning; however, standard on-screen mapping, such as Google Maps, presents several challenges for those with impairments. For example, zooming in will increase the width of a street but it does not increase the font size.

With these limitations in mind, a selection of parameters have been identified as important to low-vision users of on-screen maps: font size, font style, color choice for text, line thickness for streets, overall color and contrast, and quality of informa-

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**Pedestrians interact with a RIAS installation.**

*Reference:* Marston, J.R. (2002). Towards an Accessible City: Empirical Measurement and Modeling of Access to Urban Opportunities for those with Vision Impairments, Using Remote Infrared Audible Signage. Dissertation, University of California, Santa Barbara (www.geog.ucsb.edu/~marstonj/DIS/OVERVIEW.html).

tion displayed. If users were offered a customization tool, they would be able to set up their page according to personal preference.

## Signs That Talk

One useful tool to aid a visually impaired person getting around is RIAS, a system that labels the environment so people who cannot read printed signs still have access to that information. A receiver on the unit converts a transmitted infrared signal into a voice message.

A user can scan the area for infrared transmitter labeling on many things, including bus stops, ticket machines, boarding areas, restrooms, elevators, and stairs. Its other functionality includes detecting and providing information on wait times, destination information, and pedestrian crossings. The directional system means that as a user walks in the direction of a particular sign, the message becomes clearer and louder—RIAS only detects the strongest signal a user is pointing towards.

An example of another RIAS application could be a person approaching an intersection: the system could provide a message about the crossing, such as whether it is a one-way street or has a diagonal crosswalk. The narrow-beam signal could also tell one pedestrian to wait, and inform another when they are in the crosswalk. RIAS can also be used for museum exhibit information, and it is in use in many applications outside the United States, including the Oslo opera house, and locations in Japan, Italy, and Canada.

## Convergent Technology

There are many other convergent technologies involved with RIAS. For example, a bus stop system installed in Italy has implemented RIAS developments with mobile communications technology and features a wireless, solar-powered connection providing bus information to travelers.

Other technologies that RIAS can interact with include smart phones, which feature many built-in useful features, such as a keyboard and touch screen. They also offer several communication options including Wi-Fi and Bluetooth. For example, with access to the wireless Web community, mobile RIAS could send a request via Bluetooth to retrieve information; a mobile phone could send that request to a server, receive a reply from the server, and then communicate that back to the handset via Bluetooth. The handset can then provide that information and receive speech input to navigate menu options.

# 4. Using Robotics and Artificial Intelligence to Improve Mobility and Navigation of People With Special Needs

**David Bruemmer,** *Vice President of Research, 5D Robotics*

## Robotics Market

Much like personal computers were once predicted to enter every home, robots are also predicted to take that same market trajectory. According to a study by the International Federation of Robotics, over 11 million personal robots will be in use around the world in the next 2 years with an estimated market value of $5 billion --predicted to reach maturity by 2020.[2] Currently robots perform poorly in many situations, so it is important to find the right task allocation for them and design better and simpler robots to meet specific requirements.

## Establishing Needs

The biggest problem to focus on, as well as the hardest, is that of shared control. Creating autonomous systems for a task such as driving is not as complex as driving in an interactive situation—people do not necessarily want to relinquish control to a machine but instead want assistive and intelligent robots. It is important to take time to establish what users want from a system; for example, a washing machine could be considered autonomous in getting a job done but it is not intelligent, in the same way that a 2-year-old child is highly intelligent but not autonomous.

In the field of artificial intelligence there is an ardent desire to create "optimal" systems, which usually drives researchers to centralized control, filtering out the issues associated with computer and human interaction as much as possible. The failings of a centralized system was a lesson learned during the Department of Defense Future Combat Systems project and is something that should be heeded when developing a transportation system.

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**5D Robotics is working with a variety of commercial vehicle manufacturers including Segway to provide an add-on kit that can transport low-cost personal transportation vehicles into intelligent helpers with assisted driving capabilities.**

## Overcoming Challenges

A lot of work is already being conducted in the area of autonomous driving. Google is already embedding technology in real cars and logging test miles in California; however, there is still a general need to emphasize local interaction and develop reactive behaviors. For example, although GPS-based systems are useful, they are not able to navigate through a crowd, whereas an intelligent system could use scanners to assess developments in the surrounding environment and present that information to a user in real time.

2 "World Robotics 2010 - Service Robots," International Federation of Robotics Statistical Department, Frankfurt, Germany, 2010.

Another challenge is that of building trust in a system. To enable that trust, it is important to understand what robotics is not able to do. Once people understand how a system can fail, they are more inclined to use it and deal with problems that arise. There is also a need to focus on the acceptance of real-time responsiveness—much like anti-lock brakes take control without people thinking about it but fail when people do think about it and release the brakes, autonomy should be assistive but not autonomous.

## Current Technology

Most current technology in use is expensive—just one Velodyne system with rotating laser imaging costs approximately $75,000. Previous research has harnessed the capabilities of Nintendo's Wii controllers for several tasks, including finding and dismantling bombs or working with radiation spills.

Moving forward, one approach to consider is the reconfiguration of existing, commercially viable technology. A common operating system that can be moved between many vehicles would allow existing technology to be augmented with an add-on kit. A system that treats the vehicle as a peripheral, with GPS, Bluetooth, communication, and computing capabilities could easily be moved between different vehicles to make them helpful to the user. The company's current Segway system serves as a test-bed for developing guarded motion and obstacle avoidance and autonomous navigation. It is able to demonstrate local area navigation and point and click navigation—all of which can support "last mile" transit for people with disabilities.

An assistive driving system could even help people with perfect eyesight. Removing the information load can improve performance because it removes the distraction. Defense research shows better results using display with limited feature information over video.[3] Whatever the level of visual impairment, having the ability to extract the world into a simple real-time display is very beneficial.

3 "The Impact of Automated Cognitive Assistants on Situational Awareness in the Brigade Combat Team," Carl E. Fischer, University of Kansas, 2010.

## Future Developments

One vision for the future is for everyone to carry a personalized intelligent system. Whenever that user interacts with transportation technology, all the customized data could be stored so that any information received is tailored to each user's requirements.

In the area of assistive technology, developments to focus on in the near term should include steering assistance, obstacle avoidance, path guidance, and personal transportation systems. Additionally, very little work is currently being undertaken to merge robotics technology with service animals.

The fundamental point is to keep things simple and avoid too many inputs and complication. The aim is to simplify system interaction, reduce inputs, and offer plug-and-play functionality with existing hardware. Offering these features will bring true value to an assistive system.

Optimal functionality will ultimately come from the correct balance between human insight, infrastructure, and reactive control. Assuming that infrastructure can accept signals and embed critical messaging into information systems, there can then be a seamless flow of information from humans to reactive system elements and back to infrastructure. Alternatively, a two-way flow of information would allow infrastructure to pass information about real-time conditions to a traveler and vice versa. Making something portable that could capture real-time data would be an interesting long-term research question.

# 5. Opportunities and Innovations in ITS and Mobile Technology for Accessible Transportation

**Larry Head,** *Department Head of Systems and Industrial Engineering, University of Arizona*

## Vehicle Communications

Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) systems refer to vehicles with onboard equipment offering positioning and computing capabilities to a traveler and the ability to interact with infrastructure.

Onboard equipment communicates with roadside equipment, and a "backhaul" network then transports this roadside data to and from a central location. The ultimate vision is to move into a completely connected vehicle environment, utilizing systems that communicate with roadside equipment using many tools, including dedicated short range communications (DSRC), 3G, 4G, Wi-Fi, and Bluetooth.

## Connected Infrastructure

The V2I system uses DSRC, a highly reliable 5.9 GHz radio, with a 1 km range, operating on an allocated bandwidth set aside by the Federal Communications Commission specifically for vehicle communication. V2I also utilizes public Map Data (MAP), a complete geometry showing where sidewalks and crosswalks are located as well as what the roadway geometry looks like and how it relates to information coming from traffic signals or other vehicles.

## Navigating Intersections

Intersections are complex systems, with crosswalks, turn lanes, signal controllers, and signal heads. Despite this complexity, they remain a relatively sterile environment in terms of available information, although, once equipped with DSRC and MAP, that information becomes much richer, and it becomes possible to build awareness of the position of equipped vehicles as they report in to the intersection.

Several recent cases have involved avoidable fatal collisions between emergency vehicles at intersections—a connected V2I system offers a safe and efficient way for a responding emergency vehicle to navigate an intersection and prevent such incidents. As an equipped vehicle approaches, it can request permission to cross, the intersection can evaluate if it can accommodate the vehicle, and then share that information with other road users so they all know about each other. A priority request can then be sent to the signal controller and the emergency vehicle can be informed if it is safe to proceed.

## Pedestrian Safety

Traveler-to-vehicle and traveler to infrastructure (T2X) communication would enable a pedestrian with a disability to enter the dialog of what's going on at an intersection using a smart phone. On arrival at an intersection, an equipped pedestrian would send a request to cross the street, which the DSRC then communicates to the traffic controller. Information about the pedestrian's status and location is then broadcast to all other travelers on the network, including approaching emergency vehicles.

Being informed about signal phase and timing and other important intersection status information would spare many people with a visual impairment the necessity of waiting two or three signal cycles to assess traffic movements and would increase their safety. The system could also transmit a message to other road users alerting vehicles to the pedestrian's exact position while flagging up a disability. In addition, the available MAP information could be used for wayfinding—for example, showing exactly where a curb is, or where the entrance to a building is.

## Traveler Requirements

Several user requirements have been identified for travelers: they want convenience, comfort, safety, and low fare cost. T2X applications could improve many of these user requirements, including transit service requests to locate a bus, or a smart device that could activate the fans on a bus during the summer. There are many other potential applications for a connected infrastructure, including safety and emergency notifications, fare collection, and parking.

## Conclusions

The current economics of integrating this technology into infrastructure make it hard to get deployed.

Next steps should include a complete systems engineering effort, the establishment of a set of requirements, and—importantly—the active participation of standards committees. Standards are hard work, especially when trying to reach the least common denominator without offending anybody.

# 6. Making Technology Universally Accessible for all Users, Including Those With Sensory and Cognitive Impairments

**Katharine Hunter-Zaworski,** *Director, National Center for Accessible Transportation, Oregon State University*

## Accessible Transportation

Accessible transportation has changed a great deal in the last 30 years. Over this period, there has been a move toward independent living and transitions from separate transit systems to fully inclusive transit systems.

## Urban–Rural Divide

There are many specific challenges associated with accessible transportation in suburban and rural communities. Increasingly high numbers of people living on the land they were born to are waking up and realizing they are unable to drive, and that leads to them having to relocate as opposed to aging in place.

A revolution in consumer electronics is leading to huge changes in public transportation and communication systems that can greatly benefit those in rural communities, and there has been a change from having all the information provided "out there" to having it arrive on handheld personal devices. For example, bus schedule information has evolved to real-time bus arrival information. This also applies to real-time emergency management information.

Wayfinding with talking signs.



## Technological Revolution

Those in rural communities can now use personal mobility devices such as Segways (Oregon was one of the first places to permit the devices on buses). Digital hearing aids and technology such as cochlear implants function better than ever before, and more and more buildings are better equipped with accessible systems. As people rely on personal devices, there has been a transition away from pay phones, and many public places—including Chicago's O'Hare Airport—are implementing video phones and relay systems in their place.

Infrastructure technology changes include improved visual paging systems, tactile pavers with special staircase delineation, accessible information systems for wheelchair users, and an increased number of common-use self-service kiosks on all modes of public transportation but there is always the ongoing issue of getting widespread deployment of accessible technologies.

Like many assistive technologies, they often evolve into something to benefit everyone; for example, a garage door opener was originally designed for a quadriplegic and curb cutouts were originally incorporated for wheelchairs—both features that everyone now benefits from.

## Assistive Technologies

Like the move from separate to integrated systems, another transformation taking place is in the area of assistive technology. Like many assistive technologies, they often evolve into something to benefit everyone; for example, a garage door opener was originally designed for a quadriplegic and curb cutouts were originally incorporated for wheelchairs—both features that everyone now benefits from.

A recent technology to offer amazing assistive benefits is the electronic book. Systems such as Kindle offer an amazing advancement in education technology and follow a long struggle to get books in an electronic format to allow text-to-speech. Students with visual impairments and learning disabilities are now gaining new educational opportunities from simple text-to-speech technology. Another area of interest is speech-to-text technology and the concept of getting real-time captioning of live speech. There has been an ongoing project to get accessible in-flight entertainment, but it is also important to get basic announcements from the flight crew to everybody onboard, particularly during an emergency situation.

## Future Direction

Although the population demographic is changing, the aging population is increasingly remaining active. With this in mind, there is a drive toward social inclusion to ensure that elderly people are engaged in the community and not socially isolated. Research indicates people age much better in this situation.

There is also an ongoing need to fully integrate real-time information and communication systems to make them accessible in a simple format to all, across multiple languages, media, and platforms. Although underlying system architecture standards for personal devices are robust in accommodating people with disabilities, the end implementation of these open-source systems into usable applications is a problem. Also, the increasing use of accessible real-time delivery across all platforms leads to the question of who is responsible for validating information accuracy to avoid getting users into trouble.

Finally, as with many new technologies, it is important to make a business case for inclusive technology. For example, when working to make accessible information available in an airport terminal, the motivation for doing so should be what happens in an emergency situation. Can staff locate passengers with disabilities? Can they communicate and get them out of the building? The other part of successful implementation is working with vendors and ensuring that they are designing for an older-brain population and are aware that multiple levels of menus are not user friendly. Ongoing development of private-public partnerships is another crucial factor; working together can ensure that technologies are accessible and innovative, and reach the end user.

Part Two
# Group Discussion

For the afternoon session of the workshop, attendees were divided into four small groups, each tasked with identifying gaps, challenges, and opportunities specific to the topic of their breakout group. Following extensive discussion, each group summarized their findings and made recommendations.

# 1. ITS, Wireless Technologies, and Mobile Computing

**Facilitator:** *Deborah Curtis, Office of Operations R&D, FHWA*
**Lead:** *Bill Curtis-Davidson, IBM Research*

## Mobility Problems

Group 1 began by looking at some of the issues and observations that specifically relate to ITS technology.

The first need to be addressed is mobility and the concept of mobile technology—smart phones and other specialized devices are the key. Getting basic transport information to these devices is a challenge but at the base of the pyramid of needs. There is also a lack of consistency between transport authorities in providing the basic information required for trip planning.

Another need identified was the ability to navigate and respond based on real-time information, including using the idea of sharing, contributing, and crowdsourcing transportation network information.

## Technological Solutions

Currently, there are many different projects in motion but not one integrated framework that can be delivered to mobile devices. Where data is provided from transit authorities to networks, many areas are being explored using mainstream computing, data mining, data analytics, and data aggregation.

The current smart phone application proliferation is something that is being embraced by many people with disabilities, and it is a safe assumption that the smart phone is a viable option to utilize in the future. Affordability is something to bear in mind, and government regulation can prevent certain types of technology from proliferating. Cost is something that will inevitably come down over time, and the devices should be sustainable in the future.

## Gaps and Challenges

Some of the challenges currently faced by those working on mobile applications include whether to focus on native applications (e.g., for iPhones) or Web-based applications that are multiplatform. Access to reliable real-time baseline data, such as which elevators are working, is also important.

Small operational strategies are another recommendation that would make a huge difference to people with accessibility needs, such as the ability to hold a bus for 5 minutes. There should also be a strategy for emergency procedures and how this technology can assist the accessibility community during emergencies. Although, when trying to mix these smaller special requests with normal travel demands, there could be an issue unless accessibility demands are given greater weight in the system.

The most important thing in planning ahead is to create open data—without that open data in 5 to 10 years, the applications will not be buildable. Open data is going to be required for total journey management across multiple modes of transport. The issue of liability was raised in relation to open data—if the wrong data are provided, who would be liable? Privacy and liability issues remain a major barrier for many, but need not be an obstacle at the research stage.

## Potential Research

Technology development could look at what is important to the accessibility community, as well as what the community can do in terms of sending information back.

Technology development could also consider how to quantify the benefits of the technology, not only to the accessibility community but to everyone. No one is going to spend millions of dollars developing technology that may help a few people, but if the benefit to all communities can be quantified through simulation, then the support will follow. Another idea is to quantify on the basis that such technology would increase the productivity of the accessibility community by allowing them to get around more, which could reduce a burden on social services, for example.

# 2. Robotics, Artificial Intelligence, and Object Detection

**Facilitator:** *Gene McHale, Office of Operations R&D, FHWA*
**Lead:** *Aaron Steinfeld, Robotics Institute, Carnegie Mellon University*

## Mobility Problems

Group 2 began by looking at some of the mobility problems faced by a traveler with a visual impairment. There is a general lack of accessible mass transit available to these travelers.

For the visually-impaired person, from first arrival at a train station, there is no way to read the train time display board—in this situation a button on a kiosk could easily tell a traveler everything they need to know. The preference is always to do these things independently and not rely on fellow travelers or station staff for information.

## Technological Solutions

Group discussion continued by looking at possible solutions to solve some of the issues faced during a trip, particularly for a traveler with a visual impairment using a white cane to get through a crowd. Possible solutions discussed included indoor positioning systems or a device that would show where to be in 20 to 30 ft (6 to 9 m). Although a cane solves the immediate navigation problem by preventing a user bumping into things, it does not address long-path planning or adherance. Increased spatial awareness would be useful for knowing if there is a sidewalk on the other side of a street, if there are temporary obstacles such as a truck loading goods across a sidewalk, or whether to avoid walking down a street that has been closed at the end for construction—something a sighted person could easily avoid.

The concept of "event horizon" was raised in relation to the point of becoming aware of an obstacle. Currently, this is the length of the cane, but there is potential to extend this horizon using information and sensory technology. This information could change dynamically to reflect a closed road or sidewalk, or anything that will affect the projected path by more than a preset distance. The event horizon could be adapted to each user's preference, and the sensitivity adjusted according to the situation—for example, if a user is jogging with a dog, it could look further ahead.

## Gaps and Challenges

Discussion continued around the problems in applying new technology solutions to improve mobility, particularly the idea of driving. The National Federation of the Blind's "Blind Driver Challenge" aims to empower blind people to drive a car independently using a nonvisual interface to convey real-time information. The challenge utilized a Ford Escape equipped with laser range finders, optical cameras, computers, and GPS to communicate to a blind driver as he drove around the Daytona International Speedway. It should be noted that this was a preset route—the next step would be for the system to turn the vehicle according to driver decision.

Technology should enhance perception, not substitute control and human decisionmaking; therefore assistive technology is considered the way to proceed. A vehicle sensor could identify a turn, bring the speed down, and detect obstacles—things that all drivers could benefit from. Vehicles can already take control if a driver is out of his or her lane or does not brake when approaching an obstacle, using the concept of "virtual walls" or "bumpers" pushing a driver back on course.

The limited "bandwidth" of humans versus robots was also discussed—without sight or sound, it becomes hard to sense lots of information rapidly. The concept of dimension reduction was put forward as a solution, where rich information is boiled down to a far simpler extraction. To keep costs down, there is a need to evaluate what sensor requirements would be good enough for blind driving, or even assisting sighted drivers in low-visibility conditions.

## Potential Research

Group 2 proceeded to discuss research that could address the existing gaps. To start, the idea of where to draw the line between a driver and an assistive system was put forward. There is also a need for cheaper and smaller sensing solutions for assistance for pedestrian or driver.

The concept of demonstrations and evaluations was discussed as an important step for gathering stakeholder acceptance—often, people will not want something until they see it in action. To start, research could include conducting simulation studies. The event horizon issue could also be investigated in simulation and an interface evaluated depending on a particular driver disability.

# 3. Navigation, Wayfinding, Orientation, and Guidance

**Facilitator:** *Jim Arnold, Office of Operations R&D, FHWA*
**Lead:** *Beezy Bentzen, Accessible Design for the Blind*

## Mobility Problems

When analyzing the wayfinding requirements for visually-impaired travelers, it is important to consider a multimodal journey, which often involves public transit.

Airports and large transportation facilities present a serious problem for wayfinding, and it is important for audible announcements to always be be displayed visually. Roundabouts also present a major safety issue to persons with visual impairment when it comes to locating the crosswalk.

## Technological Solutions

Many technological solutions put forward are aimed at a problem that a blind person may not necessarily perceive as a problem; it is important to evaluate wayfinding technologies and ensure that they address a real problem. Everyday obstacles, like potholes, are not really considered a major problem to a blind person but are something that a developer would assume needs to be addressed. Of more importance in getting around is the ability to know where there are raised or uneven sidewalks.

It is important to look at the broad picture and aim at helping the largest part of the population while meeting the functional needs of individuals. Narrative route maps are an example of something that is useful to a wide spectrum of users. Real-time information regarding transit system and signal status incorporated into a database would enable many people to plan their travel in a better way. Despite this, the high-tech solution is not always the best solution to the problem—a simple solution is often suitable. The idea of landscaping at roundabouts to guide pedestrians to the crosswalk is one example of a low-tech and simple solution.

## Gaps and Challenges

Discussion continued around the gaps and challenges in applying wayfinding technology solutions to improve mobility. The group concluded by proposing research to address gaps in wayfinding technology. One measure to use when considering research opportunities was the idea of increased confidence when traveling. Although a difficult factor to measure, it is of great importance to the community and should be paid attention to. Another measure is getting people back on track without their having to request assistance, something that is also related to confidence.

Infrastructure needs to be addressed so that someone with a visual impairment who can use an accessible transit system is able to get off a bus and proceed to cross a street safely. The basic foundation for any ongoing research should therefore be improved access and improved confidence.

# 4. Universal Design and Accessible Transportation

**Facilitator:** *Dale Thompson, Office of Operations R&D, FHWA*
**Lead:** *Mary Leary, Easter Seals Project ACTION*

## Mobility Problems

Group 4 began by addressing some of the mobility problems related to universal design and accessible transportation. When faced with mobility problems, an individual's life is impacted in many fundamental ways—they are excluded from jobs, serendipitous or unplanned routes, and leisure. Something as simple as an uneven or broken sidewalk can become a barrier.

## Technological Solutions

There are many variations of cognitive impairments. The requirement for universal design does not mean common design, but should be a multidimensional design that avoids conflicting issues between individuals and offers equal access to all. For example, standardized smart cards would help interoperability across different jurisdictions and level the playing field for everyone. There is also a need to develop technologies for cross-disability support; for example, signals that communicate information (in multiple languages) to multiple formats.

There is also a need for technology to enable effective asset management so that elevator outages or broken sidewalks can be reported and fixed—similar telemetry systems are already fitted on buses to enable preemptive maintenance. Smart phones could also be used to capture asset and service information. In addition, the Internet and social media could be harnessed to show real-time images of sidewalks, enabling people to see obstacles and determine the feasibility of a route in advance. It is also important not to always rely on high-tech solutions; there are many lower tech possibilities like ramps, signage, and signals.

Modeling and simulation tools are also needed to process some of the different scenarios that exist in a community relating to the need for universal design. Solutions should then be tested within the diversity of the disability community.

## Gaps and Challenges

The group identified many gaps and challenges in applying universal design solutions. First of all, there needs to be quality control and a way to assess information that is being gathered. Additionally, many organizations are risk averse and have different perspectives and internal cultures, so risk management and assessment should be looked at.

Consideration needs to be placed on how an individual with cognitive challenges responds to an unexpected event, such as a pothole. Individuals with cognitive impairments are usually trained for the expected but not the unexpected. It was also noted that some disabilities are well covered by transit operators but others are not—for example, people with autism spectrum disorders. There is a lot to understand and a lot of work to be done in this field—it is not just a case of training operators to understand behavioral differences.

## Potential Research

More questions need to be asked related to physical mobility, and a detailed understanding achieved of the problems people face on a daily basis.

# Next Steps

Following the breakout groups, workshop attendees returned to present the group reports and discuss future research and potential next steps. The goal was to identify, from the small group discussions, a few good ideas where research could lead to breakthrough advances.

## Research Opportunities

- Simulation opportunities—The concepts of event horizon and bounding of movement in a pathway could be coded in a simulation. It then would be possible to have volunteers interact with the simulation in a laboratory setting. Before piloting new technology on a full-scale test in the field, a few parameters in existing code could be changed, and after a few studies, there would be quantitative and qualitative assessments available. Presently, it is not possible to measure the impact of a new technology, which makes it impossible to know where an investor should place his money.
- Improving confidence—Increased confidence when traveling is important but difficult to measure. One measure could be getting people back on track without having to request assistance, which is related to confidence.
- Expanding research studies—Driver assistance technology research and studies could benefit by using drivers with disabilities. Studies often will only feature college-aged, middle-aged, and 65- to 70-year-old participants.

## Development and Deployment

Should the translation of fundamental advances in science and engineering lead to new concepts or prototypes of assistive technology, then there will be a need to respond to market issues including cost, privacy, liability, and usability.

Performance metrics are going to be something that is very important in this field moving forward. It will be critical to know if a technology has succeeded and if something is accessible. One idea could be to look at accessible transportation as a supply chain process, with the chain running from the time somebody leaves their house to when they get home. By assessing the value of each link of the chain, researchers and developers could attack problems with the biggest impact.

# Appendices

# Appendix A—Agenda

## Technological Innovations in Transportation for People with Disabilities

***Turner-Fairbank Highway Research Center, McLean, VA, February 23, 2011***

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|---|---|
| 8–8:30 a.m. | **Registration** |
| 8:30–9:15 a.m. | **Welcome**<br>Michael Trentacoste, *Associate Administrator for RD&T and Director of TFHRC* |
| | **Overview of Office of Operations R&D**<br>Joe Peters, *Director, Office of Operations R&D, FHWA* |
| | **EAR Program Overview**<br>David Kuehn, *EAR Program Manager, FHWA* |
| | **Seeking Technology Solutions to Mainstream Accessible Transportation**<br>Richard Devylder, *Senior Advisor for Accessible Transportation, U.S. Department of Transportation* |
| | **Technological Innovations in Transportation for People With Disabilities**<br>Mohammed Yousuf, *Office of Operations R&D, FHWA* |
| 9:15 a.m.–12:30 p.m. | **Speaker Presentations** |
| | **Triggering a Virtuous Circle of Self-Sustaining Accessibility and Transportation**<br>David Lewis, *Senior Vice President, Henningson, Durham & Richardson, Inc.* |
| | **Environmental Awareness for People With Visual Impairments—Gaps, Challenges, and Opportunities**<br>Gil Lutz, *Chief Pioneering Officer, Sendero Group* |
| 10:15–10:30 a.m. | **Break** |
| | **Getting There If You Are Blind: Synergistic Convergence of Technologies to Improve Wayfinding**<br>Bill Crandall, *Scientist, Smith-Kettlewell Eye Institute* |
| | **Using Robotics and Artificial Intelligence to Improve Mobility and Navigation of People With Special Needs**<br>David Bruemmer, *Vice President, Research, 5D Robotics* |
| | **Opportunities and Innovations in ITS and Mobile Technology for Accessible Transportation**<br>Larry Head, *Department Head of Systems and Industrial Engineering, University of Arizona* |
| | **Making Technology Universally Accessible for All Users, Including Those With Sensory and Cognitive Impairments**<br>Katharine Hunter-Zaworski, *Director, National Center for Accessible Transportation, Oregon State University* |

| | |
|---|---|
| 12:30–1 p.m. | **Lunch** |
| 1–3 p.m. | **Breakout Groups** |
| | **GROUP 1: ITS, Wireless Technologies, and Mobile Computing**<br>*Facilitated by Deborah Curtis, Office of Operations R&D, FHWA* |
| | **GROUP 2: Robotics, Artificial Intelligence, and Object Detection**<br>*Facilitated by Gene McHale, Office of Operations R&D, FHWA* |
| | **GROUP 3: Navigation, Wayfinding, Orientation, and Guidance**<br>*Facilitated by Jim Arnold, Office of Operations R&D, FHWA* |
| | **GROUP 4: Universal Design and Accessible Transportation**<br>*Facilitated by Dale Thompson, Office of Operations R&D, FHWA* |
| 2:45–3 p.m. | **Break** |
| 3–3:45 p.m. | **Breakout Reports** |
| 3:45–4:30 p.m. | **Future Research Discussion and Wrap-Up** |
| | **Adjournment** |

# Appendix B—Workshop Participants

**James Arnold**
*Electronic Engineer*
Office of Operations R&D, FHWA

**Bruce Bailey**
*Accessibility IT Specialist*
United States Access Board

**Billie Louise (Beezy) Bentzen**
Accessible Design for the Blind

**David Bruemmer**
*Vice President of Research*
5D Robotics

**Bill Crandall**
*Scientist*
Smith-Kettlewell Eye Insitute

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*Highway Research Engineer*
Office of Operations R&D, FHWA

**Bill Curtis-Davidson**
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IBM Research: Human Ability & Accessibility Center

**Richard Devylder**
*Senior Advisor on Accessible Transportation*
Office of the Secretary, U.S. Department of Transportation

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*Trails and Enhancements Program Manager*
FHWA

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*EAR Program Manager*
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*Senior Director*
Easter Seals Project ACTION

**Jonathan LeClere**
*Trails Specialist*
FHWA Recreational Trails Program

**David Lewis**
*National Director*
Economics and Financial Services, HDR

**Gil Lutz**
*Chief Pioneering Officer*
Sendero Group

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*Enabling Technologies Team Leader*
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Research and Innovative Technology Administration
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*Executive Director for Strategic Initiatives*
National Federation of the Blind

**Rudy Persaud**
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Office of Operations R&D, FHWA

**Joe Peters**
*Director*
Office of Operations R&D, FHWA

**Dick Schaffer**
Office of Safety Research and Development, FHWA

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*Senior Director for Government Affairs*
American Association of People with Disabilities (AAPD)

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