INTERNATIONAL SURVEY OF BEST PRACTICES IN CONNECTED VEHICLE TECHNOLOGIES

2012 UPDATE

September, 2012

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EXECUTIVE SUMMARY

The Michigan Department of Transportation (MDOT) is a national leader in connected vehicle technology and is interested in lessons learned from connected vehicle and related Intelligent Transportation Systems (ITS) efforts in other states and countries. By examining how connected vehicle technology is addressed and operated elsewhere in the world, MDOT seeks to identify and implement best practices that will allow it to further strengthen its own connected vehicle program. To help fill this knowledge gap, MDOT requested that the Center for Automotive Research (CAR) conduct an international survey of best practices and report the findings of this research to MDOT.

To accomplish this task, CAR staff conducted electronic searches for information and published material describing connected vehicle activities throughout the world. The gathered information was then analyzed for common and contrasting themes, drivers of success, types of technology tested or deployed, and so on to develop lessons learned for MDOT.

To catalog the international assets in connected vehicle technologies and achieve a better understanding of what is currently occurring with regard to testing and deployment of these systems, CAR created a database of projects and papers related to connected vehicles. The database was originally compiled in 2010 and has been updated repeatedly since then. It includes details on the organizations conducting research or deploying assets, the type(s) of technology used, nature of the work, applications, and descriptions of work. Over time, some projects have been completed, put on hold, or discontinued, while new ones have launched or old ones expanded. With this in mind, the database continues to be updated to ensure that it remains current. At the time of publication of this report (September 2012), the database contained information on 74 projects based in Asia, 110 in Europe, 132 in North America, and seven in Oceania.

This report is largely an update and expansion of previous work on domestic and international connected vehicle programs that CAR has previously conducted for MDOT. This updated report includes new information about projects and other efforts that were already underway in earlier versions of the report, as well as information about additional programs that were not covered in previous CAR reports.

This report is intended to provide MDOT with the information needed to inform Michigan connected vehicle decision-makers and to assist MDOT in its efforts to continue to be the national leader in connected vehicles.

CONCLUSIONS AND RECOMMENDATIONS

Despite the regional differences in connected vehicle programs, many overarching themes have merged that are useful to consider with respect to connected vehicle technology deployment. CAR research and analysis has identified funding strategies that have been used to support connected vehicle programs, as well as important factors that can affect the success of connected vehicle deployment. These funding strategies and other important success factors are listed below; a full description of each point can be found in the Conclusions and Recommendations section of this report.

COMMON CONNECTED VEHICLE FUNDING OPTIONS

- Require matching funds in budget allocations
- Pursue funding at a national level
- Use tolls to fund program

OTHER IMPORTANT FACTORS FOR SUCCESS OF CONNECTED VEHICLE PROGRAMS

- Form coalitions
- Create industry competition

• Develop programmatic themes and bold goals • Generate expertise • Regulate technology to make a strong business case	• Standardize global/regional architectures

I. Introduction

The Michigan Department of Transportation (MDOT) is a national leader among public agencies in the development and deployment of connected vehicle technology. MDOT, however, understands that a national deployment of connected vehicles requires coordination among states, and vehicle owners in particular will expect to be able to use their connected vehicle technology beyond their home location. As a result, MDOT requested that the Center for Automotive Research (CAR) investigate connected vehicle and connected vehicle-related activities underway outside Michigan, especially international examples of connected vehicle work, for the purpose of understanding and describing overall best practices in connected vehicles.

Previous Work

In response to a request to document national best practices, CAR had conducted electronic searches of ongoing connected vehicle and connected vehicle-related activities outside Michigan, phone interviews with connected vehicle experts outside Michigan, and met personally with informants through attendance at the January 2008 meeting of the Transportation Research Board and a brief trip to the Bay Area in California, where much of the U.S. activity outside Michigan is concentrated. These efforts resulted in contacts with numerous organizations (Wallace and Sathe Brugeman 2008). In 2011, CAR conducted an update to the previous study (Wallace et al. 2011). Additional programs in the United States were described and broader documentation of international best practices was undertaken.

To investigate and analyze the extent of connected vehicle technology assets, deployments, research projects, and the like internationally and achieve a better understanding of what testing and deployment is currently occurring, CAR created a database of projects and papers related to connected vehicles. This database, included details on the organizations conducting research, type of technology used, nature of the work, applications, and descriptions of work.

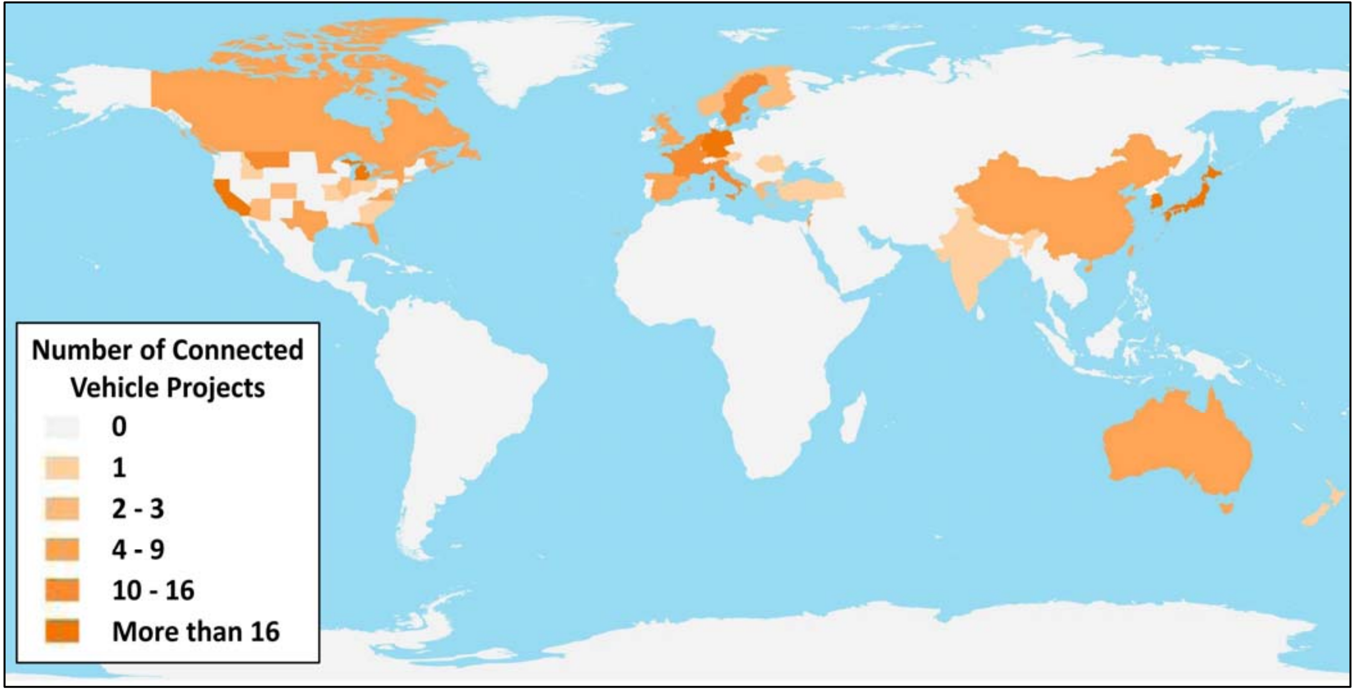


Figure 1: World Map Showing Projects by Country (State for U.S.-Based Projects)
Source: CAR 2012

2012 UPDATE

This paper is an update and expansion of all previous CAR work on international connected vehicle best practices that has been done for MDOT. This paper contains descriptions of numerous selected projects across the United States and across the world. These descriptions cover both completed and ongoing projects.

The accompanying database has been updated since it was originally created one year ago to ensure it remains current. Over the past year, some projects have been completed, put on hold, or discontinued while new ones have been created or expanded.

At the time of this paper's publication, the database has hundreds of entries. Of those projects, 78 were based in Asia, 134 in Europe, 133 in North America, and seven in Oceania. Figure 1 shows the geographical distribution of projects throughout the world.

This paper contains two appendices: Appendix A contains explanations for all abbreviations used in this paper. Appendix B contains country-by-country (and state-by-state) count of connected vehicle projects in the database.

WHAT IS NEW?

This study includes all of the coverage provided by the previous paper; however, it also contains several new projects not covered in the previous version as well as updates to several projects which were covered previously.

NEW PROJECTS

There are several new projects covered in this paper. In North America, the major new addition is coverage of the *Connected Vehicle Safety Pilot*, which includes *Connected Vehicle Driver Clinics* and *Connected Vehicle Model Deployment*. Within Asia there is a new section on *ITS Spot Service* in Japan and a new section on the *Intelligent Access Program* in Australia. In Europe there are several new projects covered; these include: *Harmonized eCall European Pilot* (HeERO), *Co-Operative Systems for Sustainable Mobility and Energy Efficiency* (COSMO), *Information and Communication Technologies (ICT) for Electro-Mobility*, and *Cooperative Mobility Systems and Services for Energy Efficiency* (eCoMove).

UPDATED PROJECTS

Several projects have been updated for this version. The European project, DRIVE C2X has been updated along with its sub-projects DITCM, sim^{TD}, SCORE@F, *Coop TS Finland*, SAFER, SISCOGA, *Test Site Italy*. There is also additional coverage on the *Connected Cruise Control* (CCC) project as well as the *Safe Road Trains for the Environment* (SARTRE) project.

ONWARDS

The remainder of this report presents CAR's findings and analysis of these findings to provide MDOT with insights into best practices. CAR's intent is to provide information needed to inform Michigan connected vehicle decision-makers and to assist MDOT in its efforts to continue to be the national leader in connected vehicles among the states. The report is organized largely by continent and country, with cross-cutting lessons provided in the Conclusions and Recommendations section.

II. Connected Vehicle Efforts in North America

In North America, the majority of connected vehicle research is conducted in the United States. A significant portion of this work has been done at the state level by state agencies and universities. The states of Michigan and California have been responsible for much of this work, but other states, such as Florida, Minnesota, Montana, New York, Texas, and Virginia, also have active research and development programs.

The approach in the United States is not totally decentralized, however, as the U.S. Department of Transportation (USDOT) has taken an active role in connected vehicle research and has providing significant funding for much of the work that has been done across the country.

The recent focus of USDOT connected vehicle research related to a National Highway Traffic Safety Administration (NHTSA) regulatory decision on connected vehicle technology. That decision, on whether to regulate connected vehicle technology in new passenger vehicles is scheduled for 2013. A similar decision for heavy-duty commercial vehicles is planned for 2014.

Figure 2 below shows the geographical distribution of projects throughout North America. Some projects are spread across several states; for mapping purposes, such projects are assigned to the state of their lead coordinator.

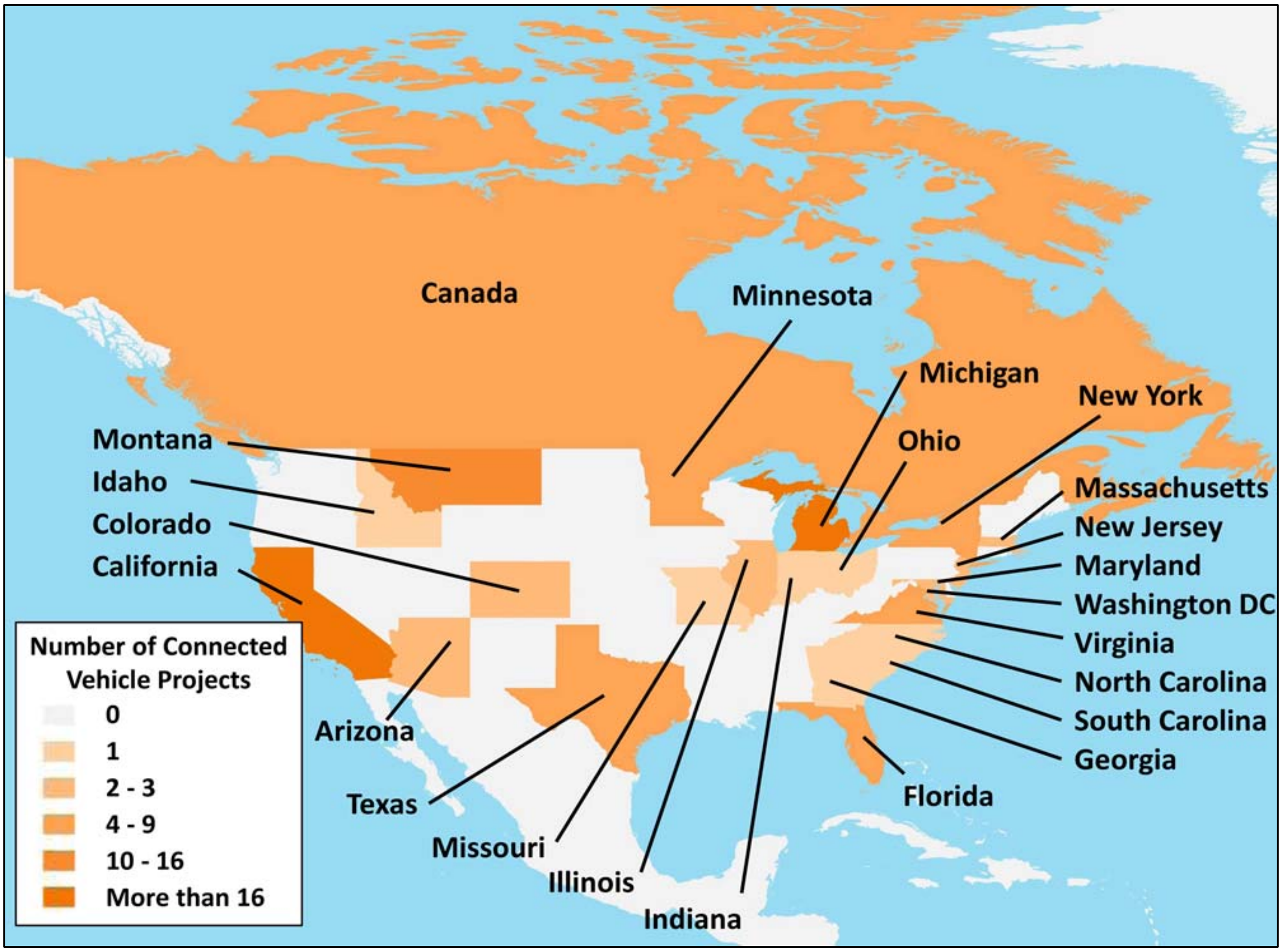


Figure 2: Connected Vehicle Projects in North America
Source: CAR 2012

U.S. NATIONAL-LEVEL PROJECTS

CONNECTED VEHICLE SAFETY PILOT

Safety Pilot Driver Clinics

Most demonstrations of connected vehicle and ITS applications have focused on proving and presenting technical capabilities to those in the transportation community. Until recently, most connected vehicle testing has been done using trained drivers and experimenters. There has been little testing that has used inexperienced drivers that were not familiar with connected vehicles before test drives. These tests have been limited to closed test populations and self-selected groups (Hill and Garrett 2011).

From August 2011 through January 2012, the Crash Avoidance Metrics Partnership (CAMP) held driver acceptance clinics with naïve drivers that were unfamiliar with connected vehicle tech-nologies. The clinics were held in six different locations across the country:

- Michigan International Speedway: Brooklyn, MI (August 2011)
- Brainerd International Raceway: Brainerd, MN (September 2011)
- Walt Disney World Speedway: Orlando, FL (October 2011)
- VTTI Smart Road: Blacksburg, VA (November 2011)
- Texas Motor Speedway: Fort Worth, TX (De-cember 2011)
- Alameda Naval Air Station: Alameda, CA (Jan-uary 2012)

Each clinic involved four days of testing, 112 drivers, and 24 vehicles equipped with connected vehicle technology. Each driver was accompanied by a tester who monitored the drivers throughout the clinic. Care was taken to get a diverse range of driver characteristics such that drivers were evenly divided between genders and spread evenly across different age categories (Ahmed-Zaid 2012). In addition, the clinics targeted different regional populations such as environmentally conscious drivers in California and pickup and sports utility vehicle drivers in Texas (Kuchinskas 2012). A total of 688 drivers participated in the clinics and shared opinions on the usefulness and effectiveness the technology (Toyota 2012).

In testing, the vehicles would broadcast information (including brake status, Global Positioning System (GPS) location, rate of acceleration, speed, and steering-wheel angle) ten times each second (Kuchinskas 2012). Each of the eight participating automakers had different systems to provide safety information to drivers; these systems used sounds, lights, displays, and seat vibrations to alert drivers of various threats. Drivers tested several scenarios that involved applications of connected vehicle technology including emergency electronic brake lights, forward collision warning, blind spot warning/lane change warning, do not pass warning, intersection movement assist, and left turn assist (Ahmed-Zaid 2012). After driving through sever-al scenarios, drivers would pull over and interviewed to find out which features seemed useful (Kuchinskas 2012).

After the driver clinic trials, each location hosted a small focus group involving 16 of the drivers that participated in the clinic. The two main points made by the participants were (Ahmed-Zaid 2012):

- When it comes to accident prevention, there is nothing better than defensive driving. Overreliance on technology is bad.
- All vehicles on the road must be equipped with connected vehicle technology for the system to work. Retrofits for older vehicles will be important.

Safety Pilot Model Deployment

After the completion of the driver acceptance clinics, the project has begun its second phase, a yearlong model deployment field test in the northwestern part of Ann Arbor, Michigan. The University of Michigan Transportation Research Institute (UMTRI) is conducting the $14.9 million test, which officially began on August 21, 2012 (Fancher 2012). The Ann Arbor tests involve 2,836 vehicles equipped with vehicle-to-vehicle (V2V) communications devices using 5.9 Gigahertz (GHz) Dedicated Short Range Communications (DSRC). DSRC gives the ability to transmit data at a rate of ten times per second (Fancher 2012). The test vehicles, which include cars, trucks, commercial vehicles, and transit vehicles, will transmit information such as location, direction, speed, and other vehicle data (Ahmed-Zaid 2012).

The 16 CAMP vehicles with integrated systems that were used in the driver acceptance testing are being reused for the safety pilot deployment. Another 48 light-duty vehicles with integrated systems are also being provided as are three Freightliner heavy-duty trucks, making a total of 67 vehicles with integrated systems for the deployment. The vehicles with integrated systems will be provided by eight automakers, including Ford, General Motors, Honda, Hyundai-Kia, Mercedes-Benz, Nissan, Toyota, and Volkswagen (Ahmed-Zaid 2012).

An additional 300 light-duty vehicles, 16 heavy-duty trucks, and 3 transit vehicles will be outfitted with retrofit and aftermarket devices, which send and receive data and are able to issue warnings to drivers (Bezzina 2012). All vehicles with integrated systems and 100 of the vehicles with aftermarket devices will also be outfitted with a data acquisition system (DAS), which will collect data on driver performance and response to warnings (Fancher 2012). The remaining 2,450 vehicles (2,200 light-duty vehicles, 50 heavy-duty trucks, 100 transit vehicles, and 100 medium-duty vehicles) will be outfitted with a vehicle awareness device (VAD), which will

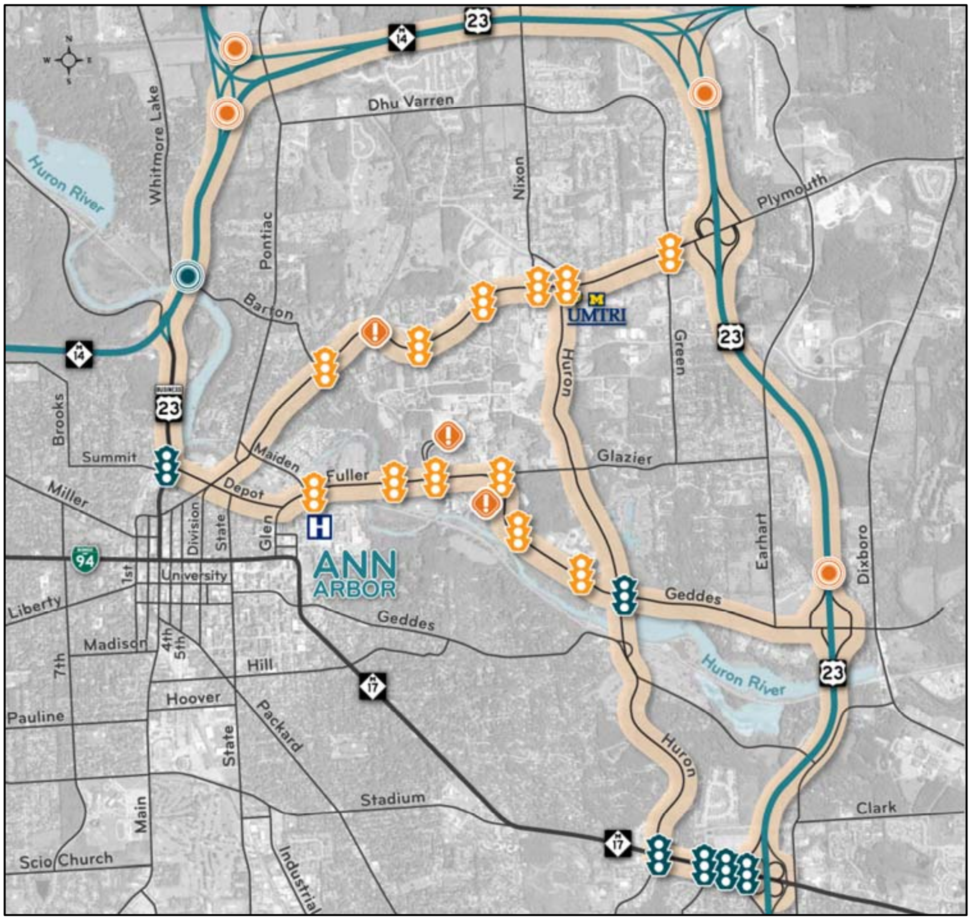


Figure 3: Layout of Ann Arbor Safety Model Deployment Roadside Infrastructure
Source: Bezzina 2012

only send data to other vehicles and will not be able to generate warnings.

The roadside infrastructure for the deployment will cover 73 lane-miles of roadway with equipment installed at 29 sites (Bezzina 2012). The layout of the infrastructure for the deployment can be seen in Figure 3. In the map, traffic light symbols designate areas where roadside equipment is co-located with traffic signals; orange symbols indicate signal phase and timing (SPAT) enabled traffic signals and blue symbols indicate roadside equipment without SPAT capabilities. Orange dot symbols indicate equipment co-located with a freeway ITS installation and the blue dot symbol indicates a prototype solar/cellular equipment installation.

As of August, UMTRI already had 3,500 local volunteers, hundreds more than are needed for the testing (Priddle 2012). The first 500 vehicles were put on the road in early August and by the end of October, the entire fleet should be in operation (Priddle 2012). This deployment is significant because it involves the long-term observation of so many vehicles in real-world driving conditions. Previous connected vehicles studies have collected data over shorter periods of time, involved fewer vehicles, and used staged scenarios rather than observing normal driving conditions (Fancher 2012). The study will analyze the system's effectiveness at reducing crashes and its results will be used to inform regulatory agency decisions concerning connected vehicle technology (Fancher 2012).

PREPASS FOR COMMERCIAL VEHICLES

PrePass is a system that can automatically identify, cross-reference, and clear commercial vehicles, allowing them to bypass weigh stations. Participating commercial vehicles can be pre-screened at designated weigh station facilities and are equipped with transponders that enable V2I communications. These pre-screened vehicles can then bypass the other weigh stations while traveling along highways, eliminating the need to pull over for additional inspections, and thus saving time, fuel, and labor costs. The program also benefits states and other drivers by reducing congestion and enabling inspection staff to focus their efforts on carriers that demand the most attention (PrePass 2012).

CALIFORNIA

CALTRANS AND PATH ACTIVITIES

The State of California is the locus of numerous connected vehicle activities, and the California efforts are rooted in a close working relationship between the California Department of Transportation (Caltrans) and the California Partners for Advanced Transit and Highways (PATH), part of the University of California - Berkeley's Institute of Transportation Studies. These two organizations are leading the way on a variety of efforts, with aide from several private-sector entities, including a handful of automotive research facilities located in Silicon Valley. The sections below elaborate on the role being played by various organizations involved with connected vehicles in California. Information in this California section is based primarily on in-person discussions with Greg Larsen (Caltrans), Jim Misener (Booz Allen Hamilton, formerly PATH), Chuhee Lee (VW NA), and Alex Busch (BMW).

A significant portion of the connected vehicle work done in California is part of the efforts of Caltrans and PATH. Caltrans manages California's freeways, provides inter-city rail services, and permits airports and heliports. Its mission is to improve mobility across California, and its goals include improving safety, mobility, delivery, stewardship, and service (CA.GOV 2010). As the state department of transportation, Caltrans is the lead state agency responsible for connected vehicle efforts in California.

PATH is a multi-disciplinary program that includes employees and students from universities throughout California working on projects in conjunction with industry, government agencies, and non-profit institutions.

The program emphasizes long-term, high-impact solutions, within the three program areas of safety, traffic operations, and modal applications and receives funding from Caltrans, the U.S. Department of Transportation, state and local governments, and private sources (ITS Berkeley 2010).

Caltrans and PATH have a tight working relationship and are engaged in many joint efforts to expedite deployment of connected vehicle assets in the state. These have included establishing a wireless test area in Richmond, California, that supports vehicle-to-infrastructure (V2I) communications and application development and testing. Originally, the intelligent intersection used Wi-Fi for in-vehicle warnings and to facilitate communication between vehicles and between vehicles and the intersection. Later an IEEE 1609 capable Multiband Configurable Networking Unit (MCNU) was installed. Figure 4 contains an overview of the field station. Caltrans also has some test sites in San Jose and Palo Alto.

In 2004, Caltrans and PATH worked with other universities and agencies to design a DSRC development in the San Francisco Bay Area. Partners included the Metropolitan Transportation Commission, Telvent Farradyne, Daimler Chrysler, Volkswagen of America, and Navteq. Currently, however, funding resources for further work with connected vehicle in California have been halted. While options to obtain federal funding are being considered, additional stakeholder support will be needed to resume connected vehicle work in California (PB 2010).

Caltrans and PATH have been working on several other fronts. For instance, they were both part of an Urban Partnership proposal that was submitted to the federal government. The funding of this proposal provided Caltrans and PATH with additional resources to expedite their connected vehicle deployment and conduct research associated with it. For the project, Caltrans and PATH partnered with the Metropolitan Transportation Commission (MTC) to implement and expand programs in the San Francisco Bay Area to relieve congestion, among these programs was a pilot which would demonstrate the capabilities and feasibility of connected vehicle technology (Mixon Hill 2009a). The total amount of federal funding for the program was $158.7 million (MTC 2007).

Another joint Caltrans and PATH project was a field test with Nokia featuring 100 vehicles that served as cellular-based traffic probes. Their field test took place February 8, 2008 and is described in more detail in the *Safe and Efficient Travel through Innovation and Partnerships in the 21st Century* (SAFE TRIP-21) section of this report. Local automotive facilities, such as the Volkswagen

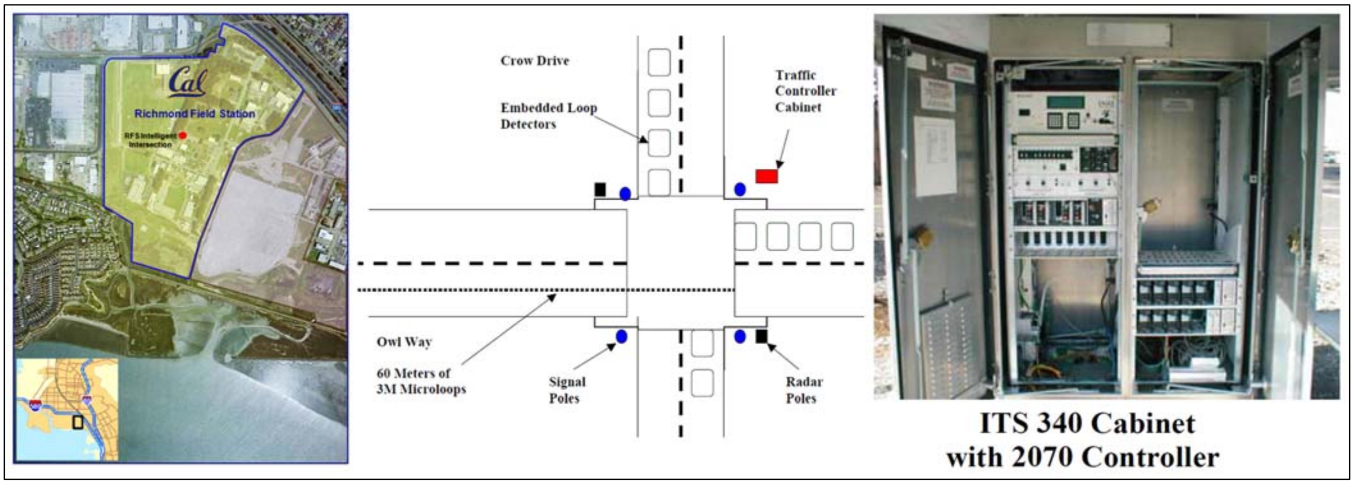


Figure 4: Richmond Field Station Intelligent Intersection Location, Layout, and Traffic Controller
Source: PATH 2008

North America research lab, also participated in this test.

Currently, PATH is conducting an ongoing project at its Richmond Field Station to investigate the potential benefits of broadcasting SPAT data. The work utilizes the *Intelligent Intersection* facility (Dickey et al. 2010), which is highlighted in Figure 4. In October of 2009, Caltrans, along with partners BMW and Siemens, demonstrated connected vehicle technology that used DSRC and SPAT information to detect vehicles and save fuel (Larsen 2010). The demonstration took place during the American Association of State Highway and Transportation Officials (AASHTO) meeting in Palm Desert, California, and showed fuel savings of up to 15 percent (Siemens 2010). Furthermore, in 2009, the USDOT awarded $8.5 million to Caltrans to expand its *Pioneer Site Demonstration and Evaluation Project* along the San Diego I-15 corridor. This project is furthering development of several mobility applications, including provisioning of multi-modal travel times and real-time incident information, among others (PATH 2010).

The USDOT also awarded $1.57 million to Caltrans in partnership with the Western Transportation Institute for the *Coordinated Speed Management in Work Zones* project. This project is designed to provide highway patrol officers with information on excessive vehicle speed and a picture of the license plate. Nearby workers can be provided with vibrating pagers to alert them when a vehicle is speeding (PATH 2010).

Looking forward, Caltrans envisions eventual deployment of connected vehicle infrastructure at every signalized intersection and every ten miles on state highways. Caltrans believes this will be privately funded, with incentives provided to attract private investment. It also recognizes that it will face some challenges in some of the extreme topographical and climatic regions of California (e.g., high mountains, extreme winter snow, deserts), especially where these exist in remote areas that lack good communication backhaul options.

Caltrans and PATH are also active at the national level, participating in ITS America, Transportation Research Board (TRB) committees, Vehicle Infrastructure Integration Consortium (VII-C) Steering Committee, and other organizations that affect the national connected vehicle effort. Eventually, Caltrans and PATH activities became recognized as part of the connected vehicle proof-of-concept tests being undertaken by the VII-C. PATH's approach for expediting connected vehicle deployment has been published, at least in part (Dong et al. 2006).

SAFE AND EFFICIENT TRAVEL THROUGH INNOVATION AND PARTNERSHIPS IN THE 21ST CENTURY (SAFE TRIP-21)

In the first half of 2008, Caltrans applied for and was awarded a USDOT grant under the auspices of SAFE TRIP-21, a connected vehicle program managed by the Volpe Center. This program was intended to build upon lessons from previous ITS proof-of-concept tests to improve safety, mobility, energy independence, and environmental stewardship. It involved testing and integrating applications into field test environments, and it also was used to develop and provide demonstrations for the 2008 ITS World Congress testing environments in New York. California was initially awarded $2.9 million from USDOT for a field test site, with the possibility of receiving additional funding if available. The total cost of the field test, which was planned in 2008 and implemented in 2009, was $12.4 million (Sengupta 2010).

In 2009, the SafeTrip-21 Initiative was awarded a research grant for an additional $943,000 from the USDOT. The partners receiving the grant included Caltrans and PATH, as well as Navteq and ParkingCarma. Using this grant, the partners developed and tested a traveler information tool. The tool combines information on real-time traffic, train and bus, and parking space availability information to enable travelers to plan more efficient trips. The tool makes use of data collected along the US-101 corridor between San Francisco and San Jose (PATH 2010).

MOBILE MILLENNIUM

Through its contacts at Navteq (owned by Nokia) and the Connected Vehicle Trade Association (CVTA), CAR understands that the Caltrans project most likely builds upon previous work that Nokia and Caltrans conducted together. Specifically, in February of 2008, they performed a test for which they gave 100 university students a Nokia phone equipped with GPS and traffic-monitoring software developed by the team. The students drove a 10-mile stretch of freeway, while the phones sent data on speed and location back to Nokia's research facilities (Mobile Millenium 2011). The original test, known as *Mobile Century* was followed up by *Mobile Millennium*, an 18-month project that was announced in November 2008. As part of SAFE TRIP-21, Caltrans will expand this fleet considerably with more test probes and possibly other connected vehicle aftermarket mobility applications. To date, the details of Caltrans's proposal have not yet been made public.

PRIVATE SECTOR ACTIVITIES

In addition to public-sector and university activities, California is also involved with private-sector connected vehicle activities. The state is home to several automotive electronics research units belonging to the major automotive manufacturers. This includes facilities operated by BMW, Daimler, and Volkswagen North America. While much smaller than, for example, the Chrysler Tech Center, these facilities are heavily focused on vehicle electronics and applications being developed by these automakers for the U.S. market. BMW, for example, is very interested in using wireless pipelines to connect BMW drivers for safety, mobility, and commercial applications. The traditional Michigan-based automakers, however, effectively have had no role in the California efforts.

ARIZONA

ARIZONA E-VII PROGRAM

Arizona is researching connected vehicle applications and strategies to support incident management and enhanced traffic control. The name of the project is *Arizona E-VII Program*, which consists of two projects under Arizona DOT: SPR-653, *Arizona VII Initiative: Proof of Concept/Operational Testing* and SPR-678, *Dynamic Routing for Incident Management*. Prototype applications for the program include traffic signal preemption and priority, ramp meter preemption, and mobile incident warning. The project started in early 2008 and a site demonstration occurred in late 2008 (Gettman 2009). Figure 5 below shows photographs of the ramp meter priori-

Figure 5: Ramp Meter Priority and Signal Preemption Field Demonstrations
Source: Gettman 2009

ty (left) and signal preemption (right) field demonstrations.

The project is divided into two phases. Phase 1 developed and tested potential incident management applications. Phase II is the testing of applications in a pilot deployment, evaluating functionality of hardware and software, the human factors, and viability applications for incident management. Phase II field deployment is subject to funding availability.

The University of Arizona (UA) and Arizona State University (ASU) are involved, with UA developing technology and software as well as field demonstration scenarios, and ASU evaluating the program's outcomes. UA is responsible for writing the research report with support from ASU (Arizona DOT 2008).

MARICOPA COUNTY ACTIVITIES

The *Next Generation of Smart Traffic Signals* project is an Exploratory Advanced Research (EAR) program project that was started by the Federal Highway Administration (FHWA) in 2007 and has been conducted by Arizona State University in Phoenix. The traffic signal system being researched in this project is called *Real-Time Hierarchical Optimized Distributed Effective System Next Generation* (RHODES$^{NG)}$. Though smart traffic signals have been used by some countries for decades, they are relatively rare in the U.S. due to their associated high infrastructure costs. These systems, however, have considerable value in that they are able to reduce travel time, delays, and stops as compared to the more common fixed-length, time-of-day traffic signals. The system is designed to continuously adapt operations based on changing conditions using data from vehicles, infrastructure sensors, and transmitters. It uses self-adaptive algorithms that integrate the position, speed, and queue data, accurately perform high-speed computations, make predictions, and continuously adjust critical parameters.

Continued development of the RHODES^{NG} system is focused on integrating connected vehicle technology components. Because these technologies are in a constant state of change and development as innovations are introduced and tested, incorporating them into the RHODES^{NG} system is a major challenge. With better information from a vehicle itself, including location, destination, speed, and acceleration, smart signal control systems could more effectively allocate signal phasing times to handle changing traffic demands. A field test of RHODES^{NG} with connected vehicle capabilities will take place at the Maricopa Proving Grounds (according to FHWA site updated May 2012, this testing is still planned). In addition to FHWA and Arizona State University, the City of Tucson and Maricopa County are involved in the testing work (FHWA 2012).

The Maricopa County's state-of-the-art field lab is known as the *SMARTDrive Multi-modal Intelligent Traffic Signal System* prototype. It consists of six traffic lights along a 2.3 mile streach of Daisy Mountain Drive in Anthem, Arizona. The earliest application that has been tested is an emergency vehicle prioritization system. The test bed has been equipped with DSRC devices, integrated WiFi-Bluetooth connections, closed-circuit television (CCTV) cameras, traffic detection software, data collection software, fiber optic systems, and communication connections to the Maricopa County Department of Transportation Traffic Management Center (Maricopa County 2012).

The Maricopa County test bed was selected, along with a Caltrans test site, to serve as a national test sites for the USDOT and Cooperative Transportation Systems Pooled Fund Study-funded *Multi-Modal Intelligent Traffic Signal System* project. The Daisy Mountain Fire District and Valley Metro buses have agreed to participate in live SMARTDrive field testing in order to simulate real traffic conditions (Maricopa County 2012).

COLORADO

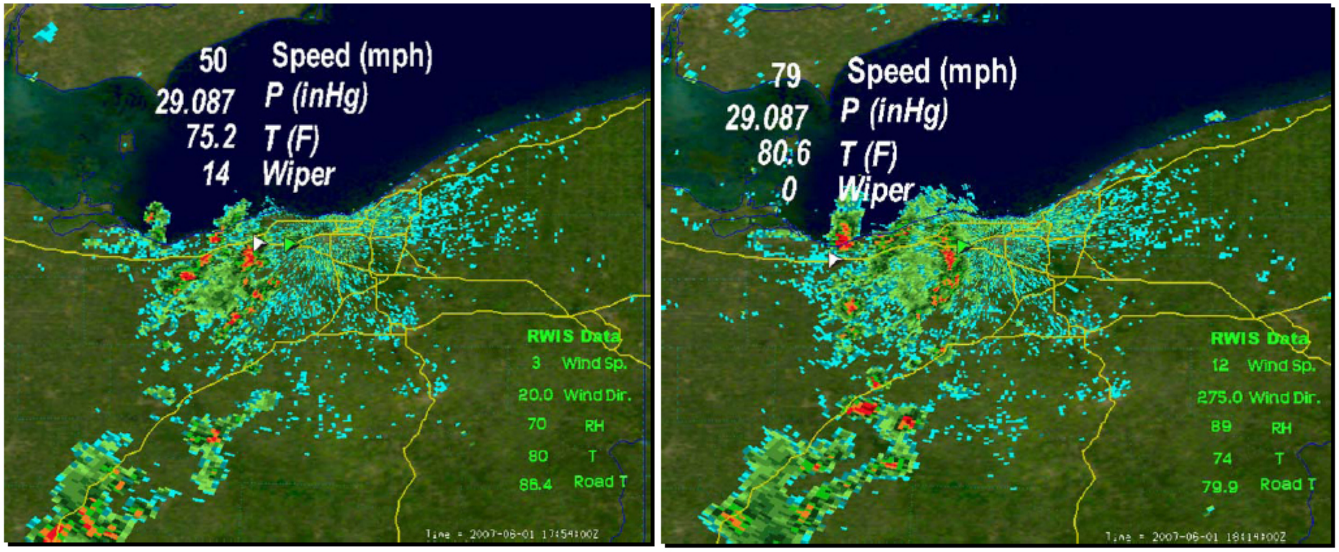
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (NCAR) ACTIVITIES

The National Center for Atmospheric Research (NCAR) in Boulder, Colorado has been conducting research on how connected vehicles can be used to document real-time weather conditions (NCAR 2011). The goal of this research and development effort is to gain a better understanding of how to effectively utilize weather-related data retrieved from connected vehicles. The projects at NCAR are applied research and involve acquiring, analyzing, and processing data from vehicles and using it to improve knowledge of current road conditions as well as forecasts of future road conditions. With improved knowledge of road conditions, warnings can be issued to drivers about hazardous conditions.

A major connected vehicle project at NCAR is the *Weather Data Translator* (WDT). The WDT is a demonstration system that can receive and analyze probe data from vehicles driving through connected vehicle test beds (Petty and Chapman 2008). The information created by the WDT can be used by the *Clarus Initiative* (an integrated surface transportation weather observing, forecasting, and data management system) or other applications (FHWA 2011). An example case of the WDT is shown in Figure 6.

DENVER TEST BED

Another example of connected vehicle work in Colorado is the Denver Test Bed, also known as the Denver E-470 test. The purpose of this test was to demonstrate multi-lane free flow (MLFF) and open road tolling (ORT) high performance tolling and enforcement. The system being used is based on Kapsch TrafficCom's 5.9 GHz DSRC technology. It was installed on three southbound lanes next to an existing toll collection system on the E-470 highway (Kapsch 2008). The installation includes 5.9 GHz DSRC roadside infrastructure and in-vehicle units as well as lane cameras with illumination units, overview cameras with external infrared (IR)-flashes and the laser units. Applications tested included toll tags and detectors, vehicle detection and classification, and automatic license plate recognition solutions. The testing was completed using a fleet of 27 vehicles and lasted for a few weeks (Mixon Hill 2009b). An independent research and development laboratory evaluated the system and concluded that 100 percent of the



1 June 2007 17:54 UTC (1:54 PM)

1 June 2007 18:14 UTC (2:45 PM)

Figure 6: Weather Data Translator Example Case
Source: Petty and Chapman 2008

over 10,500 samples that were identified using a GPS data logger were also identified using the DSRC toll tags (Kapsch 2008).

FLORIDA

FLORIDA'S TURNPIKE ENTERPRISE (FTE) ACTIVITIES

Florida's Turnpike Enterprise (FTE) presents an instructive model for one approach for operating public assets as a business. Florida's Turnpike is responsible for all operations on every Florida Department of Transportation (FDOT) owned and operated toll road and bridge. FTE is a part of FDOT, but it operates with a uniquely-defined charter. Created in 2002, the Enterprise aims to use private-sector business methods to operate in the public good. In transitioning to this new charter, FTE engaged in intense training sessions to help employees understand and accept the new mentality of operation. FTE's business model, which places more emphasis on paying customers, is feasible given that turnpikes actually have paying customers in the form of motorists paying to use the toll facilities. Florida's Turnpike Enterprise operations are 100 percent self-financed from toll revenues.

Florida's Turnpike recently installed a fiber optic backbone on its 600 miles of roadway. Additionally, FTE has installed cameras placed every mile and vehicle sensors every half mile. The video cameras help with accident detection, as well as with data augmentation through FTE's routine visual scans. The sensors use radio-frequency identification (RFID) technology and detect vehicle motion and traffic density using radar. These data are then sent to Traffic Management Centers (TMCs), which use the data both for congestion mitigation and safety applications (Suarez 2008).

Florida's Turnpike has several interesting initiatives aimed at reducing drive times, traffic congestion, and improving safety. The initiatives include Highway Advisory Radio (HAR), Citizen Band (CB) transmission systems, tolling maintenance, the SunPass prepaid tolls program, and the Rapid Incident Scene Clearance (RISC) program.

Sensor data contribute to the HAR program. The data are sent to TMCs which then transmit the data to informational signs along the road. These signs contain radio frequency information for the driver to tune into and change driving patterns as appropriate. This quickly allows the driver to receive the most updated traffic information (Suarez 2008).

The CB program is intended to assist truck and commercial drivers who frequently rely on CB radios. In practice, this program operates quite similar to how the HAR program operates: sensors send data to TMCs, and the TMCs then transmit information over CB radio frequency. The CB program also includes information about weather-related incidents, and FTE uses video cameras for fog and smoke (from wild fires) detection (Suarez 2008).

To ensure that toll station malfunctions do not cause major delays for drivers, Florida's Turnpike uses a grid system that tracks all the toll stations on a map. Additionally, the grid is able to track toll maintenance vehicles so that the TMC knows where each maintenance person is at any given time. When a toll station is not working properly, the grid indicates the problem, as well as shows where the nearest maintenance person is to fix the problem. This allows for speedy correction of toll collection problems (Suarez 2008).

The SunPass program participants pre-pay their toll fees and receive a discount of about $0.25 per mile for doing so. When they sign up for this service, they attach a transponder to the windshield of their vehicle. This transponder sends radio signals to sensors mounted on the SunPass toll lanes, which then automatically deduct the proper toll amount from the prepaid account (SunPass 2011).

The RISC program is designed to enable

emergency responders to arrive at a scene quickly and begin to clear away any crashes and associated debris. This helps to ensure that the road is once again fully operational as soon as possible (Suarez 2008).

ITS WORLD CONGRESS ROADSIDE UNIT DEPLOYMENT

Florida is becoming a leader in ITS technologies and as a result, the state hosted both the Transpo2010 Conference (Mobile Synergetics 2010) and the combined 2011 World Congress in Intelligent Transport Systems and Annual Meeting of ITS America (Florida DOT 2010). Transpo2010 was held in Ponte Vedra Beach, Florida and previewed many of the emerging technologies that would later be showcased at the ITS World Congress which was held in Orlando. Roadside infrastructure was deployed for the demonstrations that took place at the ITS World Congress in the fall. Five units were installed along John Young Parkway, 11 units were installed along I-4, and 11 units were installed along International Drive/Universal Boulevard. The installations can be seen in Figure 7.

MINNESOTA

MINNESOTA DEPARTMENT OF TRANSPORTATION (MNDOT) ACTIVITIES

The Minnesota Department of Transportation (MnDOT) has made significant headway in developing and deploying ITS systems. MnDOT's Office of Traffic, Safety and Operations manages most of the Department's ITS activities. This office is located within the central MnDOT office, but works with satellite offices in the eight regional MnDOT districts, as necessary. It also works with the University of Minnesota's ITS Institute, which has numerous programs dedicated to ITS research.

The office used to rely heavily on earmarks, matched with state funds, to finance its ITS program and achieve its goals, but it has received no new earmarks since 2004. Currently, the office is using state and federal construction funds to accomplish its mission, and it has obtained federal support for specific programs, as described in detail below (Starr 2008).

MNPASS PROGRAM

MnDOT developed an innovative program for

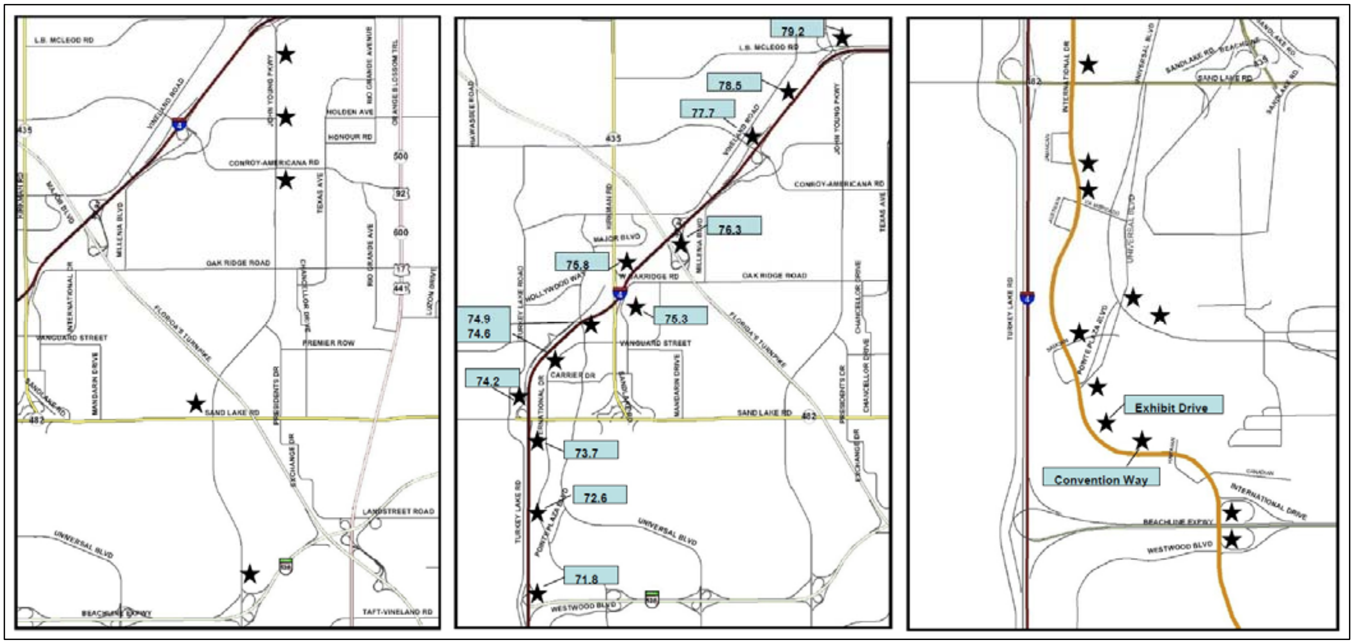


Figure 7: Roadside Unit Sites for 18th ITS World Congress Demonstrations
Source: Gilhooley 2011

using market mechanisms to allow access to faster travel lanes, without turning entire roadways into toll roads. This program, called *MnPass*, is designed to charge a fee for faster travel (less congested lanes), without the need to designate the entire road as a toll road. In the Twin Cities metro area, *MnPass* is implemented on 18 miles of high occupancy vehicle (HOV) lanes intended to reduce congestion by encouraging carpooling. However, single-occupancy vehicles also may use some of these lanes, called high occupancy toll (HOT) lanes, provided that they pay a toll to do so. Drivers wishing to use the program obtain and place a transponder in their vehicle. As a vehicle enters the HOT lane, an electronic sign indicates the price to drive in that lane at that point in time, and the appropriate fee is debited from the driver's pre-paid account. The charges vary depending on how relatively busy or free the HOV lane is, and this represents an interesting attempt to harness the power of marginal cost pricing into the freeway management system (MnDOT 2011a).

INTELLIDRIVE^{SM} FOR SAFETY, MOBILITY, AND USER FEES (ISMUF)

MnDOT's *IntelliDrive*^{SM} *for Safety, Mobility, and User Fee Project: Driver Performance and Distraction Evaluation* (ISMUF) project began in May 2011 and, as of the publication of this document, is not completed. The project used DSRC enabled aftermarket onboard equipment and roadside equipment. Specifically, the applications that were explored in the project included mileage based user fees, in-vehicle signing, curve and intersection collision warnings, and enhanced traveler information using probe vehicles. This project's goal was to evaluate the effectiveness of in-vehicle signing safety and mileage based user fee applications of VII (MnDOT 2012).

FEDERAL FUNDING FOR PROJECTS

Federal Projects are also an important part of connected vehicle programs in Minnesota. MnDOT receives directed federal funding for several initiatives that contribute to its overall efforts in ITS and connected vehicle-related areas. Indeed, the state has been quite successful (at least up until 2004) in securing such funding beyond its normal annual allocation for US DOT, and these funds have helped extend the state's ITS capabilities. Since 2004, the state has had success with some competitive programs, including the Urban Partnerships program. Federal funding, obtained through earmarks or other means, have led to ITS and connected vehicle projects.

COOPERATIVE INTERSECTION COLLISION AVOIDANCE SYSTEM (CICAS)

MnDOT, working in collaboration with the University of Minnesota's ITS Institute, has obtained funding from USDOT RITA under the *Cooperative Intersection Collision Avoidance System* (CICAS) program. Michigan is also home to CICAS activities, notably those being performed by CAMP, a consortium of automotive companies. This program focuses on installing signage at rural intersections to alert drivers as to whether or not the gaps in traffic are large enough to enable vehicles to safely cross the intersection (Starr 2008). This project builds on a previous program called *Intersection Decision Support* that was completed by the ITS Institute.

Field-testing of *CICAS Stop Sign Assist* (CICAS-SSA) began in 2010. Initial testing was staged near Cannon Falls, Minnesota (US-52 and County State Aid Highway 9) and Spooner, Wisconsin (US-53 and Wisconsin Highway 77). In June 2011, two additional tests began near the Minnesota cities of Marshall (Minnesota Highway 23 and County State Aid Highway 7) and Milaca (US-169 and County State Aid Highway 11). Testing will occur at these intersections over the course of three years (ITS Institute 2012).

MONTANA

WESTERN TRANSPORTATION INSTITUTE (WTI) ACTIVITIES

The Western Transportation Institute (WTI) was founded in 1994 by Montana State University (MSU), the Montana Department of Transportation, and the California Department of Transportation. WTI's main facility is located next to the MSU campus, where it is a department in MSU's College of Engineering. In 1998, WTI was designated as one of the USDOT RITA National University Transportation Centers (UTC), with the recognition renewed in 2005. In addition, WTI is the nation's largest UTC focused on rural transportation. While the focus of WTI is rural transportation issues, the institute also works on projects addressing urban environments and sustainability (WTI 2011).

There are eight research groups within WTI: Safety & Operations, Winter Maintenance & Effects, Road Ecology, Infrastructure Maintenance & Materials, Systems Engineering Development & Integration, Mobility & Public Transportation, Logistics & Freight Management, and Transportation Planning & Economics. In its work, WTI often partners with MSU faculty, other universities, transportation agencies, and private sector partners. Besides its research labs on MSU's campus, WTI has other offices in Alberta, Washington, and Montana.

All of the connected vehicle projects that were documented in Montana were connected to WTI, either as the sole research institution for the project or as a research partner. These projects were generally scoped as rural projects, or had obvious applications for rural areas. The national connected vehicle (formerly VII or *IntelliDrive*) initiative, mobile ad hoc networks, dissemination of traveler information, ant colony optimization (an artificial intelligence algorithm that mimics the behavior of ants searching for food, used in this case for selecting the optimal placement of communications infrastructure), and animal-vehicle crashes (mitigation and road kill documentation) were among the topics covered in WTI projects (WTI 2011).

NEW YORK

NEW YORK WORLD CONGRESS VII TEST BED

The New York World Congress VII Test Bed was created for the 2008 World Congress in New York City. There were 23 5.9 GHz locations placed along I-495. Eight of these are integrated with traffic signals. The connected vehicle applications that were used during the 2008 World Congress included travel time information, DMS messages, emissions calculations, intersection safety, transit priority, multimodal information, connected vehicle probe data, work zone safety warning, warning sign enhancement, curve warning, commercial vehicle routing information, and vehicle restrictions. On top of the DSRC roadside units that were already in place, an additional 13 DSRC units were deployed along NYS Thruway I-87; installation occurred in 2011. By April 2011, two DSRC units were installed along I-90 at Schodack commercial vehicle integrated screening site (*Intellidrive*USA 2010a).

COMMERCIAL VEHICLE INFRASTRUCTURE INTEGRATION (CVII)

The *Commercial Vehicle Infrastructure Integration* (CVII) program was created to demonstrate connected vehicle applications for commercial vehicles in the New York City region. The CVII program was created to develop, test and demonstrate commercial vehicle based data communication with 5.9 GHz DSRC roadside and on-board equipment and software. Test corridors include 13 miles along the I-87 Spring Valley Corridor and 42 miles along the I-495 Long Island Expressway. The project has received $1.05 million in funding from the I-95 Corridor Coalition with an additional $400,000 available. The team doing the work is led by Volvo Technology of America, and partners include

Kapsch, Booz Allen, Cambridge Systematics, Southwest Research Institute, and Fitzgerald & Halliday. Phase 1 of the program began in May 2009 and finished in May 2011. Phase 2 includes testing heavy-duty to light-duty vehicle driver safety warnings and grade crossing driver warnings. A Phase 3 has been proposed for funding and will focus on real time routing with driver warnings (I-95 Corridor Coalition 2011).

TENNESSEE

OAK RIDGE NATIONAL LABORATORY (ORNL) ACTIVITIES

Oak Ridge National Laboratory (ORNL) in Tennessee is involved in transportation-related activities largely through its involvement in the National Transportation Research Center (NTRC), which is staffed by both ORNL and University of Tennessee researchers. NTRC studies a wide array of transportation system concerns, including fuels and emissions, geographic information systems, heavy-vehicle safety, electronics, logistics, materials, structures, and systems analysis. NTRC also is home to the National Transportation Research Center, Inc. (NTRCI), a nonprofit organization that houses a federally funded UTC and the Heavy Vehicle Research Center. In addition to the two partners involved in NTRC, NTRCI also includes Battelle Memorial Labs and the economic development wing of Knox County as partners.

Given its connections with both NTRC and NTRCI, ORNL has a particular interest in connected vehicle technologies for heavy trucks (commercial vehicles). The NTRCI UTC funds primarily truck-related research projects at a level of about $750,000 per year, and it has an interest in connected vehicle technology as an approach for enhancing truck safety. Connected vehicles, however, are not the sole, or even primary, focus of

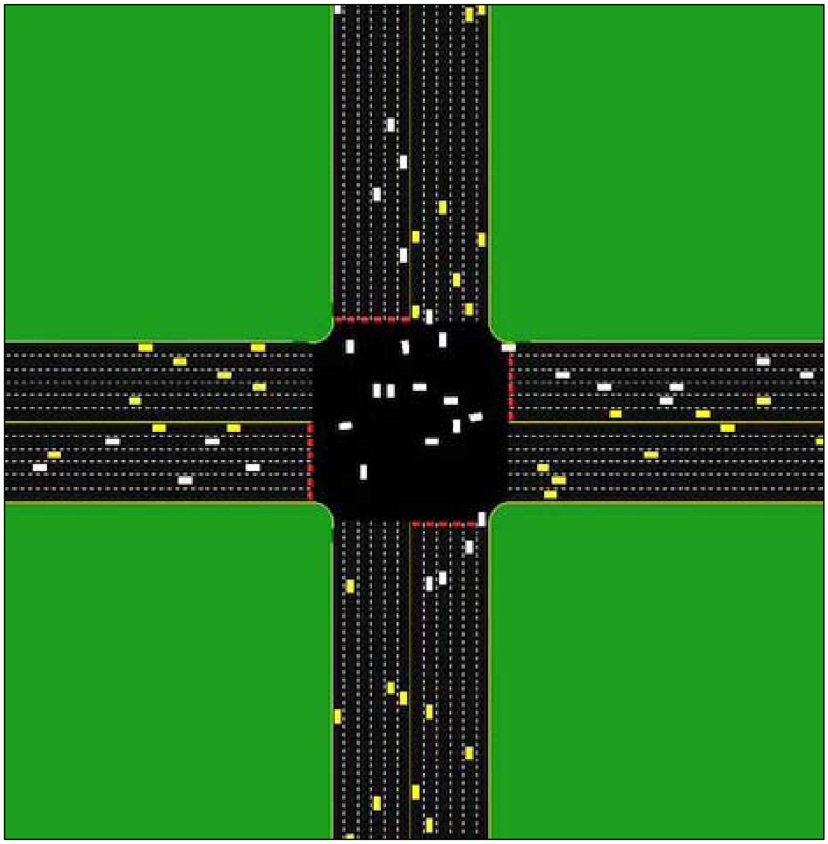


Figure 8: Image of Custom Simulator for Autonomous Intersection Management Project
Source: Unnikrishnan 2009

research within this UTC. Given its rural surroundings (not counting Knoxville proper), ORNL also is concerned about rural transportation issues, including concerns about difficulties in rural DSRC deployment. Thus, it has looked at cellular technology for traffic probe data collection as an alternative DSRC or other system dependent on roadside infrastructure (Knee et al. 2003).

While DSRC may not be the focus of ORNL's connected vehicle work, ORNL researchers associated with the NTRC have obtained and tested a number of Technocom DSRC units on heavy trucks. This activity has resulted in some basic familiarity with how DSRC works and in a small number of applications field tested.

TEXAS

AUTONOMOUS INTERSECTION MANAGEMENT

One project in Texas that is related to connected vehicles and autonomous vehicles is titled *Autonomous Intersection Management*. The project, which is conducted at the University of Texas at Austin, investigates how intersection control mechanisms can use autonomous vehicles in order to improve both safety and efficiency. The research uses the concept of "space-time reservation" to direct autonomous vehicles through intersections (Unnikrishnan 2009). By using V2I communications capabilities, vehicles can request time slots for using intersections. By using this reservation system, automated vehicles can use the intersection without colliding with each other. The research involved simulation as well as the use of actual robots and ultimately a full size vehicle. An image of the simulator interface can be seen in Figure 8. The project has led to numerous publications in the form of workshop papers, technical reports, and journal articles (AIM 2011).

VIRGINIA

VIRGINIA TECH TRANSPORTATION INSTITUTE (VTTI) ACTIVITIES

The Virginia Tech Transportation Institute (VTTI) is a research organization whose primary goal is to develop the tools and technologies to solve transportation safety and mobility issues. VTTI includes several different centers within its realm, and each has a specific focus within the transportation sector. As lessons on best practices in VII and VII-related areas, two of these centers are relevant:

Virginia Smart Road

The *Virginia Smart Road* is a full-scale closed test-bed research facility that is managed by VTTI but owned and maintained by Virginia Department of Transportation (VDOT). The *Smart Road* is a 2.2 mile two-lane road that will eventually be made part of the public transportation system surrounding Blacksburg, Virginia (VTTI 2011a). The *Smart Road* offers many different simulations and services for interested parties to test their equipment. Examples of these services include (VTTI 2011a):

- Weather-making capabilities: Researchers can make rain, snow, wind, and ice
- Variable lighting test-bed: Can reproduce 95 percent of all lighting situations a driver may encounter on U.S. roads
- Pavement markings
- On-site data acquisition system
- Road weather information systems
- Differential GPS system
- Road access and surveillance
- Signalized intersection: A reconfigurable intersection that consists of two high-speed and two low-speed approaches. It is also equipped with customized controllers, vehicle presence sensors, and wireless communications.

In addition to the services listed above, the *Smart Road* features four hundred electronic sensors buried in the pavement that can determine the weight and speed of vehicles, as well as the stress on the pavement. The road is equipped with an advanced communication system including a wireless local area network (LAN) that works with a fiber optic backbone. The network interfaces with several on-site data acquisition systems and road feature controls, and also has the ability to transfer data between the vehicle, research building, and infrastructure within the road (VTTI 2011a). The *Smart Road* has many applications for companies and organizations interested in testing and evaluating various items.

Center for Vehicle-Infrastructure Safety

The focus of the Center for Vehicle-Infrastructure Safety at VTTI is cooperative safety systems, intersection collision avoidance, roadway delineation, and roadway and vehicle lighting (VTTI 2011b). Two different research groups, the Cooperative Safety Systems (CSS) group and the Lighting and Infrastructure Technology (LIT) group, help the center achieve its goal of providing solutions to real-world issues. The CSS group focuses on algorithms, warning methods, and driver behavior associated with cooperative safety systems at traffic signal and stop-controlled intersections (VTTI 2011b). The LIT group investigates how different lighting techniques and applications affect driver safety. It also studies road-user safety in adverse weather conditions. Current center work includes the CICAS for Violations (CICAS-V) program, which aims to reduce and prevent vehicle crashes at intersections by providing warnings to violating drivers (VTTI 2011b). This work has resulted in a number of papers related to intersection violation warning systems and intersection decision support systems (Neale et al. 2006 and Neale et al. 2007).

UNIVERSITY OF VIRGINIA CENTER FOR TRANSPORTATION STUDIES ACTIVITIES

The University of Virginia is also actively involved in researching connected vehicle technologies through their Center for Transportation Studies. Among the research are several connected vehicle projects.

One project that concluded in 2007 was *Real-Time Accident Management across Multiple Agencies Using Ad-Hoc Wireless Networks*. The project proposes a system of ad-hoc wireless networks which will create real-time accident information sharing between the vehicles involved in an accident, rescue squads, a crash evaluation system, the Virginia Department of Transportation, hospitals, police, and other parties. The system is initiated when a vehicle crashes, automatically triggering the emission of accelerometer data wirelessly to the remote vehicle crash model facility. There, vehicle models interpret the data and determine the severity of the accident and likely injuries, sending the data to VDOT, rescue squads, and hospitals, which then use the information to determine an appropriate response. This information can be used not only to improve response time for first responders, but can also be used by VDOT to manage traffic (through variable message signs, signal timing, reversible lanes, etc.), reducing congestion and further improving accident response time (Kripalani and Scherer 2007).

Another project conducted by the Center for Transportation Studies that was completed in 2009 was the *Research Foundation to Support Cooperative Infrastructure/Vehicle Surface Transportation Control/Management*. This project's key objectives were to develop an integrated modeling environment that allows existing component models to emulate a cooperative infrastructure/vehicle control/management system, create and explore cooperative control strategies, and evaluate tradeoffs relating to transportation system performance measures (Smith 2009).

A recently finished project, *Advanced Freeway Merge Assistance: Harnessing the Potential of IntelliDrive*, attempted to develop a connected vehicle simulation environment that is capable of replicating vehicular movements, incorporating wireless communications (Wireless Access in Vehicular Environments (WAVE)/DSRC standards) and simulate message sets (Society of Automotive Engineers (SAE) J2735 standard) (Smith and Park 2011). Additional simulations could be conducted in further research. Success in simulation testing could result in prototype testing on a closed course. Course testing would be used to identify technical questions, assess human factors, and support technology transfer (FHWA 2011). The study began in October 2009 and ended in June 2012. The project was funded by the FHWA EAR program with a budget of $500,000 (Ferlis 2012).

Several projects at the University of Virginia have been part of the *Cooperative Transportation Systems Pooled Fund Study*. The study was created by a group of transportation agencies. Besides Virginia DOT, the participating agencies are FHWA, and the departments of transportation in California, Florida, Michigan, New York, Texas, and Washington. Virginia DOT is the lead agency, with the University of Virginia Center for Transportation Studies serving as technical leadership provider (Center for Transportation Studies 2011). The current pooled study project is entitled *Multi-Modal Intelligent Traffic Signal System: Development of Concept of Operations, System Requirements, System Design and a Test Plan*. Previously completed projects under the Cooperative Transportation Systems Pooled Fund Study include *Certification Program for Cooperative Transportation Systems: Preparing to Develop a Standards Compliance and Interoperability Certification Program for Cooperative Transportation Systems Hardware and Software*, *IntelliDrive Traffic Signal Control Algorithms*, *Investigation of Pavement Maintenance Support Applications of IntelliDrive*, and *Investigating the Potential Benefits of Broadcasted Signal Phase and Timing Data under IntelliDrive* (Center for Transportation Studies 2012).

CANADA

ITS FOR RAPID BUS SERVICE

While the majority of connected vehicle work in North America has been done in the United States, Canada is also working on its own research. The *Intelligent Transportation Systems in 98 B-Line Rapid Bus Service: Advanced Technology at Work* project improves bus efficiency. The 98 B-Line is 16 kilometers long with as many as 24 buses in operation at the same time. Busses stop every 5 to 6 minutes in peak periods and every 15 minutes in the evening. Among the measures taken to increase transit efficiency, traffic signals have been installed that give priority to B-Line buses when they are behind schedule. Most of the signalized intersections (87 percent) along the 98 B-Line can give priority to buses by minimizing the need to stop or the duration of red signals. An on-board computer sends a signal using bus-mounted transponders to request priority from roadside traffic signal controllers (Kitasaka 2011).

The ITS system for the buses uses automatic vehicle location and schedule adherence monitoring which is enabled by a differential global positioning system and the on-board computer that has schedule information and can process GPS data. Bus operators can view their real-time schedule adherence on a mobile data terminal. The terminal also supports two-way messaging between buses and the control center. The system allows transit controllers to identify and respond to traffic conditions and operational needs by communicating with drivers.

Real-time information on bus arrivals is displayed on buses and at stations through dynamic message signs and speakers that announce the station being approached. The station information is determined using information from the GPS unit. Dynamic message signs installed at stations, such as the one shown in Figure 9, display arrival times for the next B-Line buses approaching the station, based on real-time vehicle positions and speeds. Such applications are becoming common for bus systems. For instance in Ireland, Dublin's *Automatic Vehicle Location System* and in Michigan, the University of Michigan's *Magic Bus* provide real-time bus location data and estimated arrival times to passengers (NTA 2011 and University of Michigan 2011).

COMMERCIAL VEHICLE BORDER WAIT TIME PROJECT

Transport Canada is working to build a smarter border by conducting a major border wait time project in Ontario called the *Commercial Vehicle Border Wait Time Project*. The project is a collaboration of Transport Canada and trucking associations. The goal of the project is to estimate commercial border crossing times by gathering data from trucks at five border crossing locations along the Ontario border. As of June 2008, the project had gathered over 250,000 observations. These observations can be used to improve traffic management and border efficiency (Shallow 2008).

- At the Ontario border crossings, Bluetooth readers have been deployed. These readers can read and record digital signals from a distance of a ten meters. The data that they acquire can then be sent over the Internet. The readers can get signal information from all Bluetooth-enabled cell phones, hands-free headsets, and car in-dash units, which continuously emit a signal when turned on. This means that every Bluetooth device that passes a reader will create a data entry with a time stamp and unique identifier specific to that device. A series of Bluetooth readers could be used to measure queue and crossing times for border traffic (Sabean and Jones 2008).

Figure 9: Real-time Passenger Information Display at Bus Terminals
Source: Kitasaka 2011

III. CONNECTED VEHICLE EFFORTS IN ASIA AND OCEANIA

In Asia and Oceania, the majority of connected vehicle research and infrastructure deployment is conducted in Japan. A significant portion of the work has been done at the national level. Once nationally funded infrastructure has been deployed, industry partners have tested and released technologies that can interact with the infrastructure. Companies that have gained experience in connected vehicle technologies (mostly in Japan, but also in Taiwan and Australia) have applied their knowledge to aiding research and deployment efforts in other countries as well.

Figure 10 shows the geographical distribution of projects throughout Asia and Oceania.

JAPAN

HISTORY OF ITS IN JAPAN

Japan has a long history of ITS and connected vehicle technology. Early research and development on Japanese ITS systems included work on the *Comprehensive Automobile Traffic Control System* (CACS) which began in 1973, the *Road Automobile Com-*

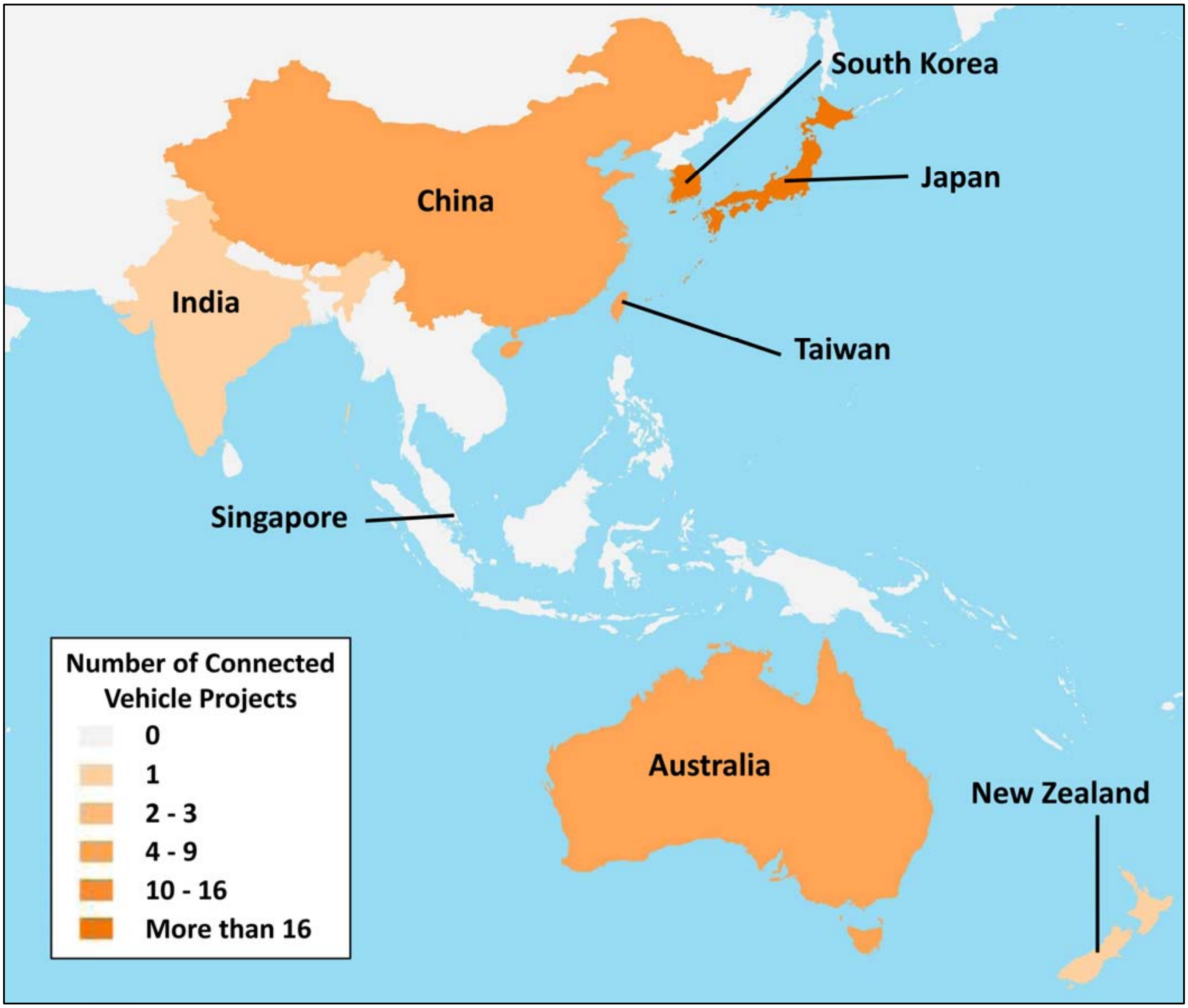


Figure 10: Connected Vehicle Projects in Asia and Oceania

Source: CAR 2012

munication System (RACS) which began in 1984, the *Advanced Mobile Traffic Information and Communication System* (AMTICS) which began in 1989, and the *Advanced Safety Vehicle* (ASV) which began in 1991 (MLIT 2007).

Vehicle Information and Communication System (VICS)

These projects led to the development of the *Vehicle Information and Communication System* (VICS). Three government agencies (Ministry of Construction, National Police Agency, and the former Ministry of Post and Telecommunications) began collaborating on VICS in 1990, and in 1991, began working with industry. In 1996, VICS service began. VICS delivers traffic and travel information such as traffic congestion data, data on availability of service and parking areas, and information on road construction and traffic collisions to drivers. It can be transmitted using: infrared, microwaves (on industrial, scientific and medical (ISM) radio band, 2.4 GHz), or FM. VICS can be displayed as simple text data, simple diagrams, or maps on navigation units (VICS 2011).

ITS Japan

The Vehicle, Road and Traffic Intelligence Society (VERTIS) was formed in 1994 and brought together government entities, university experts, industry, and associations. In 1996, the overall framework for ITS in Japan was created. VERTIS became ITS Japan in 2001 and also in that year, the IT Strategic Headquarters was formed as part of the government of Japan's Cabinet (Cabinet Secretariat 2011). The purpose of this headquarters is to help Japan keep pace with the telecommunication technology and to promote advanced information and telecommunications networks.

Electronic Tolling

Electronic toll collection (ETC) service in Japan began in 2001. The toll service uses a 5.8 GHz antenna to manage transactions. As of 2011, 90 percent of all toll transactions were conducted using ETC. On board equipment originally cost around US$400 when the service began, but as of 2008, the cost was around US$150. Some models of Japanese cars come with the on-board unit (OBU) for ETC already installed. Over 40 million toll transponders are in use in Japan (up from 24 million in 2008) and there are around 5.6 million toll transactions per day. Japan uses one standard electronic toll system for the whole country so one transponder and payment card can be used on any toll network in the country (Ogata 2008). In addition, almost all Japanese highways are toll roads, making this system rather ubiquitous (Fukushima 2011).

Japan's ITS Plan

In January of 2006, the IT Strategic Headquarters developed a document entitled the *New IT Reform Strategy*, which outlines the overall IT plan. This plan discusses collaboration between the public and private sectors to "realize advanced ITS that can integrate pedestrians, roads, and vehicles and lead Japan into the world's safest road traffic society." The goals of this plan are to reduce traffic fatalities and serious injuries by deploying *Driving Safety Support Systems* (DSSS) and to reduce the time between when an accident occurs and when the person is admitted to a medical facility.

ITS SPOT SERVICE

In March 2011, Japan began a nationwide *ITS Spot Service*. ITS Spots are roadside units that can transmit and receive messages. So far 1,600 Spot units have been installed across the country (Japan 2012). These Spots can be used to inform drivers of road obstacles, weather events, or other hazardous conditions. Figure 11 depicts the *Spot Service* infrastructure unit (1) and in-vehicle unit (2).

In one case where this technology has been deployed near a curve on a major expressway running through Tokyo, accidents have been reduced by 60 percent. Another example of the usefulness of *Spot Service* occurred after the earthquake that hit Japan in March 2011. Using data from the *Spot Service*, ITS Japan was able to obtain information on which roads were closed, which was then used to assist in rescue operations. Warning information was also broadcast from ITS Spots immediately following the earthquake (Japan 2012).

DRIVING SAFETY SUPPORT SYSTEMS (DSSS), ADVANCED SAFETY VEHICLE (ASV), AND SMARTWAY

The DSSS system describes a typical connected vehicle system in which vehicles obtain information from roadside units (RSUs), other vehicles, or pedestrians, and those devices can also pass information back to the vehicle enabling a driver to respond to traffic conditions. The V2I system is based on the same IR light beacon RSUs used for VICS (European Commission 2009 and Fukushima 2011).

The National Police Agency of Japan has an organization called the Universal Traffic Management Society of Japan (UTMS) is working on the DSSS project. The project allows automakers such as Honda, Toyota, Nissan, Mitsubishi, and Mazda to use public roadways to test inter-vehicle and road-to-vehicle communications. As part of deployment, the National Police Agency of Japan planned to install RSUs at around 1,000 dangerous intersections across Japan but in mid-2009, a regime change led to police infrastructure budget cuts, shelving many of the RSU plans. Some intersections in Tokyo and Kanagawa were still approved, however, and automotive manufacturers have been lobbying to get funding for RSUs back (Fukushima 2011).

Figure 11: ITS Spot Service in Japan
Source: Japan 2012

Honda began its DSSS testing with two vehicles, a Forza scooter and an Odyssey, to verify inter-vehicle and road-to-vehicle communication functions (ASV-4), DSSS functions, and to collect and present data to contribute to evaluating system effectiveness. Overall, Honda is hoping to prevent rear-end collisions, collisions involving a vehicle turning into oncoming traffic, and collisions from vehicles passing each other. After completing these initial tests, Honda participated in joint government and private-sector large scale verification testing from March 24 to March 28, 2008 in Utsunomiya City, Tochigi Prefecture, Japan (Honda 2008). More recently, Honda demonstrated its DSSS and ASV equipped vehicles, including an Odyssey minivan, Forza motorcycle, and IT Mopal 4 electric cart. These demonstrations occurred while Honda participated in *ITS-Safety 2010*, a large-scale verification testing project for DSSS, ASV, and *Smartway*. ITS-Safety 2010 ran from December 2008 to March 2009 and had the goal of achieving practical application of vehicle-infrastructure cooperative systems by March 2011 (Toyota 2009).

Toyota has also participated in DSSS tests on public roads. It used 100 vehicles equipped with drive recorders and were meant to determine whether communication devices on traffic signals and stop signs affect traffic accident rates at high-risk intersections. To test this, Toyota used infrared beacons placed at five intersections that communicate with on-board navigation display systems in the participating vehicles. These tests began in December of 2006 were completed in June of 2007 (Toyota 2006). Toyota participated in additional tests that in early 2009 which were part of the *ITS-Safety 2010* intelligent transport systems testing program (Toyota 2009). They involved 200 participants, half of which were Toyota employees, and half of which were members of the general public. Toyota demonstrated ITS technologies that it developed at a public event hosted by the Universal Traffic Management Society of Japan in April of 2009.

In January of 2009, Nissan announced that it would participate in the *ITS-Safety 2010* tests. Nissan's advanced vehicle-to-infrastructure communications system is among the items to be tested at the event. The system has been undergoing testing within the company since 2006 with the participation of 2,000 people (Nissan 2009).

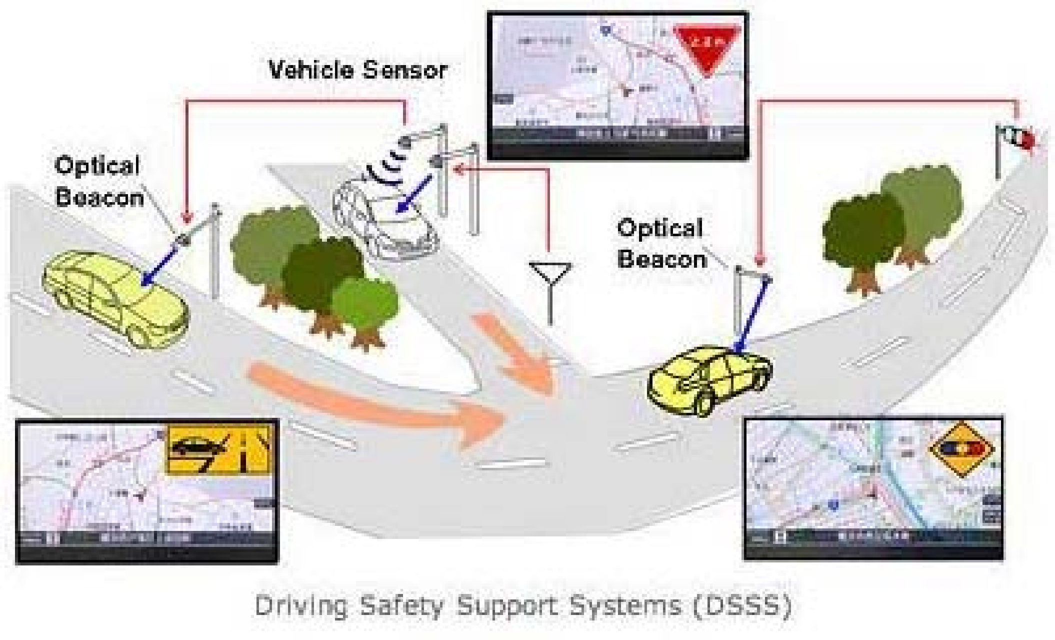


Figure 12: Diagram of Driving Safety Support Systems
Source: Nissan 2009

Mazda was also a demonstration participant, showing the Mazda MPV and Mazda Atenza and has been involved in validation trials for ITS technologies on public roads since 2006 (Mazda 2009). Other participants in *ITS-Safety 2010* demonstrations were Mitsubishi, NEC Corporation, Panasonic, Yamaha, Kawasaki, and Suzuki (Nippon News 2009).

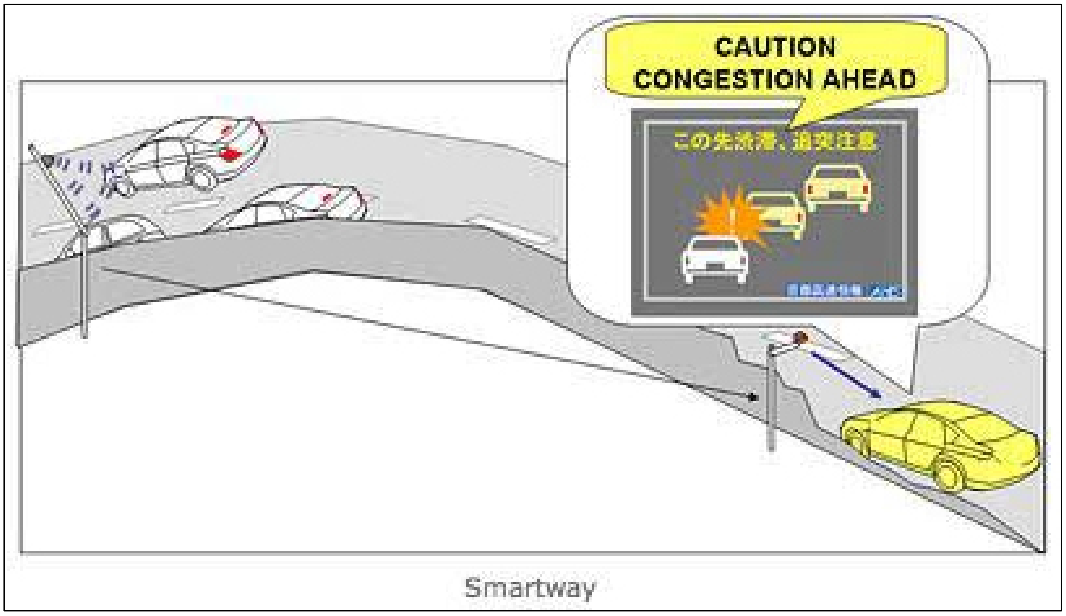


Figure 13: Diagram of Smartway System
Source: Nissan 2009

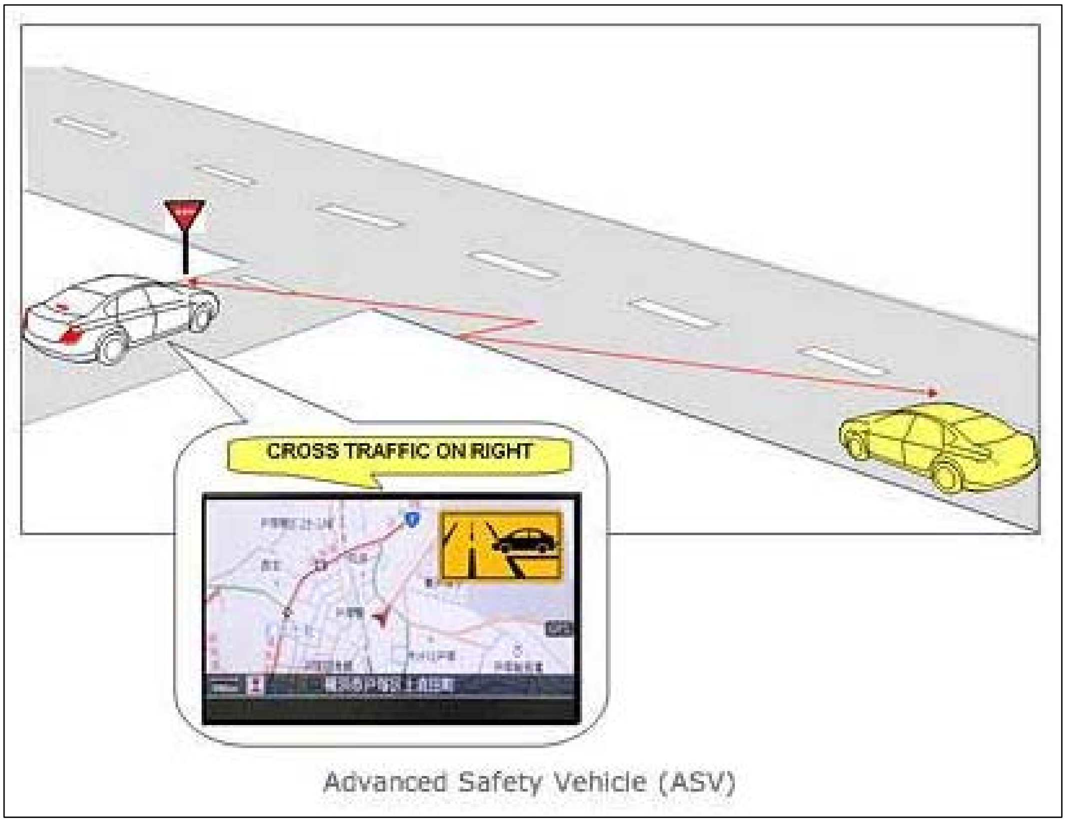


Figure 14: Diagram of Advanced Safety Vehicle System
Source: Nissan 2009

Smartway 2007 is a project to create a road system that can exchange information among cars, drivers, pedestrians, and users using DSRC (Harris 2010). It was originally a field test of various road warning applications, such as merge assist, curve warning, congestion warning, and weather information. In the original test, sensors were placed in vehicles which received input from the applications on the road. In 2008, there were additional field tests, with the intent of leaving the infrastructure in place as was the case with the 2007 test. In 2009, these test beds were expanded and made available to the public (*IntelliDrive*USA 2010b). By 2010, around 1,600 ITS Spot units were installed with most located on expressways. For instance, on the Tokyo Metropolitan Expressway, 32 Spot units were installed in 2009 and another 166 units were installed in 2010. The plan is to install a unit every 10 to 15 kilometers, and every four kilometers on urban expressways (Harris 2010). As of November 2010, five manufacturers have released systems that interact with ITS Spot units, including Toyota, Pioneer, Mitsubishi Electric Co., Panasonic, and Mitsubishi Heavy Industries (Adams 2010).

Though the three systems tested at the *ITS-Safety 2010 Industry-Wide Tests* were all connected vehicle systems, they are uniquely different. DSSS uses V2I communications with vehicle sensors and optical beacons sending information from infrastructure to drivers, warning them of potentially dangerous situations. Features of DSSS include alerts for traffic signals and stop signs; rear-end, crossing, and turning collision avoidance; and information on other vehicles turning and changing lanes. The ASV system uses both 5.8 GHz DSRC and 700 MHz communications for V2V communications to warn drivers of potential collisions with other drivers (Fukushima 2011). Features of ASV include rear-end, crossing, and turning collision avoidance and information on nearby emergency vehicles. *Smartway* uses 5.8 GHz DSRC V2I communication to gather information about congestion or road obstacles and relays that information to other vehicles, helping them avoid congested areas. *Smartway* features include information on obstacles and conditions ahead, merge assist, and location information via electronic signs (Nissan 2009). Figures 12, 13, and 14 diagrammatically display the function of DSS, *Smartway*, and ASV respectively.

START ITS FROM KANAGAWA, YOKOHAMA (SKY) PROJECT

Another Japanese initiative is the *Start ITS from Kanagawa, Yokohama* (SKY) project, whose goals are to ease traffic congestion and reduce accidents. The project began in October 2004 in Yokohama, Japan and collects real world vehicle data from other users. Nissan and Panasonic are working with various units of the Japanese government to communicate between vehicles and the infrastructure to achieve these goals. A similar effort is underway at Nissan called *Carwings*, which connects mobile phones and navigation systems to promote fuel-efficient driving and ease congestion. Like the SKY project, *Carwings* obtains information from other users to plot energy efficient driving routes (Nissan 2011a).

CARWINGS PROJECT

In 2008, Japan gave the annual Energy Conservation Prize to Nissan’s *Carwings*, an onboard computer navigation system. On top of simply navigating, the system tracks fuel efficiency and provides suggestions on how to improve fuel efficiency. The service was also provided in the United States for owners of the Nissan Leaf. In the United States the system tracks energy usage information and displays daily, monthly, and annual reports with distances traveled and energy consumption (Yoney 2010). Besides just tracking information, however, *Carwings* sends and receives data though a built-in general packet radio service (GPRS) radio. Using information received through the communications device, it tracks the driver’s efficiency ranking compared to other Leaf drivers globally and regionally (Austin 2011). The U.S. version of *Carwings* does not yet have the same ability to leverage a readily available nationwide database of real-time traffic conditions as it has in Japan. This database is operated by the Japanese Transportation Ministry and the police, and an equivalent does not exist currently in the United States.

CHINA

STAR WINGS PROJECT

Beijing Transportation Information Center and Nissan developed *Star Wings*, a navigation system that is designed to reduce congestion and decrease travel times. Using probe data collected from 10,000 taxis, the system aggregates real-time traffic information that is then transmitted to vehicles to plan the fastest route and avoid congested areas (DueMotori 2007). Research suggests it can reduce travel time by 16 to 20 percent (Nissan 2008).

NEW TRAFFIC INFORMATION SYSTEM MODEL PROJECT

More recently Nissan and the China have partnered to pilot a route guidance system through their work on *New Traffic Information System Model Project*, which was launched in the Wangjing district of Beijing City in January 2012. The project involves the use of 12,000 user-equipped portable navigation devices and 600 Nissan vehicles equipped with devices to record detailed driving data. This technology is expected to reduce traffic congestion and greenhouse gas emissions (Nissan 2011b).

SINGAPORE

REAL-TIME INFORMATION

In 1998, Singapore installed an electronic congestion pricing system. Ten years later, Singapore launched a parking guidance system. By 2010, the country had 5,000 probe vehicles to generate and disseminate real-time traffic information. The information generated by the probes is sent to its *i-Transport System* which uses both historic and real-time traffic data. Throughout the country, adaptive computerized traffic signals have been deployed and at most bus stops, there are traffic information data terminals that show real-time bus status (Ezell 2010).

SOUTH KOREA

NATIONAL ITS 21 PLAN

Through its *National ITS 21 Plan*, South Korea will invest $3.2 billion in ITS deployment from 2008 to 2020. The country's ITS infrastructure was built by establishing four initial *ITS Model Cities*, which used adaptive traffic signal control, real-time traffic information, public transportation management, and automated speed violation enforcement. There are now 29 cities with ITS technologies deployed. As of the beginning of 2010, over 9,000 buses and 300 bus stops had been outfitted with operation management systems and traffic information data terminals. Public transit systems have now instituted an electronic payment system that uses cards or a mobile phone application to conduct transactions. Installation of these e-pay systems on mass transit is expected to be completed by the end of 2011. Electronic toll collection is available for half of all highway roads and will continue to expand to cover 70 percent of highways by 2013 (Ezell 2010).

UBIQUITOUS CITY (U-CITY)

South Korea has embraced the concept of the "Ubiquitous City" (U-City) as part of their national urban development policy. The government finalized the first Comprehensive U-City Plan (2009-2013) to outline and support this policy. The core of the U-City vision is the integration of information and communication technologies with the urban landscape to create a system where information is available anywhere and city management is efficient and informed. As part of the U-City vision, transportation systems are connected (Korea Herald 2010). The vision for U-Transportation in U-Cities includes a traffic information service, public transportation information service, real-time traffic control, U-parking applications, and traffic information on roads connecting suburbs (Bang 2011).

The first U-City to be completed was Hwaseong-Dongtan which was finished in September 2008. The Ministry of Land, Transport and Maritime Affairs reports that a total of 36 local governments in existing cities including Seoul, Busan and Jeju and new cities including Incheon-Songdo and Paju-Woonjeong are developing U-City projects (Korea Herald 2010).

TAIWAN

AUTOMOTIVE RESEARCH AND TESTING CENTER (ARTC) ACTIVITIES

Taiwan is home to several organizations that are advancing vehicle and technology research, most notably the Automotive Research and Testing Center (ARTC), founded in 1990 by the Taiwanese Ministry of Economic Affairs with the joint efforts of the Ministry of Transportation and the Communication, Environmental Protection Administration (ARTC 2011a). ARTC is particularly focused on helping Taiwanese automotive-related companies test products so that they can successfully launch them on the market. The center offers testing laboratories, test equipment, and a proving ground and provides a collaborative environment for the industrial, academic, and research communities (ARTC 2011a).

The ARTC has several connected vehicle-related initiatives, primarily revolving around safety. ARTC is researching lane-departure warnings, forward collision warnings, parking assist systems, blind spot information systems, and vehicle safety and security systems, among others (ARTC 2011b). Both the lane-departure and forward collision warning technologies involve a camera mounted behind the rear-view mirror that can detect lane markings or the vehicle ahead and alert the driver accordingly (ARTC 2011b). The parking assist system can, in real time, calculate the reverse trajectory using a signal from the steering angle sensor, which displays the image on a monitor in the vehicle (ARTC 2011b). This sensor provides the driver assistance with both backward and parallel parking.

ARTC offers several state-of-the-art laboratories. One in particular is the electro-magnetic compatibility (EMC) lab. The lab won certification of the American Association for Laboratory Accreditation/Automotive EMC Laboratory Accreditation Program and validation from General Motors, Ford, and Chrysler (CENS 2008). Therefore, the Center is able to certify companies' products for compatibility, and this line of business has been very successful for the Center. ARTC also offers a proving ground which has nine test tracks, including test hills; a curvy and bumpy "Belgium Road" track constructed with granite blocks; a coast-down test track; a noise, vibration, and harshness surface test track; a brake performance test track; a pass-by noise test track; a general durability test track; a high-speed circuit; and a general performance test track (CENS 2008).

INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE (ITRI) ACTIVITIES

Another organization that is researching cutting edge connected vehicle technology is the Industrial Technology Research Institute (ITRI) of Taiwan. ITRI has developed a WAVE/DSRC Communication Unit (IWCU) which provides V2V and V2I communication capabilities enabling ITS applications. In October 2010, ITRI won a bid from CAMP for its IWCU technology to support the *Vehicle-to-Vehicle Interoperability* project, a connected vehicle project in the U.S. which is part of NHTSA's *Vehicle-to-Vehicle Safety Application Research plan*. The Ministry of Economic Affairs has strongly supported telematics research projects in Taiwan beginning in 2008, and winning the bid is seen as a result of this support (ITRI 2010).

AUSTRALIA

SECURING 5.9 GHZ BANDWIDTH FOR ITS

Since 2008, Austroads, an organization composed of six state and two territory road transport and traffic authorities has conducted a series of studies making the case for securing 5.9 GHz bandwidth for ITS applications, developing management arrangements for applications using the spectrum, and identifying pilot applications once the DSRC bandwidth has been secured (Austroads 2009). As of the publication of the *2012 Policy Framework for Intelligent Transportation Systems in Australia*, the 5.9 GHz band has yet to be allocated for cooperative vehicle safety and mobility applications, though Australia is expected to allocate the 5.9 GHz band (Australia 2012).

In 2009, the Australian Communications Media Authority (ACMA) outlined proposals to secure the 5.9 GHz band of the spectrum for ITS (ACMA 2010). Australia currently has several services allocated to the 5.9 GHz band, including fixed satellite services and mobile services to support the introduction of ITS technologies.

INTELLIGENT SPEED ADAPTATION TRIAL

In 2009, the New South Wales Centre for Road Safety conducted an *Intelligent Speed Adaptation Trial*. Over 100 vehicles were connected to a centralized computer system which supplied drivers with information about changes to speed zones. These test vehicles provided more than 2 million individual speed compliance records. Initial results from the trial showed that using the technology decreased the proportion of time drivers spent traveling over the speed limit. These findings were presented at the 2009 Intelligent Speed Adaptation Conference in Sydney (Wall et al. 2009).

COHDA WIRELESS ACTIVITIES

Cohda Wireless is a technology company that was spun-off from the University of South Australia in 2004 (Leung 2012) and has developed a signal processing technology that improves transmission quality of the 802.11p radios used in connected vehicles (Stone 2009). The technology increases receiver sensitivity, transmission range, data speed, connection reliability, providing a robust, low-latency radio connection that could potentially be used for safety applications. Cohda's technology also allows signals to be bounced around corners, improving data reception, especially in urban environments (Cohda 2012).

The technology has so far been tested in over 17,000 kilometers of on-road trials which have involved the transmission of more than 200GB of data (Cohda 2012). Cohda technology has been used for connected vehicle testing in six different countries (Australia, Austria, Germany, Italy, Sweden, and the United States) as part of large deployments such as Germany's sim^{TD} in Frankfurt, Germany and the *Safety Pilot Model Deployment* in Ann Arbor, Michigan (TTT 2009a and Cohda 2012).

A large scale, three-month test of Cohda Wireless technology was approved in 2011. The test involved V2V and V2I technology and was run by South Australia‘s Motor Accident Commission, the Department for Transport, Energy, and Infrastructure; and the University of south Australia‘s Institute for Telecommunications Research. The initial tests included a fleet of ten vehicles collecting data in normal driving conditions with data being uploaded via roadside equipment(RSE) at the Norwood Traffic Management Center (TTT 2011).

INTELLIGENT ACCESS PROGRAM (IAP)

In 2006, Australia's national government passed legislation providing the legal foundation for the *Intelligent Access Program* (IAP). The IAP provides improved access to the Australian road network for heavy-duty commercial vehicles. The program uses a combination of satellite tracking and wireless communications technology to monitor heavy vehicles on the road network. The program can notify the government agencies if a vehicle deviates from approved routes or times.

Hardware installed for IAP includes an in-vehicle unit and a self-declaration input device. The in-vehicle unit automatically monitors and stores information, such as: date, time, vehicle position, vehicle speed, potential malfunctions, and attempts at tampering, which it can relay to government agencies. The self-declaration input device allows the vehicle operator to input information and explain behavior that may appear to be non-compliant to the Department of Planning, Transport and Infrastructure (TCA 2012).

NEW ZEALAND

NATIONAL ITS ARCHITECTURE

- The New Zealand Transport Agency produced a research report in March 2010 that proposed a framework for a national ITS architecture. This report reviewed international ITS models and research in the United States, Canada, Europe, and Australia and proposed a framework for developing an ITS architecture for New Zealand which included some connected vehicle technologies such as the use of DSRC and connected vehicles as probes for dynamic route guidance (James et al. 2010).

IV. CONNECTED VEHICLE EFFORTS IN EUROPE AND THE MIDDLE EAST

Many of the large connected vehicle research projects in Europe are at least partially funded by the European Commission, national governments, and industry partners. These projects are often characterized by the large consortia involved in conducting the work, which often include representatives from automakers, suppliers, universities, municipalities, and other government agencies.

Figure 15 below shows the geographical distribution of projects throughout Europe/Middle East. Many projects in Europe are spread across several countries; for mapping purposes, such projects are assigned to the country of their lead coordinator.

EUROPE-WIDE PROJECTS

EUROPEAN ROAD TRANSPORT TELEMATICS IMPLEMENTATION CO-ORDINATION ORGANIZATION (ERTICO-ITS EUROPE)

The European Road Transport Telematics Implementation Co-ordination Organization (ERTICO) is Europe's premier ITS organization (akin to ITS America in the U.S.). It brings together several European countries, automotive companies, suppliers, and other organizations and fosters research in various ITS-related activities. The organization has

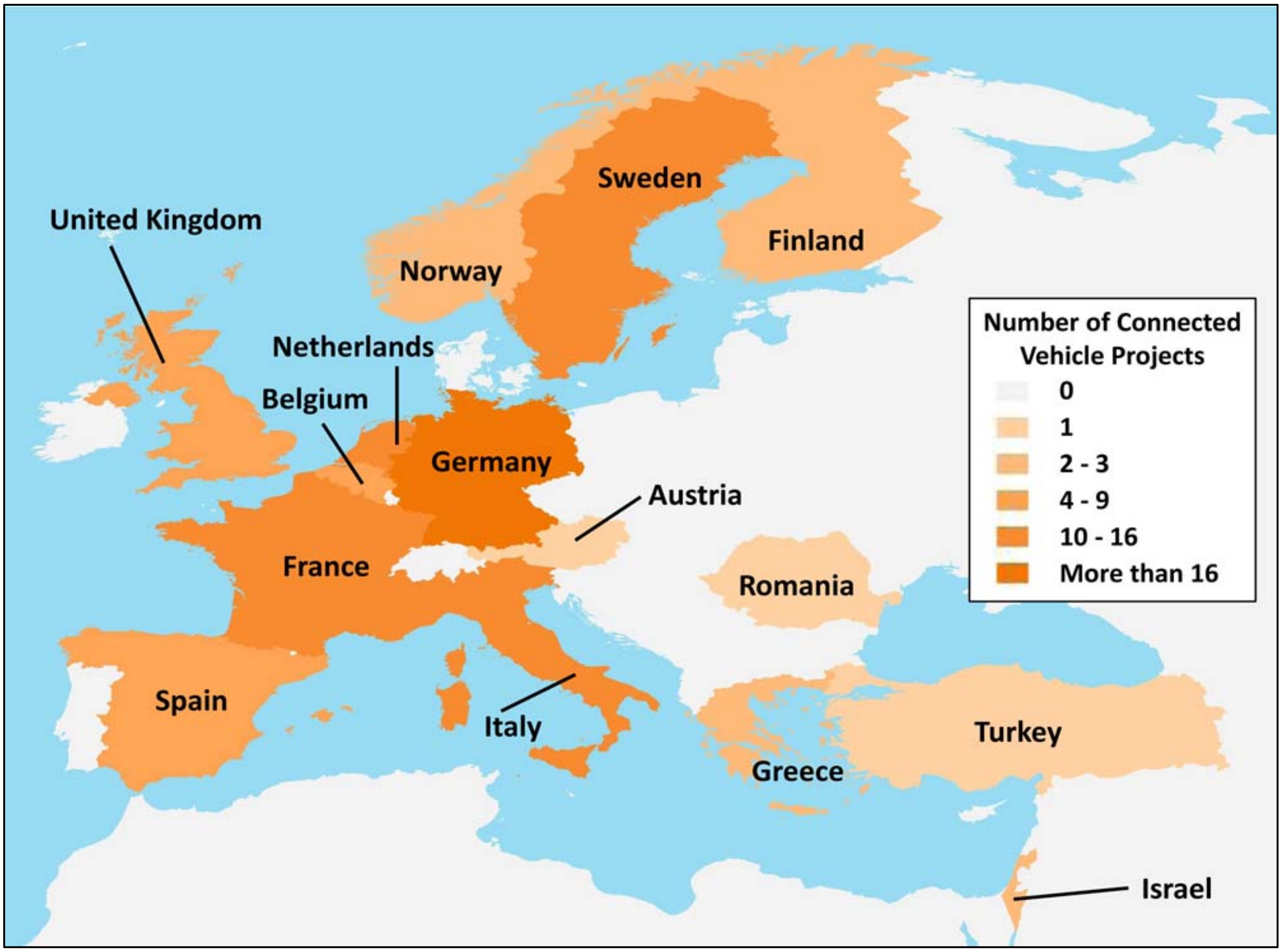


Figure 15: Connected Vehicle Projects in Europe and the Middle East
Source: CAR 2012

several activities in the safety, security, efficiency, and environment realms.

In the safety realm, ERTICO is firmly committed to the tremendous effect that ITS-related technology can have on reducing the number of motor vehicle accidents. ERTICO estimates the cost of motor vehicle crashes in Europe to be €200 billion per year and thus views crashes as a significant cost to society (Commission of the European Communities 2006). In the realm of security, priority areas include border control, the fight against terrorism, and civilian emergency and critical infrastructure protection. In addition Europe is certainly not immune to the issue of congestion and all the problems it causes. As a result of these numerous issues, ERTICO is involved in several different types of ITS-related initiatives. ERTICO's website provides a full listing of these initiatives (ERTICO 2012). ERTICO divides its projects between the topics of cooperative mobility, eco-mobility, safe mobility, and info-mobility.

Cooperative mobility projects include

Sustainability and Efficiency of City Logistics (CITYLOG) (January 2010-December 2012), which is focused on increasing the efficiency of deliveries using adaptive and integrated mission management and innovative vehicle solutions. The *Communications for eSafety 2* (COMeSafety2) project (January 2011-December 2013) involves coordinating activities related to the deployment of cooperative ITS on European roads. The focus of these projects includes standardization issues; best practices from European, Japanese, and US field operational tests (FOTs); a cooperative multimodal ITS architecture concept; and needs analysis among others. The *Instant Mobility* project (April 2011-March 2013) centers around providing Internet access for transport and mobility. *Support Action for a Transport ICT European large scale action* (SATIE) (September 2011-August 2014) is intended to serve a consulting role to the European Commission with regards to planning large-scale actions.

DRIVING IMPLEMENTATION AND EVALUATION OF C2X COMMUNICATION TECHNOLOGY (DRIVE C2X)

The *PREparation for DRIVing implementation and Evaluation of C2X communication technology* (PRE-DRIVE C2X) project was an FOT that used European COMeSafety architecture to create a V2X communication system. The project developed specifications for the system and created a functional prototype that could be used in future FOTs. A major goal of PRE-DRIVE C2X was to develop a simulation model to estimate the benefits of a cooperative system in terms of safety, efficiency, and environment. This model includes the tools and methods needed to perform functional verification and testing of cooperative systems in both the laboratory and on the road. The project ran from 2008 to 2010. The budget was €8.4 million and the project received funding of €5.0 million from the European Commission Information Society and Media as part of the 7th Framework Programme. The project was also supported by the European Council for Automotive R&D (EUCAR) (PRE-DRIVE C2X 2011).

The goal of the follow-up project to PRE-DRIVE C2X, *DRIVing implementation and Evaluation of C2X communication technology* (DRIVE C2X), is to create a Europe-wide testing environment for C2X technologies. The project is designed to raise public awareness on connected vehicle technologies, inform standardization organizations, and initiate new public-private ventures. All of these activities will create a better environment for the commercialization of connected vehicles in Europe (DRIVE C2X 2012).

DRIVE C2X, which will run from 2011 to 2013, has 31 partners and 15 support partners. The total budget for DRIVE C2X is €18.8 million, with €12.4 million coming from the European Commission. The DRIVE C2X test deployment will include seven test sites in Finland, France, Germany, Italy, Netherlands, Spain and Sweden (DRIVE C2X

2012). Projects under C2X include:

- *Dutch Integrated Testsite Cooperative Mobility* (DITCM) (Helmond, Neatherlands)
- *Safe and Intelligent Mobility Test Germany* (sim^{TD}) (Frankfurt/Main, Germany)
- *System Coopératif Routier Expérimental Français* (SCORE@F) (Yvelines, France)
- *Cooperative Test Site Finland* (Coop TS Finland) (Tampere, Finland)
- *Vehicle and Traffic Safety Center* (SAFER) (Gothenburg, Sweden)
- *SIStemas COoperativos Galicia* (SISCOGA) (Galicia, Spain)
- *Test Site Italy* (Brenner Motorway, Italy)

The lead coordinator on the project is Daimler and partners include ten other automakers, eight suppliers, 16 research institutions, and 11 other organizations (EICT 2011 and DRIVE C2X 2012). The functions to be tested are related to traffic flow, traffic management, local danger alert, driving assistance, internet access and local information services, and test site-specific functions to be defined independently by each test site, but the final list of use cases for the tests is still under preparation (Flament 2011). The test sites can be seen in a map in Figure 16. Detailed information on individual projects can be found in the country sections on subsequent pages.

HARMONIZED ECALL EUROPEAN PILOT (HEERO)

The objective of the *Harmonized eCall European Pilot* (HeEro) is to prepare the infrastructure necessary for a European in-vehicle emergency communication service that will harmonize the disparate national services and ensure cross-border interoperability. The pilot participants will then share their experiences and best practices with other countries and help expand the program (HeERO 2012). This service uses “112,” the single European emergency number.

In the event of a serious automobile accident, the system will automatically notify emergency services. The system will trans-

Figure 16: DRIVE C2X Projects throughout Europe
Source: DRIVE C2X 2012

mit location information on the accident, as well as allow voice contact between operators and crash victims.

Several countries are working together to develop this emergency call service. The HeERO consortium consists of nine countries:

- Croatia
- Czech Republic
- Finland
- Germany
- Greece
- Netherlands
- Italy
- Romania
- Sweden

These countries are carrying out the work needed to start up the system that will soon be used across the European Union as well as in the countries of Iceland, Norway and Switzerland (HeERO 2012).

Ideally, the HeERO technology will cost around €100 per vehicle once it is implemented in all new vehicles. Part of the rationale for standardizing the technology across all of Europe is to take advantage of economies of scale and reduce cost. In addition to being used for emergency calls, the in-vehicle devices could be used for commercial uses such as usage-based insurance, electronic tolling, and stolen vehicle tracking (HeERO 2012).

The project started in January 2011 and will continue through December 2013. The project's total budget is €10 million, €5 million of which is being provided by the European Commission under the *Information and Communication Technologies Policy Support Program* (ICT PSP) (HeERO 2012).

COOPERATIVE VEHICLE INFRASTRUCTURE SYSTEMS (CVIS)

The *Cooperative Vehicle Infrastructure Systems* (CVIS) project was an ERTICO program with 61 partners and was coordinated in Belgium. The goals of CVIS were to design, develop, and test vehicle communication technologies. CVIS used a hybrid of M5, infrared light, 2G/3G, and DSRC for communication, and Global Navigation Satellite System (GNSS) for positioning (Eriksen et al 2006). It was demonstrated that CVIS could increase road safety and efficiency while decreasing the environmental impact of road transport. Deliverables from CVIS included a standardized networking terminal for V2V

Application Sub-Project	France	Germany	Italy	Netherlands-Belgium	Sweden	United Kingdom
Monitoring		x	x	x	x	
Urban						
Cooperative Network Management			x	x		
Cooperative Area Routing			x			
Cooperative Local Traffic Control		x	x	x		
Dynamic Bus Lanes			x			
Interurban						
Enhanced Driver Awareness	x	x			x	
Cooperative Traveller's Assistance		x	x	x		
Freight and Fleet						
Dangerous Goods			x		x	
Booking and Monitoring of Parking Zones	x			x		x
Vehicle Access Control for Sensitive Zones	x		x			

Table 1: Diagram of the CVIS System
Source: CVIS 2012

and V2I communications, techniques for improving dynamic maps, new systems for vehicle and roadside equipment, development of cooperative applications, and a toolkit addressing key non-technical challenges to deployment. The CVIS activities took place at seven different test sites, one each in France, Germany, Netherlands-Belgium, Italy, Sweden, United Kingdom, and Norway. The types of tests that took place at each test location are shown in Table 1. Local road authorities and operators, system integrators, suppliers, vehicle manufacturers, and service providers participated at each test site (CVIS 2012). The project was launched in February 2006 and was completed in mid-2010. The project budget was €41 million, with roughly half contributed by the European Union.

FIELD OPERATIONAL TEST NETWORK (FOT-NET)

The aim of the *Field Operational Test Network* (FOT-Net*) project* is to gather European and international researchers with FOT experience together to present results of FOTs and promote the *Field Operational Test Support Action* (FESTA) methodology as a common approach for FOTs. FOTs are large-scale testing programs for the assessment of the efficiency, quality, robustness and acceptance of information and communication technologies (e.g. navigation, traffic information, advanced driver assistance, and cooperative systems). FOT-Net is jointly funded by the European Commission DG Information Society and Media under the Seventh Framework Programme. The FOT-NET website contains a plethora of information on FOTs that have occurred or are planned in Europe, North America, and Asia (FOT-NET 2011).

CO-OPERATIVE SYSTEMS FOR SUSTAINABLE MOBILITY AND ENERGY EFFICIENCY (COSMO)

Co-Operative Systems for Sustainable Mobility and Energy Efficiency (COSMO) is a 32 month pilot project which began in November 2010 and will run through June 2013. The project's goal is to demonstrate the benefits of cooperative traffic management applications. Three pilot sites are being used for this demonstration: Salerno, Italy; Vienna, Austria; and Gothenburg, Sweden. These sites are implementing cooperative technologies developed in the recent European projects such as *Co-Operative Systems for Intelligent Road Safety* (COOPERS), CVIS, and *Smart Vehicles on Smart Roads* (SAFESPOT). Partners include Mizar Automazione, SWARCO FUTURIT Verkehrssignalsysteme GmbH, ASFINAG Service GmbH, Kapsch TrafficCom, Geo Solutions, ERTICO–ITS Europe, Societé pour le Developpement de l'Innovation dans les Transports, Università degli Studi di Salerno, Centro Ricerche Fiat, Volvo Technology, Lindholmen Science Park, and Tecnalia-Transporte. The budget for the project is €3.8 million, €1.9 million of which comes from the European Commission (COSMO 2012).

INFORMATION COMMUNICATIONS TECHNOLOGY (ICT) FOR ELECTRO-MOBILITY

Four European electro-mobility pilot projects were launched together on February 8, 2012. The projects each use ICT to enhance driving experiences for electric vehicle users.

SmartCEM

The *Smart Connected Electro Mobility* (smartCEM) project is designed to demonstrate how ICT solutions can make commuting in electric vehicles more practical and overcome shortcomings associated with them (smartCEM 2012). SmartCEM services being tested include:

- Navigation
- Efficient driving
- Trip management
- Charging station management
- Vehicle sharing managements

The Barcelona, Spain pilot is focused on electric motorcycles and scooters. The major mobility application being tested is an advanced open sharing service for vehicles. The pilot involves 45 motorcycles and 234 charging locations. The Gipuzkoa-San Sebastian, Spain pilot tests a hybrid bus application and a car sharing application. Testing will involve 1one hybrid bus, 30 electric cars, and 33 charging points. The Newcastle, United Kingdom pilot will test an eco-driving interface for 44 electric cars which can be charged at 1,300 charging points that will be available (though just over 200 charging points currently exist). The Turin, Italy pilot is focused on a sharing service for electric delivery vans. The test will involve ten delivery vans, five minivans, and two charging points (smartCEM 2012).

ICT 4 EVEU

The project *Information and Communication Technologies for Electric Vehicles European Union* (ICT 4 EVEU) project uses communications technologies to:

- Monitor use status of charging points
- Monitor status of vehicles
- Remotely reserve charging points
- Integrate payment methods for users
- Create a network of charging points

While specific technology is not specified on the website, it is made clear that the system being tested will make use of V2I communication technology. The pilots will take place at Bristol, United Kingdom; Pamplona and Vitoria, Spain; and Ljubljana and Maribor, Slovenia (ICT 4 EVU 2012).

MOBI.Europe

Mobility services offered under *Integrated and Interoperable ICT Applications for Electro-Mobility in Europe* (MOBI.Europe) include remote information on parking availability, remote parking reservations, and enhanced car sharing. The pilots will take place in Ireland, the Netherlands, Portugal, and Spain and will involve 1,200 electric vehicles and 1,850 charging points (MOBI.Europe 2012). As of September 2012, specific vehicle and infrastructure technologies are not listed on the MOBI.Europe website.

MOLECULES

Services being tested under the *Mobility based on eLEctric Connected vehicles in Urban and interurban smart, cLean, EnvironmentS* (MOLECULES) pilot project include:

- Personal trip planning
- Electric Vehicle sharing/pooling
- Personal recharging advisor
- Personal carbon footprint advisor
- Electro-mobility billing support
- Incentives to electro-mobility
- Network strategies

The three pilot sites for MOLECULES are Barcelona, Spain; Berlin, Germany; and Grand Paris, France. The project began in early 2012 and will run through December 2014. The budget for the project is €4.3 million (MOLECULES 2012).

GERMANY

SAFE AND INTELLIGENT MOBILITY TEST GERMANY (SIM^{TD})

As part of Drive C2X, the German state of Hessen and the city of Frankfurt are working with several automakers, Tier 1 suppliers, and communication companies on a four-year test involving vehicles and road side units with wireless communication capabilities. The project involves the testing of car-to-x communication, which includes V2V and V2I communication.

The project, which started in 2008 and was planned to run for four years, is called *Safe and Intelligent Mobility Test Germany* (sim^{TD}). The project has a €53 million budget, €30 million of which is being paid by the German government (TN 2012). In addition to the €53 million, the project is further supported with infrastructure investment from German government agencies and the state of Hessen. The technology used in the project is based on the wireless local area network (WLAN) standard 802.11p and 802.11b/g (DRIVE C2X 2012). Other communications technologies are also integrated into the system, such as Universal Mobile Telecommunications System (UMTS) and GPRS.

The project is headed up by Daimler and other private-sector partners include Audi, BMW, Bosch, Continental, Deutsche Telekom, Ford, Opel, and Volkswagen. Automaker partners are providing equipped vehicles for the testing, with Ford providing 20 S-Max models (TN 2012). Research partners include Fraunhofer-Gesellschaft, German Research Center for Artificial Intelligence, Technical University of Berlin, Munich University of Technology, Saarland University of Applied Sciences, and University of Würzburg. Public-sector partners include the Federal Ministry of Transport, Building, and Urban Affairs, the Federal Ministry of Education and Research, the Federal Ministry of Economics and Technology, the Hessen State Office for Road and Transport, and the City of Frankfurt (sim^{TD} 2012).

The vision for sim^{TD} is to enhance road safety, improve traffic efficiency, and integrate value-added services. Applications being tested include (TN 2012):

- Electronic brake light
- Obstacle warning system
- Traffic sign assistance
- Public traffic management
- In-car internet access

On August 6, 2012, after years of research, the project began a field testing on urban roads and rural highways using 120 test vehicles (sim^{TD} 2012). The test field is located in the Frankfurt-Rhine-Main area and includes 104 RSUs, 69 of which are linked with traffic lights and another 21 positioned at intersections. The testing area includes 96 kilometers of highway, 53 kilometers of rural road, and 24 kilometers of urban road. An additional closed testing site is located at Ray Barracks in Friedberg. That site has three planned RSUs, one of which will be linked to a traffic light (DRIVE C2X 2012).

DYNAMIC INFORMATION AND APPLICATIONS FOR ASSURED MOBILITY WITH ADAPTIVE NETWORKS AND TELEMATICS INFRASTRUCTURE (DIAMANT)

Also in Hessen, the Hessian State Office of Road and Traffic Affairs (HLSV) is conducting *Dynamische Informationen und Anwendungen zur Mobilitätssicherung mit Adaptiven Netzwerken und Telematikanwendungen* or *Dynamic Information and Applications for assured Mobility with Adaptive Networks and Telematics infrastructure* (DIAMANT). Project partners include Adam Opel GmbH, Continental AG, Dambach-Werke GmbH. and the state of Hessen. The project has a five-year runtime, and total costs of €5.2 million. There is no external funding; each of the project partners bear their own costs. The vehicles used for testing are supplied by Adam Opel GmbH, the on-board units are from Continental AG, the roadside communication points are manufactured by Dambach-Werke GmbH, and the HLSV manages the road. Together this consortium is attempting to promote C2X safety and efficiency applications in hopes of bringing them rapidly onto the market. Between them, the partners have the ability and expertise to conduct connected vehicle field tests (Hessen 2009). Applications tested under this program will provide information and warnings for drivers as well as allow for traffic management. AKTIV used cellular mobile communication technologies, including Universal Mobile Telecommunications System (UMTS), High-Speed Packet Access (HSPA), and 3GPP Long Term Evolution (LTE), for communications tests (ETH 2009).

ADAPTIVE AND COOPERATIVE TECHNOLOGIES FOR INTELLIGENT TRAFFIC (AKTIV)

The German *Adaptive and Cooperative Technologies for Intelligent Traffic* (AKTIV) project, backed by a consortium of 28 partners, is developing an assistance system to prevent accidents, intelligent traffic management systems, and mobile communications technologies for connected vehicles. The project is funded in part by the Federal Ministry of Economics and Technology. The Hessen test bed is being used to evaluate applications such as traffic modeling and in-vehicle signing (Hessen 2009). Among the technologies used in AKTIV are cameras, radar, and laser sensors (Abuelsamid 2010). The AKTIV Communication Unit, developed as part of the project, complies with the IEEE 802.11p wireless standard for 5.9 GHz. The device is also available for WLAN standards IEEE 802.11a-g for 5.8 and 2.4 GHz (AKTIV 2011).

WIRELESS WOLFSBURG

The *Wireless Wolfsburg* project was a concept that would provide internet connectivity to vehicles in the city. The network went live in 2008. At that time, the concept consisted of 66 wireless access points in part of the city, with each one costing approximately €2,000. At that point, the plan was to eventually install 400 access points across the city. In addition, the project was considering expanding to include other cities. The network was created to serve the Volkswagen Research Group in testing new vehicle information applications and to provide vehicle passengers with access to local information about events, cultural attractions, points of interests, weather, and traffic conditions (TTT 2008). Currently, the official website is up and running and has a map of access areas. For more information, visit the *Wireless Wolfsburg* website (Wireless Wolfsburg 2012). Figure 17 displays the WLAN coverage area for *Wireless Wolfsburg*.

BELGIUM

ITS TEST BEDS

The *ITS Test Beds* project was created to design an ITS framework that promotes sharing among various ITS projects. The test environment would be used to serve as a basis for large FOTs. The prototype software designed by *ITS Test Beds* allows test sites to centrally store test data and information so that work done by one test site can be accessed and re-used by another one (Vermassen 2010). The environment is designed to be flexible by allowing interested parties to

Figure 17: WLAN Coverage Area for Wireless Wolfsburg
Source: Wireless Wolfsburg 2011

"plug in" their applications and components to run field tests. The test environment can be used to observe performance and validate compliance of applications with European and national standards. The project is conducted by members of national ITS organizations, European research organizations, and industrial partners such as NXP Semiconductors, Technolution, TC-Matix, and Q-Free. The project started on the February 2010 and was scheduled to run through August 2012 (ITS Test Beds 2011).

NEXT GENERATION INTELLIGENT TRANSPORT SYSTEMS (NEXTGENITS)

The *Next Generation Intelligent Transport Systems* (NextGenITS) project brings together some of the most prominent stakeholders in Belgium's ICT sector. The goal of the project is to create an environment where the private sector, research institutes, and governments can cooperatively come together to develop and demonstrate various intelligent transportation technologies. Partners include Alcatel-Lucent Bell, VRT-medialab, Be-Mobile, Tele Atlas, Touring, NXP Semiconductors, Group4Securicor, ITS Belgium, Mobistar, Nimera, Belgacom Group/Proximus, and Flemisch Traffic Center. Under NextGenITS, there are several subprojects for the applications to be tested including e-call, traffic information, intelligent speed adaptation, road charging, and cooperative vehicle systems. The cooperative systems subproject involves determining a suitable communication platform for V2V and V2I applications. The focus of this subproject was the Communications, Air-interface, Long and Medium range (CALM) platform (IBBT 2011). The NextGenITS closing event was held in March 2010.

COOPERATIVE MOBILITY SYSTEMS AND SERVICES FOR ENERGY EFFICIENCY (ECOMOVE)

The environmental initiative, *Cooperative Mobility Systems and Services for Energy Efficiency* (eCoMove), is a European Commission sponsored connected vehicle project. Its vision is the application of V2V and V2I communications technology to provide driving support and traffic management that can reduce vehicular energy waste and emissions (eCoMove 2012).

Applications under eCoMove include:

- Pre-trip planning
- Dynamic driver coaching
- Traffic information
- Smart navigation assistance
- Traffic signal optimization
- Traffic management tools

The project has more than 30 partners including automakers BMW, Fiat, Ford, and Volvo. It began in April 2010 and is planned to continue through March 2013. The project's total budget is €22.5 million, €13.7 million of which is being provided by the European Commission (eCoMove 2012).

FRANCE

SYSTEM COOPÉRATIF ROUTIER EXPÉRIMENTAL FRANÇAIS (SCORE@F)

Similar to Germany's sim^{TD}, France is currently conducting its own field operational test for cooperative systems, known as *System Coopératif Routier Expérimental Français* (SCORE@F). This project is being conducted in collaboration with the DRIVE C2X project. This project led by Renault and contains 12 industry partners, seven laboratories, and a local community (SCORE@F 2012). The project will use 30 equipped vehicles for testing. The applications being studied include road safety, traffic efficiency management, and comfort uses (e.g. co-operative navigation and Internet access). Among the goals for SCORE@F are to quantify benefits of the system, identify stakeholders, validate or evolve standards and applications, develop qualification tests to ensure interoperability, and calculate deployment costs. Among others, use cases include co-operative awareness, longitudinal risk warning, intersection collision risk warning, traffic light violation warning, green light optimal speed advisory, and electric vehicle (EV) charging, automotive sharing, and indermodality transport point location determination. Data collection will be done in accordance with FESTA methodology (Segarra 2011).

The project is using simulation, test track facilities, open highways, and suburban and urban roadways (SCORE@F 2012). The project tests are being conducted at Mov'eo-Lab, Union Technique de l'Automobile du motocycle et du Cycle, and Cofiroute SA-A10 Highway (COMeSafety 2010). The scheduled 30 month project launched in September 2010 (COMeSafety 2010). Development for the project took place from March 2011 to March 2012; the evaluation phase is now underway and will be completed by February 2013. Data collection is being done in accordance with the FESTA methodology (Segarra 2011).

Technology used for the project is based on 802.11p and 2G/3G technologies (INRIA 2012). The total budget for the project is €5.6 million, with €2.7 million coming from public sources and €2.9 million coming from private sources (SCORE@F 2012). A SCORE@F vehicle and roadside unit can be seen in Figure 18.

CYBERCARS

CyberCars-2 was the follow-up to the *CyberCars* and *CyberMove* projects. All three projects included components relating to V2V and V2I communications. In particular, the CyberCars-2 addressed V2V communications between vehicles running at close range (platooning) and V2I communications at intersections (merging, crossing). CyberCars-2 is based on a cooperative cybernetic transport system architecture that is compatible with Car2Car Communication Consortium and CALM standards. The project's vision was based on the idea that eventually urban vehicles will be fully automated. For testing, the project used existing vehicles that were available at the French National Institute for Research in Computer Science and Control (INRIA). The communication technologies and control algorithms installed in those eight vehicles were upgraded for the project. In addition, other Cybercars available in Spain, China, and in Australia were used for the project. The project included the con-

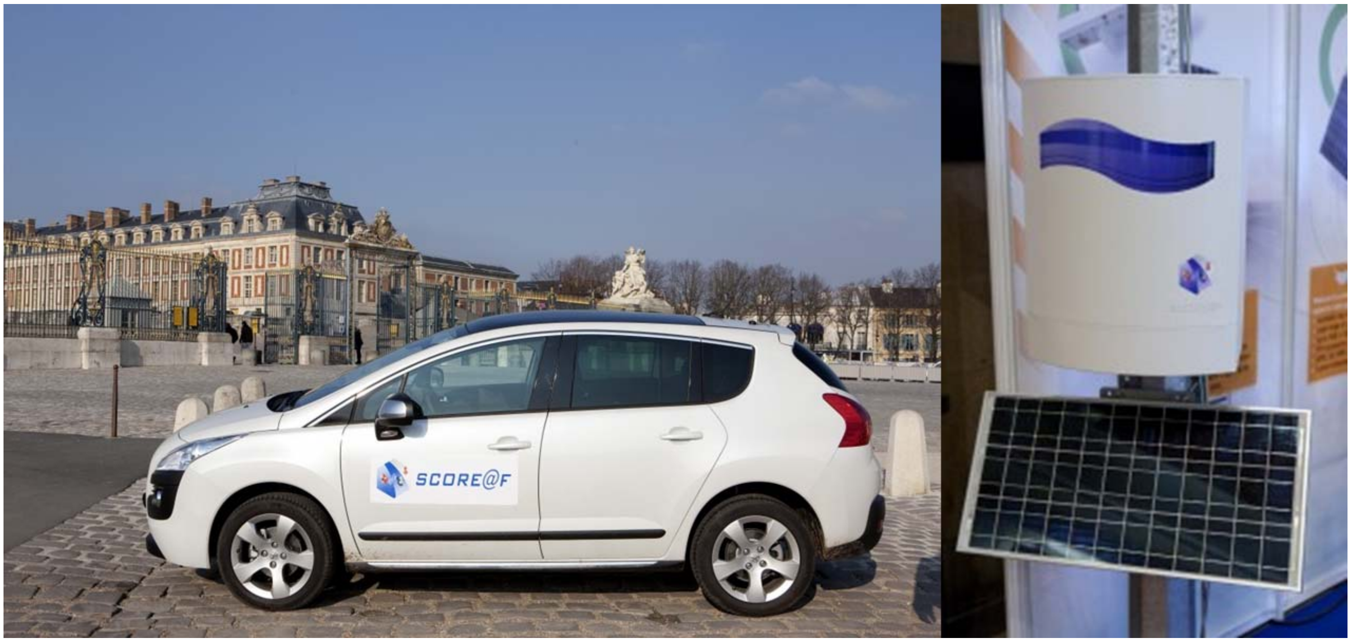


Figure 18: SCORE@F Vehicle and Solar Roadside Infrastructure on Display at ATEXPO 2012 in Versailles, France
Source: SCORE@F 2012

struction of a small-scale system which was prototyped based on a fleet of Cybercars. Road testing occurred in La Rochelle, France. The project began in January 2006. Runs at the test track occurred in September 2008. The final report for the project was submitted in February 2009 (CyberCars2 2009). The project resulted in the development of dual-mode vehicle prototypes capable of autonomous and co-operative driving, a communication architecture that was implemented in testing, algorithms for various maneuvers, a management center to support communications, and a simulation for evaluating the impact of larger deployments.

SECURE VEHICULAR COMMUNICATION (SEVECOM)

Secure Vehicular Communication (Sevecom) was an EU-funded project that ran from 2006 to 2009. The focus of the Sevecom was to provide define and implement security requirements for vehicular communications. Sevecom addresses security of vehicle communication networks, including both V2V and V2I data security. The project defined security architecture of networks and proposed a roadmap for integrating security functions. The Sevecom baseline architecture is not based on a fixed platform; it was created to be flexible so it could adapt to future changes in applications or technologies. This flexibility in design was required because protocols, system architectures, and security mechanisms are continuously changing (Kargl et al. 2008). There were three major aspects that were emphasized in the project: threats, (bogus information, denial of service, or identity cheating), requirements (authentication, availability, and privacy), and operational properties (network scale, privacy, cost, and trust). Sevecom presented a demo at a at the 2009 ITS World Congress (Sevecom 2011).

ITALY

INTELLIGENT CO-OPERATIVE SYSTEM IN CARS FOR ROAD SAFETY (I-WAY)

In Italy, too, safety has been the motivation for connected vehicle-related activities. One of these projects is *Intelligent Co-Operative System in Cars for Road Safety* (I-WAY), which had the goal of enhancing driver perception of the road, thereby improving safety. The project encompassed both V2V and V2I communications and lasted from February 2006 to January 2009. It integrated in-vehicle subsystems with the external transport system with the goal of greater safety. I-WAY's driving platform monitors and recognizes the road environment and the driver's state in real time using data obtained from three sources: a vehicle sensing system, data from road infrastructure, and data from neighboring cars. The I-WAY platform combined two independent sub-systems, the in-vehicle subsystem and the external transport subsystem. The in-vehicle subsystem includes modules for vehicle sensing, data acquisition, mobile interfaces of the vehicle, situation assessment, and communication. The external transport system includes the roadside equipment and the road management system. Funded under the Sixth Framework Programme, the total cost for the project was €4.59 million, €2.6 million of which was paid for by the European Commission (European Commission 2011a).

TEST SITE ITALY

Located in northern Italy, the Brennero test site is a 49 kilometer stretch along the Autostrada del Brennero (A22). The site is operated by Fiat and the motorway operator Autostrada del Brennero SpA. The stretch is a two-lane tollway with room for a provisional third lane on the shoulder. A shorter nine kilometer subsection of the stretch has higher equipment density for tests involving V2I communication. The speed limit along the test site is 130 kilometers per hour (DRIVE C2X 2012).

Applications being tested include (DRIVE C2X 2012):

- Traffic warnings
- Construction warnings
- Car breakdown assistance
- Slow vehicle warnings
- Traffic sign assistance
- Point of interest notification

The test fleet includes ten equipped vehicles. Network coverage along the site includes UMTS/3G, GPRS, and 802.11p. Equipment along the stretch includes five roadside units, variable message signs, TVCC cameras, traffic loops, Ethernet connectivity (traffic control center and roadside units), and on-site processing modules (DRIVE C2X 2012). All of the Brennero testing has been done on the public road; however, closed testing areas are proximate to the A22 stretch.

SMART VEHICLES ON SMART ROADS (SAFESPOT)

Smart Vehicles on Smart Roads (SAFESPOT), another connected vehicle project in Italy, is co-financed by the EU's Sixth Framework Programme for Research and Technological Development. The project brings together more than 50 partners including original equipment manufacturers (OEMs), operators, and research organizations from across Europe. The SAFESPOT project is one of the European flagship projects for cooperative mobility. It aims to prevent crashes by using a safety margin assistant that detects an appropriate following distance between cars. As with I-WAY, SAFESPOT employs both V2V and V2I communication to enhance the vehicle’s field of view. The SAFESPOT architecture complies with the European ITS architecture which allocates the 30 MHz frequency band in the 5.9 GHz range to connected vehicle safety applications (Brakemeier et al 2009).

Figure 19: SAFESPOT Test Site Locations
Source: SAFESPOT 2011

The project tested applications and scenarios through work done at six different test sites, each in a different country that had infrastructures equipped with SAFESPOT systems. Four of these test sites were shared with the CVIS project. All six sites are displayed in Figure 19. The Cooperative Mobility Showcase 2010, which took place in Amsterdam on 23-26 March 2010, was one of the world's largest demonstrations of connected vehicle technologies and applications. SAFESPOT demonstrated there and had a very strong presence (SAFESPOT 2011).

FIELD OPERATIONAL TEST SUPPORT ACTION (FESTA)

Italy also hosted the *Field Operational Test Support Action* (FESTA), which was a comprehensive research program assessing the impacts of information and communication technology systems on driver behavior, covering both individual safety benefits and broader socio-economic benefits. While the work on FESTA finished in April 2008, it laid the foundation for many other European FOTs. The objectives for FESTA included generating expertise and experience to promote the creation of a best practice handbook for the design and implementation of FOTs, providing additional guidance on how FOTs should be undertaken and reported, and involving major stakeholders to create a common vision. The project was coordinated by Centro Ricerche Fiat and consisted of a broad consortium of partners including A.D.C. Automotive Distance Control Systems GmbH, BMW Forschung und Technik GmbH, Bundesanstalt fuer Strassenwesen, Chalmers University of Technology, DaimlerChrysler AG, Delphi France, ERTICO – ITS Europe, Gie Recherches et Etudes, PSA Renault, Infoblu S.p.A., Institut National de Recherche sur les Transports et leur Sécurité, Loughborough University, Orange France, Robert Bosch GmbH, Statens Väg- och Transportforskningsinstitut, TNO, Universitaet zu Koeln, University of Leeds, Valtion Teknillinen, Volvo Car Corporation, and Volvo Technology Corporation (ERTICO 2012).

NETHERLANDS

DUTCH INTEGRATED TESTSITE FOR COOPERATIVE MOBILITY (DITCM)

The DRIVE C2X project being conducted in the Netherlands is known as the *Dutch Integrated Testsite for Cooperative Mobility* (DITCM). The DITCM is a stretch of highway containing several intersections. It has full coverage from both 802.11p and cameras. The Netherlands site is used as the “master” test site where all applications under DRIVE C2X have been tested before being deployed at the other six sites (DRIVE C2X 2012).

The test site is composed of 4.2 kilometers of highway and 1.8 kilometers of urban roadway, along which 20 vehicles with installed on-board units conduct tests. The stretch contains two traffic lights, four viaducts, an entrance, and exit, and a bus entrance. There are 48 poles for equipment installation, which currently includes 11 communications units (802.11p), 47 fixed cameras, and nine dome cameras. Network coverage includes UMTS/3G, 802.11p, and dGPS (DRIVE C2X 2012).

CONNECTED CRUISE CONTROL (CCC)

The €4 million *Connected Cruise Control* (CCC) project will result in a built-in solution to provide driving advice regarding speed, headway, and lane so drivers can anticipate and prevent congestion (HTAS 2012). The technology integrates in-vehicle and roadside systems to improve traffic flow. Plans are to initially introduce it as a nomadic aftermarket device in order to increase penetration rate and make the technology attractive for inclusion in OEM vehicle systems. The project began in December 2009 and end in November 2012, but currently the project is expected to run through 2014 (University of Twente 2012). Testing and evaluation was scheduled to occur during 2012 and product development was originally scheduled for

2012 and 2013. The partnership is headed up by TU Delft and includes Navteq, NXP Semiconductors, TNO, Universiteit Twente, SAM, Technolution, and Clifford (HTAS 2012).

STRATEGIC PLATFORM FOR INTELLIGENT TRAFFIC SYSTEMS (SPITS)

The goal of the *Strategic Platform for Intelligent Traffic Systems* (SPITS) project was to build the next generation of on-board technology for connected vehicles and to make it open and easily configurable for OEM specific requirements. The units created were upgradeable, allowing for improvements during the lifetime of an automobile, and decreasing the amount of time required for the adoption of new technologies. The project also focused on creating the next generation of roadside units and back office equipment (CVIS 2012). Project partners included Logica, NXP Semiconductors, Catena, GreenCat, Peek Traffic, Nspyre, Fourtress, TNO, and TomTom, as well as several universities throughout the Netherlands (SPITS 2012). Experimental testing was conducted in February 2010 on the A270 highway in the Netherlands between Helmond and Eindhoven. The project was funded by the Dutch Ministry of Economic Affairs and 13 partners. The project officially ended in May 2011 (SPITS 2012).

OPEN PLATFORM FOR INTELLIGENT MOBILITY (OPIM)

The follow up to SPITS is the *Open Platform for Intelligent Mobility* (OPIM) project, which is working to define an open platform for ITS systems across Europe. Among the program's goals are to keep the system affordable and flexible so it can be applied to the full range of transport vehicles, including cars, coaches, light trucks, and heavy goods vehicles. OPIM builds on lessons learned by the SPITS Project as well as programs and projects in which partners have participated - including CVIS, COOPERS, SAFESPOT, PRE-DRIVE C2X, ITS Test Beds, AUTOMATICS (France), AKTIV (Germany), sim^{TD} (Germany), NextGenITS (Belgium/Flanders). The project is designed to become the realistic start of ITS on a broad scale (HTAS 2012).

SPAIN

SISTEMAS COOPERATIVOS GALICIA (SISCOGA)

The *SIStemas COoperativos Galicia* (SISCOGA) project is participating in DRIVE C2X with its test site in northwestern Spain. The test site runs along two highway corridors (A-52 and A-55) and is around 60 kilometers long. This road network is displayed on a map in Figure 20. Centro Tecnológico de Automoción de Galicia (CTAG) and Dirección General de Tráfico (DGT)—the Spanish Ministry of Traffic—have created and currently operate the site (DRIVE C2X 2012).

Applications being tested include (DRIVE C2X 2012):

- Construction warnings
- Car breakdown assistance
- Traffic warnings
- Post-crash warnings
- Emergency brake warnings
- Cooperative merging assistance
- Weather warnings
- Traffic sign assistance
- Speed limit notification
- Traffic information and recommended itinerary
- Floating Car data

The speed limit along the test corridors is generally 120 kilometers per hour, but in places the speed limit decreases due to features such as curves or visibility limitations. The test area contains 15 roadside units (5.9 GHz, 802.11p), with another 30 planned for deployment. In addition, there are 19 variable message signs, seven meteorological stations, 21 camera units, and inductive wiring spots located along the corridors. Network

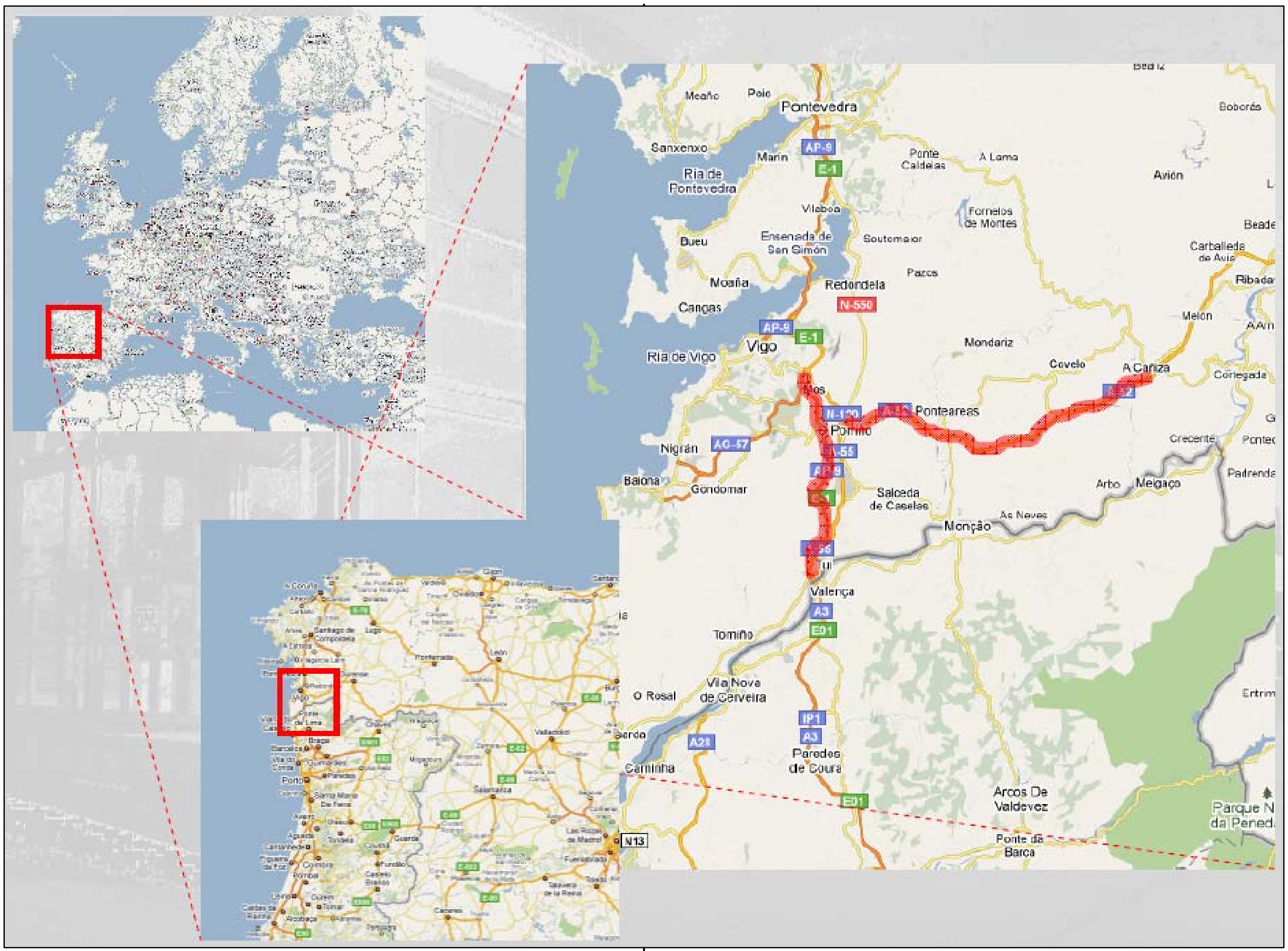


Figure 20: Map of SISCOGA Test Area
Source: Sánchez Fernández 2010

technology includes GPRS, UMTS, and 802.11p. The test area currently contains only highways, but current plans involve extending the test site to include urban areas (DRIVE C2X 2012). Some of the equipment used in testing is displayed in Figure 21.

Currently there are seven vehicles (three prototypes and four personal vehicles) being used to conduct tests. Eventually there will be 20 vehicles used to conduct tests, with the majority being personal vehicles (DRIVE C2X 2012). Those 20 vehicles were equipped with 5.9 GHz on-board communication units, GPS, specific human-machine interface (HMI), and controller area network (CAN) logging. The test also included 80 vehicles equipped with just GPS and UMTS units. SISCOGA is a follow-up project to C2ECom, which was also led by CTAG (Sánchez Fernández 2010).

SWEDEN

SAFER VEHICLE AND TRAFFIC SAFETY CENTRE

The SAFER Vehicle and Traffic Safety Centre at Chalmers University is “a joint research unit where 24 partners from the Swedish automotive industry, academia and authorities cooperate to make a center of excellence within the field of vehicle and traffic safety” (Chalmers 2012). Research at SAFER covers a broad range of fields relating to traffic safety and includes connected vehicle technologies (Chalmers 2010a).

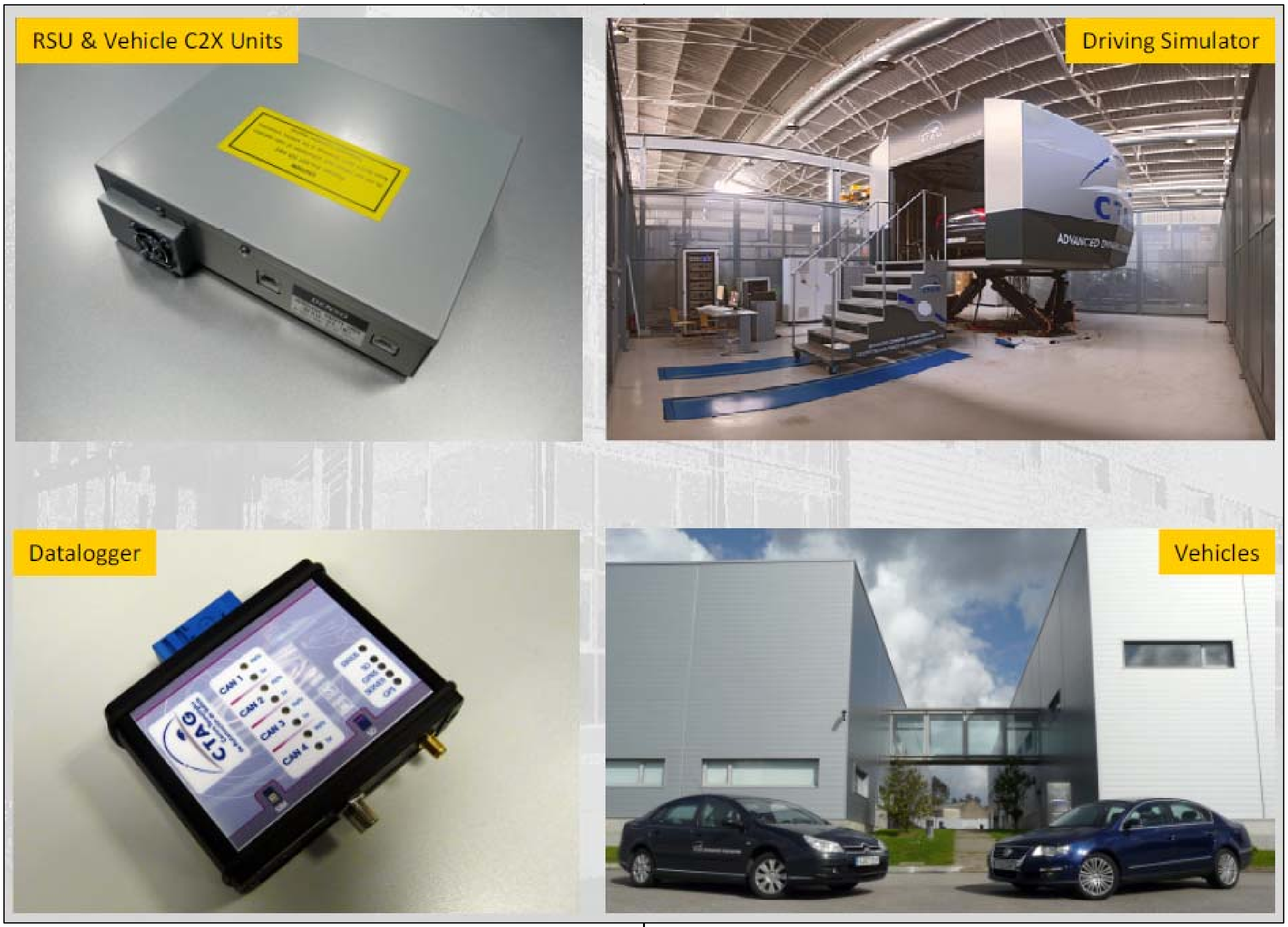


Figure 21: SISCOGA Equipment
Source: Sánchez Fernández 2010

SAFER (DRIVE C2X GOTHENBURG SITE)

The large-scale test site in Gothenburg is located in south of Sweden. The city is the nexus of three major highways. In addition to the open road track, the project also uses closed testing facilities. SAFER has operated the test site since 2008.

The open road portion of the testing area consists of more than 100 kilometers of highway, 100 kilometers of urban roadway, and more than 50 kilometers rural roadway. These stretches have more than 100 traffic light controlled intersections.

The closed testing facilities include Stora Holm and the City Race Track. Stora Holm is a Volvo test track that is used for testing safety critical applications and other applications involving non-traffic regulation compliant performance. The City Race Track opened in October 2009 and has hosted numerous demonstrations of cooperative systems (DRIVE C2X 2012).

Functions tested at the Gothenburg site include (DRIVE C2X 2012):

- Traffic warnings
- Construction warnings
- Car breakdown assistance
- Traffic sign assistance
- Optimal speed advisory for traffic lights,
- Floating car data

The test site contains seven roadside units as well as three traffic light controllers using 802.11p and VMSs on the main highway. On-board units have been provided by

Figure 22: Volvo FH12, Cameras, and Location for System Installation in Side Compartment
Source: SAFER 2008

Figure 23: Volvo S80, Cameras, and Logger Installation in Luggage Compartment
Source: SAFER 2008

Delphi, and equipment from EuroFOT includes touch screens, naturalistic loggers and cameras. Network technologies used include UMTS, 3G, GPRS, and 802.11p. The Gothenburg test fleet includes 20 cars (DRIVE C2X 2012).

TEST SITE SWEDEN (TSS)

Another major project carried out at SAFER was *Test Site Sweden* (TSS) which ended in 2008. TSS was a joint project between Autoliv, Chalmers, Volvo Car Corporation and AB Volvo. The project was very important for building-up competence in and establishing tools for conducting FOTs. Driving data was collected using two vehicles that were driven by 100 different drivers over the course of six months. The two test vehicles were provided by Volvo and included a car (Volvo S80) and a truck (Volvo FH12). These vehicles and the equipment that was installed in them can be seen in Figures 22 and 23. The project was very useful in positioning Sweden to take a strong role in proposal phases for a number of important European projects including FESTA, Sweden-Michigan Naturalistic Field Operational Tests (SeMiFOT), and EuroFOT as well as future FOT related projects (SAFER 2008).

BASFOT

Another FOT that SAFER is involved in is Sweden's BasFOT. While there is limited information available on BasFOT, it is currently setting up the platform for the SAFER *Field Operational Test/Naturalistic Driving Study* long term by working out issues with data acquisition, storage/database, analysis tools, data processing and quality, and procedures such as data sharing, manual annotation, etc. (Bärgman 2010). Phase 1, which involved building-up competence in conducting a FOT occurred in the 2009 through 2010 period. The project is currently in its second phase which involves continuing to build competency, as well as working on strategy and platform management. Phase 2 also includes secondary analysis and doctor of philosophy (PhD) projects (Victor 2010). There is potential for a phase three.

SWEDEN-MICHIGAN NATURALISTIC FIELD OPERATIONAL TESTS (SEMIFOT)

In 2007, MDOT, the Michigan Economic Development Corporation (MEDC), the Swedish Governmental Agency for Innovation Systems, and the Swedish Road Administration (Vägverket) signed a cooperative VII research agreement (MDOT 2007). The agreement is meant to foster cooperative, international research efforts between these organizations. Such efforts are underway, especially in the area of road weather information systems (RWIS).

The work with MDOT led to the *Sweden-Michigan Naturalistic Field Operational Test*s (SeMiFOT and SeMiFOT2). SeMiFOT was intended to be a pilot project for a larger FOT, but resulted in several large scale FOTs including EuroFOT and TeleFOT. Projects that have benefited from the work done on SeMiFOT include FESTA, EuroFOT, FOT-NET, BasFOT, TeleFOT, and DREAMi. Testing involved seven Volvo cars, three SAAB cars, two Volvo trucks, and two Scania trucks. Over the course of testing, there were nearly 8,000 trips totaling over 170,000 km and lasting nearly 3,000 hours over the course of six months. There were 39 different drivers. Equipment that was installed on vehicles included eye trackers, CAN-gateways, cameras, IR illumination, accelerometers, Ethernet devices, GPS devices, wireless communications devices (GPRS/3G), and hard drives. The follow-up project, SeMiFOT2 began in January 2010 (Chalmers 2010b).

SAFE ROAD TRAINS FOR THE ENVIRONMENT (SARTRE)

The *Safe Road Trains for the Environment* (SARTRE) project is led by Volvo and Ricardo. Other members include Idiada (Spain), Robotiker (Spain), the Institut für Kraftfahrwesen Aachen (Germany), and the SP Technical Research Institute of Sweden (Sweden). The project's budget is €6.4 million with around 60 percent of the funding being provided by the European Commission (McKeegan 2012). The main goal of the project is to develop and test vehicles that can autonomously drive in long convoys or road trains. A visualization of the concept can be seen in Figure 24. The project began in September 2009 and was scheduled to be completed by the end of August 2012 (SARTRE 2012). The first demonstrations were conducted at the Volvo Proving Ground near Gothenburg in Sweden in 2010 (SARTRE 2011 and McKeegan 2012).

In May 2012, a demonstration on public roads occurred outside Barcelona, Spain. The public roads demonstration featured a Volvo XC60, a Volvo V60, a Volvo S60 and a truck following a lead vehicle at 85 kilometers per hour with tested distances between vehicles ranging between five and 15 meters. Testing involved having the vehicles drive 200 kilometers in a single day. During testing, the follower vehicles were able to accelerate, brake, and turn in a manner that was synchronized with the lead vehicle, maintaining a consistent following distance despite these maneuvers (McKeegan 2012).

The test vehicles have cameras, radar, laser sensors, navigation systems, and transmitter/receiver units installed that will allow them to take measurements and communicate with each other. Because the system is V2V only, no infrastructure testing is involved (TTT 2009a and McKeegan 2012). The system itself has been designed such that it does not require expensive additions to vehicles—the only difference between SARTRE cars and those in today's showrooms is the

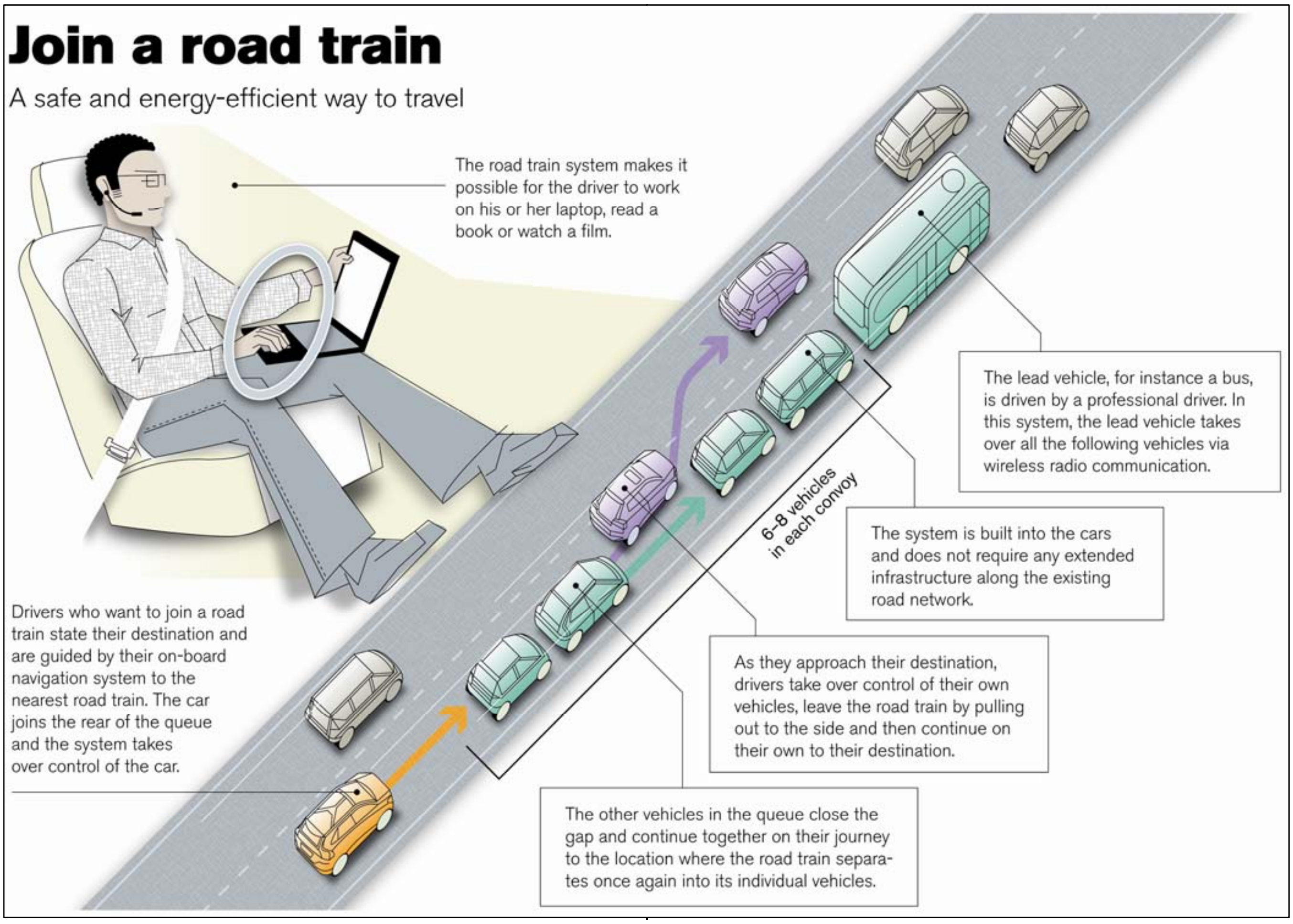


Figure 24: Safe Road Trains for the Environment Platooning Concept
Source: SARTRE 2011

wireless network equipment installed in the vehicles. In addition, the system is designed such that existing vehicles can be retrofitted with the technology.

SAFETY IN SWEDEN

As with Europe in general, as demonstrated by ERTICO, Sweden has taken a strong policy stand on automotive safety. Most notably, in 1997, Sweden initiated a governmental program called *Vision Zero* that is intended to eliminate traffic-related deaths and incapacitating crashes (Whitelegg and Haq 2006). This program is managed by the Swedish Road Administration. While the program recognizes that it is impossible to prevent all crashes from occurring, it focuses on protecting the vehicle passengers as much as possible. Essentially, *Vision Zero* places a greater responsibility for road safety on those who design road networks and build vehicles as opposed to placing most of the responsibility on the driver. Specific approaches include installing central safety barriers to reduce the number of head-on collisions, building more roundabouts, and lowering speed limits in urban areas (Whitelegg and Haq 2006). Approaches under consideration include redesigning intersections and removing rigid roadside objects like trees and large rocks.

Sweden also integrates advanced automotive electronics into its *Vision Zero* plan. One example of this integration is Sweden's *Slippery Road Information System* (SRIS). Led by Vägverket, in cooperation with Volvo and Saab, this program places sensors in the vehicles that detect slippery spots on the road. These sensors then send information back to traffic management centers, which therefore can better manage plowing snow, salting roads, and alerting drivers of icy spots. In addition, SRIS compares the vehicle-based sensor data with information obtained from RWIS, such as air and surface temperatures, humidity, and barometric pressure, to validate the vehicle sensor data (Vägverket Document 2007). During the winter of 2007-2008, the SRIS partners conducted tests using 100 vehicles, and these tests clearly demonstrated that SRIS is cost effective and increases safety on the roads (SRA 2008). The SRIS project is expected to help Sweden meet its *Vision Zero* objectives.

Another advanced automotive electronics development arising from Sweden is Volvo's optional collision avoidance package, as well as its blind spot detection and front and back parking assistance applications (Volvo 2011). Several other promising safety technologies are under development, such as built-in alcohol sensors, night vision systems, and adaptive cruise control, to ensure that drivers maintain a safe distance from vehicles ahead. While these examples largely represent autonomous, as opposed to cooperative, technologies, the latter also are under development in Sweden.

While Sweden already had a very low number of traffic fatalities compared to other countries before *Vision Zero* went into effect, the program appears to have worked well. Between 1997 and 2007, the first ten years of *Vision Zero*, the number traffic fatalities decreased by more than 20 percent, from 541 to 431 (Wiles 2007). While literally reaching zero fatalities remains a distant goal, Sweden is making important strides toward this ultimate goal.

AUSTRIA

CO-OPERATIVE SYSTEMS FOR INTELLIGENT ROAD SAFETY (COOPERS)

Headed up by AustriaTech in Austria, the *Co-operative Systems for Intelligent Road Safety* (COOPERS) project used existing equipment and infrastructure as a foundation when developing standardized wireless bidirectional infrastructure-vehicle technology (Schalk 2011). The project included 39 partners and ran from 2006 to 2010. The project included several demonstration sites across Europe including stretches of roadway in Austria, Belgium, France, Germany, Italy, and Netherlands. These sites are marked on the map in Figure 25. COOPERS service messages were generated out of existing data sources and no additional sensor installations were needed. The *Traffic Information Platform* (PVIS) for COOPERS was a common platform for easier access to all the traffic information sources and systems, such as traffic messages, travel times, weather data, and variable message sign states (Meckel 2008).

FINLAND

COOPERATIVE TEST SITE FINLAND (COOP TS FINLAND)

The Finnish test site includes an eight kilometer open road stretch from Tampere to Hervanta as well as a closed test area. The open road section contains three roadside ITS units (802.11p) and one moveable roadside unit (3G/802.11p). The route also contains a motorway junction, which will be used to monitor ramp issues (Laitinen 2012). The layout of the open road test site can be seen in Figure 26.

The closed test facility is Nokian Tyres Proving Ground in Ivalo, Finland. The facility can simulate almost any driving situation. The track includes an 1,800 meter long lap, a 400 meter long straight, five intersections, and a reduced-visibility turn. The track tests make use of the moveable roadside unit for V2I tests (Laitinen 2012) as well as two fully instrumented VTT vehicles (Tarkiainen 2010).

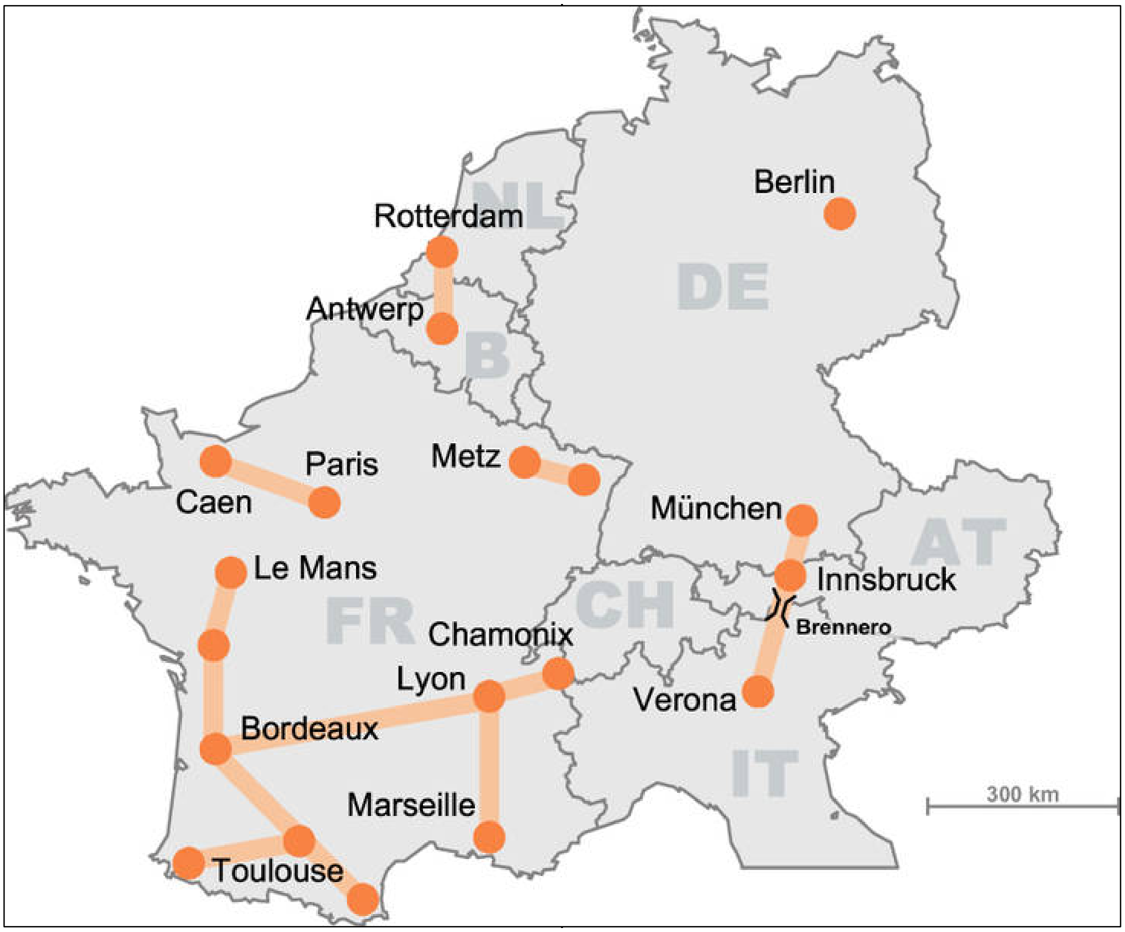


Figure 25: Locations of COOPERS Test Sites
Source: COOPERS 2011

Applications being tested include (Laitinen 2012):

- Road weather warnings
- Construction warnings
- Traffic sign assistance
- Car breakdown assistance
- Slow vehicle warnings
- Emergency vehicle warnings

FIELD OPERATIONAL TESTS OF AFTERMARKET AND NOMADIC DEVICES IN VEHICLES (TELEFOT)

The *Field Operational Tests of Aftermarket and Nomadic Devices in Vehicles* (TeleFOT) project is funded by the Seventh Framework Programme and the European Commission DG Information Society and Media focused on developing information and communication technologies for cooperative systems. The project began in June 2008 and will last for 48 months. The purpose of the project is to test driver support functions with large fleets of test drivers in real-world driving conditions. The project focuses on aftermarket and nomadic devices. TeleFOT will involve up to 3,000 drivers in TeleFOT-equipped vehicles and will span Finland, Sweden, Germany, United Kingdom, France, Greece, Italy, and Spain (TeleFOT 2012). While the tests will be conducted in three test communities (Finland/Sweden, Germany/France/UK, and Greece/Italy/Spain), the project is coordinated out of the VTT Technical Research Centre of Finland. The final event will be held in late November 2012.

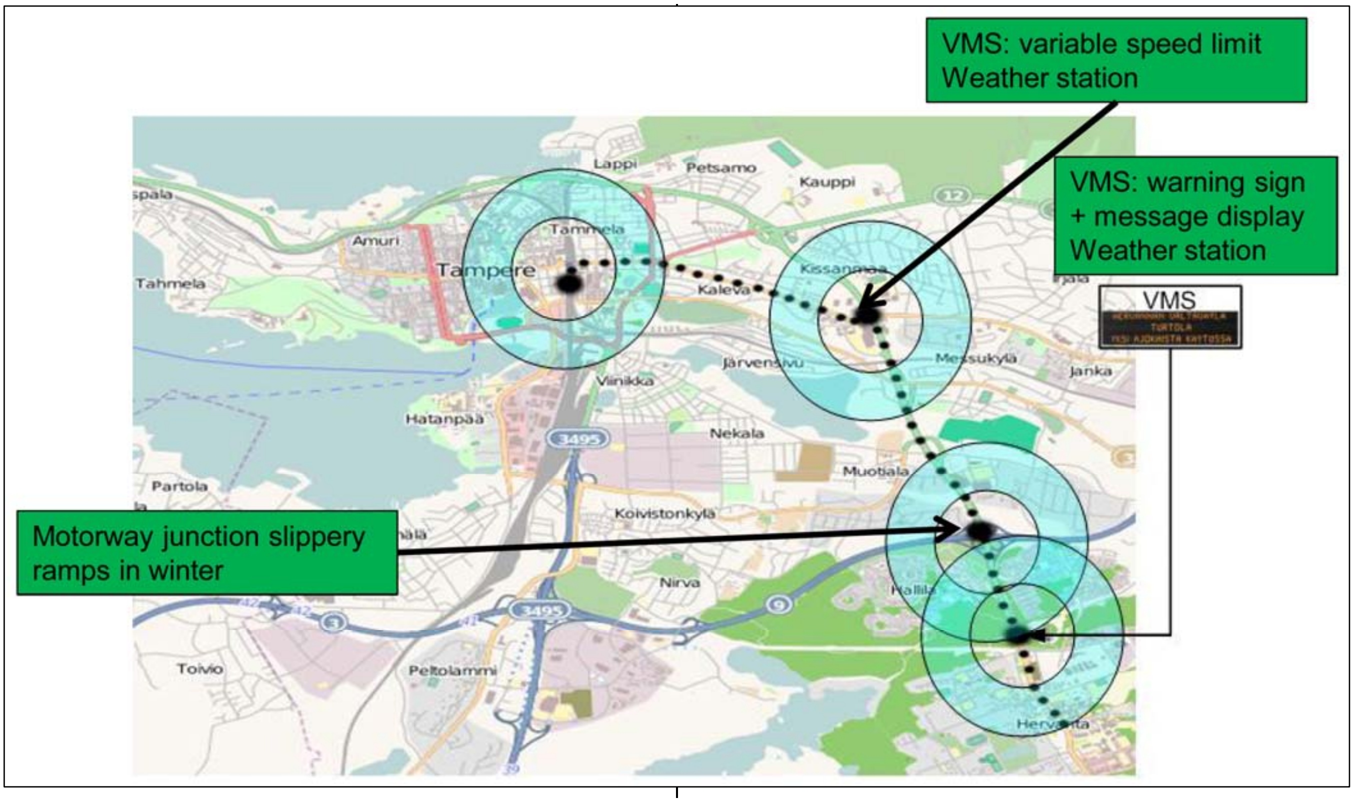


Figure 26: Open Road Test Site for Coop TS Finland (Tampere to Hervanta)
Source: Laitinen 2012

Semantic Driven Cooperative Vehicle Infrastructure Systems For Advanced eSafety Applications (COVER)

Another project that was conducted in Finland was *Semantic Driven Cooperative Vehicle Infrastructure Systems for Advanced eSafety Applications* (COVER). The central focus of COVER was V2I applications such as intelligent speed adaptation (static, temporary, and dynamic speed limits) and cooperative early information. The project ran from March 2006 to February 2009. COVER conducted two field trials. One was carried out on roads (E18 Corridor) in Finland and focused on truck drivers. The other was carried out on a road segment (Turin-Florence) in Italy, and focused on non-professional drivers (Ellmén 2006).

Norway

Smart Freight Transport in Urban Areas (SMARTFREIGHT)

The *Smart Freight Transport in Urban Areas* (SMARTFREIGHT) project aims to improve urban freight transport efficiency, environmental impact, and safety through use of distribution networks. The project researched the integration of urban traffic management systems with freight management and onboard systems. SMARTFREIGHT could lead to improved freight operations by providing access to real travel time and traffic status information through use of onboard units, sensors, smart tags, and wireless. In addition, those technologies enable monitoring of goods transport, loading, and unloading. The program evaluated technical solutions, through real and simulated test applications. Participants included Asociacion para el Desarrollo de la Logistica (Spain), Dublin Transportation Office (Ireland), Statens

Vegvesen Vegdirektoratet (Norway), Comune di Bologna (Italy), Polis - Promotion of Operational Links with Integrated Services aisbl (Belgium), University of Southampton (United Kingdom), Q-free ASA (Norway), Chalmers Tekniska Hoegskola Aktiebolag (Sweden), and Etra Investigacion y Desarrollo, S.A (Spain). Work on SMARTFREIGHT began in January 2008, and the end date for the project was set at June 2010 (European Commission 2011b).

ISRAEL

COOPERATIVE COMMUNICATION SYSTEM TO REALIZE ENHANCED SAFETY AND EFFICIENCY IN EUROPEAN ROAD TRANSPORT (COM2REACT)

Cooperative Communication System to Realize Enhanced Safety and Efficiency in European Road Transport (COM2REACT) is establishing a system using V2V and V2I communication over 2.4 GHz Wi-Fi (802.11b IEEE WLAN standard). This system improves the quality and reliability of information acquired by moving vehicles. An important part of the system is its virtual traffic control sub center (VSC), which controls a moving group of vehicles in close proximity. The VSC creates a network out of vehicles near each other that creates information about local traffic and safety situations. Using V2I communication, the VSC transmits this information to a regional control center which sends back instructions to distribute to the vehicles. This project builds upon the *Realize Enhanced Safety and Efficiency in European Road Transport* (REACT) project which involved sensor-equipped vehicles and a regional control center. In addition to the work that was done for the REACT project, COM2REACT developed VSC and integrated it with REACT to obtain a more complex, but more effective system. COM2REACT is a partnership of 13 organizations, including an automaker, road authority, and several high tech enterprises (C2R 2011). COM2REACT conducted testing in 2007 and 2008, but little to no information could be gathered on the project’s current activities or any follow-up projects.

V. CONCLUSIONS AND RECOMMENDATIONS

Various regions throughout the world are exploring connected vehicle technologies, and there have been several different approaches to developing these technologies. Research, demonstration, and deployment projects, in particular those in the United States, Europe, and Japan, have demonstrated the potential of connected vehicles to improve transportation systems. In the United States, the focus is primarily on connected vehicle safety research. While some states currently have roadside infrastructure deployed, this is largely for research and demonstration purposes. Europe has a similar research-based approach, emphasizing safety and efficiency. However, projects in Europe have been significantly more top-down and have involved large coalitions of countries, industry partners, and universities. Japan already has deployed a connected vehicle system that uses mobile phone technology, DSRC, and infrared and already has a significant user base due to its ubiquitous electronic tolling system.

Despite the regional difference in connected vehicle programs, there have been many overarching themes that could be useful to consider with respect to connected vehicle technology deployment. The following subsections discuss potential funding strategies that have been used to support connected vehicle programs as well as important factors that can affect the success of connected vehicle deployment.

FUNDING STRATEGIES

CAR's review of connected vehicle and connected vehicle-related activities both domestically and abroad has revealed at least three distinct, but successful, strategies for funding such activities. These include making large budget allocations that require matching funds from private or public sources, securing a large source of funding from the national government through competitive grants or earmarks, and tying the collection of tolls to connected vehicle projects.

COMMIT BUDGET ALLOCATIONS REQUIRING MATCHING FUNDS

This method of leveraging initial funds to attract additional investment from other private and public sources is extremely common at the national level and is not limited to the United States. For example, several of the European projects that received funding through the European Commission also had to obtain funding from other sources. Projects such as PRE-DRIVE C2X, I-WAY, and SMARTFREIGHT were funded in this manner. This approach is not only limited to national governments; domestically, California has committed significant state funding to connected vehicle efforts and is actively pursuing private-sector funding, through incentive programs, to supplement these dollars. It also has strong participation from California-based automotive facilities in its programs, as well as participation from other private-sector entities, such as Nokia.

PURSUE FUNDING AT THE NATIONAL LEVEL

Beyond the first approach listed, California is also active in pursuing federal dollars, as witnessed by its Urban Partnership grant application, its share of USDOT RITA funding, and its SAFE TRIP-21 award. An even more salient example of this approach can be found in Minnesota's efforts to secure funding. Minnesota has both sought and won federal dollars well beyond its normal share of Highway Trust Fund dollars, allowing the state to deploy technologies and other resources beyond what its formula-based share of the federal gas tax would have allowed. In Germany, the state of Hessen has leveraged past experience and actively pursued connected vehicle projects, receiving funding from the Federal Ministry of Economics and Technology to host the AKTIV project.

TOLLS TO FUND PROGRAMS

Though most of the ITS technologies used are not technically connected vehicle applications, Florida is a prime example of a state using toll revenues to increase its pool of available funds for deploying innovative solutions. Minnesota also has an active electronic tolling program that supports the market pricing of its high occupancy toll lanes. Transponders placed in vehicles enable automatic fee deduction from an account. The system uses marginal cost pricing by varying fees depending on how busy the HOV lane is. Colorado's tests using DSRC in tolling represent a great progress towards integrating electronic tolling with connected vehicle technologies. In Japan, electronic tolling was an early application of the nation's ITS program. Also in Asia, South Korea is working to make electronic toll collection available on its highways and is instituting e-pay on public transit. By integrating tolling into ITS systems, transportation managers have another potential source of revenue for new projects.

All three of these approaches reinforce the need for adequate and additional funding streams to allow a state or country to lead in the area of ITS technologies.

IMPORTANT FACTORS

In CAR's review of connected vehicle and connected vehicle-related activities, several important factors arose regarding the research, development, and deployment of these technologies.

FORMING COALITIONS

Compared to projects in the United States, successful projects in Europe tended to be backed by larger coalitions. European projects tended to have significant participation from transportation agencies, communities, universities, research institutions, and private industry. These public-private partnerships have been instrumental to successful tests and deployment, often driven by a common goal of enhanced vehicle safety. On the other hand, partnerships for Asian projects were smaller and often similar to the size of American project partnerships, but tended to involve national government agencies and manufacturers whereas American partnerships more frequently focused on universities and state agencies. These differences may reflect differences in funding mechanisms, governance, or stage in research and development for connected vehicle programs across regions.

CREATING INDUSTRY COMPETITION

An approach used by Japan, one of the most advanced countries in ITS and connected vehicle deployment, is to set standards and create infrastructure test deployments and invite manufacturers to participate in field tests. This was done for the DSSS, ASV, and *Smartway* projects. By using such a method, Japan has driven its manufacturers to create and test systems meeting the criteria of these three projects. Several vehicle manufacturers including Toyota, Honda, Nissan, Mazda, Mitsubishi, NEC Corporation, Panasonic, Yamaha, Kawasaki, and Suzuki participated in tests for DSSS and ASV and by the end of 2010, systems compatible with *Smartway* infrastructure had been developed by Toyota, Pioneer, Mitsubishi Electric Co., Panasonic, and Mitsubishi Heavy Industries.

DEVELOPING PROGRAMMATIC THEMES AND BOLD GOALS

Internationally, having a strong programmatic theme was particularly useful in moving projects and deployments forward. In Europe, the major theme centered around safety and in particular on using technology to make the vehicle-roadway environment an active participant in assisting drivers. Projects focused largely on decreasing crash risks and reducing the negative consequences of crashes that do occur. In Asia, themes were just as important: South Korea's concept of the "Ubiquitous City" has generated enthusiasm from several cities who want to implement communications technologies. Like Europe, Japan has focused on safety as a central theme. In its *ITS Introduction Guide*, the Ministry of Land, Infrastructure and Transport Japan credits a tragic bus accident as the impetus to improve road safety systems that lead to its ITS program. The international examples have also demonstrated the usefulness of bold goals in motivating achievements, such as Sweden's *Vision Zero*.

GENERATING EXPERTISE

Working on connected vehicle projects has been a boon to several private companies, research institutions, countries, states, and transportation management agencies. This survey of international efforts has stressed the global nature of vehicle electronics, including the advantages of standardization to make it easier for automotive OEMs to offer the same communication technologies globally and the potential competition among suppliers worldwide.

The example of the Industrial Technology Research Institute of Taiwan providing WAVE/DSRC communication units to support a connected vehicle project in the U.S. demonstrates the global nature of automotive research and development. Similarly Cohda Wireless of Australia has developed technology that has been involved in on-road trials around the world in projects such as DRIVE C2X in Europe and, the *Connected Vehicle Safety Pilot* in the United States. Michigan companies wishing to play a role in connected vehicle technologies will need to keep this global lesson in mind and could stand to benefit from capturing larger markets if they take leadership roles and foster international partnerships. Ford, through its *Urban Mobility Initiative*, has shown signs of grasping this concept; GM, too, through its European brands, is active overseas in connected vehicle-related initiatives.

Developing expertise as a way to create future opportunities is also applicable to national and state agencies. For example, the *Test Site Sweden* project was very useful in building up competence in Field Operational Tests and positioned Sweden to take a strong role in proposal phases for a number of important European projects including FESTA, SeMiFOT, and EuroFOT as well as other FOT related projects. Domestically, leading states have used past successes to demonstrate their ability to carry out work in competitive bids for federal projects.

REGULATING TECHNOLOGY TO MAKE A STRONG BUSINESS CASE

Successful deployment of connected vehicle technologies requires a strong business case. Some applications such as infotainment, internet, and navigation systems will likely be covered by industry actors responding to consumer demand. Due to the costs of deployment, technological constraints, and the number of equipped vehicles required for safety applications, however, leadership from national and state governments is crucial to the deployment of connected vehicle safety technology. Regulation has an important role; without legal requirements requiring integration of safety units into vehicles, adoption of DSRC based safety applications will be severely stunted or simply may not occur. Government agencies have the ability and obligation to establish the argument for connected vehicle mandates to ensure adequate coverage necessary to realize safety benefits.

STANDARDIZING GLOBAL/REGIONAL ARCHITECTURES

Global standards and architectures for connected vehicle technologies would strengthen the case for connected vehicle deployment. By using common equipment, the production volumes of in-vehicle and roadside units can be increased, helping to bring down unit costs. If not at the global level, then at least at the continental level, it makes sense to standardize equipment and architectures so that vehicle technologies can cross borders without losing the benefits of a connected vehicle system and automakers can use a single system in vehicles rather than using different systems for vehicles being purchased in different markets.

- DSRC varies from 5.85 to 5.925 GHz in the United States to 5.875 to 5.925 GHz in Europe and 5.775 to 5.845 GHz in Japan (PIARC-FISITA 2012). While various regions of the world have slightly different standards, there has been significant work to harmonize standards. The European Commission, for instance, has funded several projects to create harmonized systems throughout Europe. Australia's strongest argument for securing 5.9 GHz bandwidth for ITS applications was that it would allow an Australian connected vehicle system to be consistent with those in other countries. To some extent, this logic may have already proved to be sound as the *Connected Vehicle Safety Pilot* in Michigan in the U.S. includes DSRC equipment vendors based in Australia (Cohda Wireless) and Taiwan (ITRI). The United States and Europe signed a joint declaration in 2009 pledging to use global standards when possible (RITA 2009). A similar agreement was signed between the United States and Japan in 2010 (RITA 2010).

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APPENDIX A. ABBREVIATIONS

AASHTO – American Association of State Highway and Transportation Officials

ACMA – Australian Communications Media Authority

AKTIV – Adaptive and Cooperative Technologies for Intelligent Traffic

AMTICS – Advanced Mobile Traffic Information and Communication System

ARTC – Automotive Research and Testing Center (Taiwan)

ASU – Arizona State University

ASV – Advanced Safety Vehicle

BRT – Bus Rapid Transit

C2X – Car to anything (e.g. vehicle, infrastructure, cellular phone, handheld device, etc.)

CACS – Comprehensive Automobile Traffic Control System

CALM – Communications, Air-interface, Long and Medium range (wireless communication protocol)

Caltrans – California Department of Transportation

CAMP – Crash Avoidance Metrics Partnership

CAN – Controller Area Network

CAR – Center for Automotive Research

CB – Citizen Band

CCC – Connected Cruise Control

CCTV – Closed Circuit Television

CICAS – Cooperative Intersection Collision Avoidance System

CICAS-SSA – Cooperative Intersection Collision Avoidance System Stop Sign Assist

CICAS-V – Cooperative Intersection Collision Avoidance System for Violations

CITYLOG Sustainability and Efficiency of City Logistics

COM2REACT – Cooperative Communication System to Realize Enhanced Safety and Efficiency in European Road Transport

COOPERS – Co-operative Systems for Intelligent Road Safety

COSMO – Co-Operative Systems for Sustainable Mobility and Energy Efficiency

COVER – Semantic Driven Cooperative Vehicle Infrastructure Systems for Advanced eSafety Applications

CSS – Cooperative Safety Systems

CTAG – Centro Tecnológico de Automoción de Galicia

CVII – Commercial Vehicle Infrastructure Integration

CVIS – Cooperative Vehicle Infrastructure Systems

CVTA – Connected Vehicle Trade Association

DAS – Data Acquisition Systems DGT – Dirección General de Tráfico

DIAMANT – Dynamische Informationen und Anwendungen zur Mobilitätssicherung mit Adaptiven Netzwerken und Telematikanwendungen or Dynamic Information and Applications for assured Mobility with Adaptive Networks and Telematics infrastructure

DITCM – Dutch Integrated Testsite for Cooperative Mobility

DMS – Dynamic Message Signs

DOT – Department of Transportation

DRIVE C2X – DRIVing implementation and Evaluation of C2X communication technology

DSRC – Dedicated Short Range Communication

DSSS – Driving Support Safety Systems

EAR – Exploratory Advanced Research

eCoMove – Cooperative Mobility Systems and Services for Energy Efficiency

EMC – Electro-magnetic Compatibility

ERTICO – European Road Transport Telematics Implementation Co-ordination Organization

ETC – Electronic Toll Collection

EV – Electronic Vehicle

FDOT – Florida Department of Transportation

FESTA – Field Operational Test Support Action

FHWA – Federal Highway Administration

FIRST – Freeway Incident Response Safety Team

FOT – Field Operational Test

FOT-Net – Field Operational Test Network

FTE – Florida Turnpike Enterprise

GHz – Gigahertz

GNSS – Global Navigation Satellite System

GPRS – General Packet Radio Service

GPS – Global Positioning System or Global Position Satellite

HAR – Highway Advisory Radio

HeERO – Harmonized eCall European Pilot

HLSV – Hessian State Office of Road and Traffic Affairs

HMI – Human-Machine Interface

HOT – High Occupancy Toll (traffic lane)

HOV – High Occupancy Vehicle (traffic lane)

HSPA – High-Speed Packet Access

IAP – Intelligent Access Program

ICM – Integrated Corridor Management

ICT – Information and Communication Technologies

ICT PSP – Information and Communication Technologies Policy Support Program

INRIA – French National Institute for Research in Computer Science and Control

IR – Infrared

ISM – Industrial, Scientific, and Medical (radio band, 2.4 GHz)

ISMUF – *IntelliDrive*^{SM} for Safety, Mobility, and User Fee Project

ITRI – Industrial Technology Research Institute of Taiwan

ITS – Intelligent Transportation Systems

I-WAY – Intelligent Co-Operative System in Cars for Road Safety

IWCU – ITRI WAVE/DSRC Communication Unit

LAN – Local Area Network

LIT – Lighting and Infrastructure Technology

LTE – 3GPP Long Term Evolution

M5 – CALM microwave medium at 5 GHz

MCNU – Multiband Configurable Networking Unit

MDOT – Michigan Department of Transportation

MEDC – Michigan Economic Development Corporation

MLFF – Multi Lane Free Flow

MnDOT – Minnesota Department of Transportation

MOBI.Europe – Integrated and Interoperable ICT Applications for Electro-Mobility in Europe

MOLECULES – Mobility based on eLEctric Connected vehicles in Urban and interurban smart, cLean, EnvironmentS

MSU – Montana State University

MTC – Metropolitan Transportation Commission

NCAR – National Center for Atmospheric Research

NDS – Naturalistic Driving Studies

NextGenITS – Next Generation Intelligent Transportation Systems

NHTSA – National Highway Transportation Safety Administration

NTRC – National Transportation Research Center

NTRCI – National Transportation Research Center, Inc.

OBE – On Board Equipment

OBU– On Board Unit

OEM – Original Equipment Manufacturer

OPIM – Open Platform for Intelligent Mobility

ORNL – Oak Ridge National Laboratory

ORT – Open Road Tolling

PATH – Partnership for Advanced Transit and Highways

PhD – Doctor of Philosophy

PRE-DRIVE C2X – PREparation for DRIVing implementation and Evaluation of C2X communication technology

PVIS – Traffic Information Platform (For COOPERS Project)

RACS – Road Automobile Communication System

REACT – Realize Enhanced Safety and Efficiency in European Road Transport

RFID – Radio Frequency Identification

RHODES^{NG} – Real-Time Hierarchical Optimized Distributed Effective System Next Generation

RISC – Rapid Incident Scene Clearance

RITA – Research and Innovative Technology Administration

RSE – Road-side Equipment

RSU – Road-side Unit

RTMC – Regional Transportation Management Center

RWIS – Road Weather Information System

SAE J2735 – Society of Automotive Engineers standard for DSRC message sets

SAFE TRIP-21 – Safe and Efficient Travel through Innovation and Partnerships in the 21st Century, a USDOT program managed by the Volpe Center

SAFESPOT – Smart Vehicles on Smart Roads

SAFETEA-LU – Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users

SARTRE – Safe Road Trains for the Environment

SCORE@F – System Coopératif Routier Expérimental Français

SeMiFOT – Sweden-Michigan Naturalistic Field Operational Test

Sevecom – Secure Vehicular Communication

sim^{TD} – Safe and Intelligent Mobility Test Germany

SISCOGA – Sistemas Cooperativos Galicia

SKY – Start ITS from Kanagawa, Yokohama

smartCEM – Smart Connected Electro Mobility

SMARTFREIGHT – Smart Freight Transport in Urban Areas

SPAT – Signal Phase and Timing

SPITS – Strategic Platform for Intelligent Traffic Systems

SRIS – Slippery Road Information System [in Sweden]

TeleFOT – Field Operational Tests of Aftermarket and No-madic Devices in Vehicles

TMC – Traffic Management Center or Transportation Management Center

TOCC – Transportation and Operations Communication Center

TRB – Transportation Research Board [of the National Academies of Science and Engineering]

TSS – Test Site Sweden

U-City – Ubiquitous City

UA – University of Arizona

UMTRI – University of Michigan Transportation Research Institute

UMTS – Universal Mobile Telecommunications System or Universal Traffic Management Society of Japan

USDOT – United States Department of Transportation

UTC – University Transportation Center

UTMS – Universal Traffic Management Society of Japan

V2D, V2X – Vehicle to Device Communications

V2I – Vehicle-to-Infrastructure

V2V – Vehicle-to-Vehicle

VAD – Vehicle Awareness Device

VDOT – Virginia Department of Transportation

VERTIS – Vehicle, Road and Traffic Intelligence Society

VICS – Vehicle Information and Communication System

VII – Vehicle-Infrastructure Integration

VII-C – Vehicle-Infrastructure Integration Consortium

VSC – Virtual Traffic Control Sub-Center

VTTI – Virginia Tech Transportation Institute

WAVE – Wireless Access in Vehicular Environment

WDT – Weather Data Translator

WiMAX – Worldwide Interoperability for Microwave Access, a telecommunications technology providing wireless data, voice and video over long distances

WLAN – Wireless Local Area Network

WTI – Western Transportation Institute

APPENDIX B. GEOGRAPHICAL SUMMARY OF PROJECTS

By Continent

Continent	Projects
Asia	78
Europe	134
North America	133
Oceania	7
Grand Total	**352**

By Country

Country	Projects
China	6
India	1
Israel	4
Japan	42
Singapore	1
South Korea	17
Taiwan	6
Turkey	1
Austria	1
Belgium	10
Finland	2
France	12
Germany	38
Greece	2
Italy	10
Netherlands	14
Norway	2
Romania	1
Spain	5
Sweden	15
United Kingdom	8
Europe-Wide	14
Canada	5
USA	128
Australia	6
New Zealand	1
Grand Total	**352**

By U.S. State

State	Projects
Arizona	3
California	22
Colorado	2
District of Columbia	3
Florida	5
Georgia	1
Idaho	1
Illinois	2
Indiana	1
Maryland	3
Massachusetts	2
Michigan	27
Minnesota	7
Missouri	1
Montana	10
New Jersey	2
New York	6
North Carolina	1
Ohio	1
South Carolina	1
Texas	5
Virginia	7
US-Wide	15
Grand Total	**128**