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CENTER FOR TRANSPORTATION RESEARCH

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WORK PLAN FOR ESTABLISHING TEST PLATFORMS FOR NEW TRANSPORTATION SYSTEMS

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TxDOT Project 0-6803: Technology Task Force

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1. Background

The Texas Technology Task Force (TTTF) reviewed the status and potential of autonomous vehicles (AV), connected vehicles (CV), electric vehicles (EV), and cloud computing (CC) and crowdsourcing technologies. The main objectives of TTTF is to make Texas the pioneering state in the research, development, and deployment of new transportation technologies, to take advantage of its long-standing role as an early adopter, and help to create a market for these new technologies.

A cost-effective solution to achieve such goals is the establishment of test platforms, or *testbeds*. Testbeds can become major resources for accomplishing beta testing (multi-month, pre-commercial testing, etc.) and demonstrating technologies. They allow developers to perform testing in a safe and controlled environment, helping to ensure functionality and quality of the application across multiple platforms and technologies. Testing for feedback and improvement can take place before products go to market.

2. Transportation Test Platforms

Transportation testbeds are platforms for experimentation and transportation technology development. They provide development environments that shield potential testing technology hazards that could be encountered in live or fully operational environments. A typical transportation testbed includes software, hardware, a network and communication component, testing vehicles, testing tracks/routes, and detection systems. Transportation testbeds are usually established as simplified or scale-down simulations of a real-world or field environment, e.g., a freeway corridor, a local transportation network, or an intersection. They are an intermediate evaluation platform between a simulation-based evaluation platform and the full field testing and operations that occur in the public space. These environments still reflect the real-world scenarios since testbeds are built and configured based on real-world situations, though they are not as complex as the live and operational transportation system.

3. Existing Transportation Test Platforms

Testbeds have been widely established in the research and development of different transportation technologies. Many test environments have been established for the four technologies investigated by the TTTF.

3.1 Connected Vehicle (DSRC) Testbeds

Testbed for CVs (those based on dedicated short-range communications—DSRC) have been established under the US Department of Transportation’s (USDOT) RITA (Research and Innovative Technology Administration) Connected Vehicle program [1]. The existing testbeds are located in California, Tennessee, Michigan, Virginia, Florida, and New York. Table 1 summarizes their main characteristics and highlights [2].

Table 1. USDOT Connected Vehicle Testbeds [2]

Testbed	Location	Purpose	Assets	Applications
California	Palo Alto	Assess/evaluate real-world implementations, inform future investment decisions on system management programs	Vehicles, OBEs, RSEs, backend servers	Multi-modal intelligent signal, CV mobility applications, CV safety warning
Florida	Orlando	Support 18th ITS World Congress Technology Showcase demos in Orlando	Vehicles, RSEs, servers, data management systems	SunGuide software CV module
Michigan	Oakland County	Research and testing resource for private developers to test DSRC-enabled applications	OBEs, RSEs, SPaT, vehicles, trailers, 3000 volunteer vehicles	Connected intersection, security network, safety pilot
Minnesota	Multiple locations	Minnesota road fee test, road weather information system, testing DSRC standards	500 volunteer vehicles, DSRC safety, Android apps, MnDOT snow plows	Road fee test, safety clinic, road weather information
New York	Long Island	To support the 2008 ITS World Congress in Manhattan and demonstrate CV capabilities of CV technologies	Vehicles, OBEs, RSEs, freeway and arterial	OBE management, DSRC wireless safety inspection, DSRC safety warning
Virginia	McLean	Test CV technologies in congested urban areas, focus on enhancing the state of the art of transportation operations research	Vehicles, OBEs (DSRC), OBEs (cellular), RSEs, fiber network, backend servers, data warehouse	CV-DSRC, CV-cellular mobility and safety applications, multi-modal solutions
OBE: onboard equipment, **RSE:** roadside equipment, **SPaT:** signal phase and timing				

Michigan

The experiment in Ann Arbor, Michigan, places Michigan at the forefront of CV research. The University of Michigan’s Transportation Research Institute was awarded a $14.9 million dollar contract from the USDOT in 2011 to conduct a safety pilot model of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) applications [3, 4]. This experiment is a 30-month program that will establish real-world, multimodal test sites for wireless communication amongst vehicles and the surrounding environment, using everyday drivers (Figure 1). The 2,850 vehicles in the study include passenger cars, commercial trucks, and transit vehicles, which will include both embedded and aftermarket V2V- and V2I-based safety systems. All of these devices emit a basic safety message 10 times per second, which forms the basic data stream that other in-vehicle devices use to determine when a potential conflict exists. The effort will test the performance, evaluate human factors and usability, observe policies and processes, and collect empirical data to present a more accurate, detailed understanding of the potential safety benefits of these technologies. Separately, three trucks were studied in clinics designed for commercial truck drivers.

These efforts began in August 2011 with a series of driver clinics to determine how drivers respond to the wireless devices for safety. In all, six closed road clinics were held with about 100 drivers participating in each. Not only were the researchers assessing how drivers react to the in-vehicle alerts and warnings, they were also trying to ensure that the in-vehicle devices did not create additional distractions. Because driver preferences vary, the driver clinics will be geographically dispersed across the United States, with tests held in Michigan, Minnesota, Florida, Virginia, Texas, and California. To further diversify the sample, the participating drivers were selected so that there would be an even split in gender and age. The clinic tests gathered qualitative human factors data on driver acceptance of safety technologies. The V2V safety applications tested included emergency brake-light warning, forward-collision warning, intersection movement assist, blind-spot and lane-change warning, do-not-pass warning, and left-turn assist. Preliminary results show that drivers across age groups and gender desire V2V technology. More than 90% of the respondents indicated that they would like to have these wireless safety features in their vehicles, with the intersection-movement-assist application rated the highest in desirability, usefulness, and intuitiveness. However, all of the safety features received a positive response in all three areas. Fears of driver distraction may also be settled by the results, where 75% of the drivers felt that the safety features would not be any more distracting than using the car radio. Most participants were either neutral or did not feel that the safety features would cause drivers to pay less attention to their driving environment. The participants were also asked what percentage of vehicles on the road would need these features before any benefit would be felt, and the majority felt that at least 70% saturation would be the required proportion. The majority of the respondents also said they would be willing to pay up to $250 for the V2V technology in their vehicle. Overall, respondents felt the potential benefits of CV technology outweigh potential drawbacks.

The data generated is being collected and archived to evaluate the safety benefits of such systems, and to inform the future decisions of the USDOT as well as the transportation community in developing additional applications utilizing wireless technology. The testing phase will last approximately 12 months, from the fall of 2012 to the fall of 2013. Assisting in this project will be Michigan DOT, the City of Ann Arbor, Parsons Brinkerhoff, Mixon Hill, HNTB, SAIC, Texas Transportation Institute, AAA of Michigan, and ESCRYPT.

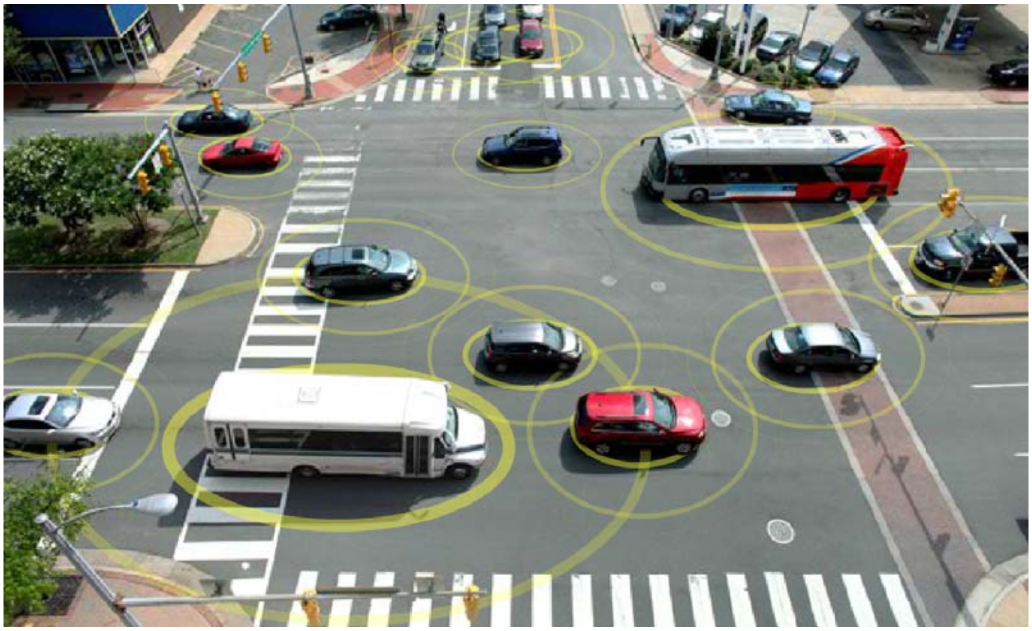

Figure 1. Connected Vehicle Safety Pilot Program (USDOT)

Virginia

The McLean, Virginia, testbed consists of a 4-mile stretch of I-66 , and parallel sections of State Highways 29 and 50[5]. The testbed has 43 locations equipped with wireless infrastructure units and two additional mobile wireless units for data collection. Twelve vehicles, including the only four connected motorcycles, a commercial truck, and a bus, will be used to collect information on things such as acceleration, braking, curve handling, and emissions. The $14 million project is led by the Virginia Tech Transportation Institute, with assistance coming from the University of Virginia's Center for Transportation Studies, Morgan State University in Maryland, and the Virginia Center for Transportation Innovation. This testbed is designed to evaluate emerging V2V and V2I technologies.

The project will test a device that alerts drivers the vehicles are on a collision course, thereby seeking to reduce the number of accidents. In this study, vehicles are alerted if they are at risk of a crash and critical roadside information is communicated directly to the driver on the dashboard. The aftermarket device is small (approximately the size of a GPS) and could be available on the market for about $35. Information gathered from on-vehicle sensors will also be sent to the infrastructure communications devices and shared with other vehicles.

Florida

The Florida DOT demonstrated a CV test bed as a part of the 18th World Congress on Intelligent Transport Systems in 2011 [6]. In this demonstration, 26 USDOT-provided roadside devices were placed in an area surrounding the Orange County Convention Center, tracing a 25-mile loop that included parts of Interstate 4, International Drive, and John Young Parkway. The roadside devices interface with onboard vehicle devices, and connect to the Florida DOT District 5 using SunGuide advanced transportation management system production software and fiber optic network connections. This was the only transportation management center-based CV test bed in the country. The demonstration was undertaken by 42 vehicles, provided by Lynx, I-Ride Trolley, and the Florida DOT, which were specially equipped with onboard devices. The roadside devices communicate with vehicles through GPS-equipped two-way radios. In addition to basic safety messages, the current traffic signal status and approaching drivers at signals are communicated to the driver.

To enable CV communications, the Florida DOT teamed with the Southwest Research Institute to update the SunGuide software [7]. The SunGuide software is a highly modular architecture that facilitates coordination and cooperation between control centers, where each has a slightly different concept of operations. To make the system more consistent, a CV subsystem was added to the SunGuide software to support data collection from vehicles through the roadside devices and to use this data in traffic flow analysis, incident detection algorithms, and automated travel time updates. Traveler information is then transmitted by SunGuide to the vehicles via the roadside devices to support the Florida DOT's typical incident management and traveler information needs. Figure 2 provides an overview of the SunGuide system.

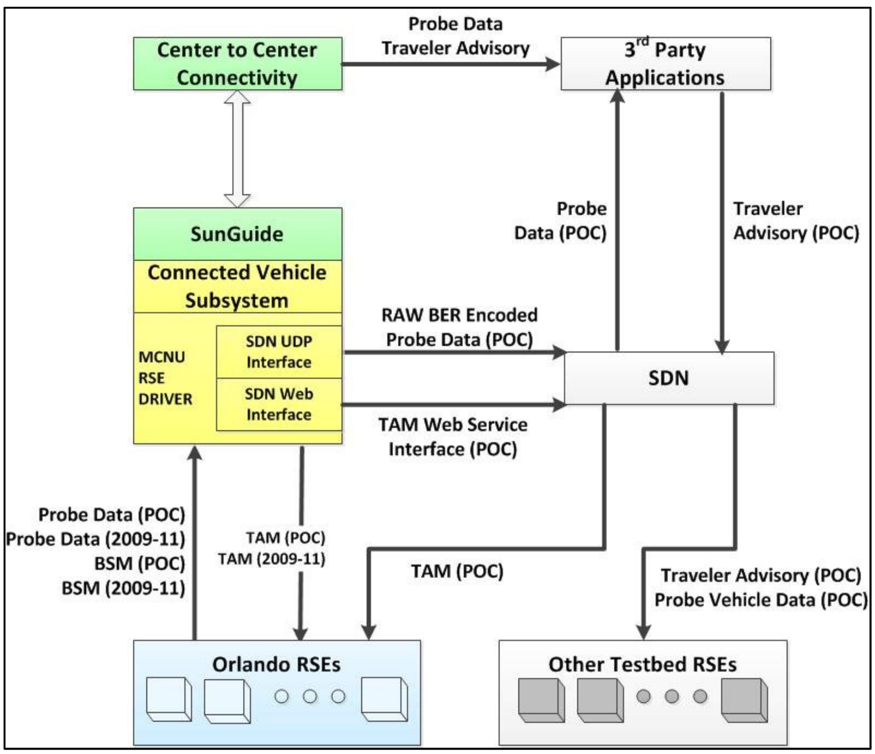

Figure 2. Overview of the Florida SunGuide system (Southwest Research Institute)

3.2 Autonomous Vehicle Testing

AV technologies have been tested both in closed testing sites and open road. The technologies are usually tested first in closed controlled testing facilities of car manufacturers, auto parts suppliers, or technology companies, such as Audi, BMW, Cadillac, Ford, GM, Mercedes-Benz, Nissan, Toyota, Volkswagen, Volvo, Bosch, Continental, AutonomouStuff, and Google [8]. Notable public-road tests are summarized in Table 2.

Table 2. Public Road Autonomous Vehicle Testing [8, 9]

Company/ Institute	Year	Project	Testing Miles	Testing Environment
Google	2011–present	Google driverless car	435, 000 miles (as of April 2013)	Real-world streets
UniBwM	1994	EUREKA Prometheus Project	Two robot vehicles, more than 1000 miles	Three-lane highway, heavy traffic, with human interventions
UniBwM	1995	EUREKA Prometheus Project	S-Class Mercedes-Benz, 1600 km	Regular traffic, German Autobahn, without human intervention
University of Parma	1996–2001	ARGO Project	2000 km over six days	Regular traffic, 94% fully automatic, longest automatic stretch of 54km
VIAC	2010	VisLab Intercontinental Autonomous Challenge (VIAC)	Italy to China, 4 vehicles, 100 days, 9,900 miles	Real-world street, limited intervention in traffic jam and toll stations
European Union	2013–present	CityMobil2 driverless vehicle project	N/A	Low-speed, fixed transit route

The most famous AV open-road testing has been performed by tech giant Google. Google claims the technology has the potential to reduce traffic accidents, wasted commute time and energy, and the number of cars by 90% each [10]. The Google fleet consists of about 10 retrofitted vehicles, each operated using a driver in the driver's seat and an engineer in the passenger seat. They have already performed extensive on-road tests, racking up at least 435,000 miles. The system drives the vehicles at the speed limit that is programmed into its GPS system. An override feature is included, where control of the vehicle can be turned over to the human driver by tapping the brake or turning the steering wheel. After Nevada passed the legislation enabling AVs to operate in the state, Google received the first state-issued AV plate. Google leadership believes the technology could be available for commercial use as soon as 2017, but the current price tag of over $100,000 for the additional equipment would need to fall substantially in order to gain any notable market share.

Another project of note is the European Commission-sponsored $52 million CityMobil project [9]. This project is considering four classes of potential AVs that could be used for transit-type services:

- CyberCars – Driverless low-speed vehicles that operate within somewhat restricted environments, such as a low-density pedestrian zone.
- Advanced buses – Buses that use guidance and control technologies in regular busways.
- Personal rapid transit – Small vehicles that operate between stations on a special dedicated guideway.
- Advanced city cars – Cars with driver-assistance systems for partial automation and the ability to operate under automatic control under some specialized conditions, such as platooning of empty vehicles without drivers behind a lead vehicle operated by a specially trained driver.

In May 2011, the CityMobil project performed a demonstration of the CyberCars concept. This involved the use of a single driverless vehicle with room for four standing passengers, resembling a golf cart. This vehicle was capable of interactions with pedestrians, as it could slow or stop if a person was detected nearby.

The CityMobil project also deployed a personal rapid transit (PRT) system at Heathrow Airport in London[11]. The Heathrow PRT carries passengers between the new Terminal 5 and an outdoor parking area. The PRT vehicles are captive to their special guideway, but their driving is automated, including acceleration, deceleration, and automatic steering control for route choice at diverge points and when entering station loading docks. These types of PRT systems are more like rail vehicles than the road vehicles featured in the rest of the project, even though they do not run on steel wheels. They are confined to a special guideway instead of being able to use the same road space as other vehicles, and they lack a manual driving mode for access to unequipped locations.

The advanced city cars element of the project has included the development of a concept car for the 2010 Torino motor show, which included fully automated driving on dedicated highway lanes and in-motion recharging of the EV propulsion batteries.

With states start to pass legislation on AV testing, the technology will be able to test more intensively in complicated real-world environments. As illustrated in Figure 3, highway systems in California, Nevada, Florida, Michigan, and Washington DC (together comprising around 11% of U.S. highway miles) are being opened to provide sufficient testing environments in order to truly validate the reliability of the technology.

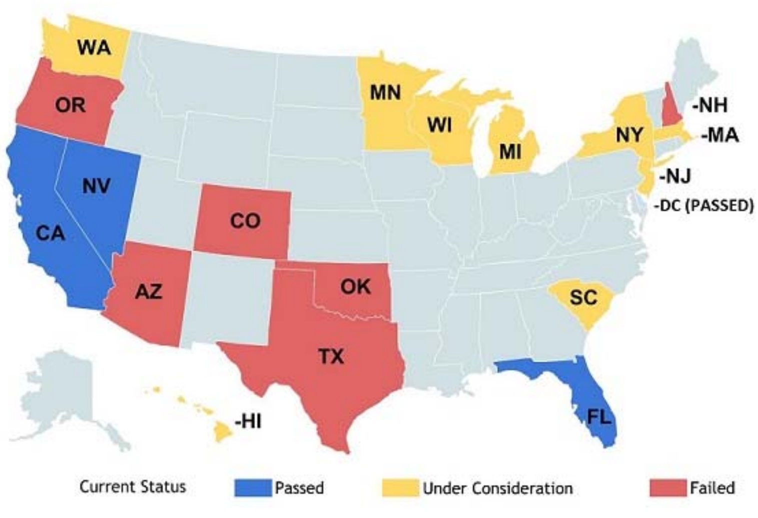

Figure 3. State Autonomous Vehicle Legislative Efforts (CIS 2013)
(Note: Michigan has since Passed Enabling Legislation)

3.3 Electric Vehicle On-Road Wireless Charging Testbeds

In EV technologies reviewed by the TTTF, the open-road wireless EV charging technologies are recognized as the promising technologies fitting the strategic goals of this task force. Although the technology is relatively new, testbeds are already established for evaluating the technologies.

WAVE (Wireless Advanced Vehicle Electrification) and Utah State University's (USU) Wireless Power Transfer Charging (WPTC) Testbed

In July 2011, the USU research foundations demonstrated the charging efficiency of the WPTC system in a 5kW and 10-inch air gap system [12]. In 2012, WAVE, in partnership with USU, further improved the original system and developed a 25kW wireless power transfer charging system using solid-state technologies for bus transit. Starting spring 2013, the system will be tested in the USU's campus shuttle system with two wireless charging stations located in bus stops around campus.

South Korea's Online Electric Vehicle (OLEV) Testbed

The online electric vehicle (OLEV) technology recharges an EV while stationary or driving, eliminating the need to stop at charging stations. Recharging the on-board batteries occurs via special plates underneath the vehicle that use magnetism to literally "collect" electricity from power strips or cables buried underground as it passes overhead [13]. Recently, the Korea Advanced Institute of Science and Technology established a testbed with the South Korean city of Gumi to outfit two mass transit electric buses in a field pilot. They run an inner-city route between Gumi Train Station and the In-dong district, for a total of 24 km (14.9 miles) round trip. Each bus receives 20 kHz and 100 kW (136 horsepower) electricity at an 85% maximum power transmission efficiency rate, according to researchers, while maintaining a 17-cm air gap between the vehicle's underbody and the road surface.

Volvo's In-Road Wireless EV Charging Solution Test Tracks

Volvo has also developed similar in-road chargers for electric trucks and buses. It eliminates the need of carrying large batteries on board and the dependence on overhead power lines. The technology can also be used to charge vehicle of all sizes. Volvo has been testing their version of the technology on a 400-meter track in Hällered near its Gothenburg headquarters since fall 2012 [14].

3.4 Cloud Computing Testbeds

Existing CC testbeds can be classified into application-oriented and system-oriented testbeds. Table 3 provides the leading system-oriented CC testbeds and their services [15].

Table 3. System-Oriented Cloud Computing Testbeds [15]

Testbeds	Research	Approach	Participants	Distribution
Open Cirrus	System & services	Data center cluster	HP, Intel, IDA, KIT, UIUC, Yahoo	Six sites
IBM/Google	Data-intensive applications research	A cluster supported by Google and IBM	IBM, Google, MIT, Stanford, etc.	Centralized, based in Atlanta
TerraGrid	Scientific applications	Clusters of supercomputers	Universities	11 partners in US
PlanetLab	Systems and services	Nodes hosted by research institutes	Universities	700+ nodes world-wide
EmuLab	Systems	Single-site cluster with flexible control	University of Utah	300+ machines at University of Utah
Open Cloud Consortium	Cloud APIs	Cluster of multiple sites	Four data centers	480 cores, distributed in four locations
Amazon EC2	Commercial use	Raw access to virtual machine	Amazon	Unified data centers
LANL/NSF Cluster	Systems	Re-use of LANL's retiring clusters	CMU, LANL, NSF	1000s of nodes at one site
IDA: Infocomm Development Authority of Singapore; **KIT**: Karlsruhe Institute of Technology; **UIUC**: University of Illinois at Urbana-Champaign; **LANL**: Los Alamos National Laboratory; **NSF**: National Science Foundation; **CMU**: Carnegie Mellon University				

The latest PaaS (Platform as a Service) and SaaS (Software as a Service) cloud providers [16]—Google, Apple, and Windows Azure—also have test platforms and tools built into their services. These test platforms incorporate debugging and application development into their frameworks. Third-party companies such as AppScale, initially funded by Google, IBM, the National Science Foundation, and the National Institute of Health also offer development platforms to help users deploy applications based on a Google App engine along with database services. Figure 4 depicts many of the corporations and entities involved in providing cloud services.

Figure 4. Cloud Service Providers [16]

3.5 Transportation Databed

Another significant trend in today's technology development is the emergence of public databeds. With government agencies hosting large public datasets, sometimes real-time datasets can facilitate the development new data-centric information technologies. One typical example is the open-data act of the New York City.

The New York City Council voted on and passed this legislation on February 29, 2012. Mayor Michael Bloomberg signed it into law on March 7, 2012 [17]. After this law, New York agencies and departments were required to make their data available online using open standards. The law aims to make city government operation more transparent, effective, and accountable to the public, and open government to increased civic engagement. The website Open.NY.Gov was launched by Governor Cuomo with an aim to provide user-friendly, one-stop access to data from New York State agencies, localities, and the federal government [18]. One of the benefits of having a common data source is it allows data from various agencies to merge and relate. In New York, over 200 datasets, maps, and charts are available today, with some datasets comprising thousands of pieces of information. Merging information from multiple agencies and allowing mapping should substantially increase the usability of this information. Data is presented on the website by category, by city agency, or by other city organization. Descriptions of the data, the collection method, and other contextual metadata material make the datasets easier to understand and use.

Major fields in which the provided data can be used for new plans and incentives include economic development, education, energy and the environment, government and finance, health, human services, public safety, recreation, transparency, and transportation. Beyond presenting information to the public, these datasets serve as a rich resource for developers, civic groups, or anyone else to build applications on their own. The creation of new apps using city data fosters innovation and leverages talents beyond city government for create solutions to tough problems.

These data can be very helpful for transportation researchers. Recent transportation data was published on July 24, 2013, from agencies including the Metropolitan Transportation Authority, Port Authority of New York and New Jersey, and the New York State Department of Motor Vehicles [19]. One example dataset provides information on the New York City subway entrances and exits, including division, line, station name, and location. Developers can harness this type of data for creating mobile applications that help guide subway riders to station entrances and exits based on the physical location identified on their smartphones. With real-time mapping, riders might have an easier time navigating the multiple entrances and exits of a subway station.

4. Implications for Texas Transportation Technologies Test Environment

Testbeds play substantial roles in the research and development of the reviewed technologies. Testbeds are typically established by companies or research institutes, with the exception of the CV-DSRC testbeds efforts led by the USDOT in collaboration with research labs and manufacturers. Although closed-road testbeds are useful in the initial prototyping and development of vehicle-based technologies, most developing groups actively pursue “field” testbeds to put their technology into real-world testing. Current test platform practices for the emerging transportation technologies shed light on possible implications for establishing testbed platform in Texas.

- **Cost-effectiveness**: Creating a dedicated testing platform for a specific technology may not be cost-effective in Texas. Since Texas is already behind in the development of technologies such as CV-DSRC and AVs, it may not be cost-effective to follow other testbed developers’ footsteps and replicate infrastructures and facilities for testing similar technologies.
- **Open-road testing environment**: Compared with closed testing environments, technology developers could actively pursue conducting testing on public roads in real-world environments. Compared with the construction and establishment of a closed-road testing facility, the open-road testing environment is more cost-effective if built with the pre-existing IT infrastructure widely available on Texas highway.
- **Leadership**: Test platforms can be initiated by government agencies; however, the main players in testbed studies are still research and development groups from research institutes or technology companies. Even in the case of CV-DSRC, the USDOT’s role is the facilitator that oversees, coordinates, evaluates, and provides support for funding and policies for the testbed program. Texas has several key advantages to establishing test environments with its vibrant economy, technology industry presence, investment environment, and rich cases of testing scenarios with transportation system. Texas will likely need to attract private sector developers and independent innovation groups to bring their prototype products to the state.
- **Time frame**: With new technologies and test platforms coming online every year, it is necessary for Texas to act quickly in order to capture, participate, and lead the

current wave of innovations in transportation technologies. Other than the funding and resources, related legislative and policy adjustment should be expedited.

- **Funding**: Most of the reviewed technology testbeds use partial or no public funding. Testbed operations are usually carried out by private sector entities or research labs primarily using their own funding sources and resources. Texas may invest in the initial development and routine maintenance on testing environment. Furthermore, Texas should pursue sustainable business models that allow the testbed to operate, upgrade, and expand, all of which can be feasible when combined with the public-private consortium and incubator strategies also proposed by the TTTF in this project.
- **Databed**: One final testbed trend is the emphasis on data sharing. Technologies like CVs (DSRC and cellular), crowdsourcing, or even AV technologies could lead the new wave of data-centric technologies that not only reply using real-time data inputs, but also generate data themselves in real time.

To address the above-described needs of a test environment in today's transportation technology development, TTTF proposes the establishment of a test environment that possesses the following functionalities and characteristics.

- **Public road**: Testing uses the real-world transportation network with conventional traffic.
- **Full-scale transportation system**: The testing transportation system should include major freeway corridors, arterial street networks, and signalized intersections. The selected test site is expected to have recurrent commuting travel patterns, severe congestion, and safety issues.
- **Open data**: Publicly owned data (like signal timing, incidents, and traffic detector data) should be made available in real time. Supplementary datasets (like private sector travel time data and real-time travel demand data) may be available upon request.
- **Technology-neutral setup**: The testbed allows for installation and configuration of different technologies and implementations, not necessarily dedicated to any single technology.
- **Publicly accepted and engaged facility**: Although challenging, the testbed should be approved by affected communities and regular travelers from affected communities. Such communities can engage in the testing through volunteering programs in collaboration with organizations such as TxTag, the American Automobile Association (AAA), and insurance companies.
- **Financially sustainable:** Aside from the initial configuration and startup periods, the testbed should have a business model that ensures sufficient funding for maintenance, upgrading, and expansion.

- **Policy and legislation readiness**: Necessary policy and legislative recommendations should be developed to address related issues such as permission, licensing, liabilities, ownership, and agency collaboration requirements.
- **Regulation and licensing enforcement**: Testing activities and groups should be certified and regulated. Contingency plans should also be developed in case of emergency.

5. Work Plan

To establish the proposed open-road multi-technology data-centric testing environment—a Texas Transportation Technology Test Platform (TTTTP)—the following work plan is proposed. The work plan is a two-phase plan with Phase I focusing on communication with stakeholders and the development of business plan, and Phase II focusing on testbed establishment and operation. The work plan will be coordinated with the public-private consortium and incubator work plan.

Phase I: Stakeholder communications and business plan development (12 months)

The first phase will last around a year, focusing on stakeholder communication; preparation for the testbed; obtaining policy, legislative, community, and funding support; and developing business plan.

Task 1: Testbed stakeholder identification and communications (6 months)

The TTTF will compile a stakeholder list related to establishing the proposed test environment. TTTF will communicate with the identified stakeholders to identify their testbed needs and perspectives through surveys, workshops, or focus group meetings. The potential stakeholders may include the following:

- Technology development groups: The TTTF will collect firsthand information on the testing needs from developers from both research community and private sector.
- Transportation agencies: The TTTF will communicate with major TxDOT districts and traffic management centers to identify their perspectives and assess willingness to establish testbeds. Potential sites and locations may also be identified for interested TxDOT districts. Special discussion should be conducted regarding public transportation data open access.
- Other public agencies: The TTTF will establish conversations with non-transportation agencies to seek collaboration as well as policy and legislative support.
- Private sector interest parties: The TTTF will consult companies such as traveler information and service providers, automobile associations, insurance companies, and car manufacturers.

Task 2: Testbed startup funding establishment (6–12 months)

The TTTF will develop a detailed budget on initial funding needed for testbed establishment. The TTTF will meet with public funding agencies and private sector investors to seek and secure funding for the testbed. This step is a crucial to ensure that the rest of the work plan is supported with sufficient funding. Testbed startup funding may include public research funding as well as private investment on technology development.

Task 3: Site specification and selection (3–6 months)

Through the initial communication in Task 1, the TTTF will summarize the specifications for testbed sites and create a list of sites that fit such specifications. The TTTF will then investigate the detailed characteristics of each site including 1) transportation network size, link types, and road geometries, 2) location and travel demand, 3) existing ITS infrastructure such as intersections, sensors, fiber network and electrical devices, 4) surrounding research, technology, and computational resources, and 5) surrounding community type and demographics.

The selection process of testbed sites will include several steps. As a first step, the TTTF will conduct an initial screening of all candidate sites, reducing it to short list with three to five candidate sites. Next, the TTTF will communicate with local transportation agencies regarding their resources, concerns, and interests. The TTTF will also reach out to local communities regarding the potential impact and volunteering programs. Based on the feedback, TTTF will make the final selection on the testbed location(s).

Task 4: Business plan development (6 months)

The main task in Phase I is to develop a business plan that ensures testbed sustainability. The business plan should include strategies for attracting development groups, establishing data platforms, collaborating with public and private sectors, and coordinating with the public-private consortium and incubator.

Phase II: Testbed Establishment (18 months)

Phase II tasks will establish the testbed and bring the testbed into full operation.

Task 5: Testbed initialization, formalization, and organization (6 months)

This task will initiate the testbed establishment by organizing a testbed management team, preparing management, legal, policy, accounting, workflow, licensing and evaluation procedure documents, and purchasing, configuring, and installing testbed software and hardware.

Task 6: Data platform establishment (6–12 months)

One key attraction factor of the proposed testbed is the data platform. A specialized team with technical, operational, legislative, and policy background will be organized to establish data platform. The team will negotiate with local government agencies (transportation and non-transportation) in providing public access of their data for the testing corridor or network. The team should fully utilize existing ITS and computational infrastructures available at local transportation agencies and nearby research institutes. The team will also identify critical data needs to be fulfilled through hardware and software purchasing, for example installing roadside devices to broadcast signal timing, signage, and traveler information. The team will initiate conversations and with private traveler information and service providers on potential collaboration on data acquisition. It should be noted that the initial emphasis should be on building the data platform rather than collecting and providing full real-time data, which ultimately will be conducted based on demand.

Task 7: Public relations and community outreaching (6–9 months)

The TTTF will collaborate with local transportation agencies to host public hearings and conversations with local community and address any concerns and questions. The TTTF may also collaborate with insurance companies and automobile associations to establish volunteering programs for testing involves volunteering drivers or vehicles.

Task 8: Advertisement and partnership (6 months)

The TTTF will help introduce the testbed to the research community and industry through conference sessions and workshops to attract participants and testbed users. Partnership with the research community may be established through collaboration on funding competitions. Partnership with private sector developers may be facilitated through the public-private consortium. The TTTF will also ensure the testbeds are established with full support from local transportation agencies, emergency services, and highway patrol services and streamlining the approval and licensing procedure for the testing process.

Task 9: Trial operation and evaluation (6 months)

The testbeds will be trial run for about six months. Through the evaluation of the testing results, the testbed management team, along with the TTTF, will identify and address issues in the procedures, policies, and hardware and software systems. An extended trial period may be needed to evaluate additional improvement efforts. The TTTF will also help develop a future maintenance, upgrading, and expansion plan for the full operation of the testbed.

The detailed timeline for the proposed work is summarized in Table 4.

Table 4. Timeline of Texas Transportation Technology Test Platform Work Plan

FY	FY2013 (Phase I)				FY2014 (Phase II)				FY2015 (Phase II)	
Month	10–12	1–3	4–6	7–9	10–12	1–3	4–6	7–9	10–12	1–3
Task 1										
Task 2										
Task 3										
Task 4										
Task 5										
Task 6										
Task 7										
Task 8										
Task 9										

References

[1] USDOT, "Transforming Transportation through Connectivity: ITS Strategic Research Plan, 2010–2014 (Progress Update, 2012)," U. S. Department of Transportation (USDOT), FHWA-JPO-12-019, 2012.

[2] W. Fehr. (2012). *Affiliated Connected Vehicle Test Bed Summit: Lessons Learned, Next Steps*. Available: http://www.its.dot.gov/presentations/CV_Safety_sept2012/pdf/Day%202%20-%20Affiliated%20Test%20Bed.pdf (Accessed August, 2013)

[3] USDOT. (2013). *U. S. Department of Transportation, Research and Innovative Technology Administration (RITA), Safety Pilot Program Overview*. Available: http://www.its.dot.gov/safety_pilot/ (Accessed August, 2013)

[4] MDOT, "International survey of best practices in connected vehicle technologies 2012 update - Michigan Department of Transportation (MDOT)," 2012.

[5] VTTI. (2013). *Gov. Bob McDonnell helps Virginia Tech Transportation Institute (VTTI) launch Virginia connected vehicle test bed*. Available: http://www.vtnews.vt.edu/articles/2013/06/061213-vtti-testbed.html (Accessed August, 2013)

[6] FDOT. (2013). *Florida Department of Transportation (FDOT): Connected vehicle now*. Available: http://www.dot.state.fl.us/trafficoperations/its/projects_deploy/cv/connected_vehicles-wc.shtm (Accessed August, 2013)

[7] SwRI. (2013). *Southwest Research Institute (SwRI) - Enhancement of the FDOT(Florida Department of Transportation) SunGuide® Software to Support Connected Vehicle Functionality*. Available: http://www.swri.edu/4org/d10/isd/ivs/connected-veh.htm (Accessed August, 2013)

[8] J. Schmidhuber. (2011). *Prof. Schmidhuber's highlights of robot car history*. Available: http://www.idsia.ch/~juergen/robotcars.html (Accessed August, 2013)

[9] A. Alessandrini. (2013). *CityMobil, CityMobil2 and other EC Projects* [Presentation]. Available: http://amonline.trb.org/39givl/1?highlightText=%20citymobil (Accessed August, 2013)

[10] C. Mui. (2013). *Google's Trillion-Dollar Driverless Car -- Part 2: The Ripple Effects*. Available: http://www.forbes.com/sites/chunkamui/2013/01/24/googles-trillion-dollar-driverless-car-part-2-the-ripple-effects/ (Accessed August, 2013)

[11] FHWA, "Recent International Activity in Cooperative Vehicle–Highway Automation Systems," U. S. Department of Transportation (USDOT), FHWA-HRT-12-033, 2012.

[12] WAVE. (2013). *Aggie Bus Powered by WAVE (Wireless Advanced Vehicle Electrification)*. Available: http://www.waveipt.com/project/aggie-bus-powered-wave (Accessed August, 2013)

[13] N. Marchetti. (2013). *On The Go Wireless EV Charging Tested In South Korea*. Available: http://www.earthtechling.com/2013/08/on-the-go-wireless-ev-charging-tested-in-south-korea/ (Accessed August, 2013)

[14] CleanTechnica. (2013). *Volvo Testing Wireless Road-Mounted Car Charger*. Available: http://cleantechnica.com/2013/06/25/volvo-testing-wireless-road-mounted-car-charger/ (Accessed August, 2013)

[15] K. Lai, "Open CirrusTM Cloud Computing Testbed: Federated Data Centers for Open Source Systems and Services Research," in *Hot topics in cloud computing,* USENIX Association Berkeley, CA, USA, 2009.

[16] CloudTimes. (2011). *Top PaaS, SaaS and IaaS Cloud Companies by CloudTimes*. Available: http://cloudtimes.org/2011/11/30/top-paas-saas-and-iaas-cloud-companies-by-cloudtimes/ (Accessed August, 2013)

[17] NYC, "NYC(New York City) Information Technology and Telecommunications - Local Law 11 of 2012 – Publishing Open Data," 2013.

[18] A. M. Cuomo. (2013). *Governor Cuomo Launches Open.NY.Gov Providing Public Unprecedented User-Friendly Access to Federal, State and Local Data*. Available: http://www.governor.ny.gov/press/03112013open-data (Accessed August, 2013)

[19] A. M. Cuomo. (2013). *Governor Cuomo Expands Open.Ny.Gov by Adding More Than 100 Transportation Datasets Now Available to The Public*. Available: http://www.governor.ny.gov/press/07102413-opennygov-expands (Accessed August, 2013)