



Connected Vehicles – Mobility

Highlights

- The vision of the Dynamic Mobility Applications program is to expedite the development, testing, commercialization, and deployment of innovative mobility applications, fully leveraging both new technologies and federal investment to transform transportation system management, maximize the productivity of the system, and enhance the accessibility of individuals within the system.
- Six Dynamic Mobility Application bundles representing 17 connected vehicle applications concepts were developed, demonstrated and assessed to measure mobility impacts.
- During the small-scale demonstration of the INFLO DMA application bundle in Seattle, advanced in-vehicle queue warning messages reduced the need for participants to slow down or stop suddenly.



Introduction

This factsheet is based on past evaluation data contained in the ITS Knowledge Resources database at: www.itskrs.its.dot.gov. The database is maintained by the U.S. DOT's ITS JPO Evaluation Program to support informed decision making regarding ITS investments by tracking the effectiveness of deployed ITS. The factsheet presents benefits, costs and lessons learned from past evaluations of ITS projects.

The U.S. Department of Transportation's (USDOT's) Connected Vehicle program is working with state and local transportation agencies, vehicle and device makers, and the public to test and evaluate technology that will enable cars, buses, trucks, trains, roads and other infrastructure, and our smartphones and other devices to “talk” to one another. Cars on the highway, for example, would use short-range radio signals to communicate with each other so every vehicle on the road would be aware of where other nearby vehicles are. Drivers would receive notifications and alerts of dangerous situations, such as someone about to run a red light as they’re nearing an intersection or an oncoming car, out of sight beyond a curve, swerving into their lane to avoid an object on the road. Connected Vehicle technologies aim to tackle some of the biggest challenges in the surface transportation industry--in the areas of safety, mobility, and environment.

In the connected vehicle environment real-time data is captured from equipment located on board cars, trucks, and buses and from the network of connected vehicle field infrastructure. These data will be transmitted wirelessly and used by transportation managers in a wide range of applications to manage the transportation system for optimum performance.

The Dynamic Mobility Applications program is a multimodal initiative led by the Intelligent Transportation Systems Joint Program Office (ITS JPO) within the U.S. Department of Transportation (USDOT). The vision of the Dynamic Mobility Applications program is to expedite the development, testing, commercialization, and deployment of innovative mobility applications, fully leveraging both new technologies and federal investment to transform transportation system management, maximize the productivity of the system, and enhance the accessibility of individuals within the system.

After years of research, concepts for six Dynamic Mobility Application bundles representing 17 connected vehicle applications were developed. The operational concepts for each bundle and their comprising applications are described below:

Multimodal Intelligent Traffic Signal System (MMITSS)

The MMITSS application bundle seeks to develop a comprehensive traffic signal system that services all modes of transportation (passenger vehicles, transit, emergency vehicles, freight fleets, pedestrians, etc.)

MMITSS component applications include:

- *I-SIG - Intelligent Traffic Signal System*: An overarching system optimization application that processes data and utilizes that data to prioritize different types of vehicles providing priority entry through a signalized intersection. The purpose is to prioritize entry for emergency vehicles, transit and freight vehicles, and pedestrian movements.
- *PREEMPT- Emergency Vehicle Preemption*: An application that provides signal preemption to emergency vehicles, and accommodates multiple emergency requests.
- *TSP - Transit Signal Priority and FSP - Freight Signal Priority*: Two applications that provide signal priority to transit at intersections and along arterial corridors as well as signal priority to freight vehicles along an arterial corridor near a freight facility.
- *PED-SIG - Mobile Accessible Pedestrian Signal System*: An application that allows for an automated call from the smartphone of a visually impaired pedestrian to the traffic signal, as well as audio cues to safely navigate the crosswalk

Intelligent Network Flow Optimization (INFLO)

INFLO applications aim to improve roadway throughput and reducing crashes through the use of frequently collected and rapidly disseminated data drawn from connected vehicles, travelers, and infrastructure.

INFLO component applications include:

- *Dynamic Speed Harmonization (SPD-HARM)*: SPD-HARM allows the vehicle operator to dynamically adjust and coordinate maximum appropriate vehicle speed in response to downstream congestion, incidents, and weather or road conditions in order to maximize traffic throughput and reduce crashes.
- *Queue Warning (Q-WARN)*: The objective Q-WARN is to provide a vehicle operator with sufficient warning of an impending queue backup in order to brake safely, change lanes, or modify the route such that secondary collisions can be minimized or even eliminated. Q-WARN uses connected vehicle technologies, including vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications, to enable vehicles within the queue event to automatically broadcast their queued status information to nearby upstream vehicles and to the TMC.
- *Cooperative Adaptive Cruise Control (CACC)*: The objective of CACC is to dynamically and automatically coordinate cruise control speeds among platooning vehicles in order to significantly increase traffic throughput. By tightly coordinating in-platoon vehicle movements, headways among vehicles can be significantly reduced, resulting in a smoothing of traffic flow and an improvement in traffic flow stability. CACC will require the use of DSRC by participating vehicles.

Response, Emergency Staging and Communications, Uniform Management, and Evaluation (R.E.S.C.U.M.E.)

R.E.S.C.U.M.E. is a bundle of applications that aim to transform the processes associated with incident management. They seek to quickly detect and assess incidents and their effects on traffic flow, model the evacuation flow, push information to evacuees, and help responders identify the best available resources and ways to allocate them in the timeliest manner.

The R.E.S.C.U.M.E. Bundle includes 3 applications:

- *Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)*: This application provides situational awareness information to public safety responders while enroute to an incident. It can also help establish incident work zones that are safe for responders, travelers, and crash victims by providing input regarding routing, staging, and secondary dispatch decisions and staging plans.
- *Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)*: This application bundle has two components, one that warns drivers that are approaching temporary work zones at unsafe speeds, and or trajectory; and another that warns public safety personnel and other officials working in the zone through an audible warning system.
- *Emergency Communications and Evacuation (EVAC)*: This application addresses the needs of two different evacuee groups:

For those using their own transportation, EVAC provides dynamic route guidance information, current traffic and road conditions, location of available lodging, and location of fuel, food, water, cash machines, and other necessities. For those requiring assistance, EVAC provides information to identify and locate people who are more likely to require guidance and assistance, and information to identify existing service providers and other available resources.

Integrated Dynamic Transit Operations (IDTO)

The IDTO application bundle aims to integrate passenger connection protection, dynamic scheduling, dispatching, and routing of transit vehicles, and dynamic ridesharing into a single system that benefits both travelers and operators.

The following applications comprise the IDTO bundle:

- *T-Connect (Connection Protection)*: Increases the likelihood of making successful transfers by monitoring inbound and outbound vehicles, as well as travelers, determining if/how a connection can be preserved, and initiating the necessary notifications to these parties to support.
- *T-DISP (Dynamic Transit Operations)*: For travelers, T-DISP provides an ability to access real-time information about available travel options in order to best manage their commutes. For an agency, T-DISP extends demand/response services to support dynamic routing and scheduling.
- *D-Ride (Dynamic Rideshare)*: New, more efficient approach to rideshare concepts including real-time scheduling. Moving beyond the 24 advance notification typically required by paratransit.

Freight Advanced Traveler Information Systems (FRATIS)

The FRATIS application bundle seeks to provide freight-specific route guidance and optimize drayage operations so that load movements are coordinated between freight facilities to reduce empty-load trips.

FRATIS has two component applications:

- *Freight-Specific Dynamic Travel Planning and Performance*: This application seeks to aggregate traveler information, dynamic routing, and performance monitoring elements desired by freight operators. It is expected that this application will leverage existing data in the public domain, as well as emerging private sector applications, to provide benefits to both sectors. Other data includes real-time freeway and key arterial speeds and volumes, incident information, road closure information, route restrictions, bridge heights, truck parking availability, cell phone and/or Bluetooth movement/speed data, weather data, and real-time speed data from fleet management systems.
- *Drayage Optimization*: This application seeks to combine container load matching and freight information exchange systems to fully optimize drayage operations, thereby minimizing bobtails/dry runs and wasted miles, as well as dispersing truck arrivals at intermodal terminals throughout the day. With this application, the U.S. DOT and freight industry also have an opportunity to address some key industry gaps. To truly optimize a freight carrier's itinerary, extensive communication is required from a wide range of entities (including rail carriers, metropolitan planning organizations, traffic management centers, customers, and the freight carriers themselves) in a manner that assesses all of the variables and produces an optimized itinerary.

Enabling Advanced Traveler Information Systems (EnableATIS)

EnableATIS is unique among the other Mobility Applications as its focus is on providing support to the marketplace for application development—i.e., enabling development of Advanced Traveler Information Systems—rather than developing the foundational applications. The EnableATIS effort did not follow a process of application concept development, prototyping and demonstration. Instead, EnableATIS initiated two exploratory basic research studies on advanced methods and technologies to infer disaggregate traveler behavior data (MIT's CloudCar and University of Minnesota's SmarTrac). Testing of these two research studies is still ongoing.

Figure 1 below illustrates the locations of the DMA application prototype demonstrations.

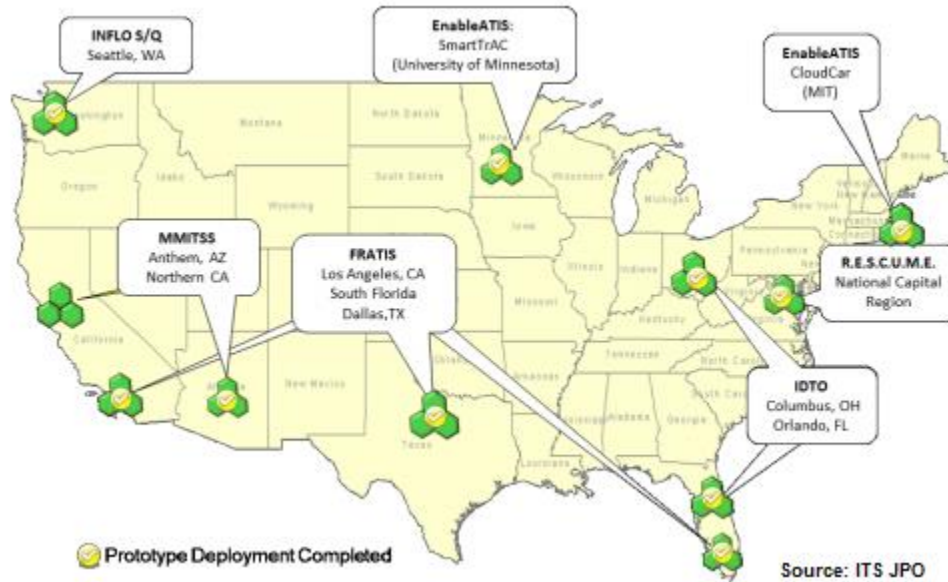


Figure 1: Locations of DMA Prototype Demonstrations

Benefits

Benefits of the DMA prototypes that were tested are summarized in the table below.

Table 1: Summary of DMA Bundle Prototype Benefits

Application	Findings
MMITSS	<ul style="list-style-type: none"> Signal Priority operations shown to improve connected bus travel times by 8.2 percent and connected truck travel times by 39.7 percent. For a coordinated corridor, the application provided up to 13 percent fuel reduction benefits. (Benefit ID: 2015-01052)
INFLO	<ul style="list-style-type: none"> A microsimulation model of a Speed Harmonization and Queue Warning application prototype demonstration found these applications may reduce extreme, unsafe speed drops with average speeds reduced by up to 20 percent. (Benefit ID: 2015-01046) Deployed results found volunteer drivers equipped with CV technologies saw immediate value in queue warning applications whereas the value of speed harmonization was not as clear to them. (Benefit ID: 2016-01102)
R.E.S.C.U.M.E.	<ul style="list-style-type: none"> Modeling and evaluation results of the Emergency Communications for Evacuation (EVAC) application found that the route guidance provided by the evacuation information system shown to decrease congestion time by 20 percent. (Benefit ID: 2015-01047) Simulation of incident-related applications such as INC-ZONE and RESP-STG can potentially reduce network delay up to 14 percent. (Benefit ID: 2015-01048)
IDTO	<ul style="list-style-type: none"> During field testing, <i>Connection Protection</i> users indicated that there is high value added by knowing when connecting vehicles will arrive, and whether a connection is feasible. The value of information on connections led to new travel patterns (travel quality dependent upon information via T-CONNECT), repeat usage, and a limited number of protected connections. In addition, there was demand for the trip-planning features of Dynamic Transit Operations [1].

Application	Findings
FRATIS	<ul style="list-style-type: none"> The Freight Advanced Traveler Information Systems (FRATIS) bundle of applications can provide significant improvements in freight travel times (approximately 20 percent in the one available study), as well as significantly reducing the total number of truck movements (which also reduces overall congestion) as well as other benefits. (Benefit ID: 2013-00845)
—	<ul style="list-style-type: none"> Simulated results found that connected vehicles with a market penetration rate of 33 percent or more can support V2I applications and significantly reduce delays at urban intersections. (Benefit ID: 2015-01025)
—	<ul style="list-style-type: none"> In Toronto, connected vehicles have potential to reduce travel times by 37 percent, reduce emissions by 30 percent, and improve safety indicators by 45 percent. (Benefit ID: 2015-00980)
—	<ul style="list-style-type: none"> Simulation models show that a network of connected vehicles that support platoon-based intersection management applications can reduce average travel times by 30 percent when traffic volume is high. (Benefit ID: 2016-01082)

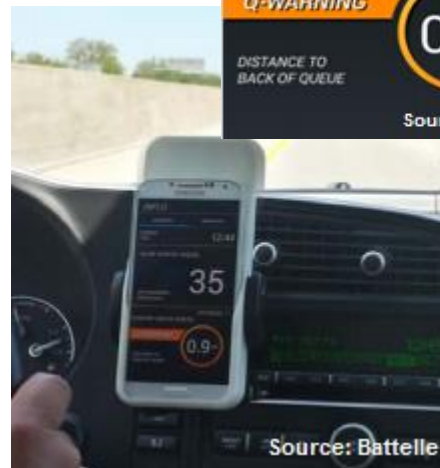
Case Study – INFLO Small-Scale Demonstration in Seattle, WA

A small-scale demonstration of the INFLO prototype system was deployed in the Seattle, Washington area to demonstrate the DMA bundle’s functionality and performance in an operational traffic environment and to capture data that could help assess hypotheses pertaining to system functionality, system performance, algorithm performance and driver feedback. The INFLO prototype system was designed to collect vehicle speed data from connected vehicles as well as infrastructure based speed detectors, and provide queue warning, speed harmonization, and weather responsive traffic management (WRTM) messages to connected vehicle drivers in a fully operational highway traffic environment.

Researchers recruited 21 volunteer participants from the local area in Seattle. They agreed to have on-board INFO equipment installed in their private vehicles and perform a variety of driving scenarios during peak periods on I-5 during a one week period in January 2015. The evaluation team collected vehicle speed data from both the WSDOT infrastructure based speed detector system and in-vehicle INFLO equipment. The data collected were processed by the evaluation team in real-time, and Q-WARN and SPD-HARM messages were sent to drivers as needed to accommodate prevailing traffic conditions. A smartphone graphical display mounted on the dashboard of each CV equipped vehicle provided drivers with the following types of information:

- SPD-HARM Recommended Speed
- Q-WARN Queue Ahead message with distance to the back of queue
- Q-WARN In-Queue message with distance and estimated time to the end of queue
- Vehicle weather and other data.

At the conclusion of testing, participants were requested to fill out a post demonstration questionnaire and receive agreed upon compensation for participation.



As a prototype, the INFLO project successfully demonstrated connected vehicle data capture and dissemination functionality using both cellular communications and DSRC communications. Although not rigorously tested, performance in terms of latency and processing speed was sufficient to support CV functionality in an operational traffic environment. In general, the process of capturing vehicle data, storing it in the database, processing it, and then delivering basic safety messages (BSMs) took less than 10 seconds. Drivers could expect to receive messages at least a mile in advance of the back of a queue. In one case, the INFLO prototype system detected a queue three minutes earlier using connected vehicle data than was achieved using infrastructure data only ([2016-01102](#)).

- The assessment of survey data collected from driver participants (n=21) indicated that drivers saw immediate value in the Queue Ahead and In-Queue messages that informed them of the location and duration of congestion and queues. Participants were able to take action in advance of congestion, reducing the need to slow down or stop suddenly.
- The value of Speed Harmonization messages, however, was not clear to participants.

References

[1] Estimated Benefit of Connected Vehicles: Dynamic Mobility Applications, AERIS, V2I Safety, and Road Weather Management Applications. FHWA. Final Report. Report No. FHWA-JPO-15-255. August 2015.

All other data referenced is available through the ITS Knowledge Resources Database, which can be found at <http://www.itsknowledgeresources.its.dot.gov/>.