GATEWAY CITIES
TECHNOLOGY PLAN
FOR GOODS MOVEMENT

I-710 Technology and Autonomous Vehicle Research Summary

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Gateway Cities Technology Plan for Goods Movement

I-710 Technology and Autonomous Vehicle Research Summary

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December 2012
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# Definition of Terms

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<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>ACC</td>
<td>Adaptive Cruise Control</td>
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<td>ADAS</td>
<td>Advanced Driver Assistance Systems</td>
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<td>AEB</td>
<td>Autonomous Emergency Braking</td>
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<td>BUC</td>
<td>Back Office Use Cases</td>
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<tr>
<td>BMV</td>
<td>Bureau of Motor Vehicles</td>
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<td>Caltrans</td>
<td>California Department of Transportation</td>
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<td>CAR</td>
<td>Center for Automotive Research</td>
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<td>CHP</td>
<td>California Highway Patrol</td>
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<td>CO₂</td>
<td>Carbon dioxide</td>
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<td>ConOps</td>
<td>Concept of Operations</td>
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<td>DARPA</td>
<td>U.S. Defense Advanced Research Projects</td>
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<td>DMV</td>
<td>Department of Motor Vehicles</td>
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<td>DSRC</td>
<td>Dedicated Short-Range Communication</td>
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<td>EU</td>
<td>European Union</td>
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<td>FCC</td>
<td>Federal Communications Commission</td>
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<td>FHWA</td>
<td>Federal Highway Administration</td>
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<td>FMVSS</td>
<td>Federal Motor Vehicle Safety Standards</td>
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<td>GP</td>
<td>General Purpose lanes on Freeway</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<td>ITS</td>
<td>Intelligent Transportation Systems</td>
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<td>IV</td>
<td>Intelligent vehicles</td>
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<td>LIDAR</td>
<td>Laser radar</td>
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<td>MARS</td>
<td>Mobile Autonomous Robot Software</td>
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<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
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<tr>
<td>MTBF</td>
<td>Mean Time between Failure</td>
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<td>Acronym</td>
<td>Description</td>
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<tr>
<td>MTTR</td>
<td>Mean Time to Repair</td>
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<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
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<td>PATH</td>
<td>Partners for Advanced Transportation Technology</td>
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<td>PUC</td>
<td>Platoon Use Cases</td>
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<td>R&amp;D</td>
<td>Research and Development</td>
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<td>RSE</td>
<td>Roadside Equipment</td>
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<td>SARTRE</td>
<td>Safe Road Trains for the Environment</td>
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<td>TED</td>
<td>Technology, Entertainment and Design</td>
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<td>TENS</td>
<td>Truck Enforcement Network Systems</td>
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<td>TIS</td>
<td>Transportation Information System</td>
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<td>TMC</td>
<td>Traffic Management Center</td>
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<td>V2I</td>
<td>Vehicle-to-Infrastructure</td>
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<td>V2V</td>
<td>Vehicle-to-Vehicle</td>
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<td>WIM</td>
<td>Weight-in-motion</td>
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<td>VSCC</td>
<td>Vehicle Safety Communications Consortium</td>
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<td>VTTI</td>
<td>Virginia Tech Transportation Institute</td>
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1.0 Introduction

The Gateway Cities Technology Plan for Goods Movement Study creates a wide ranging program and details how technology can be leveraged to improve and make goods movement more efficient in the Gateway Cities and the larger Los Angeles County region. This program is comprised of six separate but interrelated projects (from the 13 technology projects from the Final Conceptual Goods Movement Project Descriptions Report and the Final Concept of Operations Report), focusing on traveler information, traffic management infrastructure, and safety/enforcement, as well as private sector drayage and terminal management technologies.

One of the projects proposed is the I-710 Automated Truck Research Project. This project is focused primarily on the future needs of the I-710 Freight Corridor, which is now under the planning and environmental process. However, the benefits of automated truck operation could extend well beyond I-710 to the Ports, the freight industry, the Gateway Cities region, and the entire Southern California region. Potential benefits include more efficient port and freight industry operation, reduced neighborhood impacts, and economic benefits that could accrue from making Southern California a global center for automated vehicle research and deployment.

This project will build upon the unique operational environment and potential partnerships of the Gateway Cities region to promote and enhance truck automated commercial vehicle research by bringing together the applications of automated commercial vehicle and automation technologies with the real-world operational realities of a heavily congested truck corridor. The project will provide for staged operational testing over time with an eye towards understanding the specific design and operational concerns that impact the future development of the I-710 and its approaches. The results of the test could provide valuable inputs to the design approach for a related I-710 freeway development project that will safely increase truck throughput on the proposed I-710 freight corridor, reducing truck volumes and congestion on the adjacent I-710 General Purpose Lanes.
This project has several objectives that address traffic concerns, as well as economic development issues:

- Helping ensure the future viability of the Ports and Gateway Cities region, as well as the I-710 corridor;
- Building upon ongoing and rapidly advancing intelligent vehicle (IV) technologies for trucks to define an effective conveyor operation of trucks is on the I-710 freight corridor that will safely maximize the throughput of trucks in the freight corridor;
- Helping Southern California establish a leadership position in Connected Vehicle technologies that will enhance the local economy;
- Establishing an ongoing partnership and environment that attract additional funding opportunities to bridge the gap between research efforts and effective real-world solutions in a real-world freight corridor; and
- Promoting the state of the art in truck guidance and flow efficiency.

Benefits will accrue to the Ports and freight industry stakeholders in the region by providing increased capacity on the proposed I-710 freight corridor. The vision is to achieve maximum effective capacity within the substantial physical constraints of the region’s key truck corridors. This will reduce congestion and result in more cost-effective and safe freight operations. By safely increasing the capacity of the I-710 freight corridor, fewer vehicles will be inclined to use the arterial system and the adjacent freeway GP lane, reducing the negative impacts of truck traffic on Gateway Cities communities.

There also is potential economic benefit for Southern California in developing and supporting a test site in the region, where technologies and operational concepts can be tested in conjunction with public and private partners. The test site and subsequent implementation on the I-710 Freight Corridor and possibly other locations will leverage Original Equipment Manufacturer (OEM) and Tier 1 vehicle supplier technologies to provide a viable real-world operational model focused on the needs and characteristics of the region. This will help create opportunities to spin off businesses that specialize in freight-related applications of Connected Vehicle technology, and will encourage widespread deployments using OEM available equipment.

The I-710 freight corridor will heavily leverage technology for its operations. In addition to autonomous vehicles, toll technology, zero emission, and traffic management technologies will all play a role in the daily operations of that corridor. A general concept has been advanced through this project, but more precise functional requirements need to be developed. Key questions to be addressed over the next three years include:

- How are incidents or periodic maintenance approached?
- Do solutions to those issues lead to design impacts and backbone technology infrastructure needs?
• How will impacts from changing technology be managed to avoid significant delays or cost increases?
• Who is responsible for operations and costs (capital and O&M) of the corridor?

This progression of design can continue without knowing the precise technologies to be used. No matter which suite of technologies is ultimately implemented, a key next step is development of a full Concept of Operations (ConOps) to guide the systems design work that currently is underway. The ConOps will establish and describe the set of functions that the system(s) must perform, identify implementation and operating responsibilities, and establish a set of needs for the design teams to address. It is important that the ConOps identify the universe of technology options that are known as of today, and understanding there will be changes over time. A strategy for tracking and responding to technological developments also should be included.

This project was defined through several of the interim products of the overall technology study. These findings included general research on the rapidly advancing field of autonomous vehicle technology, including continuous tracking of ongoing research and development of design concepts for the I-710 freight corridor to accommodate advanced technology. This report represents a summary of the following project documents:

• Task 1, Background Research Report Section 5 – I-710 Freight Corridor Opportunities;
• Task 3, Final Initial Conceptual Project Descriptions Section 7 – Automated Truck Research Project;
• Concept of Operations – Automated Truck Research;
• Implementation Plan – Section 2.5 Automated Truck Research;
• Autonomous Vehicle News Summary; and
• Autonomous Vehicle Research Full Text of Articles.

The remainder of this report summarizes the work conducted related to the I-710 Freight Corridor, autonomous vehicle technology, and other key technologies that may be required in the corridor:

• Section 2.0 summarizes the background research conducted for this project, including recent demonstration projects, ongoing research activities, and major issues that have been identified to date;
• Section 3.0 summarizes the design requirements for I-710 and the freight corridor, which relate to autonomous vehicles and other key technologies;
• Section 4.0 summarizes the next steps required to advance autonomous vehicle research, as documented in the Task 3 report and the Implementation Plan;
• **Section 5.0** outlines the Con Ops that will be one of the key next steps in advancing this project;

• **Section 6.0** includes summaries and articles on Autonomous Vehicle research that were collected during 2012; and

• **Section 7.0** briefly summarizes the findings of this report.
2.0 Background Research

This section summarizes background research on autonomous vehicle technology. The project’s Task 1 report summarized recent research and current developments in the area of platooning and Autonomous Vehicle operations. The focus was on technologies that could be applied to the I-710 corridor. Rapidly moving developments in this area, both domestically and internationally, require continuous tracking. As a result, news articles were tracked on a regular basis during the project and summarized in Section 6.0 of this report. The key issues identified through those news articles are summarized in this section and recommendations for implementing a change management process are included.

2.1 SUMMARY OF INITIAL REPORT

This section includes a summary of initial research conducted for this project, including a brief history of autonomous vehicle activity and an update on current activities and initiatives.

2.1.1 History of Autonomous Vehicle Activities

The purpose of this work was to identify vehicle platooning strategies that can be applied to the I-710 Freight Corridor. This information was obtained through a review of literature published within the past 20 years, with an emphasis on the most recent research that is applicable to commercial vehicle traffic. Additionally, interviews were conducted with researchers in the field of intelligent vehicles and professionals within the industry. The search identified both organizations active in platooning research and specific demonstration projects relevant to the I-710 freight corridor. While a number of demonstration projects are in the planning or initial development stages, five projects were identified that have relevance to the I-710 freight corridor and have produced results.

Vehicle platooning or autonomous vehicles fall generally under the broader category of “intelligent vehicles.” “Intelligent vehicles” (IV) or “intelligent vehicle systems” (IV systems) are general terms that refer to cars, trucks, or other vehicles equipped with technology that gathers information from the driving environment, and provides that information to the driver or assists the driver in optimal vehicle operation. These IV systems are involved with the tactical part of driving, including steering, braking, and working the throttle, rather than the strategic part of driving that includes route choice. Other technologies such navigation systems help with the strategic aspect. Both the tactical and strategic
aspects are relevant to vehicle platooning and its potential use in the I-710 freight corridor.¹

IV and related concepts have been researched for many years both in the United States and in other countries. A major goal in employing this technology is to improve roadway safety. Many countries have implemented safety-related programs over the past few decades with the goal of reducing roadway crashes and reducing the overall cost of transportation to society. One key turning point in this field of research occurred in the 1990s, when transportation professionals started to realize that they could obtain affordable information through sensor technologies, and computing. The new accessibility of this information helped lead to the growth of Intelligent Transportation Systems (ITS).² Since then, much research has been done related to the concepts of IV, automated vehicles, and other topics in this area of transportation.

2.1.3 Update of Current Activities and Initiatives

Five major demonstrations are described in this section (two of them conducted by the European Union, CHAUFFEUR and SARTRE are covered in the same section). While these are not an exhaustive list of activities, these include the largest efforts and those most relevant to the issues in the Gateway Cities area and the I-710 freight corridor.

California PATH Advanced Transportation Technology

A series of platooning studies and demonstrations were conducted by the University of California Partners for Advanced Transportation Technology (PATH) program between 1997 and the present. The most recent of these was a 2011 demonstration, in which Dedicated Short Range Communications (DSRC) technology was used for vehicle-vehicle communications in place of the WiFi technology used in a 2003 demonstration. DSRC are wireless communication channels that allow for the short-range transfer of information between vehicles and roadway infrastructure. In 1999, the Federal Communications Commission (FCC) allocated 75 megahertz of spectrum for the use of intelligent transportation services. The FCC decided to use the 5.9 GHz band because it is appropriate for these short-range applications. This allocation was part of the U.S. Department of Transportation’s (DOT) ITS program.³

The 2011 experiment studied the feasibility of platooning with more than two vehicles; in this case, three-vehicle platoons were tested with a focus on auto

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¹ Bishop, R., Intelligent Vehicle Technology and Trends, 2005, page 3.
speed and spacing control. The purpose was to increase roadway capacity, find out how closely together the vehicles can travel, and how much fuel they could save. Researchers also evaluated maneuvering capabilities and the ability of the platooned vehicles to drive on different grades.

The testing location was in central Nevada on a 5+ mile stretch track and used 5.9 GHz DSRC communication. Freightliner trucks were used. The trucks were first tested at a distance of 10 meters from one another, then the spacings in subsequent test runs were gradually decreased to 4-meters between vehicles. The assumptions for this research were that these trucks would operate in a dedicated truck lane to prevent cut-ins from passenger cars.

One major conclusion was that creating a three-truck platoon was much more complicated than a two-truck platoon. This is related to the concept of string stability and making sure that, in a platoon, errors are damped out. In the concept of platooning, string stability is a desired state, in which errors decrease along a string of vehicles. If errors were to grow, they could eventually lead to collisions between vehicles further back in the platoon. This research was completed under the Federal Highway Administration (FHWA) Exploratory Advanced Research Program. In order for this type of project to be implemented on a large scale, further research and funding would be required. Another challenge is fault recovery maneuvers. Barriers to implementation include achieving consistent results with three-vehicle truck platoons and difficulties in defining maneuvers that are guaranteed to be safe (challenges that apply to all truck platoon concepts).

European Union (EU) Safe Road Trains for the Environment (SARTRE)/CHAUFFEUR Programs

Two demonstrations being conducted under the auspices of the EU are the SARTRE program and the CHAUFFEUR/CHAUFFER2 programs. The CHAUFFEUR project (including both CHAUFFEUR and CHAUFFEUR 2 phases) was a joint European project, begun in the mid-1990s and completed in 2003. It was led by DaimlerChrysler in partnership with IVECO, CRF, and Renault. The project’s purpose was to develop “electronic tow-bar” technology, which allows trucks to follow one another as an automated platoon. Project goals included reducing fuel consumption and general environmental impacts, improving traffic flow, improving comfort for drivers, and increasing safety. Another possible benefit is reduced labor costs if the technology allows for the follower vehicles to operate without a driver present.

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5 Shladover, S. (Discussion and correspondence in December 2011 and January 2012).
The CHAUFFEUR 2 project researched additional issues, including the interface of humans and machines, system evaluation, safety, traffic simulations, freight logistics concepts, cost/benefit analysis, user-related issues, and legal issues. CHAUFFEUR 2 also demonstrated additional maneuvers related to heavy-truck platooning. In the CHAUFFEUR 2 project, three-vehicle platoons were tested at highway speeds. They were spaced 10 meters apart. Maneuvers tested included coupling with and decoupling from the platoon, changing lanes, accelerating from a stop, and braking to a stop. This project evaluated platoons as large as 10 trucks, but only in computer simulations. In this phase, the vehicles were electronically actuated, which also is known as “drive-by-wire”.

Components include a distance controller and a lateral controller. The distance controller used data from sensors in the truck itself, as well as sensor data from the lead vehicle and the vehicle directly in front of it. The lateral controller used the inputs of the infrared image processing of the infrared pattern on the back of the vehicle directly in front of it. In summary, in this system, the vehicle follows the vehicle directly in front of it rather than the road.

At the time of the research, many experts believed that the implementation of truck platooning would not be expected in the near future because it would require the use of dedicated truck facilities. CHAUFFEUR 2 included a “Chauffeur Assistant” that provided driver assistance rather than full automation or platoon capabilities, which could be implemented without any infrastructure changes. Given that I-710 has dedicated freight corridor lanes as planned, the Chauffeur Assistant feature would not be essential, but it could be a helpful feature if there is any interaction between the platoon and vehicles outside the platoon.

The SARTRE project began in 2009, was funded in part by the European Commission and includes involvement from seven project partners: Fundacion Robotiker – Tecnalia; IDIADA Automotive Technology SA; IKA (a university in Aachen); Ricardo UK Ltd; SP Technical Research Institute of Sweden; Volvo Car Corporation; and Volvo Technology AB. There was a successful test track run in January 2010 in Sweden. One key feature that is relevant to I-710 is creation of a vehicle platooning/road train system that can operate without changes to roadway infrastructure.

Project goals include:

- Defining platooning strategies that will work on public highways without infrastructure changes;

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7 Ibid.


• Creating prototype platooning system that can be tested in real-world scenarios;
• Illustrating benefits of the system; and
• Illustrating how to encourage/incentivize platoons for lead vehicle operators and other members of platoon.

The SARTRE project addressed three major problems: safety, the environment, and congestion. There was a focus on changing personal transportation through platooning without major infrastructure modifications. The “human factor” is given significant consideration in this research, particularly the topic of “acceptability” of this technology and major change in transportation and the human experience with regard to platooning. The project culminated with a platooning demonstration in 2012.10

To address the problem of congestion and the environment, the SARTRE concept hoped to improve overall traffic flow by reducing the speed variability of cars and trucks. Reducing congestion would have a positive effect on the environment through emissions reduction.

The SARTRE concept includes a number of different technologies and use cases. There are two types of “use cases” or scenarios that may arise in platooning behavior: 1) Platoon Use Cases (PUC) and 2) Back Office Use Cases (BUC). The “high-level” use cases are as follows: Create Platoon, Join Platoon, Maintain Platoon, Leave Platoon, Dissolve Platoon, Register, Guide to Platoon, Handle Platoon Status, and Charge Platooning Vehicle.11 The SARTRE project is the only research project to date that has defined the full range of activity required to operate a dedicated truck platooning system, such as the one proposed for I-710. Although the SARTRE project is testing specific technologies, most of these issues cut across any technology that would be considered.12

Many different scenarios have been simulated to test the platooning capabilities. Preliminary results have been summarized. Functions tested thus far include the space needed to join or leave a platoon, string stability, and fuel consumption, among others. For example, in the “Create Platoon” use case, various combinations can be tested, including the I-710 four-lane exclusive freight corridor.13

There was a successful, publicized demonstration of the platooning vehicle concept with trucks and passenger vehicles in Gothenburg, Sweden, in January 2011. In early 2012, a successful demonstration of autonomous vehicle technology was completed near Barcelona, Spain. Partners included the European Commission,

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11Ibid.
13Ibid.
Ricardo UK Ltd., Volvo, and others. This event took place on a public roadway near Barcelona with other traffic present. During this event, four vehicles – three Volvo passenger cars (models XC60, V60, and S60) and one Volvo truck – successfully joined the lead vehicle and created a platoon. The nonlead vehicles were able to follow the lead vehicle at a speed of 85 kilometers per hour (53 mph). In total, the platoon traveled 200 kilometers throughout this demonstration with gaps between vehicles ranging from 15 to 5 meters. The autonomous control system allowed the following vehicles to mimic the lead vehicle’s movements, including accelerating, braking, and turning. The project’s next phase relates to fuel consumption analysis.

Many hurdles have yet to be addressed, including the issues of governance and implementation, particularly as it relates to more than 20 countries in the EU with different laws and structures.14

The MARS Autonomous Vehicle Program – the Defense Advanced Research Projects Agency (DARPA) Grand Challenge

The U.S. DARPA has been involved in IV research. The 2020 Mobile Autonomous Robot Software (MARS) project aims to develop perception-based autonomous vehicle driving and navigation for a variety of real-world environments using high-performing vehicle intelligence close to human levels. Because military actions often take place in cities, where other cars and pedestrians are present, DARPA would like for these vehicles to be able to perform in a variety of environments, including basic highway, advanced highway, hybrid road/cross-country, basic urban driving, and advanced urban driving. This effort is relevant to the I-710 freight corridor project because if the technology that would allow the vehicles to operate in advanced urban driving conditions is successful, it could be applied to commercial vehicles traveling on the I-710 freight corridor. Advanced urban driving conditions include congested facilities on which traffic is unpredictable and vehicles and other pedestrians are present. While that description does not match I-710 conditions exactly, the technology could be modified to work well in the I-710 freight corridor.15

This project achieved its goal by developing and implementing a MARS architecture, in which the operator gave commands about the proposed destination that were then translated into routes and vehicle behaviors. Tools and technologies used included radar, laser radar (LIDAR), and machine vision. Vision was used to detect pedestrians, signs, intersections, and ramps. In 2004, a test was completed in the form of a trip from Denver to New Orleans. The system

14Ibid.

achieved almost 100 percent automated vehicle detection. The test parameters included the absence of road construction and medium to light traffic.\textsuperscript{16}

Another relevant project is the DARPA Grand Challenge, which is a competition intended to be a catalyst for autonomous vehicle research and development. It was created in response to directives from Congress and the Department of Defense. The event involves field testing vehicles created by researchers and other across many industries with a cash prize as an incentive. The first challenge was held in 2004, but the $1 million prize was not claimed as no one completed the course.

However, the 2005 DARPA Grand Challenge showed greater success when a team from Stanford University won the competition using its car named “Stanley,” completing the 132-mile desert course in less than seven hours. Many components comprised “Stanley,” a Volkswagen Touareg that was retrofitted for this competition. These components included forward-facing laser range finders, a radar system to “see” over a long range, stereo cameras, and a monocular vision system. The vehicle also took measurements using the following technologies/systems: a Global Positioning System (GPS), an inertial measurement unit (with six degrees-of-freedom), laser radar (LIDAR), and a wheel speed measurement system. The software also was critical to the success of this vehicle given the large amount of data collected, so “Stanley” was equipped with seven Pentium M computers. Six custom software modules were used to gather and interpret data and three artificial intelligence (AI) modules processed the data to determine what lay ahead in the road.\textsuperscript{17}

A major challenge in creating such a complex system is successfully integrating the various hardware and software systems. Some of the issues found in “Stanley’s” code related to road boundaries. For example, if the road were very wide, the guidance system would crash. This touches upon a larger issue within this field, which is the successful integration of systems. The lack of standardization in vehicle systems is an issue is a challenge for automakers, who are constantly feeling pressure to update software, but because of the lack of standardization find it difficult to connect the pieces correctly.\textsuperscript{18}

\textbf{Autonomous Truck Hauling System Operated by the Rio Tinto Company in Australia}

In Australia, mining company Rio Tinto has implemented the use of driverless trucks for its operations in West Angelas Mine, East Pilbara operation, in Western

\textsuperscript{16}Bishop, R., \textit{Intelligent Vehicle Technology and Trends}.


\textsuperscript{18}Ibid.
Australia. The trucks were manufactured by Komatsu. The system is an Autonomous Haulage System known as FrontRunner that involves dump trucks, as well as other machines such as an excavator, bulldozer, wheel dozer, and motor grader. These trucks have the capability to haul a load of 320 U.S. tons without a driver. Instead, they are controlled by a computer in a remote operations center. From the supervisory computer, one can review all data from the trucks used at the mine. Data include location of vehicles and running status.19

As of November 2011, Rio Tinto increased its fleet of autonomous trucks from 10 to 150 for its Western Australia mine in order to be able to meet its productivity goals.20

The supervisory computer sends data about target course and speed to the (driverless) dump trucks. Data about the trucks’ positions are collected using a GPS device. In order to load the dump trucks, the dump truck determines the location of bucket of the excavator or wheel loader and moves to that spot. The course taken by the dump truck to loading location is sent by the supervisory computer. Benefits of this technology include increased safety due to fewer collisions with other dump trucks or other equipment. In terms of safety, the obstacle detection system directs the truck to reduce speed or stop when it detects an object in the vehicle’s hauling course. For the purposes of mining, this technology also offers better reliability of operations, particularly when dealing with an extreme climate such as arid Western Australia or areas at high altitudes. Additional goals of employing this technology include reducing maintenance costs, energy use, and carbon dioxide (CO2) emissions.21

The ability of this technology to control heavy trucks precisely and use intelligence to avoid obstacles or stop in the case of unexpected activity is relevant to commercial vehicle platooning in the I-710 freight corridor. These attributes are desirable in a commercial vehicle fleet as they could help provide efficient goods movement in a safe manner.

Summary of Test Project Findings

Large research and development efforts related to vehicle platooning and other automated systems are ongoing throughout the world. Safety has been a major impetus for these efforts, particularly those conducted by governments ranging from the U.S. DOT’s initiatives to those in Asia and Europe. Environmental benefits, reduced congestion, and greater driver comfort also have become major


reasons for this research. These reasons are consistent with the goals of the I-710 freight corridor project.

The range of technology across experiments is great. Some technical options for platooning are simpler than others. For example, the PATH technology and that from the CHAFFEUR and CHAFFEUR2 projects focus on commercial vehicles, while the integration of both passenger and commercial vehicles in the SARTRE project adds a level of complexity.

Actions and processes in the various platooning concepts will have to be rigorously tested through many simulations and field tests in order to ensure that this technology is safe for those in the platoon and other roadway travelers. The issue of string stability within a platoon is important and a comfort level must be reached with this technology. This brings up a larger issue of acceptability; mentioned in particular by SARTRE researchers. There is an important human element; people are being asked to make a significant change in their daily lives with regard to transportation. This is the case to an even greater degree in Europe with the possibility that passenger vehicles will be part of an automated platoon. Structuring a system that uses dedicated truck lanes for commercial vehicle platooning would minimize the issue of interaction with nonplatooning vehicles, but it would still be possible for a vehicle that was not part of the platoon to get into the dedicated lane. With regard to commercial vehicles, another aspect is the desire or financial capacity of people within the trucking industry to purchase vehicles or add the necessary technology to their vehicles that would allow them to be part of vehicle platoons on certain routes such as I-710.

A major factor that works in favor of this technology is the relatively small infrastructure investment required. Some infrastructure would be required to enable vehicle-to-infrastructure communication, but relative to large capital transportation projects, the capital cost is small. Operating costs, however, are unknown and could be significant depending on the level of human monitoring required of the system. Maintenance requirements also are likely to be very stringent since failure of key components cannot be tolerated; a factor that will impact ongoing costs. Management of such a system may be more similar to air traffic control that current highway operations in that redundant, fail-safe systems will be required since the consequences of failure are so severe.

2.2 SUMMARY OF CONTINUING RESEARCH REPORTS (AUTONOMOUS VEHICLE RESEARCH SUMMARY)

As part of the Gateway Cities Technology Plan for Goods Movement, the consultant team actively tracked news and research developments related to autonomous vehicle technology. The information obtained was compiled in a report that presented a summary of news articles, conference proceedings, and other relevant papers related to the topic of autonomous vehicles and vehicle platooning between April and December 2012. Articles were found via Internet
news searches, as well as through searches of research institute web sites and publications. When multiple sources included similar information, only one was selected to avoid duplication of material. The articles were organized by topic area and separated into two sections: news and conferences/research papers. An appendix was prepared that includes the full text of all articles, conference details, and research papers. The sections below summarize the topical areas covered and ongoing developments that should be tracked as work on I-710 and the Autonomous Truck Research Project progress.

Summary of Each Topical Area

Topical areas covered in the review included:

- **Specific demonstration projects** - These are documented both in both Sections 2.1 and 2.2 of this report, and include both public and private projects.

- **Legal issues** - Legal issues focus on operating authority for autonomous vehicles, which requires state-by-state legislation, and liability issues. Autonomous vehicle operation will impact both insurance and the application of liability laws for any accidents that occur.

- **Technology/Design Issues** - There are a range of technology and design issues that are covered in the project summaries. A range of on-board devices will be required for autonomous operation. Issues cover communications, navigation, human factors, and the gradual evolution from today’s “driver assist” technology to full autonomy.

- **Safety** - Autonomous vehicles are touted as having the potential to eliminate accidents; however, 100 percent safety is not likely to be achieved. Research is needed into how to address safety concerns in an autonomous environment, as well in the transition phase to fully autonomous operation.

- **Social/User Acceptance** - Significant research is ongoing in the area of social and user acceptance. While a gradual transition to autonomous operation will help acclimate users to the technology, there are major issues related to both control and privacy that need to be better understood.

Ongoing Projects to Watch

The projects listed below are current research efforts that should be followed during the development of the Autonomous Truck Research Project and the I-710 design process.

**SARTRE Autonomous Road Train Project – EU/Spain**

A successful demonstration of autonomous vehicle technology was recently completed near Barcelona, Spain. This test was part of the project known as Safe Road Trains for the Environment (SARTRE), a joint effort involving many partners, including the European Commission, Ricardo UK Ltd., Volvo, and others. Ricardo UK Ltd.’s autonomous control system has been applied to Volvo’s vehi-
cles. This event took place on a public roadway near Barcelona with other traffic present and was described earlier in this report in Section 2.1.3.

As SARTRE nears completion, it will be interesting to learn what the next steps are and what follow-on projects will be developed. SARTRE is a large project with implications for many countries, which could have great implications on the world of vehicle platooning. Lessons learned from it can hopefully inform plans in the I-710 freight corridor.

**Car to X Communication Test – Germany**

A test known as “Car-to-X communication” is currently taking place in and around Frankfurt, Germany. A number of automakers are participating in the test, including Audi, BMW, Ford, Mercedes-Benz, Opel, and Volkswagen. Tech institutions and government agencies also are participating. Tests will be conducted on a fleet of 120 vehicles, which will be used to gather data about the effectiveness of a number of “Car-to-X” technologies, such as obstacle warning and electronic brake light.

**U.S. DOT/University of Michigan Safety Pilot**

The U.S. DOT awarded the University of Michigan Transportation Research Institute $14.9 million in project funding in 2011 to conduct safety product model deployment of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) in Ann Arbor, Michigan. The entire project is 30 months, with 12-month testing phase. One key element is that the testing will be in a “real-world” environment. Both V2I and V2V technologies will be tested with activities to take place in and around Ann Arbor, Michigan. The testing fleet includes approximately 3,000 cars, trucks, and buses. Wireless communications among vehicles and roadside equipment will be tested. Vehicles will include passenger cars, commercial trucks, and transit buses equipped with a variety of V2V and V2I systems. This test is part of the U.S. DOT’s Safety Pilot program. The pilot will be conducted for one year, and the data from the study will be used to help the National Highway Traffic Safety Administration (NHTSA) determine the technology’s future use and address any legal topics.

**Other U.S. DOT Initiatives**

Since the early 2000s, the U.S. DOT and numerous passenger vehicle manufacturers have been working together on a research effort known as the Vehicle Safety Communications Consortium (VSCC). The consortium is studying the use of wireless communications for vehicle safety applications. In the current phase, the VSCC is focusing on user acceptance of safety applications. Eight car manufacturers have collaborated with the U.S. DOT to hold six driver safety clinics across the country in 2011 to 2012. Clinics took place in the following states from August 2011 through January 2012: Michigan, Minnesota, Florida, Virginia, Texas, and California. The driver clinics were aimed at gauging user acceptance of the technologies. Approximately 100 drivers were hired to take part in each of
these clinics after a thorough screening process. These drivers were first given information about the functions of the connected vehicle system and the scenarios they were to experience during the driver training sessions. After the sessions, they were asked to complete a survey about their experience. In addition to the driver trainings, a few demonstrations were held in which attendees were able to ride in the vehicles while the specific safety applications were demonstrated. These included lane change warnings and forward collision warnings, among others. While the focus of these demonstrations was on passenger vehicles, at least one demonstration that addresses user acceptance of safety applications on commercial vehicles is planned in the near future.22

A major objective of this project is to provide data that will inform the NHTSA rulemaking scheduled to occur in the near future. As the body that has the authority to establish Federal Motor Vehicle Safety Standards (FMVSS), NHTSA is scheduled to make a decision about standards and protocols for V2V communication safety systems in 2013.23

Google Autonomous Vehicles

Google developed a fleet of seven autonomous vehicles and has been testing them since 2010. The fleet has covered more than 140,000 miles. Sebastian Thrun, a member of the winning team in the 2005 DARPA Grand Challenge, heads Google’s Driverless Car program. Components of Google’s autonomous vehicles include (see Figure 2.1) Google Street View data, camera data, LIDAR, and RADAR data. These combined data inform the vehicle of its position on a map. Though autonomous, human drivers are present in the case that intervention is needed.24


The accomplishments of the Google project highlight the fact that in a short period of time, significant progress has been made in the field of autonomous vehicle research. In 2004, no winner emerged at the DARPA Grand Challenge on a course that covered less than 200 miles in the desert; whereas to date, Google’s vehicles have driven more than 140,000 miles at speeds greater than 60 mph. Many automakers also have made great strides in the field of autonomous vehicle research, including BMW; Audi, which sent an autonomous vehicle up Pike’s Peak; VW; Toyota; and General Motors. Safety is a major impetus behind many projects, but in the case of Google, transforming mobility is another goal. One of Google’s major functions is to collect data; that is also the case with its autonomous vehicles. In this context, however, the data are specific to transportation. The autonomous vehicles record what they see and the car’s algorithm’s figure out the rules. Google views the car as a large computer that can learn from the data it collects.\(^{25}\)

In February 2012, Nevada made it legal to operate autonomous vehicles on state roads, and Google recently received the first testing license in the State. Autonomous vehicles are identified by red license plates with an infinity symbol. Google’s test vehicles are modified Toyota Prius cars that have undergone rigorous testing and have logged more than 200,000 miles. Their features include

many components that allow them to “see” through the use of video cameras, laser range finders, and radar sensors. Google’s overall goal is to reduce roadway fatalities and improve the quality of one’s driving experience.

In order to receive the license, Google was required to conduct driving demonstrations on freeways, state highways, neighborhoods, and along areas such as the Las Vegas strip. Additionally, the Nevada Department of Motor Vehicles (DMV) reviewed Google’s documentation of the vehicle’s functions, safety plans, employee training information, and accident reporting mechanisms. The vehicles also must always have two people present— one person to take over the wheel, if necessary; and one to monitor the on-board computer. Currently, Google is the only company to hold this type of license, but a number of car manufacturers are interested in testing their own autonomous vehicles on state roads.

### 2.3 SUMMARY OF KEY ISSUE AREAS

While technological advances have been made, a number of critical issues have emerged that are being addressed through various research and development efforts.

- User acceptance is a key ingredient to the successful adoption of autonomous vehicles. Throughout the years, many processes within cars have become automated including cruise control and anti-lock brakes among others. However, the transition from humans as drivers to humans as merely passengers in a car that drives itself is a major one. Autonomous vehicles will increase the number of single-occupant autos since a larger proportion of population will be able to drive. Theoretically the technology will increase capacity of the system, but it is an open question whether there will adequate capacity in system to accommodate everyone. Since there will still be part of the population who cannot use autonomous vehicles due to cost or physical limitations other systems will still be needed. The impact on existing transit systems, for example, needs to be considered. Car sharing and carpooling arrangements will change as well.

- Legal issues have also been a common topic of discussion. Who would be sued in the case of an incident with an autonomous vehicle? Nevada and California have passed legislation allowing autonomous cars to be driven on state highways; and other states are following. However, the need for passage on a state-by-state basis is a cumbersome process that could inhibit implementation. Performance standards and other regulations that promote safe operation, including required equipment, are being implemented at the State level but may eventually have to be standardized to allow for full deployment. This is particularly true for the commercial vehicle sector, where interstate trips represent a much higher proportions of the total than passenger vehicles. Liability issues are also a major concern. Responsibility for accidents that do occur with autonomous vehicles must be established.
and may become complicated where third-party equipment is involved. Some technologies are using a lead driver concept which raises major liability concerns for the driver’s employer or the drivers themselves. Another area of legal concern is the large amount of data that is required. Regulations, or at least agreements, will be needed to make sure that the privacy of system users is protected and that they are aware of what information they are allowing to be used for public or private purposes.

- The passenger safety of these vehicles is a major focus area and technologies still need to be improved in some cases. For example, cameras and radar are negatively affected by ice and snow, so issues of extreme weather and other environmental-related issues must be addressed where those conditions exist.

2.4 **CHANGE MANAGEMENT PROCESS**

The Implementation plan prepared for this project identified the need for an ongoing Change Management process to track autonomous vehicle developments and assure that the I-710 Freight Corridor is able to incorporate new technologies that are beneficial to the goals of the project. This process will need to be incorporated into all phases of the project including planning, design and construction. The challenge is to provide adequate infrastructure for the potential range of autonomous vehicle applications, while keeping within cost and schedule constraints. It is not possible to predict all the areas that will be impacted by technological change, but general categories include:

- Detection technology for both speed and counts;
- Surveillance technology and software;
- Automated toll collection;
- In-vehicle routing and information systems;
- “Driver assist” technology, and
- Fully autonomous technology.

Key players in the change management process will be the design manager of the I-710, or their appointees, and members of the Demonstration and Operations Group that will supervise the Autonomous Truck Research project. Representatives from both groups would be appointed to a change management board that would have the following responsibilities:

- Document user needs for the I-710 Freight Corridor;
- Develop a set of criteria for evaluating new technologies that are compatible with the goals, objectives and user needs of the freight corridor;
- Identify and categorize project components and technologies that are subject to change;
• Conduct monthly reviews of research and product development activities in each category;

• When major changes are identified that may impact the I-710 project, make accommodations for vendor showcases or make other accommodations to assess vendor capabilities;

• Provide notification to I-710 design teams of potential changes;

• Conduct laboratory or field tests and cost analysis where adequate data cannot be obtained through research;

• Conduct peer reviews and obtain information from other agencies who have or are implementing the technologies;

• Organize and manage value engineering activities with I-710 design teams;

• Provide recommendations on technology adoption, including cost and schedule impacts; and

• Monitor field tests and implementation of technology.

A number of different arrangements may be used to carry out these tasks. The Automated Truck Research test facility proposed may serve many of the requirements, and participation by U.S. DOT and private parties may help to defray part of the cost. Contracts with Universities or private non-profit research laboratories can be helpful in assuring that evaluations are independent and free of financial conflict. If any case it is critical that the contracting agency and the committee obtain the expertise to effectively scope the work and closely monitor contractor activities.

Figure 2.2 below illustrates a change management process developed as part of a Detector system plan developed for Caltrans. This model can be applied to the areas of the technology identified at the beginning of this section and consolidated with other areas of technology.
Figure 2.2   Illustrative Change Management Process

Detector Need Identified → Category User Need → Identify User Need Subcategory(ies) → Screen Criteria

- Accuracy
- Capital Cost
- Annual O&M
- Lifespan
- Reliability
- Life-Cycle Cost
- Required Data Available
- Experience with Technology
- Operating Environment
- Ability to Maintain
- Vendor Support History

Selected Criteria and Thresholds

Coverage Analysis

Detector Existing in Suitable Location?

Yes → Technology Evaluation

Candidate Technologies Based on Criteria

Test Results Available

Yes → Yes

No → No

Review Test Adequate?

Yes → Yes

No → No

Revisit Test Adequate?

Yes → Yes

No → No

Test Results Available

Yes → Yes

No → No

Review Test Adequate?

Yes → Yes

No → No

Revisit Test Adequate?

Yes → Yes

No → No

Revisit Test Adequate?

Yes → Yes

No → No

Revisit Test Adequate?

Yes → Yes

No → No

Revisit Test Adequate?

Yes → Yes

No → No

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Yes → Yes

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Yes → Yes

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Yes → Yes

No → No

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No → No

Revisit Test Adequate?
3.0 I-710 Potential Design Considerations Driven by Technology

3.1 I-710 PROJECT SUMMARY AND STATUS

The I-710 freight corridor is envisioned as a freight-only limited access facility that runs in parallel with the general purpose lanes of the I-710 freeway. The freight corridor may be a tolled facility with all trucks having to pay a toll. The toll would vary based on the length and the time of day of the trip on the freight corridor. It will likely also be a zero emission facility; meaning the trucks would be powered by a zero emissions propulsion system. Finally, and relevant to this report and project, in an effort to increase capacity, reliability, and safety, the corridor will be a semi-autonomous truck corridor; meaning the trucks themselves are under semi-autonomous control with vehicle to vehicle communication and vehicle to infrastructure communications to improve throughput and safety.
3.2 I-710 OPERATIONAL COMPONENTS AND TECHNOLOGY OVERVIEW

This section provides a narrative of how, from an operational perspective, the I-710 freight corridor could operate in the future. This narrative focuses specifically on how technology could play a role in improving the efficiency and safety of the corridor. There are a variety of technological components presented in this narrative. They are technologies focused around:

- Traffic Management,
- Tolling Operations,
- Zero Emissions Operation, and
- Autonomous Truck Operations.

The narrative is followed by a summary of the how the technologies outlined in the narrative could impact the design of the facility. It is meant to provide input into the developed preliminary design work for the corridor with guidance and awareness of some of the technologies impacting infrastructure potentially required in the corridor. The design will then be developed to decide the best ways to plan for those technologies and their associated structural, power, and communications requirements on the design.

I-710 Freight Corridor Operational Narrative/Example

Bob has just picked up a container at Terminal X at the Port of Long Beach. He has completed his paperwork and is preparing to take the load to its final destination: a transloading facility just north of Slauson Avenue near the northern end of the I-710 freeway. Bob is scheduled by his dispatcher for two additional pickups today, so it is important that he get up to Slauson and back to the port, as quickly as possible.

He is thinking about taking the new I-710 freight corridor; since it usually offers the most reliable and quickest route to that part of the city. But before he goes, he decides to check the traffic conditions on his route. Using his mobile phone, and before he begins driving, he opens the LA 511 Freight Traffic App. This App was developed by the LA Metro’s 511 program to offer commercial vehicle operators in the region traveler information specifically tailored to them. It includes wait times at the terminal gates, very accurate and reliable travel times on many of the larger city streets he normally uses, and provides a very accurate and reliable picture of traffic conditions on the freeways around the ports, specifically the 710.

Bob checks the App’s traffic map whose default view is the I-710 corridor. This view gives him an at-a-glance view of the speeds on both the general purpose lanes and the freight corridor. The freight corridor’s speed map is all green, indicating that the traffic is moving at free flow and the speed limit. The travel
conditions on the general purpose lane’s speed map are not as good however. Although the speed map is green near the port, it is red north of the 91. There is an icon indicating there has been an incident of some type and it is affecting traffic. Bob decides to leave now and take the freight corridor. To make sure the traffic speed maps are correct, Bob zooms into the freight corridor map. He taps one of the camera icons on the map and brings up video of one of the many traffic cameras along the 710. He is able to visually confirm that the traffic on the freight corridor is indeed traveling at free flow. The App also tells him the current cost of the toll.

As Bob sets out on his trip, he leaves the terminal gates and turns onto X heading for the freight corridor. At the intersection of X and Y, he notices a dynamic message board on the side of the road with travel times posted for both the general purpose lanes and the freight corridor. The sign confirms the estimated travel times and toll price he saw in the App. He crosses Y and proceeds to the ramp and the entrance to the freight corridor.

As Bob takes the on-ramp to the freight corridor his vehicle will begin to go through a series of actions that are required to travel on the corridor. The first action is tolling. Since the corridor is tolled, Bob will pay the toll electronically as he enters the corridor. This transaction begins with a device on his vehicle communicating to a reader at the roadside of corridor (or through a potential uplink). An audible confirmation chime is made in his cab, as the transaction is initiated electronically.

Having a tolling transponder is required for traveling on the freight corridor. The corridor’s tolling system is an advanced electronic tolling system operated by the corridor’s operator. Bob’s company has paid for toll transponders to be integrated into the cab of his truck and has set up accounts with the tolling operator of the freight corridor. This enables the truck to travel the corridor. If a truck were to travel on the freight corridor without a transponder, it would be in violation and pay a penalty. Enforcement is coordinated with the BMV and California Highway Patrol (CHP) with the Freight corridor operator.

Once Bob’s toll entrance transaction is created, it will stay an active record until he leaves the system and passes another roadside toll reader upon exit. At this time Bob’s toll will be calculated (the amount of the toll varies based on how long Bob travels along the corridor and during what time of day). Beyond the audio confirmation, Bob does not need to do any other action to pay the toll.

The next system Bob’s truck must engage with as he joins the freight corridor is the autonomous vehicle system. In an effort to increase capacity, reliability, and safety, the mainline of the freight corridor is an autonomous vehicle corridor with trucks in the mainline having the capability to operate without driver interaction. In other words, the trucks operating in the corridor steer accelerate and brake on their own. This is made possible by having specially equipped trucks and trailers that are in constant communication with the other trucks around it and the infrastructure (i.e., roadway) itself (by a variety of potential methods –
see subsequent discussion). These specially equipped trucks have the capability to control all driver functions with no driver intervention. Having a truck instrumented for autonomous operations is a requirement; just as the zero emissions is a requirement for driving on the freight corridor. Violators are fined. Enforcement is coordinated with the CHP with the Freight corridor operator.

Bob’s company invested in the trucks with the autonomous capability. The autonomous system will take active control of the truck through devices in the truck and on the infrastructure as it approach the mainline from the on-ramp. This is all accomplished through a series of sensor (including radar), processors, and controllers on the truck that is communicating with data receivers on the roadside. The system provides an audible warning and a short audible countdown is heard, at the end of which, control is in the hands of the autonomous system (located inside his truck). The system next provides an audio prompt, asking where Bob plans to exit the system. This is done so the system knows when to disengage the autonomous system and hand control back over to Bob. Bob can respond to the autonomous system through both voice and a control panel on his dashboard. Today he chooses voice. Bob give the audio command and immediately the truck responds a confirmation of the exit point. The zero emissions system is also controlled by the autonomous system, its operation and functions are described below.

The third and final system Bob’s truck must engage with is the freight corridors zero emission system. For the freight corridor to achieve zero emissions, any truck along the corridor must, while on the corridor, emit no emissions. Standard diesel trucks without any ability to operate at zero emissions are not permitted to use the freight corridor. Violators will be fined. Enforcement is coordinated with the BMV and CHP with the Freight corridor operator.

Some trucks achieve zero emissions by being advanced hybrid trucks, which have the battery power to operate at highway speeds. Other trucks achieve zero emission by also being a slightly different advanced hybrid truck who get their power not through on board batteries, but an electrified overhead catenary system. The 710 freight corridor has a catenary system along all of the entire mainline in both directions. Trucks are required to either engage their battery or engage the catenary system as they join the main flow of traffic of the freight corridor. It is important to note all zero emissions trucks will either switch to full battery power or the catenary system automatically as part of the autonomous vehicle system described above. Bob’s truck is either equipped with a meter that determines his electric usage and is downloaded once a month to his company to pay the charge or is included a per mile charge as part of his toll.

Bob’s truck is equipped with a pantograph to engage the catenary system. As he leaves the on-ramp and joins the mainline of traffic in the freight corridor and as his truck transitions to autonomous control, his truck will also automatically raise the pantograph on his truck and engage the catenary system. His truck automatically and seamlessly then transfers over to full electric power. Bob continues on the catenary system for the remainder of his journey along the mainline.
With the autonomous system controlling his vehicle and the catenary system engaged, Bob then sits back and checks his phone for messages.

As Bob’s truck passes over Firestone Boulevard, the autonomous system does an audio alert indicating that the system will be disengaging soon. As he approaches the exit, the autonomous system disengages the catenary system and transitions over to full diesel mode again. A short audio warning counts down to when the system will return control back to Bob. Upon the conclusion of the countdown, Bob takes the wheel and he is again in control. As he exits the freight corridor, the toll transponder is read one final time from a roadside reader and an audible chime is heard inside his cab to inform him the transaction is now complete. The length of his trip is calculated and the resulting fee is debited from his company’s account.

As Bob approaches his destination and parks, he checks his phone for his next assignment, checks the traffic and prepares to begin the return trip.

### 3.3 IMPLICATIONS OF OPERATIONAL POLICIES FOR I-710 INFRASTRUCTURE

The proceeding narrative/example has a number of assumptions about how these advanced systems will operate on a daily basis. Those assumptions and associated systems in turn, create a number of requirements and impacts on overall design of the corridor. To summarize, the I-710 freight corridor will have the following core system components and potential associated impacts. (Note: The impact of autonomous system on the I-710 infrastructure is discussed in Section 3.4).

- **Advanced Toll System**, capable of electronically processing a large number of trucks traveling at near highway speeds. The system will calculate the tolls based on mileage and debit accounts accordingly. The system will require transponders/automatic ID systems of some type in each truck and associated transponder readers at the roadside at each entrance and exit to the freight corridor. Each tolling station will include toll tag readers, and associated cameras and imaging technology for enforcement typically mounted on an overhead structure. The system will need to operate in both north and south directions and operate without any driver interaction. Finally, the system must give the driver some indication that the transponder has been read as it enters and leaves the corridor. The roadside elements of the toll station system will require both communication and power to operate 24/7, 365 days a year and thus will require redundant power and uninterruptable power supplies. The redundant power network will result in more conduit and cable, but should not require more right-of-way than typical tolling and ITS systems. The roadside elements must also be easily accessible for periodic maintenance. There are associated control cabinets as well that will be needed which will need to be near to but not necessarily on the freight
corridor. The cabinets to will require both communication and power to operate 24/7, 365 days a year and be easily accessible for periodic maintenance.

- **Overhead Catenary System**, capable of powering trucks along the entire length of the mainline of the freight corridor. The system needs to support an estimated maximum number of 27 trucks/lane/mile on the corridor at one time. The system needs to be installed so that maintenance can be completed without closing the entire facility. The system must be able to operate 24/7, 365 days a year. However, as the trucks connected to the overhead catenary are “hybrid” trucks and power can be interruptible, reducing the electrical costs to develop this system. There are a significant number of power generation and support facilities needed to support this system, like substations and conduits. As previously stated, if there is a system shutdown or malfunction, trucks will resort to their own power under these abnormal situations. A charge for the electricity use will be determined and charged as part of the toll.

- **Traffic Management Systems**, capable of providing real-time detection, surveillance of the entire freight corridor and dissemination of traveler information. This would require video surveillance with sufficient deployment to provide complete visual coverage of the entire corridor to include all entranced and exits to the facility. Cameras would be full color, pan tilt zoom closed circuit cameras deployed every one-half mile to one mile (depending on geometry of the corridor). The cameras are typically mounted on 25-foot poles per the Caltrans standard. Where possible, cameras could be mounted on luminaires. Detection could be provided by a variety of devices or third party vendors. If a roadside solution is selected it would require roadside detectors with sufficient deployment to provide complete speed and volume estimates of the entire corridor. There are associated control cabinets as well for all of the above listed roadside devices that will be needed which will need to be near but not necessarily on the freight corridor. The roadside devices and cabinets will require both communication and power to operate 24/7, 365 days a year and be easily accessible for periodic maintenance. An example of the number and conceptual location of these traffic control devices is shown in the following figure. This figure illustrates the conceptual location for the southern section. Infrastructure requirements for operation and/or vehicle-to-roadway communication are outlined in Subsection 3.4 and Section 4.0. For the present conduits, pull boxes, cabinets, radios, and poles should be assumed in the design of the freight corridor for potential vehicle-to-roadway (infrastructure) control or operational scenarios.
Figure 3.1 Potential location of technology field devices – I-710 southern section

Legend
- CCTV Camera Location
- Arterial DMS Location
- Catenary Begin/End
- Tolling Stations

Tolling for all northbound trucks would begin here

Catenary ends here for all southbound trucks

Catenary begins here for all northbound trucks
• **Operations Command and Control System**, capable of controlling the operations of the catenary power (to include power generation) tolling, traffic management, and the autonomous vehicle system. This will include:
  
  – A robust Supervisory Control and Data Acquisition (SCADA) system to provide complete and redundant command and control of both the catenary and autonomous systems;
  
  – An equally robust Advanced Traffic Management System (ATMS) to control the traffic management component;
  
  – An Advance Toll Management System to control all the toll related field devices, as well as provide all the back-office monetary transactions; and
  
  – A dedicated control center (which could be within an existing center – or in the proposed TMC (or TIS) for Goods Movement) to house the associated systems, communications, and backup systems to operate such systems 24/7, 365 days a year.

As detailed above, most of the technology components listed above require some form of power and communications. Ideally, many of the systems above can share facilities such as cabinets, power, and communication. It is recommended that the corridor utilize fiber to bring all data (traffic and video) back to communication hubs along that corridor that would then run back to a headend at either a new or existing TMC. Fiber infrastructure can be shared with all communication expected on the corridor. Typically, anywhere from 48 to 96 strands of single mode fiber are considered standard installations of this magnitude for backbone communication with anywhere from 12 to 48 strands utilized for stubbed drops to each cabinet. With these many fibers, it is entirely possible to have physically separated networks between the different proposed communications systems. It is also recommended that power can also be a shared facility with all expected power on the corridor. It is possible to keep power for any of the systems above physically separated from the through isolation transformers. Finally, wireless technology is a viable option for less mission critical systems such as traffic management.

Finally, enforcement is a key consideration on this new facility as well. Although a parallel regional enforcement technology study is currently underway. It is looking not only at deploying two full enforcement facilities in the region (one on this corridor at Del Amo); but is also looking at a wider advanced enforcement network across the region that would include mobile enforcement capabilities such as virtual sorting/screening sites. Functionality of these systems includes:

• Vehicle classification detection;
• Weigh-in-motion (WIM) scales;
• Height and length detection;
• License plate readers;
- Vehicle identification detection; and
- Vehicle classification detection.

The roadside elements of the enforcement system will require both communication and power to operate 24/7, 365 days a year. The roadside elements must also be easily accessible for periodic maintenance. There are associated control cabinets as well that will be needed which will need to be near but not necessarily on the freight corridor. The cabinets to will require both communication and power to operate 24/7, 365 days a year and be easily accessible for periodic maintenance. Their communications must also be integrated with the new enforcement facilities along with any corridor-wide backbone fiber. This project will have information to share soon about proposed facilities this corridor. Once it reaches the proper milestone, the weigh-in-motion stations and other enforcement elements will be updated into this document.

### 3.4 Implications of Autonomous Vehicle Research

#### Operational Policies

The implication of autonomous vehicle research on the I-710 project is at this time hard to define with any clarity. As illustrated in other sections of this report, autonomous vehicles beg a number of very basic operational questions. Areas such as legality, liability and system interoperability are being explored at this moment and will continue to be explored as this arena matures. As the I-710 project evolves, some questions that need to begin to be answered include identifying the operating agency for the component of the autonomous system that is part of the I-710 infrastructure; specifically the RSE and its associated power as well as the communications back haul to the central system controlling the radios and interfacing with the trucks. As noted earlier this operating agency must have a 24/7 outlook on this facility. These devices must have a very high reliability and availability record and the MTBF and MTTR must be minimal to ensure continuous operation. This is a very different approach to transportation management and is more closely related to the way utilities operate than how traditional transportation systems are operated. Many of these issues need to be identified and detailed as an early stage even though the eventual system could be a number of years away.

#### Infrastructure

As discussed earlier, an autonomous System capable of enabling the trucks operating in the corridor to steer, accelerate and brake on their own could be deployed as the eventual build-out of the I-710 freight corridor. The goal of the system will be to operate all the trucks in the corridor under coordinated operations resulting in shortened headways between vehicles, increased reliability and
increased safety. The system will be a combination of vehicle to vehicle and V2I communications and associated systems. Currently, this type of technology is being considered in a significant research effort headed by the U.S. DOT known as the Connected-Vehicle program. Under this initiative, a Federal rulemaking decision is planned for Q4 2013 that may mandate a rollout of Dedicated Short Range Communication (DSRC) radios into vehicles. These DSRC radios would be integrated with software and other in-vehicle devices that would implement several envisioned application packages. Much of the enabling technology for the autonomous system will reside in the truck itself and include a wide variety of Original Equipment Manufacturer on-board vehicle systems. However, in order for the complete system to operate, roadside equipment (RSE) that send and receive vehicle location and status information will need to be mounted along the entire length of the corridor systems. These radios and their power and communications requirements would be the major impact on the I-710 infrastructure. Although the autonomous operations would only be on the mainline it’s anticipated that the roadside devices may need to begin as early as the on ramps and on some of the approaching arterials. The key roadside elements of this system that would comprise of high speed radios capable of communicating very quickly over relatively short distances to ensure timely communication with all the trucks on the corridor. These radios are deployed approximately every one-quarter to one-third of a mile ideally in the center of the roadway or alternating on either side. Roadside infrastructure needed to mount the RSEs could be existing light poles, catenary support structures, or signal pole standards. Control cabinets utilized for the ITS or tolling system can be used to also house necessary equipment for the semi-autonomous system. In short, the impact of the semi-automatic system would be minimal since the necessary equipment could be installed with already proposed infrastructure for lighting, catenary power, ITS or tolling. Currently, the U.S. DOT has approved four possible vendors of DSRCs. An example of one of these radios operating today in the field is shown below.
3.5 **NEXT STEPS**

Potential next steps in the area include:

- Refine potential types, numbers, and device locations for the entire corridor.
- Based on the test project outlined in Section 4.0 revisit the infrastructure implications on the 710 corridor.
- Leverage the findings of the Concept of Operations developed in Section 5.0 as a way to further focus the operational requirements of having such a corridor. Ensure that the appropriate technologies support those operational goals.
4.0 Autonomous Vehicle Test Activities

This section summarizes the next steps required to advance autonomous vehicle research, as documented in the Task 3 report and the Implementation Plan. It documents a project that will implement a staged progression of commercial vehicle technologies in order to transition from current research-based automated commercial vehicle demonstration efforts to staged operational testing of a flow efficiency system of trucks along the planned I-710 truck lanes, and then to the design and implementation of a fully-autonomous operational system. This project will build upon the unique operational environment and potential partnerships of the Gateway Cities region to promote and enhance truck automated commercial vehicle research by bringing together the applications of automated commercial vehicle and automation technologies with the real-world operational realities of a heavily congested truck corridor. Finally, the project will provide for staged operational testing over time with an eye towards understanding the specific design and operational concerns that impact the future development of the I-710 and its approaches.

This project addresses critical user needs identified in this project’s background research, extensive surveying, and through conversations with the ITS Working Group. It is intended to help address long-term terminal congestion, truck congestion on key roadways (especially in the I-710 corridor), enhance safety, and reduce emissions. The projections for future truck traffic on the I-710 corridor necessitate technology solutions to improve operational capacity even as infrastructure capacity is expanded.

The project encompasses three major areas of effort:

1. **Institutional/Promotional.** In order to realize the long-term vision for a technology-based flow efficiency operation of trucks, it is necessary to establish institutional relationships and partnerships that will endure over the long term. These institutional relationships will need to bring together port stakeholders, regional agencies, Caltrans, Federal entities, research organizations, truck equipment manufacturers, private shipping interests, and trucking companies. The project and partnerships also will require a cohesive and professional marketing and communications effort. Finally, this partnership will have to review and promote enabling legislation over time to support the longer-term corridor vision.
2. **Operational/Design Path Development.** The second major area of effort focuses on building on recent research efforts on truck guidance, intelligent vehicle systems, and automated commercial vehicles to define the details of what operations would look like in the I-710 corridor, given the future cross-section and design alternatives. Technical analysis needs to be conducted by an interdisciplinary team, including vehicle technology experts, truck operations experts, experienced drivers, traffic engineers, and highway designers, to develop detailed operational concepts for the I-710 corridor, which can be tested as part of this project.

3. **Staged Testing Applying Available Technologies and Operational Concepts.** The third area of effort involves the actual testing and application of the proposed operational concepts. Testing will include establishment and the recurring use of a test facility, with an initial alternative as an approximately 3.5-mile stretch of Route 103 in the Port’s region.

### 4.1 Test Goals and Objectives

The goal is not simply to test the performance of the technologies themselves, but to introduce real operational challenges and concepts specific to the real-world I-710 corridor environment, and test widely available technologies against those challenges. It is assumed other projects will continue to stretch the boundaries of intelligent vehicle technologies, while the goal of this truck technology flow efficiency project will be to test and realize staged benefits using Original Equipment Manufacturer (OEM) concepts, which can be widely adopted. Thus, the objectives of this project are to:

- Help ensure the future viability of the Ports and Gateway Cities region, as well as the I-710 corridor, by realizing the vision for achieving maximum effective capacity within the substantial physical constraints of the regions key truck corridors;
- Build upon ongoing and rapidly advancing intelligent vehicle technologies for trucks to define a detailed and staged ConOps for an effective conveyor operation of trucks on the I-710;
- Develop and support a test site in the region where technology and operational concepts can be tested in conjunction with public and private partners;
- Leverage emerging OEM and Tier 1 vehicle supplier technologies to provide a viable real-world operational model focused on the needs and characteristics of the region;
- Establish an ongoing partnership and environment that attract additional funding opportunities to bridge the gap between research efforts and effective real-world solutions in a real-world freight corridor; and
- Promote the state of the art in truck guidance and flow efficiency with an eye towards effective and widespread deployments using OEM available equipment.

For a detailed description of the project, including hypothetical project operational narratives, recommended project scope, conceptual diagrams, recommended scheduling and phasing, preliminary cost estimates, users and systems involved, the Gateway City user needs to be addressed by the project, and initial steps for deployment see Section 7.0 of the *Gateway Cities Conceptual Projects Description Report* (attached in Appendix B). This section also includes descriptions of alternative project options for consideration.

### 4.2 Broader Economic and Technical Goals

Benefits will accrue to the Ports and freight industry stakeholders in the region by providing increased capacity on the proposed I-710 freight corridor. The vision is to achieve maximum effective capacity within the substantial physical constraints of the region’s key truck corridors. This will reduce congestion and result in more cost-effective and safe freight operations. By safely increasing the capacity of the I-710 freight corridor, fewer vehicles will be inclined to use the arterial system, reducing the negative impacts of truck traffic on Gateway Cities communities (or arterial highways and freeway GP lanes).

There is also potential economic benefit for Southern California in developing and supporting a test site in the region, where technologies and operational concepts can be tested in conjunction with public and private partners. The test site and subsequent implementation on I-710 and possibly other locations will leverage Original Equipment Manufacturer (OEM) and Tier 1 vehicle supplier technologies to provide a viable real-world operational model focused on the needs and characteristics of the region. This will help create opportunities to spin off businesses that specialize in freight-related applications of Connected Vehicle technology. This will encourage widespread deployments using OEM available equipment.

### 4.3 Next Steps

A key to the success of this effort is the development and sustainability of an ongoing demonstration and operations group. This group will coordinate and act as overall project supporters and sponsors. The group will represent the partnership between government and private industry. Likely partners are OEMs, other equipment suppliers, road designers and contractors, freight industry stakeholders, and universities. It is anticipated that LA Metro will take the initiative in forming this group and, along with Caltrans, serve as the conduit for project funding.

The next step in this project will be a Concept of Operations that will bring together stakeholders to a common understanding of what will be accomplished.
on the vehicle test bed and corridor test bed. Summary components of the ConOps will help bring in funding and industry partners who want to participate. The ConOps should address operations, roles and responsibilities, and envisioned technologies for:

- **Initial Operational Tests Environment.** Defining the details of what is needed in the test corridor and test bed vehicles; and

- **I-710 Environment.** Providing an enhanced framework and understanding of how the test results will fit into the I-710 freight corridor environment.

The next step will be to use the ConOps as a basis to define test requirements and potential operational requirements for I-710. A simulation model will be developed so that actual results can be compared with anticipated results. Test facilities will be identified and detailed test plans developed, preferably with a multiyear program. One potential testbed location has been identified which is shown in Figure 4.1 below.

Test vehicles and required equipment will be specified and obtained. Three categories of test have been identified, although these may be modified by the demonstration and operations group:

1. Tests focused on the potential for the real-world application of a loosely defined conveyor of trucks using available Adaptive Cruise Control (ACC),\(^{26}\) and possibly braking technology with prescribed operational speeds for a corridor.

2. Tests designed to achieve tighter spacing (or closer) of trucks (in a safe environment) with DSRC and intertruck communications. This approach may allow for tighter spaces between trucks with forewarning of problems several trucks in advance. This also may include roadside DSRC communications stations to provide an overall corridor view of the operations of the conveyor of trucks.

3. The third test stage would use lessons learned from Stages 1 and 2, which would be applied to enhance vehicle automation, possibly including lateral guidance and control at a greater level with combined cooperative ACC, safety, braking, and vehicle-to-vehicle communications, to establish the most effective conveyor options possible. This stage would combine corridor-wide simulation and management concepts, where speeds of vehicles may be managed, given the levels of traffic and conditions in the corridor as communicated by vehicle-to-roadside DSRC methods.

\(^{26}\)ACC is an existing technology available currently available on some automobiles. It allows the driver to set and retain a specific vehicle speed, but different from traditional cruise control systems, the system is able to decrease its speed automatically when the preceding vehicle decreases its speed. It also maintains a specific distance from the preceding vehicle that can be set by the driver (IVsource.net, 2011).
Figure 4.1  Potential Area for Truck Flow Efficiency Test Corridor
Stages of the test process will include establishing the physical test corridor with the required equipment, integrated testing and proof of concept, the initial demonstration segment with non-test bed trucks. Monitoring and evaluation activities would occur throughout the course of the demonstration.

The ConOps and initial test concepts are anticipated to take one year. The physical development of the test bed will take a minimum of six months. The starting date for this activity could begin concurrently with the test plan development, but probably toward the end of this period. The initial set of tests are estimated to take approximately one year at a minimum, but this schedule depends largely on availability of vehicles, the test bed, and required equipment and the specifications developed for the test plans. These cannot be estimated with a high level of confidence until the ConOps and initial test concepts are completed.

The success of this project will depend in large part on the active participation of private sector and public sector partners. Given the highly technical nature of the work, it is likely that management of the overall demonstrations and many of the tasks will be contracted, either to private companies, nonprofit research organizations, or universities. Bringing all interested parties into the group at the outset is a critical step in accomplishing this.
5.0 ConOps Requirements to Tie Together Test Activities and I-710 Requirements

ConOps will be a critical document in tying together the Automated Truck Research project activities and the design of the I-710 freight corridor. One of the key test activities will be to explore the feasibility of deploying automated commercial vehicles and automation technologies within the I-710 freight corridor. The project will establish institutional relationships between stakeholders, regional agencies, California DOT (Caltrans), Federal entities, research organizations, truck equipment manufacturers, trucking companies and private shipping interests to promote a realistic operational vision for the I-710 that utilizes automated commercial vehicles. Staged testing of available technologies and operational concepts, including those being tested by the U.S. DOT Connected Vehicle Program, will be conducted to gauge the performance of an automated flow efficiency system for trucks in a real world environment.

The Concept of Operations will cover the following topics:

- **Goals and objectives.** An initial set of goals and objectives has been defined for this project. The ConOps will refine and modify these goals and objectives where necessary in line with stakeholder needs and technological developments.

- **Key linkages.** Linkages to other projects will be identified. The major linkage will be between the Automated Truck Research project and the ongoing I-710 freight corridor design effort. The general ConOps prepared for this study made an additional assessment of linkages, including:
  - Coordination will be required with the Freight TIS and Data Fusion project to establish a data interface to send speed data collected from the automated commercial vehicles to the Data Fusion server;
  - Coordination with the Freeway Smart Corridor project will focus on receiving data from detection devices, meters and signals that will be important to an automated flow efficiency system for trucks; and
Coordination with the Truck Enforcement Network Systems (TENS) project will primarily be in regards to inspection process accommodations for automated truck fleets.

**Implementation Steps.** Greater detail, particularly on the technical side, will be added to the implementation steps already identified. These include:

- Identifying an agency to take the lead in submitting grant applications and to oversee the contracting efforts;
- Formation of a project team composed of members from public agencies and the trucking, shipping, and manufacturing industries to develop a concept of operations for an automated truck system;
- Establishing a working relationship with the I-710 project with responsible parties identified and activities defined; and
- Establishing a change management process and obtaining the technical support required to implement it, as described in Section 2.4.

**Scenarios.** Develop additional scenarios similar to the one provided in Section 3.0 of this document:

- Identify assumptions requiring testing and further analysis; and
- Use scenarios to describe how system would operate and work together.

**Test Plans:**

- High-level test plans to be matched with goals and objectives and scenarios, documentation with matrix matching scenarios and test plans;
- Outline of specific test plans with schedule and budget; and
- Prioritization of specific test plans

**System Components.** System components will be identified along with specifications and potential sources. Examples of the components to be included are:

- Dedicated test facility – Description of location and characteristics;
- Multi-use facilities that can be used for testing – Description of location, opportunities, and operating constraints, such as available hours.
- Vehicles – Types and characteristics of vehicles to be used in tests; suppliers, modifications required.
- Roadside equipment and infrastructure – Communications equipment, structures, detection/surveillance, and safety devices.
- In-vehicle equipment – Additional equipment required in vehicles.
• **Schedule and Budget:**
  - Coordination of Autonomous Vehicle Research Program and I-710 design schedules; and
  - Next steps.
6.0 Autonomous New Articles Summaries

This section presents a summary of news articles, conference proceedings, and other relevant papers related to the topic of autonomous vehicles and vehicle platooning between April and December 2012. Articles were found via Internet news searches, as well as through searches of research institute web sites and publications. When multiple sources included similar information, only one was selected to avoid duplication of material. The articles are organized by topic area and separated into two sections: news and conferences/research papers. The appendix includes the full text of all articles, conference details, and research papers in the order in which they are summarized below. The full articles are found in Appendix A.

6.1 News Articles: Demonstrations

Article #1

Title: Autonomous Road Train Project Completes First Public Road Test


Date: May 28, 2012

A successful demonstration of autonomous vehicle technology was recently completed near Barcelona, Spain. This test was part of the project known as SARTRE (Safe Road Trains for the Environment), a joint effort involving many partners, including the European Commission, Ricardo UK Ltd., Volvo, and others. Ricardo UK Ltd.’s autonomous control system has been applied to Volvo’s vehicles. This event took place on a public roadway near Barcelona with other traffic present. During this event, four vehicles – three Volvo passenger cars (models XC60, V60, and S60) and one Volvo truck – successfully joined the lead vehicle and created a platoon. The nonlead vehicles were able to follow the lead vehicle at a speed of 85 kilometers per hour (53 mph). In total, the platoon traveled 200 kilometers throughout this demonstration with gaps between vehicles ranging from 15 to 5 meters. The autonomous control system allowed the following vehicles to mimic the lead vehicle’s movements, including accelerating, braking, and turning. The project’s next phase relates to fuel consumption analysis.
Article #2

Title: Autonomous Vehicle at Thunderhill Raceway


Date: June 29, 2012

This article provides a brief summary of an autonomous vehicle demonstration at Thunderhill Raceway. The car, an Audi TT, was built by a team of Stanford engineers led by Dr. Chris Gerdes. The car reached speeds of 100 mph and the testing was conducted both with and without a driver.

Article #3

Title: Consortium of Automakers Announces Real-World Car-to-X Communication-Tech Test


Date: August 8, 2012

This article provides a brief description of a test known as “Car-to-X communication” that is currently taking place in and around Frankfurt, Germany. A number of automakers are participating in the test including Audi, BMW, Ford, Mercedes-Benz, Opel, and Volkswagen. Tech institutions and government agencies are also participating. Tests will be conducted on a fleet of 120 vehicles, which will be used to gather data about the effectiveness of a number of “Car-to-X” technologies, such as obstacle warning and electronic brake light.

Article #4

Title: Feds Launch Largest-Ever Road Test of Connected Vehicles


Date: August 22, 2012

The U.S. DOT announced plans for its large-scale “real-world” test of V2I and V2V technologies to take place in Ann Arbor, Michigan. The testing fleet includes approximately 3,000 cars, trucks, and buses. This test is part of the U.S. DOT’s Safety Pilot program. The pilot will be conducted for one year and the data from the study will be used to help the NHTSA determine the technology’s future use and address any legal topics.
Article #5

Title: Trucks Will Roll Down an E-Highway in California Test


Date: September 24, 2012

The Wall Street Journal provides a brief summary of the Siemens catenary system for commercial trucks and the planned commercial vehicle “e-highway” tests scheduled to begin in the Los Angeles area within a period of 18 months to 2 years.

Article #6

Title: Volvo Finishes SARTRE Project, Says ‘Road Train’ Works


Date: September 18, 2012

The SARTRE project, which involved vehicle platooning with both trucks and passenger vehicles, ended in September. Volvo, the only vehicle manufacturer involved in this multi-year project considers the project and vehicle testing a success. A short project summary and a press release by Volvo are included in the appendix.

6.2 NEWS ARTICLES: LEGAL

Article #1

Title: Plan for Self-Driving Cars Passes California Senate Hurdle


Date: May 21, 2012

The California State Senate passed a bill that made it legal for autonomous vehicles to drive on the State’s roads. The bill accomplishes the following actions: establishes safety and performance standards for autonomous vehicles; allows licensed drivers to operate autonomous vehicles on the State’s public roads; requires that these vehicles meet all state and Federal safety and performance standards; and provides an opportunity for the CHP, in cooperation with the DMV, to recommend additional requirements that foster safe vehicle operation on state roads. Additionally, a person is required to be in the driver’s seat, available to take over in case problems arise.
This bill, brought forward by State Senator Alex Padilla, was unopposed and will go to the Assembly in June. Senator Padilla cited safety, improved vehicle fuel efficiency, reduced emissions, and increased traffic flow as the benefits of this technology. Supporters include Automobile Club of Southern California, the California Foundation for Independent Living Centers, TechNet, Google Inc., and TechAmerica.

This bill addresses the emerging automated vehicle technologies coming out of companies such as Google. The company believes that driverless vehicles enhance roadway safety, preventing incidents caused by driver distraction and fatigue among other risks. Many legislators were given the opportunity to test drive Google’s prototype autonomous Prius. A similar law was recently passed by Nevada and the following other states are considering similar laws: Arizona, Hawaii, Florida, and Oklahoma.

**Article #2**

**Title:** Google Receives License from Nevada for Its Autonomous Car

**Source:** Urban Transportation Monitor (available in the appendix)

**Date:** May 25, 2012, Volume 26, Number 4

In February 2012, Nevada made it legal to operate autonomous vehicles on state roads, and Google recently received the first testing license in the State. Autonomous vehicles are identified by red license plates with an infinity symbol. Google’s test vehicles are modified Toyota Prius cars that have undergone rigorous testing and have logged more than 200,000 miles. Their features include many components that allow them to “see” through the use of video cameras, laser range finders, and radar sensors. Google’s overall goal is to reduce roadway fatalities and improve the quality of one’s driving experience.

In order to receive the license, Google was required to conduct driving demonstrations on freeways, state highways, neighborhoods, and along areas such as the Las Vegas strip. Additionally, the Nevada DMV reviewed Google’s documentation of the vehicle’s functions, safety plans, employee training information, and accident reporting mechanisms. The vehicles also must always have two people present – one person to take over the wheel, if necessary; and one to monitor the onboard computer. Currently, Google is the only company to hold this type of license, but a number of car manufacturers are interested in testing their own autonomous vehicles on state roads.

**Article #3**

**Title:** Google Receives License from Nevada for Its Autonomous Car

**Source:** MSNBC, http://www.msnbc.msn.com/id/47784572/ns/technology_and_science-innovation/#.T-SGiRduabs

**Date:** June 12, 2012
One of the objectives of bringing autonomous vehicles to roadways is to decrease fatalities, but this topic also raises numerous legal questions. For example, in an accident involving an autonomous vehicle, who would pay? Would the liability shift to the manufacturer? Also, how will driverless vehicles operate with “drivered” vehicles? The article cites the Google car and looks at the various autonomous features being phased in by other manufacturers, such as adaptive cruise control that is offered in some high-end vehicles.

The story also highlights upcoming events that are part of the FHWA’s Connected Vehicle Program. This summer, approximately 3,000 Michigan residents will have the opportunity to test the program’s V2V system, which allows autos to communicate with one another. Through this system, vehicles within 1,000 feet of one another will share data about their speed, direction, and location. The information is then analyzed by the system’s computers and appropriate warnings are sent. The V2I system also will be tested, allowing cars to receive messages about traffic congestion on the roadway network or parking-related information. The Connected Vehicle system uses short-range wireless technology to communicate.

**Article #4**

**Title:** Will Robot Cars Kill Off Car Insurance?

**Source:** Fox Business, http://www.foxbusiness.com/personal-finance/2012/07/05/will-robot-cars-kill-off-car-insurance/

**Date:** July 6, 2012

A report completed for Celent, a consulting firm, discusses the possible consequences of the widespread use of autonomous vehicles with respect to car insurance. In particular, the report predicts that adoption of autonomous vehicles will lead to a significant decrease in auto accidents. This could result in a near-term increase in auto insurance premiums or the elimination of auto insurance in its current form. The article discusses how autonomous vehicles can help prevent accidents and provides perspectives from the auto insurance industry, as well as a discussion of lawsuits, which could still exist even if safety is greatly improved.

**Article #5**

**Title:** California’s Driverless Car Bill Passes Assembly Transportation Committee


**Date:** July 3, 2012

California SB 1298 was passed by the Assembly Transportation Committee on Monday, July 2nd after being passed by the State Senate in May. In August, the bill will be presented before the Assembly Appropriations Committee. This bill calls for the regulation of autonomous vehicles in California.
Article #6
Title: California Lawmakers Greenlight Autonomous Vehicle Bill
Source: PC Magazine, http://www.pcmag.com/article2/0,2817,2409211,00.asp
Date: August 31, 2012
The California State Assembly and the State Senate passed a bill related to autonomous vehicles. If it is signed into law by Governor Brown, California DMV will create standards that autonomous vehicles will be required to follow by 2015. The bill passed unanimously in the Senate and had only two opponents in the Assembly. The text of the bill is included in the appendix.

Article #7
Title: Nobody’s Driving: California Governor Signs Legislation Paving the Way for Driverless Cars
Date: September 25, 2012
On September 25, 2012, California Governor Brown signed into law the autonomous vehicle legislation passed by both the State Assembly and State Senate in August. The legislation requires that the California DMV creates regulations for autonomous vehicles. One provision is that while the cars may operate autonomously, a licensed driver is required to sit in the driver’s seat in case of emergency. The full text of the bill is included in the appendix as well.

Article #8
Title: Consumer Watchdog Chases Google’s Autonomous Car
Date: September 11, 2012
This opinion piece summarizes the advocacy group Consumer Watchdog’s effort to convince Governor Brown to veto the autonomous vehicle bill passed by the California State Assembly and State Senate. The reason for the group’s opposition to the bill relates to privacy. The group is concerned that Google will gather information from users of autonomous vehicles, such as trip information, and use that data for marketing.
Article #9
Title: California Greenlights Self-Driving Cars, But Legal Kinks Linger
Source: WBUR (NPR-Boston station),
http://www.npr.org/blogs/alltechconsidered/2012/10/03/162187419/calif-green-lights-self-driving-cars-but-legal-kinks-linger
Date: October 3, 2012
This article highlights possible legal questions that arise given the recent passage
of California’s autonomous vehicle law, allowing self-driving vehicles to operate
on the state’s roadways. Legal questions such as, “Who is at fault when an
autonomous vehicle runs a red light?” are raised. In light of developments in the
industry, Stanford Law School offers a class that focuses on legal topics related to
autonomous vehicles.

Article #10
Title: Council of District of Columbia
Source: Council of the District of Columbia,
http://www.dccouncil.us/files/user_uploads/related_materials/sept19_cheh_au
utonomousvehicle.pdf
Date: September 19, 2012
On September 19, 2012, Mary Cheh, a member of the Council of the District of
Columbia, introduced the Autonomous Vehicle Act of 2012, which allows auton-
omous vehicles to operate on the District’s roads, establishes a user tax based on
vehicle miles traveled, and requires the Department of Motor Vehicles designate
an “autonomous vehicle” class and establish safe protocols for this class. The bill
text is included in the appendix.

Article #11
Title: Driverless Cars – A New Insurance Dilemma
Source: Insurance Daily,
http://www.insurancedaily.co.uk/2012/10/14/driverless-cars-a-new-
insurance-dilemma/
Date: October 14, 2012
This brief article from the British publication Insurance Daily describes possible
effects of autonomous vehicles on auto insurance. One idea mentioned is the
possible need for manufacturers to have insurance rather than the current trend
of consumers carrying insurance. Additionally, Celent, a financial services
industry analyst, predicted that auto insurance premiums could be reduced by as
much as 80 percent within a period of 10 years.
Article #12

Title: Feds Try to Stay Ahead of the Rise of the Robo-Car

Source: Autopia (Wired blog),
http://www.wired.com/autopia/2012/10/nhtsa-autonomous-cars/

Date: October 24, 2012

At a recent forum in Washington, D.C., David Strickland, Administrator of the NHTSA, described NHTSA’s plans related to autonomous vehicles which include testing and rulemaking. In mid-October, NHTSA employee, Tim Johnson, director of crash avoidance and electronic controls research, announced the agency’s plans to conduct a $1.75 million research project with Virginia Tech over a two or three-year period focused on applications of driverless vehicle technology. This article describes the details of NHTSA’s plans, including the anticipated phases: monitored automation, conditional automation, and full automation.

Article #13

Title: Autonomous Vehicles: White Paper for Colorado General Assembly

Source: The Dynamo,

Date: November 4, 2012

This white paper provides the benefits and challenges of autonomous vehicles; and provides background about policy, technological, and market development with regard to autonomous vehicles. The paper also provides recommendations for the State of Colorado, along with a discussion of Nevada’s regulatory framework.

Article #14

Title: Bill to Legalize Self-Driving Cars under Scrutiny


Date: November 11, 2012

This article summarizes doubt over the ability of SB 1298 (California) to achieve what it set out to do: By 2015, establish safety standards and performance requirements for autonomous vehicle testing and operations on public roads in the State.
6.3 NEWS ARTICLES: OPINION

Article #1

Title: The Future of Car Commuting


Date: June 1, 2012

This article summarizes SARTRE’s vehicle platooning concept and the project’s recent Barcelona demonstration. One advantage of the vehicle platoon or road train, highlighted by SARTRE team members, is the improved commuting experience, which would remove stress from what is generally the most stressful part of one’s day. However, this article points out that, while this may improve the quality of life for system users, what about the quality of urban mobility? SARTRE’s literature does not address the question of auto-dependency and the challenges that cities face with regard to single-occupant vehicles. Another issue is the lead vehicle and the “conductor” who drives it. Lead vehicles are introduced as part of this system and wouldn’t be on the road otherwise. Will these extra vehicles contribute to congestion and vehicle emissions which the platoons are trying to alleviate? Additionally, who will provide the lead vehicles?

Article #2

Title: Drive toward Autonomous Cars Shouldn’t Be So Automatic, Critics Warn


Date: October 8, 2012

This article is in response to the recent autonomous vehicle legislation passed in California. Groups such as the Alliance of Automobile Manufacturers want to make sure that concerns such as liability are addressed early in the process of putting autonomous vehicles on the road. Other stakeholders in the automotive and technology fields have voiced concerns as well, including McAfee, which mentioned data security risks in autonomous vehicles. Other technology-related concerns are described as well.
Article #3

Title: The Driverless Road Ahead

Source: The Economist

Date: October 20, 2012

This article focuses on the fact that autonomous vehicles have emerged and may be widely used in the near future. Automakers are already devoting much time and energy to autonomous vehicle technology. The author encourages other industries to consider the benefits they might gain from this emerging technology.

6.4 NEWS ARTICLES: TECHNOLOGY/DESIGN

Article #1

Title: Self-Driving Feature Interests 1 in 5 Drivers, Survey Finds


Date: April 27, 2012

A survey by J. D. Power and Associates published in the spring of 2012 reported that one in five drivers has an interest in autonomous vehicles. Some people support this technology because of the safety benefits that could result from removing the potential harm caused by distracted drivers. According to the survey, the groups most interested in autonomous vehicles are men, drivers between ages 18 and 37, and urban residents. After learning that the cost to purchase autonomous features in a vehicle would be approximately $3,000, 20 percent of vehicle owners “definitely would” or “probably would” purchase this technology package. The survey also describes autonomous driving functions that are currently available in vehicles such as parking assistance, “active” cruise control, and low-speed collision avoidance.

27A press release from J. D. Power & Associates that describes additional findings from the survey also is included in the appendix, immediately following Article #8.
Article #2

Title: Autonomous Braking Systems to be Assessed by Euro NCAP

Source: The Engineer (UK), http://www.theengineer.co.uk/sectors/automotive/news/autonomous-braking-systems-to-be-assessed-by-euro-ncap/1012886.article#ixzz1yXACzNg9

Date: June 13, 2012

Research has been published that suggests the autonomous emergency braking system (AEB), available in Europe, can be very helpful in preventing crashes and injuries. However, this system is not yet widely available. NCAP, a European safety organization, has decided to include AEB assessments as part of its star rating in 2014. The organization hopes that AEB will be included on some or all new vehicles.

Article #3

Title: Breaker 1-9, We Got Ourselves a Road Train


Date: June 20, 2012

This article cites the recent vehicle platooning demonstration in Barcelona conducted by Volvo as part of the SARTRE project and highlights the implications for the trucking industry. The idea that drivers of the vehicles joining the platoon will have the opportunity to rest since the lead vehicle has a driver ensuring the safety of the platoon is an important one. Besides making the drivers more comfortable, it has implications for employment regulations. For example, in the United States, regulations state that commercial truckers must stop driving no longer than 14 hours after they began driving. The article also highlights Volvo’s focus on the “driver environment” in its R&D work, which is connected to Volvo’s ultimate goal of roadway safety and reducing the number of accidents involving its vehicles to zero.

Article #4

Title: Ford Debuts Autonomous Driving Technology: Video


Date: June 28, 2012

This article describes some of Ford’s new autonomous features including assistance in traffic jams and parking assistance. Both of these features are part of Ford’s objective to reduce driver stress through technology. The first feature, called Traffic Jam Assist, helps drivers keep the same pace as surrounding cars.
This technology combines two existing technologies – adaptive cruise control and lane assist. The second feature is an add-on to Ford’s “active park assist” feature, which helps cars with parallel parking. This additional technology helps drivers determine whether or not the car can fit into a perpendicular space. A video demonstration is provided as well as the author’s opinion on these features as well.

Article #5

Title: Volvo Testing New Safety Features

Source: MSN,

Date: July 14, 2012

This article briefly describes three new safety features developed by Volvo: autonomous driving, “Intersection Support”, and animal detection. Volvo has used research on driver behavior to try to create these systems. Testing is currently being conducted in a variety of environments. A demonstration video is included along with the article.

Article #6

Title: MIT’s Semi-Autonomous Car Balances Human, Computer Control

Source: Wired – Autopia (blog),
http://www.wired.com/autopia/2012/07/mits-semi-autonomous-car/

Date: July 18, 2012

This article describes the semi-autonomous vehicle system designed by two researches from the Massachusetts Institute of Technology (MIT): Sterling Anderson and Karl Iagnemma. These two researchers designed this system along with Quantum Signal LLC in Michigan and have conducted more than 1,200 trials using a Kawasaki Mule vehicle. This is different from fully autonomous systems because the sensors and software are able to evaluate the environment surrounding the vehicle and the system is able to make adjustments to boundaries. The system’s adaptability is its major benefit.
Article #7

Title: Ray Autonomous Vehicle Rotates Its Cockpit to Meet Your Needs


Date: July 2012

This article describes the “RAY”, an autonomous concept vehicle designed by Gary Gu of Hong Kong, which focuses on enhancing the passenger experience within an autonomous vehicle.

Article #8

Title: Research on Race-Car Drivers Fuels Development of Robotic Cars

Source: MSN, http://editorial.autos.msn.com/blogs/autosblogpost.aspx?post=5f17f2f7-84a0-41a2-b8f4-3f6f6fc70186

Date: July 18, 2012

Dr. Chris Gerdes, the head of Stanford University’s Center for Automotive Research, recently gave a talk at the Technology, Entertainment and Design (TED) conference. The lecture described the research that Dr. Gerdes and his team are conducting, including details about the Audi TT autonomous test vehicle and research on race-car drivers. One objective of this research is to apply knowledge about how the brains of human race car drivers operate to autonomous vehicles. An important lesson learned so far is that human qualities allow for safer driving at high speeds. The video of the TED lecture is included along with this article.

Article #9

Title: Autonomous Vehicles for Japan by 2020s?


Date: July 2, 2012

Japan is considering the possibility of building special lanes for autonomous vehicles in the early 2020s. This system will be discussed by a study panel, to be introduced soon by the Ministry of Land, Infrastructure, Transport, and Tourism. The panel will focus on an autonomous vehicle system in the country.
**Article #10**

**Title:** GM Wireless Pedestrian Detection Technology Is Another Step toward Autonomy


**Date:** July 26, 2012

General Motors announced its research and development efforts on a feature that detects pedestrians and bicyclists in situations of poor visibility before the driver can detect them. This driver assistance feature is based on wireless technology called “Wi-Fi Direct,” which is the same type of peer-to-peer technology that allows smartphones to communicate with one another.

**Article #11**

**Title:** All Cars to be Fitted with Autonomous Emergency Braking

**Source:** Transport Research Laboratory (UK), http://www.trl.co.uk/trl-news-hub/transport-news/latest-transport-news/all-cars-to-be-fitted-with-autonomous-emergency-braking_801418076.htm

**Date:** July 30, 2012

The European Commission has decided to adopt regulations requiring that all new cars include AEB technology. This decision follows a study completed by the Commission that illustrated the value of AEB in reducing roadway accidents, which should result in saved lives, as well as financial savings from avoided collisions. Currently, 79 percent of cars currently on the market in Europe do not include AEB.

**Article #12**

**Title:** Michigan DOT to Survey Private Sector on Autonomous Vehicle Testing Requirements

**Source:** Michigan Department of Transportation, http://www.michigan.gov/mdot/0,4616,7-151-9620-283451-,00.html

**Date:** July 31, 2012

The Michigan DOT and the Center for Automotive Research (CAR) are conducting an online survey aimed at members of the autonomous vehicle industry. The survey’s objective is to identify what the industry needs in order to make southeast Michigan a successful testing environment. This news brief and the full-text survey are included in the Appendix.
Article #13
Title: Valeo Works toward Autonomous Vehicles in Troy
Date: August 15, 2012
Valeo, a French auto supplier, also develops key components of autonomous vehicles including ultrasonic, infrared, radar and laser sensors. The company’s American headquarters is located in Troy, Michigan. This article describes some of Valeo’s work and technology demonstrations.

Article #14
Title: Ford GT40 Racing Drivers Give Autonomous Cars Driving Lessons
Date: August 22, 2012
Through its Revs Program, Stanford University is incorporating biological human data into their autonomous vehicle research. Scientists are studying the brain activity of race car drivers to determine what goes on when drivers are doing certain behaviors such as steering, accelerating, and others in an effort to learn about and incorporate these dynamics into the autonomous vehicle Stanford is creating.

Article #15
Title: Google Adds Lexus RX 450h to Self-Driving Fleet
Date: August 31, 2012
Google added a Lexus RX 450h to its autonomous test vehicle fleet, with a purpose of allowing Google to test and improve its technology in a variety of environments and terrain types. The vehicle testing program has covered 300,000 miles.

Article #16
Title: Look, No hands. Automotive Technology: Driverless Cars Promise to Reduce Road Accidents, Ease Congestion and Revolutionise Transport
Date: September 1, 2012
This article provides a comprehensive summary of recent autonomous vehicle research and touts the safety and other benefits of these emerging technologies. Highlights include a detailed diagram of the various components of autonomous vehicles including GPS units and various types of sensors. The article concludes with a look to the future and mentions current non-road applications of autonomous vehicles such as the use of self-driving trucks in iron ore mines in Australia. Legal and other challenges are also mentioned.

**Article #17**

**Title:** Volkswagen Trimaran Concept Previews 2025 Autonomous Vehicle  
**Date:** September 4, 2012

Volkswagen has released some information about a new design concept for an autonomous vehicle that could be released around 2025.

**Article #18**

**Title:** Autonomous Cars Will Arrive Within 10 years, Intel CTO Says  
**Source:** Computerworld,  
http://www.computerworld.com/s/article/9232722/Autonomous_cars_will_arrive_within_10_years_Intel_CTO_says  
**Date:** October 22, 2012

In late October, Intel held its European Research and Innovation Conference in Barcelona, Spain. Before that conference, Intel’s CTO, Justin Rattner, was interviewed by Computerworld and spoke about autonomous vehicles. Intel would like to provide low-wattage Intel Atom chips and Core processors in autonomous vehicles. Additionally, Rattner predicted that within 10 years, autonomous vehicles will be available.

**Article #19**

**Title:** GM to Launch a ‘Supercruise’ Driverless Car  
**Date:** September 27, 2012

General Motors (GM) is developing a semi-autonomous vehicle equipped with a “Supercruise” feature that allows it to remain in its lane, deploy brakes when needed and steer away from hazardous situations. Technology used includes radar, GPS, and cameras. The prototype is in the final stages of development and GM hopes to include this feature beginning with the 2015 model year.
Article #20
Title: Driverless Car is Wireless Star at MIT
Date: October 12, 2012
A Ph.D. student at MIT recently presented an autonomous vehicle technology project that addresses the problem of a vehicle sensing when there is a threat of colliding with a pedestrian or another vehicle. The research and technology, known as CarSpeak, is discussed in detail.

Article #21
Title: New Volvo Road Train Video Arrives
Date: September 28, 2012
Volvo recently added a new video describing the road train technology developed during the recently completed SARTRE project. The video may be accessed via the link above.

Article #22
Title: Volvo Outlines Benefits of Car 2 Car Communication
Date: October 22, 2012
Volvo recently signed a Memorandum of Understanding with other members of Europe’s CAR 2 CAR Consortium, which is helping to prepare for the implementation of “Car-2-Car” and “Car-2-Object” technology. The ultimate goal of this effort is to decide upon communication standards and technology. The article describes Volvo’s autonomous vehicle technology in greater detail.

Article #23
Title: Watch Nissan’s New Autonomous Safety System in Action: Video
Date: October 17, 2012
Nissan recently announced a prototype of its Leaf model that has a self-parking feature, which is one part of Nissan’s autonomous system, described in this article.

**Article #24**

**Title:** Kiss Your Bus Goodbye!

**Source:** Traffic Technology International

**Date:** August/September 2012

This article discusses the idea of autonomous transit and its role in cities, particularly with regard to promoting densification, reducing travel by personal vehicles and other lifestyle-related topics. An analysis of historical transit usage information, transit challenges, and other factors is included. The article concludes with a possible vision for the future in the years 2020 to 2030.

**Article #25**

**Title:** Pull Out the Stops

**Source:** Traffic Technology International

**Date:** October/November 2012

This article focuses on the idea that people around the world value “automobility,” which includes freedom, convenience, and access to things and places they desire. Given this inclination, many researchers are working to develop autonomous vehicle infrastructure that is clean, safe, and efficient. Some researchers look to nature for inspiration to help create innovative systems. This article focuses on the concept of biomimicry and how processes used in nature might be applied to solve transportation challenges such as congestion and other problems.

**Article #26**

**Title:** Autonomous Tech Coming to Volvo Cars in 2014


**Date:** October 23, 2012

This article describes Volvo’s involvement with Europe’s Car-2-Car Communication Consortium and the automaker’s eventual traffic jam assistance system. This system will include an autonomous feature in which Volvo vehicles will be able to automatically follow preceding vehicles at speeds of up to 31 mph. This system is scheduled to be ready in 2014. Given this near-term implementation timeline, legal issues are raised. Because the U.S. is in the process of working out laws related to autonomous vehicles, there is a concern that laws governing the use of Volvo’s system might not be ready by the time Volvo’s
system is ready. Volvo would like the U.S. to create Federal policy around autonomous vehicles; currently, there are only state laws (in a few states) related to autonomous vehicles.

**Article #27**

**Title:** How an Autonomous Car Gets Around


**Date:** October 26, 2012

This colorful graphic provides a detailed description of an autonomous vehicle’s components and their purpose. Also provided is a link to a comprehensive article about how autonomous vehicles work.

**Article #28**

**Title:** Google Poaches Executive Director of National Highway Traffic Safety Administration

**Source:** Wired, http://www.wired.com/autopia/2012/11/ron-medford-google-nhtsa/

**Date:** November 19, 2012

Ron Medford, Deputy Director of the National Highway Traffic Safety Administration (NHTSA) accepted a position as Google’s Director of Safety for Self-Driving Cars, beginning in January 2013.

### 6.5 NEWS ARTICLES: SAFETY

**Article #1**

**Title:** Australian Agency Urges Use of Autonomous Emergency Braking Systems


**Date (article):** July 25, 2012

The Department of Transport and Main Roads in Queensland, Australia, recently issued a report that analyzes the benefits of autonomous emergency braking technology (AEB), also known as forward collision avoidance technology to prevent head-on collisions. The system helps reduce crashes by sensing other
vehicles or objects in front of a vehicle and warning the driver and hitting the brakes. A link to the report is included at the end of the article as well as above. Due to the report’s size, it is not included in the Appendix.

Article #2
Title: Self-Driving Cars: Coming Soon to a Highway near You
Source: Environment 360 (Yale), http://e360.yale.edu/feature/self-driving_cars_coming_soon_to_a_highway_near_you/2554/
Date: July 23, 2012
This article discusses many sub-topics within the overall topic of autonomous vehicles ranging from safety benefits and environmental benefits to financial benefits as well as barriers and complications in this area. One underlying theme is that autonomous or semi-autonomous vehicles could be a reality within a decade. The article references numerous studies including a cost-related study done by the American Automobile Association (AAA) and a study by the National Highway Traffic Safety Administration (NHTSA) related to vehicle-to-vehicle communication systems and crash reduction.

6.6 NEWS ARTICLES: SOCIAL/USER ACCEPTANCE

Article #1
Title: Learning to Let the Car Drive
Date: June 25, 2012
This article discusses how people will likely transition to being a “driver” in an autonomous vehicle and provides a summary of findings from a driver behavior study conducted by the Federal government in conjunction with General Motors (GM) and the Virginia Tech Transportation Institute (VTTI). The general conclusion is that the transition from humans driving cars to humans sitting behind the wheel while the car is driven autonomously will most likely occur gradually.

Article #2
Title: The Autonomous Evolution
Date: August 2012
This article provides a brief history of the automated features added to vehicles beginning with ABS and continuing with more recent features such as Adaptive Cruise Control (ACC). Following the introduction are a number of questions and sub-topics such as freedom versus surveillance, the benefits of autonomous vehicles in terms of allowing people who cannot drive for various reasons to be more mobile, and many other considerations.

Article #3
Title: Morals and the Machine
Date: June 2, 2012
This article brings up the topic of the ever-increasing use of robots in society and how to address moral and ethical questions with regard to this technology. While this is not specific to autonomous vehicles, the questions raised are relevant to the discussion of legal and ethical issues as well as user acceptance of autonomous vehicles.

Article #4
Title: Wacky Florida Political Ad Warns of Robot-Car Menace
Date: August 14, 2012
Jeff Brandes, a Florida state representative running for a state senate seat, was recently the target of a television attack ad that spoke negatively about his support of Florida’s autonomous vehicle legislation. The ad referred to the vehicles as “remote-controlled” cars and painted a picture of the danger these vehicles pose to citizens and in particular, senior citizens. Florida is the second state in the nation to allow driverless cars.

Article #5
Title: Noise Pollution and Driverless Cars
Date: October 3, 2012

28This article is not included in the appendix, but may be accessed via the web address listed above.
With the increase of driverless vehicles on the transportation system, many changes are expected. One possible change is quieter vehicles. While this could be beneficial from a noise pollution standpoint, it could also have negative safety implications, particularly for people who are visually impaired and need audible cues to warn them about oncoming vehicles and other hazards. This article briefly describes the vehicle noise issue and offers possible solutions.

**Article #6**

**Title:** Google’s Driverless Car Draws Political Power

**Source:** Wall Street Journal, http://online.wsj.com/article/SB10000872396390443493304578034822744854696.html?project=GOOGCAR_pg%26articleTabs=article

**Date:** October 12, 2012

Three states – Nevada, Florida, and California – have recently passed laws about autonomous vehicles and other states including Hawaii, New Jersey, Oklahoma and the District of Columbia are considering similar legislation. This article describes the lobbying work Google has done in various states to help promote this cause. In addition to the article text, the Appendix includes a graphic illustrating Google’s technology.

**Article #7**

**Title:** Self-Driving Cars Are Approaching Fast – and Safely


**Date:** September 29, 2012

This article summarizes a number of autonomous features currently available in cars that have helped increase roadway safety. For example, the article cites insurance claim data from the Highway Loss Data Institute. That data include claims for the 2010 Volvo XC60 SUVs, which include a forward collision avoidance system, and claims for other 2009-10 mid-size luxury SUVs not equipped with the technology. The Volvo model experienced 27 percent fewer property damage liability claims and fewer bodily injury claims than the other models. Other vehicle manufacturers as well as the U.S. DOT’s work with the University of Michigan Transportation Research Institute are also mentioned.
6.7 **NEWS ARTICLES: CONFERENCES, RESEARCH AND INDUSTRY REPORTS**

Conference #1

**Title:** 2012 IEEE Intelligent Vehicles Symposium

**Date:** June 3 to 7, 2012

This weblink includes information about the keynote speakers at the June 2012 IEEE Intelligent Vehicles Symposium in Spain. The first keynote speaker was Chris Urmson, the Head of Engineering in the Self-Driving Car division at Google, Inc. His abstract focuses on how the car operates and his talk focused on the capabilities and limitations of Google’s vehicle. The second keynote speaker was Dariu M. Gavrila, a Senior Research Scientist at Daimler R&D, whose talk focused on the topic of devising an effective driver assistance program for vulnerable road users such as pedestrians and bicyclists. The third keynote speaker was Robert Bertini, Professor of Civil and Environmental Engineering at Portland State University. His talk focused on environmental sustainability as an important component of intelligent vehicle and other transportation-related research and development.

Conference #2

**Title:** Autonomous Vehicles, Wireless Communications and Software Security: the Topics of Three SAE International Courses at Convergence 2012


**Date:** August 21, 2012

Convergence 2012, an SAE International (Society of Automotive Engineers) conference to be held in mid-October, will feature three professional development courses focusing on autonomous and connected vehicle systems.

Conference #3

**Title:** carIT Congress: Autonomous Driving to Start with Commercial Vehicles – Continental Exec


**Date:** September 25, 2012

Michael Ruf, the head of Continental’s commercial vehicle and aftermarket operations, spoke about autonomous vehicles at the carIT-Mobility 3.0 Congress. He
believes that commercial vehicles will engage in autonomous driving before passenger cars and mentioned that legal issues provide more of a barrier than technical issues.

Research #1

Title: The Case for Driverless Cars (White Paper)

Source: Association for Unmanned Vehicle Systems International

Date: May 1, 2012

This white paper discusses the unrealized potential of driverless cars, with supporting U.S. consumer car market data, and discusses emerging issues such as legal implications. The consumer data include average annual vehicles miles, annual costs, trip length, and vehicle sales. At times, the author presents a vision of a world in which driverless cars have a significant presence. Highlights include a table of needs and how autonomous vehicles can address them. Conclusions include the fact that technological advances and demand from the U.S. consumer car market have created a climate that is ripe for driverless vehicles.

Research #2

Title: Reality Check: The Self-Driving Car


Date: June 12, 2012

In addition to summarizing information about the work of Google and SARTRE with regard to autonomous vehicles, it describes Oxford University’s work in this area, which focuses on creating an autonomous vehicle to be used within city limits. The project funding sources are the UK’s Engineering and Physical Sciences Research Council, Nissan, and the British aerospace firm BAE. In this system, a 3D map is created and it continually updates itself using sensors. Its wireless communications component allows it to connect with other cars and traffic information. In summary, the system operates in “real time”, which allows vehicles to avoid congestion and take the most efficient routes. In April, Oxford University requested to test its vehicle (the BAE Wildcat) on public roads, but the decision from the government is pending. The article concludes with legal questions related to autonomous vehicles as well as the general public’s comfort level with this concept.

Research #3

Author(s):
Anderson, Sterling J, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA
Karumanchi, Sisir B.; Iagnemma, Karl
**Title:** Constraint-Based Planning and Control for Safe, Semi-autonomous Operation of Vehicles

**Page(s):** 383-388

**This paper appears in:** Intelligent Vehicles Symposium (IV), 2012 IEEE

**Date of Conference:** 3-7 June 2012

**Link (to abstract):**
http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&arnumber=6232153&contentType=Conference+Publications

This paper addresses a new approach to avoiding hazards in a semi-autonomous vehicle that uses constraints and the selective enforcement of these constraints rather than the approach used by other autonomous vehicle systems that involves planning and tracking paths. This is the approach referenced in Article #6. Iagnemma, who was referenced in Article #6, contributed to this paper. Only the abstract is available free of charge online.

**Research #4**

**Title:** IEEE Says that 75 percent of Vehicles Will Be Autonomous by 2040

**Source:** The Car Connection,

**Date:** September 19, 2012

In September, the Institute of Electrical and Electronics Engineers (IEEE) made an announcement stating that autonomous vehicles are “the most promising form of intelligent transportation.” They also predicted that by 2040, up to 75 percent of cars on the road will be autonomous vehicles. Some highlights of IEEE’s related predictions include:

- By 2040, traffic lights will be eliminated;
- By 2040, highways will have designated lanes for autonomous vehicles;
- Car ownership will decline and car-sharing will become common; and
- By 2040, attitudes toward autonomous vehicles will have changed dramatically.

This article looks closely and provides an opinion on the likeliness that these predictions will come true.
Research Paper #5

Title: Robot Cars Could Increase Highway Efficiency 273 Percent: Study


Date: September 4, 2012

This article describes highlights from an autonomous vehicle paper presented at the IEEE conference on vehicular technology in early September authored by Patcharinee Tientrakool from Columbia University. This paper provides a comparison in vehicle efficiency between autonomous vehicles that do not communicate with one another and autonomous vehicles that act cooperatively. The research shows that vehicles that act cooperatively show a 273 percent increase in efficiency, while cars that don’t act together show a 43 percent increase in efficiency.

An additional study by Steven Shladover at the University of California at Berkeley is also mentioned because its efficiency predictions for vehicles that are part of a platoon are similar to those of Tientrakool.

Research Paper #6

Title: Advanced Driver Assistance and Autonomous Vehicles - Challenges and Opportunities to Improve Mobility and Safety


Date: September 28, 2012

This brief summary, featured on the Knowledge Center of the ITS America website describes a Technology Assessment report to be completed in 2013 that addresses the area of Advanced Driver Assistance Systems (ADAS) and the acceptance of driver assistance and automation by the public.

Industry Report #1

Title: SAE Standards for Works in Progress


Date: July 2012

The link above references the SAE Standards Works in Progress document that was published in July 2012 along with a brief description. The actual document contains definitions related to autonomous vehicles that are to be driven on public roadways.
Industry Report #2

Title: Self-Driving Cars Put Auto Industry on Cusp of Automotive Research Report Shows


Date: August 6, 2012


KPMG, LLP, and the Center for Automotive Research (CAR) recently released a report entitled Self driving cars: The next revolution. The report reviews what causes change, current and emerging technologies and how to bring these ideas to the market, as well as their likelihood of adoption and impact on the automotive industry. These findings are based on interviews with leaders in the automotive industry, technology leaders, academics, and regulators. The findings are separated into four categories: market dynamics, convergence, adoption, and implications for investment. The link above references the report released by KPMG and CAR, entitled Self-Driving Cars: The Next Revolution. Additionally, the full text version of the report is included in the appendix.
7.0 Report Summary

The Gateway Cities Technology Plan for Goods Movement study included two related elements; the Automated Truck Research Project and the incorporation of ITS infrastructure and automated system concepts into the proposed I-710 Freight Corridor. The original focus of the Automated Truck research was to assess technologies that could be used to increase capacity on the I-710 freight corridor through automation. Automated systems will allow closer headways between vehicles; thus increasing throughput. Combined with the requirement for zero emission vehicles, the technology will improve the quality of life in the Gateway Cities area by reducing commercial vehicle traffic on arterial streets and improving air quality. This and other advances in ITS technology will improve safety and provide economic benefits to the freight industry. The opportunity to become a testbed for automated truck research could be of great economic benefit for the Gateway Cities area and southern California in general. Taking advantage of this opportunity will require a commitment on the part of Gateway Cities area stakeholders to track national and international research in this area, obtain resources for testing and deployment and maintain close coordination between those doing automated Truck research and those designing the I-710 freight corridor.

This report has summarized research to date in the automated vehicle field, identified ongoing research of interest to the region and documented current efforts to make sure that up-to-date and cost-effective technology is incorporated into the I-710 Freight Corridor design. Initial steps required to implement the Automated Truck Research project are documented, including a Concept of Operations and a change management strategy for the I-710 design effort. It is inevitable that the infrastructure requirements for the I-710 project will change over time as technology advances and more information becomes available on the feasibility of various options. The major challenge is to accommodate these changes while maintaining progress and meeting the overall goals and objectives of this innovative and unique highway project.
A. Full Text Articles

This appendix includes the full text of all articles. They are in chronological order. Within each month, the articles are subdivided according to their categories.
B. Section 7 (Automated Truck Research Project) from the Gateway Cities Conceptual Projects Description Report
7.0 Automated Truck Research Project

7.1 PROJECT OVERVIEW

This project will implement a staged progression of commercial vehicle technologies in order to transition from current research-based automated commercial vehicle demonstration efforts to staged operational testing of a flow efficiency system of trucks along the planned I-710 truck lanes. This project will build upon the unique operational environment and potential partnerships of the Gateway Cities subregion to promote and enhance truck automated commercial vehicle research by bringing together the applications of automated commercial vehicle and automation technologies with the real-world operational realities of a heavily congested truck corridor. Finally, the project will provide for staged operational testing over time with an eye towards understanding the specific design and operational concerns that impact the future development of the I-710 and its approaches.

7.2 OBJECTIVES

- Help ensure the future viability of the Ports and Gateway Cities subregion, as well as the I-710 corridor, by realizing the vision for achieving maximum effective capacity within the substantial physical constraints of the region’s key truck corridors;

- Build upon ongoing and rapidly advancing intelligent vehicle technologies for trucks to define a detailed and staged ConOps for an effective conveyor operation of trucks on the I-710;

- Develop and support a test site in the region where technologies and operational concepts can be tested in conjunction with public and private partners;

- Leverage emerging Original Equipment Manufacturer (OEM) and Tier 1 vehicle supplier technologies to provide a viable real-world operational model focused on the needs and characteristics of the region;

- Establish an ongoing partnership and environment that attract additional funding opportunities to bridge the gap between research efforts and effective real-world solutions in a real-world freight corridor; and

- Promote the state of the art in truck guidance and flow efficiency with an eye towards effective and widespread deployments using Original Equipment Manufacturer (OEM) available equipment.
7.3 DESCRIPTION

The project encompasses three major areas of effort:

1. **Institutional/Promotional.** In order to realize the long-term vision for a technology-based flow efficiency operation of trucks, it is necessary to establish institutional relationships and partnerships that will endure over the long term. These institutional relationships will need to bring together port stakeholders, regional agencies, Caltrans, Federal entities, research organizations, and most importantly, truck equipment manufacturers and private shipping interests, to promote a realistic operational vision. The partnership would be held together by centralized coordination and communications efforts with the common good between all interests defined as the long-term savings of time, money, and mobility. The partnership should also be visibly represented and marketed to Federal, state, and private funding opportunities through a cohesive and professional marketing and communications effort. Finally, this partnership will have to review and promote enabling legislation over time to support the longer-term corridor vision.

2. **Operational/Design Path Development.** The second major area of effort focuses on building on recent research efforts on truck guidance, intelligent vehicle systems, and automated commercial vehicle to define the details of what operations would look like in the I-710 corridor, given the future cross-section and design alternatives. In order to realize viable future growth and maintain reasonable levels of truck and passenger traffic operations, it is necessary to stretch the boundaries of traditional volume/capacity assumptions. The only means to realize this new vision for enhanced effective capacity is to apply intelligent vehicle technologies. Technical analyses efforts need to be conducted by an interdisciplinary team, including vehicle technology experts, truck operations experts, experience drivers, traffic engineers, and highway designers, to develop detailed operational concepts for the I-710 corridor, which can be tested as part of this project. In addition, this team must assess physical and system design impacts for the I-710 truck lanes corridor in light of the planned technologies and operational concepts. This assessment must take into account truck travel and logistics patterns as part of assessing the design and operation needs of the corridor. As part of this assessment, this effort will need to build a comprehensive simulation model of the considered concepts. The simulation model should cover both the typical traffic engineering perspective as well as the OEM’s models of the trucks. This would represent a unique opportunity to merge vehicle simulation models (often developed by OEMs) with roadway/highway simulation tools.

3. **Staged Testing Applying Available Technologies and Operational Concepts.** The third area of effort involves the actual testing and application of the proposed operational concepts. Testing will include establishment and the recurring use of approximately a 3.5-mile stretch of Route 103 in the Port
region (Figure 7.1), or another route. This corridor has many characteristics similar to other major facilities providing access to the Port region and will provide a comparable setting for testing the staged progression of technology and operational concepts. The facility ranges from a six-lane (two-direction) barrier divided highway to a four-lane wide buffer separated highway.

The goal is not simply to test the performance of the technologies themselves, but to introduce real operational challenges and concepts specific to the real-world I-710 corridor environment and test widely available technologies against those challenges. It is assumed other projects will continue to stretch the boundaries of intelligent vehicle technologies, while the goal of this truck technology flow efficiency project will be to test and realize staged benefits using OEM concepts, which can be widely adopted. The three stages of progressive testing currently envisioned include:

1. **Stage 1 - Simple Adaptive Cruise Control (ACC) and Defined Speed Limits.** Focused on the potential for the real-world application of a loosely defined conveyor of trucks using available ACC\(^{29}\), and possibly braking technology with prescribed operational speeds for a corridor. Previous testing is focused more on intraplatoon performance, but this effort would look at applying test results to overall potential corridor performance.

2. **Stage 2 - Cooperative ACC and Multitruck Communications.** Limitations exist with ACC that is designed mostly to maintain safe distances between vehicles. Tighter spacing may be achieved with Dedicated Short Range Communications (DSRC) and intertruck communications. This approach may allow for tighter spaces between trucks with forewarning of problems several trucks in advance. This also may include roadside DSRC communications stations to provide an overall corridor view of the operations of the conveyor of trucks.

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\(^{29}\)ACC is an existing technology available currently available on some automobiles. It allows the driver to set and retain a specific vehicle speed, but different from traditional cruise control systems, the system is able to decrease its speed automatically when the preceding vehicle decreases its speed. It also maintains a specific distance from the preceding vehicle that can be set by the driver (IVsource.net, 2011).
Figure 7.1  Potential Area for Truck Flow Efficiency Test Corridor
3. **Stage 3 – Truck Automation Suites with Corridor-wide Optimization.** At this point, it is assumed that truck research efforts have expanded the functionality of available OEM products, and the automated commercial vehicle options are more effectively understood. Lessons learned from Stages 1 and 2 would be applied to enhance vehicle automation, possibly including lateral guidance and control at a greater level with combined cooperative ACC, safety, braking, and vehicle-to-vehicle communications, to establish the most effective conveyor options possible. Again, the end goal may not be the tightest platoons possible for smaller subsets of vehicles, but the overall effectiveness and throughput of the overall corridor. This stage would combine corridor-wide simulation and management concepts, where speeds of vehicles may be managed given the levels of traffic and conditions in the corridor as communicated by vehicle-to-roadside DSRC methods. This stage should also consider the latest updates in DSRC research, application, and decisions on U.S. DOT standards. It is crucial that simulation efforts for the project take into account the varying and dynamic performance of heavy duty trucks as part of assessing methods of ensuring operational efficiency and designs that meet future needs.

7.4 **HYPOTHETICAL OPERATIONAL NARRATIVES/EXAMPLES**

**Developing and Using a Test Bed**

A little less than a year ago, the Truck Flow Efficiency Demonstration and Operations Research Group were formed. This group brought together state, regional, and Federal agencies, along with the trucking industry and manufacturers; all of which worked hard to gain the funding and permissions needed to move into operational testing. It is very early in the morning and the drivers are climbing into their trucks, which are being gone over by technicians to ensure all systems are operating. The operational test is simple enough; the three trucks will form a rough group and activate ACC systems with similar speed settings. Three additional trucks will merge into the group and create a tighter grouping. The trick will be testing the reactions of the trucks’ ACC systems under various scenarios of speeds and vehicles leaving the queues. The ACC systems were initially developed to enhance safety and ensure truckers did not follow too closely, but the truck systems experts have adjusted the systems to maintain safety and maximize efficiency. Tests a few days from now will determine the benefits of truck to truck communications, where the vehicle in the front of the group must slow down for whatever reason and the following trucks must adjust accordingly.
Modeling Corridor Efficiency with Operational Scenarios

Testing has been underway along portions of the test bed corridor for a little over six months with the overall project having started about a year and a half ago. Today, the next big step starts as actual fleet vehicles that have been provided from local freight fleet are going to be part of the testing. The individual systems and operational concepts have been tested, and the project is moving into an extended testing with real trucks carrying real goods and real drivers.

Joe Smith knows what to expect as he has been involved in testing over several months. As Mr. Smith enters the test corridor, everything seems similar to previous tests, but now they are doing their real job of getting goods from Point A to Point B. Somewhere behind the scenes his truck and those of his fellow drivers are sending continuous communications to each other and those strange boxes mounted on some poles alongside the test corridor. Further away, a computer is tracking what occurs and making determinations of what speeds would be most effective to maintaining the overall flow of trucks. Mr. Smith thinks about what Caltrans design engineer told him last month, about how it was good they had done these tests so they could start incorporating the findings into their designs for the new truck lanes. The design engineer told him that the test program results are going to save millions in potential risks and changes to the actual construction project. Mr. Smith cannot wait for those truck lanes to get finished, as the world economy has kicked into high gear and the whole region and Ports need to stay competitive.

7.5 Scope of the Project

1. **Detailed ConOps.** The Gateway Cities Technology Plan for Goods Movement will provide an operational framework for this project, but it will not be able to delve into many of the details that will be required to move into actual development and testing for the Truck Flow Efficiency effort. A detailed ConOps will bring together stakeholders to a common understanding of what will be accomplished on the vehicle test bed and corridor test bed. Summary components of the ConOps will help bring in funding and industry partners who want to participate. The ConOps should follow ANSI G-043 standards, and address operations, roles and responsibilities, envisioned technologies for:

   a. Initial Operational Tests Environment. Defining the details of what is needed in the test corridor and test bed vehicles; and

   b. I-710 Environment. Providing an enhanced framework and understanding of how the test results may fit into the I-710 truck lanes environment.

2. **Design Validation and Impact Assessment.** A specific team should review the ConOps and the latest truck technology developments to make an initial assessment of potential design impacts for I-710 truck lanes, as well as other potential Truck Flow Efficiency roadways and corridors. This assessment
should “ask” a series of questions about how the technologies may impact operations and physical design. Each of these questions should be answered as part of the project development, testing, and lessons learned. This task would initiate the simulation development effort to model both the test corridor and the I-710 corridor. This simulation effort can assist in validating design considerations and once testing begins, it can be used to calibrate actual test corridor results with the I-710 simulation model.

3. **Demonstration and Operations Research Group.** The core institutional effort will be to develop an ongoing demonstration and operations group. This group will coordinate and act as overall project supporters and sponsors. The group will represent the partnership between government and private industry.
   a. **Project Charter.** Defining the goals, objectives, and general scope and stakeholder involvement of the project;
   b. **Initiate Coordination Meetings.** Coordination meetings should support remote involvement of truck OEM suppliers and manufacturer;
   c. **Grant/Funding Pursuit.** The project should act as an ongoing concern that seeks not only initial funding, but funding that meets the overall Project Charter goals and continues until the project concepts are deployed in the real-world operational environment;
   d. **Contracting.** The group may serve to oversee project efforts, and some members may need to participate in contracting efforts; and
   e. **Promotional and Marketing.** The group should hire expertise to promote project efforts and objectives for funding, as well as regional acceptance.

4. **Vehicle Test Bed Development.** A set of at least three trucks to start with equipped with appropriate technologies by stage of project development. It may be necessary to make decisions regarding specific technologies or equipment to be installed and used for testing. The primary goal of the project is to test operational concepts with equipment that is anticipated to be widely available to the trucking industry within a five-year period.
   a. **Partnership Truck Availability.** Partners should be sought that would be willing to supply trucks for test participation under certain guidelines/restrictions; and
   b. **Leased Truck Availability.** Some equipment changes or operational test scenarios may require additional trucks that would represent a significant impact to potential partners, so some trucks may need to be leased.

Operational testing is anticipated to ultimately require at least six trucks. Once the initial demonstration segment is underway, the desire would be to equip a wider range of trucks with the desired equipment. These trucks would use the corridor as part of their regular operations.
5. **Establish Test Corridor.** Several steps will be required to ready the proposed test corridor (Figure 7.1). This corridor is viewed as having substantial excess capacity that could support testing activities, and the corridor also has many similarities to the I-710.

   a. Traffic and Safety Design and Permitting. The test corridor will be reviewed and designs developed for necessary signage, striping, and physical modifications. In addition, permitting processes will be undertaken.

   b. Physical Modifications. Physical, striping, and signage modifications will be contracted, made, inspected, and signed-off.

   c. Equipment Provision and Maintenance. Field equipment that will be part of the testing will need to be provided and secure space arranged. This may also require an on-site field test coordinator that can ensure equipment is maintained and activities properly scheduled. Also, some equipment will require ongoing communications within the test corridor, as well as outside the test corridor.

   d. Return to Original State. Plans should be made to return the test corridor to its original state, unless a determination is made that the changes are viable for the ultimate use of the corridor in regular operations.

6. **Truck/Corridor Integrated Testing and Proof of Concept.** The core of the entire project is the actual testing, which is envisioned to occur in the three stages previously discussed. For each stage, the following basic process would apply:

   a. Test Plan/Coordination. Overall test plans should identify the testing goals, timelines, resources, equipment used, and how the test fits into the overall project effort.

   b. Individual Test Procedures. Detailed procedures should be developed well in advance and applied during actual testing. Procedures or the concepts the procedures represent should be linked to the functions and operations defined in the ConOps and Design Validation and Impact Assessment.

   c. Field Testing/Scheduling. Actual testing should occur along the test corridor using the test bed vehicles. Testing should collect comprehensive data and be subject to independent evaluation and review.

   d. Reporting and Presentation. Lead parties for the testing efforts for each stage or each portion of a stage should provide written overview reports and presentations of findings to the Demonstrations and Operations Research Group.

7. **Initial Demonstration Segment.** Once the Proof of Concept is in place for the three stages, the project can move to actual operational testing using non-test bed trucks within proper guidelines and restrictions. This effort should
only test well proven and safe concepts, and focused on variations in driver use and interactions in a real-world environment. Details of this task would have to be worked out prior to implementation.

8. **Independent Evaluation of Results.** Prior to applying the lessons learned from the Truck Flow Efficiency project to design and operations, an independent review of the final operational concept should be made. This effort should define the ultimate cost-benefit tradeoffs from a corridor, as well as a private industry perspective.

### 7.6 CONCEPTUAL DIAGRAMS

Figure 7.2 demonstrate the basic premise of the truck flow efficiency testing project by the three stages discussed earlier in this project description.

**Figure 7.1 Three Project Stages**

- **Stage 1 Concept – Simple Adaptive Cruise Control and Defined Speed Limits**

- **Stage 2 Concept – Adaptive Cruise Control with Multi-Truck Communications**

- **Stage 3 Concept – Truck Automation Suite with Corridor-wide Optimization**
7.7 **SCHEDULES AND PHASING**

The following is a conceptual schedule for implementation of the truck flow efficiency project effort. It is anticipated this project would end once the evaluation effort is completed. Naturally, the schedule would be:

- Month 1 to 4  Detailed ConOps;
- Month 4 to 12  Design Validation and Impact Assessment;
- Month 1 to Project End  Demonstration and Operations Research Group;
- Month 6 to 12  Vehicle Test Bed Development;
- Month 6 to 12  Establish Test Corridor;
- Month 12 to 18  Truck/Corridor Integrated Testing and Proof of Concept;
- Month 18 to 24  Initial Demonstration Segment; and
- Month 16 to 24  Independent Evaluation of Results.

7.8 **PRELIMINARY COST ESTIMATES**

The following are preliminary planning and programming level cost estimates. The costs estimates assume that there is substantial leveraging of other automated truck technology research projects, as the goal is to use the lessons from these technology projects and drive a real-world operational model that takes into consideration the design impacts for truck corridors such as the I-710.

Cost estimates should be revised, detailed, and updated as the project proceeds.

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<th>Capital Costs</th>
<th>Range</th>
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<tr>
<td>Detailed ConOps</td>
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<tr>
<td>Design Validation and Impact Assessment</td>
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<tr>
<td>Demonstration and Operations Research Group</td>
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<td>Trucks Technology Modifications</td>
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<td>Independent Evaluation of Results</td>
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<tr>
<td><strong>Total</strong></td>
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7.9 **Users Involved**

- **Project Research Group.** Project Ownership and Coordination, including representatives from agencies, truck OEM, and research entities;
- **Caltrans.** Permitting and Design Input/Support;
- **Vehicle OEMs.** Equipment Provision and Testing Support;
- **Freight Fleet Operators.** Vehicle Provision, Operational Input, and Testing Support;
- **Independent Evaluator.** Testing and Evaluation Reporting; and
- **Ports.** Operational Concepts and Input.

7.10 **Roles and Responsibilities**

- Ports – Planning, Design Support, Coordination, and Operational Input;
- Caltrans – Participating in Group for Planning, Operations and Design Impacts and Permitting;
- Vehicle OEM – Direct Participation and Involvement in Project Development, Vehicle Test Beds, and Testing;
- Gateway Cities Council of Governments (GCCOG) and Other Regional Agencies – Contracting, Project Coordination and Hosting, and Grant Application Development;
- Local Jurisdictions – Planning and Permitting; and
- Freight Stakeholders – Operational Review, Testing Involvement, and Project Promotion.

7.11 **Prerequisites**

None.

7.12 **Systems Involved**

This project concept is centered on moving from pure research efforts to operational concepts development and testing in a realistic environment. Current systems are not expected to play any substantial role. The systems that would be involved include:
• Intelligent Vehicle (IV) truck systems. For purposes of guidance, headway maintenance, and platooning, including:
  – Internal on board systems (All Stages);
  – Vehicle to vehicle communications (Stages 2 and 3); and
  – Vehicle to roadside communications (Stage 3).
• Specialized roadside systems and software to be developed as part of this project using DSRC (Stage 3).
• Specialized software applications with logic developed to reflect proper truck platoon formation and/or throughput optimization.
• Wireless Test Equipment. On-board test trucks.
• Wireless-leased communications (All Stages).

7.13 POTENTIAL CHALLENGES AND OBSTACLES

Challenges for implementation include the following:

• **Institutional risk – Moderate.** Many stakeholders in the region and in the truck OEM industry will need to cooperate to make the project come to fruition. Allowing the test corridor to be implemented and maintained will take detailed and ongoing coordination and project promotion.

• **Technical risk – Moderate to High.** While many of the technologies have been individually proven, there is the potential that the technologies while combined with operational environment may not provide the benefits desired for ultimate implementation on the I-710 corridor. By the same token, the whole goal of the project is to determine whether or not the operational benefits of the technologies prove themselves and what design considerations should be made for the I-710 corridor to maximize its effectiveness. In many ways, this project would act as risk mitigation for the ultimate design and deployment of dedicated truck lanes on the I-710.

• **Design complexity – Moderate.** The project should moderate physical design considerations, and it should also provide input to mitigate future integrated corridor applications.

7.14 COORDINATION AND INTEGRATION WITH OTHER PROJECTS

The Truck Flow Efficiency project is not required to be coordinated with other systems deployment efforts as part of the Gateway Cities Technology Plan for Goods Movement; however, consideration should be given of the results of the project in terms of potential long-term operational impact to other systems.
7.15 **OTHER OPTIONS CONSIDERED**

Other automated truck technology options include the following:

- **Pure truck** automated commercial vehicle research effort. Several research efforts are underway around the world to research the advantages of truck guidance and automated commercial vehicle technologies. Many rely on operational concepts that would represent major changes from current driving environments for both passenger vehicles and trucks. As part of an initial effort for this project, extensive research on these other efforts should be done and reported to the working group, including lessons learned.

- **Development of a detailed operational concept only.** The deployment timeline for the I-710 truck lanes and many of the other efforts that are directly supported by this project are uncertain or set well into the future. There was some discussion that perhaps a detailed operational concept would be adequate at this point with technology lessons drawn from other research and development efforts going on elsewhere. There was some consideration that a near-term test bed and test corridor development could be delayed until the I-710 trucks lanes were closer to actual implementation. However, this option was ruled out as there are significant lessons that can be learned through the full project, as described above, that would not become invalid over time. In addition, early consideration of these issues in a real operational test environment will help ensure that design, operations, and safety lessons learned through the Truck Flow Efficiency project could be readily incorporated into physical design and infrastructure improvements along I-710 and elsewhere.

- **No project.** This option was similar to the one above, but rejected for similar reasons. The Truck Flow Efficiency project represents a unique opportunity to test truck automated commercial vehicle, intelligent vehicle, and related technologies and operations. This opportunity is not readily available in other parts of the nation.

7.16 **OUTCOMES**

- Proven operational and technical concepts to act as inputs to the design and operations for the I-710 corridor, and in particular the truck-only lanes on the I-710 corridor;

- Direct input to the I-710 design based on test results and lessons learned;

- Established research group and partnership that would allow for continued testing and development leading up to the ultimate construction and opening of truck-only lanes on I-710; and

- Development of a system to increase throughput of trucks in the I-710 freight corridor and improve safety as well.
7.17 INITIAL STEPS FOR DEPLOYMENT

The first steps towards deployment would be to arrange an agency team that agrees to the project concept. Development of a project charter should follow leading to the involvement of partners from the trucking, shipping, and manufacturing industries. This combined group would undertake the development of the Detailed ConOps. The detailed ConOps would most likely be contracted out to an industry research group. One agency would need to take the lead role in sponsoring grant application and contracting efforts.

7.18 NEEDS ADDRESSED

- **Terminal Congestion.** The ultimate results of this project could be applied not only to the I-710 corridor, but also to terminal access roads, corridor approach roads, etc. The project also integrates well with concepts currently under discussion for future truck electrification efforts.

- **Truck Congestion on Key Roadways.** Modeling efforts for the I-710 corridor have pointed to the need to substantially increase the effective capacity of the traffic lanes. This project points the ways towards maximizing the effectiveness of the truck-only lanes on I-710.

- **Enhanced Traffic and Commercial Vehicle Safety.** The focus of the on-board devices is to enhance vehicle safety and reduce the potential or severity of crashes.

- **Supporting Reduced Emissions.** By enhancing the consistency of truck travel speeds, reducing the accordion effect, and reducing the potential and/or severity of accidents, the project should have substantial long-term benefits in emissions reduction.