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Reduce Emissions and Improve Traffic Flow Through Collaborative Autonomy

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Reduce Emissions and Improve Traffic Flow Through Collaborative Autonomy

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California Resilient and Innovative Mobility Initiative

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16. Abstract
This report explores opportunities for employing autonomous driving technology to dampen stop-and-go waves on freeways. If successful, it could reduce fuel consumption and emissions. This technology was tested in an on-road experiment with 100 vehicles over one week. Public stakeholders were engaged to assess the planning effort and feasibility of taking the technology to the next level: a pilot involving 1000+ vehicles over several months. Considerations included the possible geographical boundaries, target fleets of vehicles, and suitable facilities such as bridges or managed lanes. Flow smoothing technology may improve the user experience and operations of managed lanes or bridges, however it may require external incentives such as reduced tolls to entice the traveling public to use it. This must be matched with other goals such as verifying vehicle occupancy. It might be possible for some hybrid solution that addresses both challenges to provide a way forward. A concept of operations needs to be developed specifically for a target road geometry and a California partner. This concept should benefit from lessons learned from previous pilot projects and will need to be defined so as to achieve both (1) a penetration rate sufficient to achieve measurable effects; and (2) sufficient quality and quantity of data to confirm benefits.

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The California Resilient and Innovative Mobility Initiative

The California Resilient and Innovative Mobility Initiative (RIMI) serves as a living laboratory bringing together university experts from across the four UC ITS campuses, policymakers, public agencies, industry stakeholders, and community leaders to inform the state transportation system's immediate COVID-19 response and recovery needs, while establishing a long-term vision and pathway for directing innovative mobility to develop sustainable and resilient transportation in California. RIMI is organized around three core research pillars: Carbon Neutral Transportation, Emerging Transportation Technology, and Public Transit and Shared Mobility. Equity and high-road jobs serve as cross-cutting themes that are integrated across the three pillars.

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Table of Contents

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance System
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
AV	Autonomous Vehicle
AVL	Automated Vehicle Locater
CAV	Connected and Autonomous Vehicle
CIRCLES	Congestion Impacts Reduction via CAV-in-the-loop Lagrangian Energy Smoothing
CV	Connected Vehicle
C-V2X	Cellular Vehicle to Everything
GHG	Greenhouse gases
ICM	Integrated Corridor Management
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer
TSP	Transit Signal Priority
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle

Executive Summary

Executive Summary

Connected and automated vehicles (CAVs) will revolutionize the way we travel; however, what impact this revolution will have on advancing broader societal goals is uncertain. To date, the private sector technology rollout has emphasized the automation side of CAVs and neglected the potentially transformative possibilities brought by a more collaborative notion of connectivity. This may have significant downsides from a broader societal perspective. For example, CAVs (including those on the road today) collect a vast amount of data gathered through onboard systems (e.g., radar, lidar, camera), however, this data is not typically shared with other vehicles, roadside infrastructure, or public transportation agencies. This lack of collaboration will likely make traffic worse and forfeit the opportunity to manage traffic at the systems-level, which is where significant gains can be made in terms of improving traffic flow and safety, reducing greenhouse gas emissions and vehicle energy use, and more.

A small but growing body of research and pilot demonstrations championed by the CIRCLES consortium[1] are showing that a collaborative CAV ecosystem can support strategies for creating a more efficient, safe, and environmentally sustainable transportation system. One strategy of particular interest is "flow smoothing" where data gathered by "downstream" vehicles is transmitted to "upstream" vehicles and used to adjust upstream vehicle speeds in a manner that smooths stop-and-go traffic waves and improves traffic flow along a corridor.

A field experiment, led by UC Berkeley, called the MegaVanderTest, was performed to assess the feasibility of CIRCLES technology to dampen stop-and-go waves in traffic. To date, the MegaVanderTest is the largest deployment of CAVs for the purpose of smoothing traffic flow along a corridor. Over the course of one week (from November 14 to 18, 2022), 100 vehicles equipped with adaptive cruise control systems modified by the CIRCLES research team were deployed on a 4.2-mile stretch of Interstate-24 MObility Technology Interstate Observation Network (I-24 MOTION) near Nashville, Tennessee.

The next goal is to scale up this technology for a potential pilot project in California involving 1000+ vehicles over six months. Outreach is conducted with possible partners including several regional transportation authorities and Metropolitan Planning Organizations to understand agency priorities that can be addressed by flow smoothing, additional priorities for a pilot, existing initiatives, capabilities, or opportunities for synergy, as well as challenges and potential roadblocks.

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[1] The Congestion Impacts Reduction via CAV-in-the-loop Lagrangian Energy Smoothing (CIRCLES) project aims to reduce instabilities in traffic flow, called "phantom jams," that cause congestion and wasted energy. CIRCLES is led by UC Berkeley and the Institute of Transportation Studies (ITS) Berkeley, in coordination with Vanderbilt University, Temple University, Rutgers University-Camden, the Tennessee Department of Transportation, Toyota North America, and Nissan North America.

Contents

Introduction

Connected and automated vehicles (CAVs) will revolutionize the way we travel; however, what impact this revolution will have on advancing broader societal goals is uncertain. To date, the private sector technology rollout has emphasized the automation side of CAVs and neglected the potentially transformative possibilities brought by a more collaborative notion of connectivity. This may have significant downsides from a broader societal perspective. For example, CAVs (including those on the road today) collect a vast amount of data gathered through onboard systems (e.g., radar, lidar, camera), however, this data is not typically shared with other vehicles, roadside infrastructure, or public transportation agencies. This lack of collaboration will likely make traffic worse and forfeit the opportunity to manage traffic at the systems-level, which is where significant gains can be made in terms of improving traffic flow and safety, reducing greenhouse gas emissions and vehicle energy use, and more.

Without collaboration, adaptive cruise control is likely to make traffic worse. Adaptive cruise control technologies commonly deployed in vehicles on the market today are not "string-stable" [1]. In other words, they are not able to prevent small traffic disturbances from amplifying into stop-and-go waves. The continued deployment of these technologies may make traffic worse, and increasingly unpleasant for those driving vehicles unequipped with the latest technologies.

A small but growing body of research and pilot demonstrations championed by the Congestion Impacts Reduction via CAV-in-the-loop Lagrangian Energy Smoothing (CIRCLES) consortium are showing that a collaborative CAV ecosystem can support strategies for creating a more efficient, safe, and environmentally sustainable transportation system. One strategy of particular interest is "flow smoothing" where data gathered by "downstream" vehicles is transmitted to "upstream" vehicles and used to adjust upstream vehicle speeds in a manner that smooths stop-and-go traffic waves and improves traffic flow along a corridor.

To realize the full potential of collaborative CAV technology, we must prioritize addressing knowledge gaps through more pilot demonstrations and targeted research, and address policy and/or institutional barriers that disincentivize collaborative approaches. More testing, research, and pilot studies are needed to refine CIRCLES technology into a viable product that could be deployed at scale.

Transportation agencies who may be natural allies face both institutional and technical challenges when it comes to the prospect of deploying an ambitious pilot. Technical challenges include cybersecurity, and integration of new technology into existing systems. To deploy a large-scale pilot also requires public outreach and incentives to recruit participating drivers. Precedent exists in California to promote new technologies to advance environmental goals, such as hybrid or electric vehicles, by providing access to managed lanes. This is one possible mechanism that could both recruit drivers and limit the geographical scale of a potential pilot. This use case must also consider political complications for non-rate payers or alternative-rate payers who are authorized to use managed lanes.

Status of CAV Research and Development

In the United States, connected and automated vehicle (CAV) deployment has progressed along two parallel tracks: connected vehicle (CV) deployments that are largely led by the public sector and automated vehicle (AV) development and testing that is largely being led by the private sector. Most public sector involvement with CAV has focused on CV deployments and testing since that is an area where the public sector has some influence, particularly when it comes to deployment of vehicle to infrastructure (V2I) technology.

One source of tension is that automobile manufacturers would like to sell cars that can operate autonomously everywhere, not at just in a limited range of facilities where special connected infrastructure is deployed. Automation in a mixed traffic environment with heterogeneous vehicle fleets is a hard problem, and it is becoming clear that achieving national goals for energy, emissions, and safety will require the future of automation to be collaborative.

Unfortunately, traffic data to support collaborative automation does not exist, and it is therefore unavailable for purchase by auto manufacturers (or so-called Tier 1 suppliers--companies that manufacture and supply components directly to original equipment manufacturers or OEMs). Such data would contain attributes richer than just traffic information data: for example, acceleration recommendations, speed targets, and downstream traffic information usable for optimal speed profile generation. Yet, even as more vehicles from different manufacturers are being equipped with technology that progressively raises their level of automation from 0 (conventional) to 5 (fully automated), most, if not all, advanced driver assist and autonomy functions only make use of onboard data (e.g., radar, lidar, camera, GPS, etc.). As a result, smooth integration of partially automated vehicles in traffic flow is hard, and collaborative automation (to solve congestion or stop-and-go traffic) is not possible. As a corollary, technology to enable this collaborative automation (apps or onboard automation) is non-existent at a global scale necessary to connect vehicles with varying levels of automation. Even in the best-case scenario, a single manufacturer does not have capability to produce traffic data with sufficient spatiotemporal granularity, and lane-specific detail.

CAV Research and Deployment

Recent years have witnessed an explosion of activity in the research and development of AVs and CVs. As part of the Automated Vehicle Transparency and Engagement for Safe Testing (TEST) Initiative, the National Highway Traffic Safety Administration (NHTSA) maintains an interactive tool [2] to inform the public about the testing of AVs on public roads. The tool, illustrated in Figure 1, is intended to be updated frequently with information submitted on a voluntary basis by states and companies.

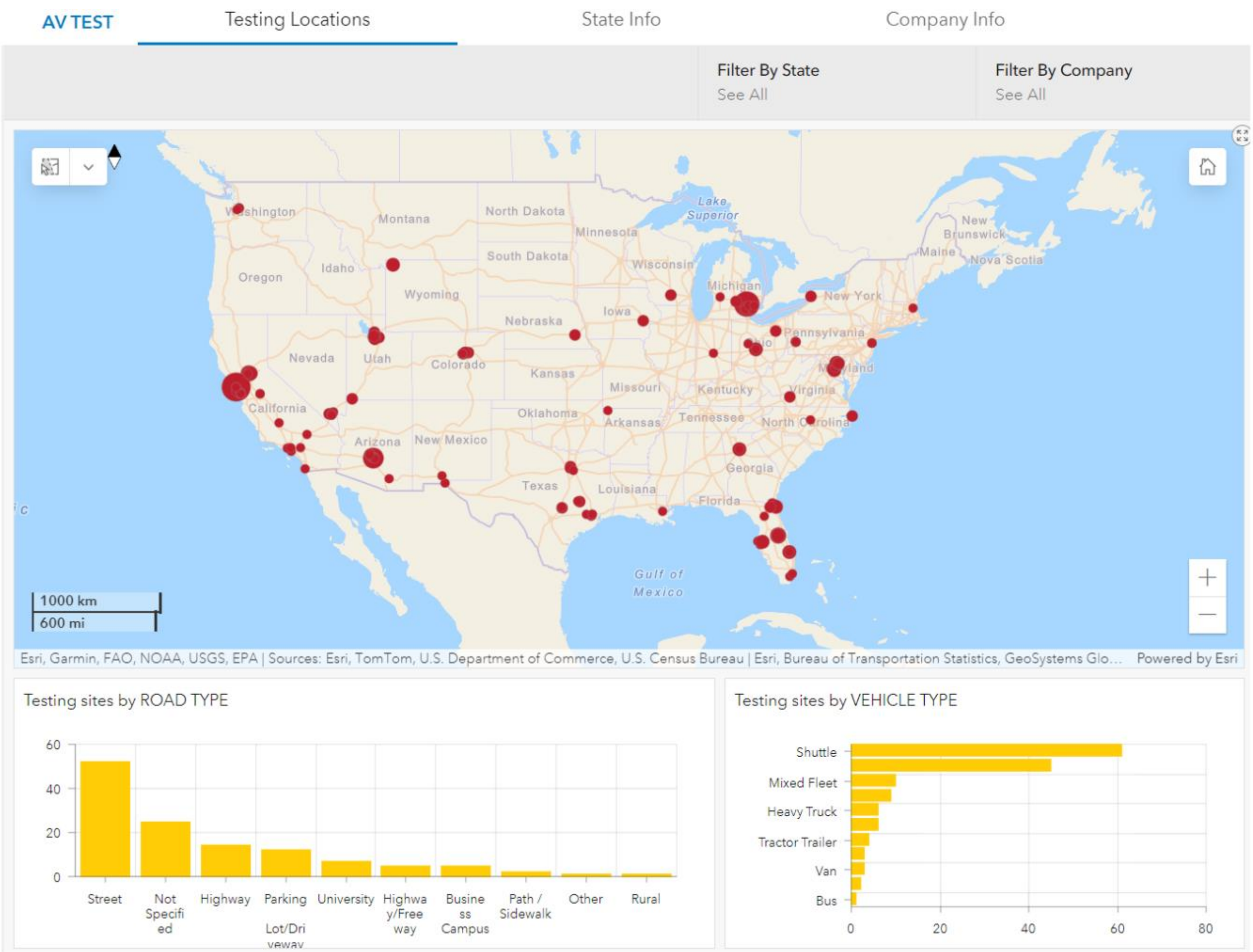

Figure 1. AV Test Sites in the US

The U.S. Department of Transportation (USDOT) maintains an online interactive connected vehicle deployment map [3]. It lists 77 operational connected vehicle deployments and another 104 planned deployments as displayed in Figure 2.

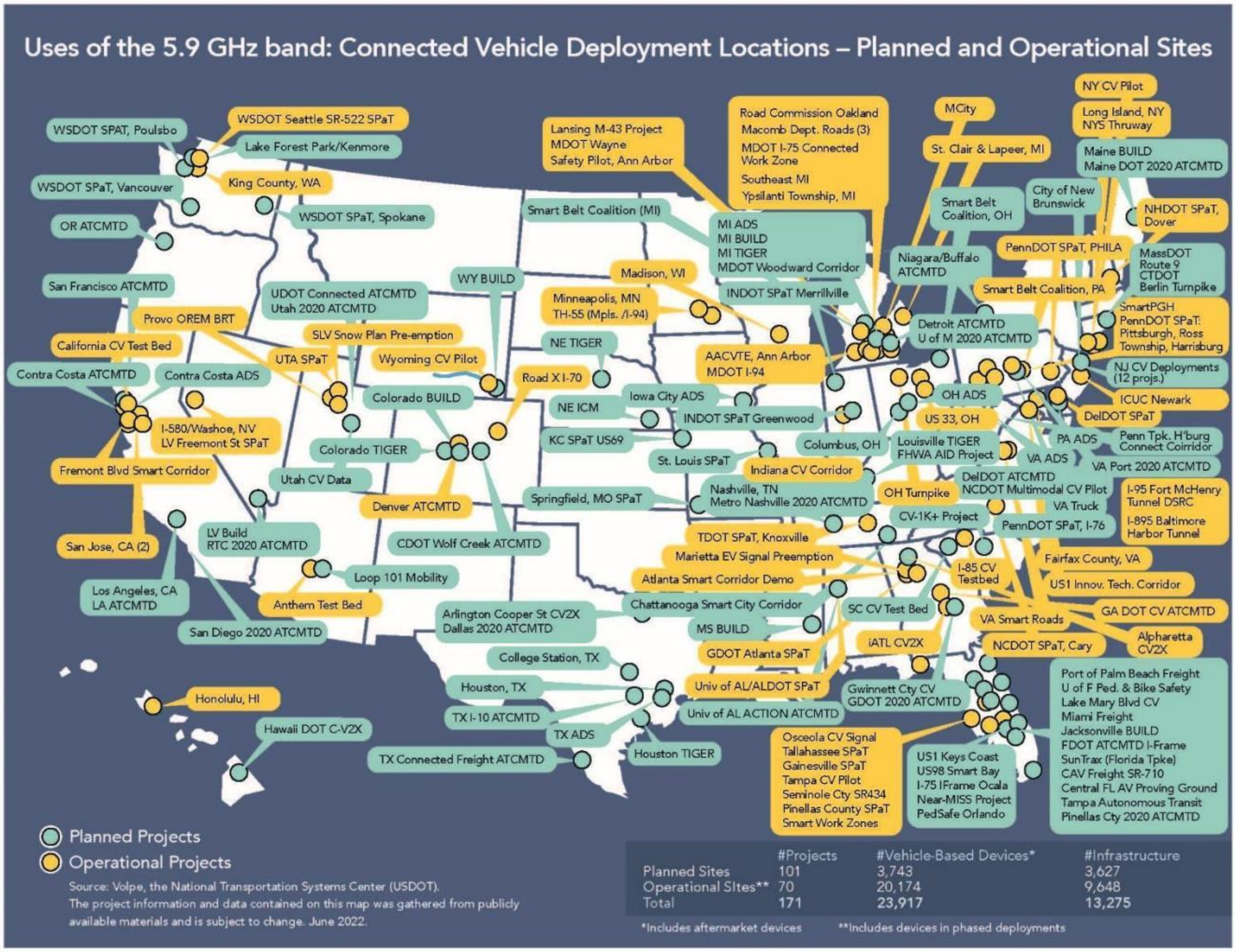

Figure 2. Connected Vehicle Test Sites in the US

Prominent CV test sites typically have a local university partner and private industry participation and collaboration. These CV test sites include a combination of state and federally funded programs. Some of the better-known CV testbed sites include:

- Arizona: Maricopa County Department of Transportation SMARTDriveSM Program [4]
- California Connected Vehicle Test Bed [5]
- Michigan: Mcity [6]
- Ohio: Smart Mobility Corridor [7]

CAV Developments in California

This section describes AV proving grounds as well as CAV and related projects and infrastructure in California. This list is not exhaustive but illustrates resources available to test the feasibility of new ideas. One indicator of healthy innovation is that as of March 24, 2023, the California Department of Motor Vehicles (DMV) has issued Autonomous Vehicle Testing Permits (with a driver) to 51 entities [8].

AV Proving Grounds

California has two major sites that allow for AV testing in controlled environments. The GoMentum Station located in the City of Concord is the largest secure testing ground for CAVs in the country [9]. AV testing takes place in a controlled environment on the facility's roadways, and CV testing takes place by using the facility's smart V2I infrastructure, including traffic signals.

Transportation Research Center (TRC) California [10], is another AV testing site recently developed in Merced County on the former Castle Air Force Base. The 225-acre facility offers a 2.2-mile oval test track, and two five-lane intersections.

Caltrans CAV Testbeds

There are several clusters of roadside equipment deployed around California that enable V2I-style communications and CAV testing. Often these facilities overlap with other improvements associated with Integrated Corridor Management (ICM) or other projects. As a result, each of these facilities are unique and geared toward local needs and priorities.

The El Camino Real (ECR) Testbed is located in Santa Clara County. This facility is focused on intersection safety, improved signal operations, and mobility applications. It was first established in 2005 as a partnership between Caltrans the Metropolitan Transportation Commission (MTC) and the California PATH program at UC Berkeley. It created the nation's first public Connected Vehicle Test Bed on El Camino Real (State Route 82), a signalized arterial roadway that serves more than 50,000 vehicles traveling each day between San Francisco and San Jose. The ECR is actively used to test how connected vehicle technologies (Multi-Modal Intelligent Traffic Signal System, CV-based traffic signal control and signal priority for transit, freight, and pedestrians, and Environmentally-Friendly Driving, etc.) perform under real-world conditions.

Another set of facilities is located in Orange County and supported by Caltrans District 12 [11]. CAV components have been installed to augment the Triangle Integrated Corridor Management (ICM) project as part of the proposed ICM strategies in response to major traffic incidents. These facilities include routes 5, 22, 55, 57, 91 and 405.

Another set of facilities is located in San Diego County and supported by Caltrans District 11 [11]. These facilities include roadside units (RSUs) installed for Cellular Vehicle-to-Everything (C-V2X) communications along routes 5, 8, and 15. Example projects include:

- Connected Vehicle Enabled Intersection Pilot Project: Safety and mobility applications
- Bus on Shoulder Pilot Project: Providing priority to buses at ramp meters on route 805

The San Diego Regional Proving Grounds (RPG) are managed by San Diego Association of Governments (SANDAG), in partnership with Caltrans District 11 and the City of Chula Vista. The RPG includes staging facilities as well as sections of public roads on I-15 and State Route 125.

Lessons Learned from Prior CV Deployments

Conducting a pilot project in a real location over an extended period of time is very different than performing a one-time controlled experiment. The design and scope of the project must ensure that adequate data can be obtained to answer the proposed research questions.

In 2015, the USDOT initiated three major CV pilot projects cooperatively with:

- New York City Department of Transportation (NYCDOT)
- Tampa Hillsborough Expressway Authority (THEA)
- Wyoming Department of Transportation (WYDOT)

These projects were designed to encourage innovation and to gain a better understanding of the impact that CV technologies might have on traffic safety, mobility, and the environment [12]. Each pilot project consisted of three phases: (1) concept development; (2) design, deploy, and test; and (3) maintain and operate. To quantify the outcomes, the US DOT's Volpe National Transportation Systems Center and the Texas Transportation Institute performed independent evaluations at each pilot test site.

One important criterion for evaluation was safety. The New York City Connected Vehicle Pilot was completed in December 2021. The THEA Connected Vehicle Pilot was completed on September 30, 2022. Detailed safety analyses were performed for these two pilots, but due to schedule and time constraints only a limited safety analysis was performed for the WYDOT pilot [13]. Despite the limited quantity of quality data produced, potential safety benefits arising from changes to vehicle/driver performance in response to broadcast safety alerts were noted in the NYCDOT experiment [14].

The 16-month THEA pilot project was conducted in a real-world environment on public roadways involving around 800 light-duty vehicles and seven fixed guideway trolleys. However, there were limited vehicle to vehicle (V2V) interactions, and few actual safety alerts issued. From the limited numbers of valid alert events, it was difficult to make statistically significant conclusions about crash avoidance effectiveness or changes in driver performance [15].

The Connected Vehicle Pilot Deployment Program website [12] provides links to the raw data as well as reports and lessons learned. These are important resources for shaping strategies to carry the technology forward. In the context of flow smoothing technology the challenge is twofold:

- achieve penetration rate of flow smoothing vehicles sufficient to make a measurable impact, and
- collect data in sufficient quality and quantity to confirm benefits.

These are significant challenges. In order to meet them, it is necessary to find both a transportation facility (such as a bridge, managed lane, or other suitable location) as well as a set of fleet vehicles and/or volunteer drivers who use said facility in significant numbers. If a critical mass can be achieved, then in theory, the benefits will follow. The benefits achievable with connectivity and collaboration are strongly related to the number of users who choose to participate (this phenomenon is sometimes referred to as network effects). The more participants, the greater the benefits.

Collaborative Technology for Flow Smoothing

Typical development of an AV involves instrumenting the vehicle with an expensive array of sensors because situational awareness is approached as an individual responsibility. What if situational awareness was approached instead as a collective responsibility? In this case, collaborative means could be used to achieve a high level of situational awareness. In this view "collaborative automation" refers to the idea of using data from other vehicles, especially downstream vehicles, as well as from infrastructure with the potential to improve safety and to reduce emissions through traffic flow smoothing.

The technology rollout of collaborative automation for traffic flow smoothing on freeways intersects a range of public and private interests in safety, climate change, cybersecurity, mobility, and traffic management. Incremental steps have already been taken among private and public sector entities, and academics to develop and deploy this technology in controlled experiments. This section provides background on the technology itself, the actors involved in its development, and the future cooperation needed for wide-scale adoption of the technology.

Background

The general concept of traffic flow smoothing, or speed harmonization, is not new. A number of approaches have been studied in the research literature that include ramp metering, variable speed limits, and other mechanisms [16]. Since the early 2000s field tests have been deployed around the world that report benefits [16] such as improved speeds, travel time reliability, and safety. Several approaches for speed harmonization also consider the opportunities afforded by emerging connected and automated vehicle (CAV) technologies [17].

The specific strategy explored here is to dampen small traffic oscillations that would otherwise grow into stop-and-go waves by automatically controlling the speed of a limited number of vehicles in the traffic queue. This strategy is called "flow smoothing," and it works when data gathered by "downstream" vehicles is transmitted to "upstream" vehicles and used to adjust upstream vehicle speeds in a manner that smooths stop-and-go traffic waves and improves traffic flow along a corridor.

Traffic improves when vehicles collaborate, which has implications for greenhouse gas (GHG) emissions and air quality. Experiments along a circular track with more than 20 vehicles with human drivers revealed that traffic waves emerge naturally and consistently but can be dampened by controlling the speed of just a single vehicle on the track [18]. This is possible in part due to the vehicles traveling in a closed circle, whereas the one "controller vehicle" sets its speed profile based on maintaining a safe following distance from the vehicle in front while making it easy for the vehicles behind to follow. One of these studies [19] specifically examined the implications on vehicle emissions and found that reducing or eliminating stop-and-go waves may reduce carbon dioxide emissions by 15 percent and nitrogen oxide emissions by 73 percent. If these results can be scaled, then controlling the speed of automated vehicles in general traffic (i.e., a mix of vehicles including those with human drivers as well as partially or fully automated vehicles) has the potential to dampen stop-and-go waves and deliver significant environmental benefits.

There are substantial challenges with regards to anticipating human behaviors (such as car following, lane-changing, etc.) in traffic involving a mix of automated and human drivers. However, recent advances in artificial intelligence have provided new algorithms and tools to address these situations. For example, a computational framework, called Flow [20], uses reinforcement learning for the design of reliable traffic controllers. Another study [21] describes a framework for training traffic smoothing cruise controllers using a small amount of human driving data collected during periods of traffic congestion. The study details the results of a field test in which the controllers were safely deployed onto the I-24 freeway in Nashville, Tennessee. A subsequent study [22] proposed a set of unified benchmarks for optimizing system metrics using cruise controllers deployed in situations involving both human-driven and automated vehicles. The study also compares the performance of a variety of deep reinforcement learning algorithms to those benchmarks to provide a baseline for further research. These benchmarks are crucial to consistent and reliable assessments of the actual benefits that may be derived by deploying automated vehicles in mixed traffic situations.

The CIRCLES project (https://circles-consortium.github.io/) is a collaborative effort to develop the mathematical models and engineering methods needed to deploy a system to reliably dissipate stop-and-go waves in bulk traffic streams [23]. This is achieved by employing a portion of the vehicles on the road as mobile traffic controllers.

The MegaVanderTest

A recent real world field experiment led by UC Berkeley, called the MegaVanderTest, was conducted to assess the feasibility of the CIRCLES approach. This experiment was designed to create the high-quality, real-time data required to enable flow-smoothing. This is crucial because in order for the experiment to succeed, downstream traffic information is needed to generate and communicate optimal speed profiles to upstream vehicles for the purposes of smoothing traffic and reducing the overall energy and emissions footprint of the vehicles. Typical online sources of downstream vehicle speeds are not lane-specific and have significant time delays. This is an issue because calculating a vehicle’s trajectory based on obsolete data (i.e., reported traffic congestion that no longer exists) will produce erroneous, and in some cases dangerous results.

The key to high-quality data is having enough vehicles along a corridor sharing data in real-time. This market penetration was achieved by the design of the MegaVanderTest. One hundred vehicles equipped with adaptive cruise control systems modified by the CIRCLES research team were deployed on a 4.2-mile stretch of Interstate-24 MObility Technology Interstate Observation Network (I-24 MOTION) near Nashville, Tennessee over the course of one week (from November 14 to 18, 2022).

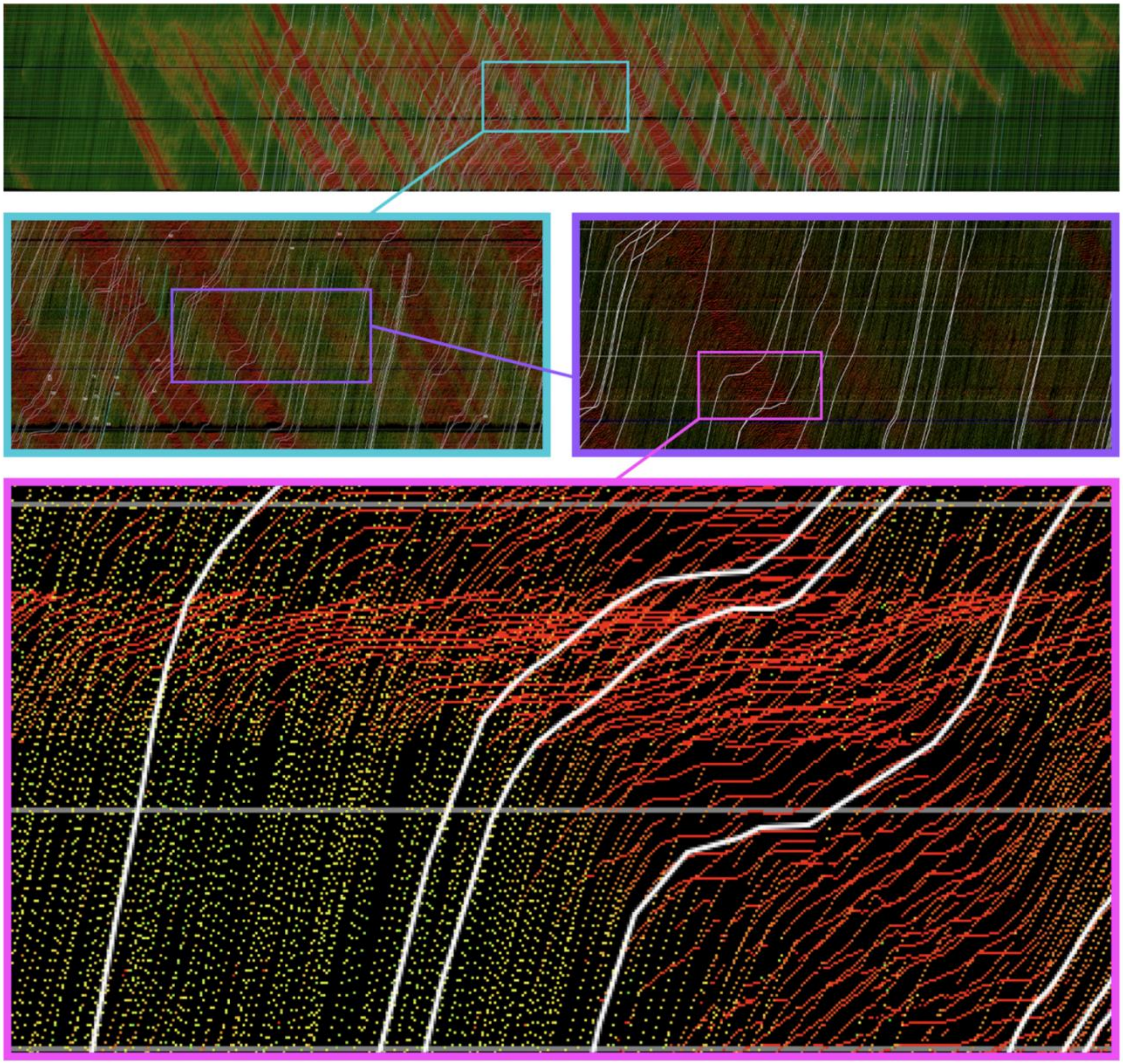

Figure 3. MegaVanderTest Data

Trajectories of vehicles on all lanes captured during the test. Vehicles traverse from bottom to top; time progresses from left to right. Red dots indicate vehicles moving slowly, green dots indicate vehicles moving quickly. White trajectories indicate instrumented vehicles. Successive rectangles show zoom in detail.

To date, the MegaVanderTest is the largest deployment of CAVs for the purpose of smoothing traffic flow along a corridor. The I-24 MOTION site was chosen, in part, because it is equipped with 276 pole-mounted high-resolution traffic cameras. These cameras made possible the observation of all vehicles along the facility and extraction of all of the vehicle trajectory paths as shown in Figure 3. This instrumentation is crucial as it allows the calculation of performance measures such as speeds, fuel use, and emissions of all the vehicles over the course of the day, not just the 100 vehicles used to implement the flow smoothing.

Collaborative CAV Challenges and Knowledge Gaps

Outreach was conducted with possible partners including several regional transportation authorities and Metropolitan Planning Organizations to develop concepts for pilot projects. Specifically, these discussions were framed with respect to flow smoothing cruise control technology developed by the CIRCLES consortium. The goal was to obtain a general sense of what kinds of planning and engagement activities are necessary to equip fleets (such as buses, taxis, trucks, delivery vehicles, etc.) to enable them actively and collaboratively to control a section of freeway, a managed lane, or an appropriately sized geographical bottleneck or problem area. The notions of “actively” and “collaboratively” are intended to encompass flow smoothing, emission improvement, safety benefits, and reduced energy consumption. However, the technology discussed was not intended specifically to increase flow or to reduce travel time. Discussions with these entities included identifying challenges, and potential opportunities to further develop a pilot concept.

Discussions with these agencies regarding flow smoothing technology included clarifying practical implementation details, constraints, as well as likely benefits. Key takeaways are summarized in the matrix of Table 1.

Table 1. Summary of key opportunities, challenges, and considerations

	MTC	SANDAG	AC Transit	Santa Clara VTA
Priorities addressed by flow smoothing	Emissions, Safety, Low-cost solutions	Emissions, GHG reduction	Collision avoidance, Driver assistance, Connectivity	Driver assistance
Adjacent priorities to be addressed in a potential pilot	Toll violations	Next generation ICM	Collision avoidance, Transit signal priority	Toll violations
Existing initiatives, capabilities, or opportunities for synergy	Smartphone App for vehicle occupancy verification and data exchange	Existing ICM on I-15, Next generation ICM on I-905, NextOS as a platform for data exchange	Existing automatic vehicle location (AVL) on buses	Existing managed lane access uses vehicle transponder. Would need to integrate

	MTC	SANDAG	AC Transit	Santa Clara VTA
Challenges and concerns for a pilot	Political complications for alternative exemptions for managed lane access	Achieving high penetration rate	Cybersecurity, Workforce agreements, Maturity of technology, Integration with existing hardware/software	Workforce agreements, achieving high penetration rate

Key priorities for the Bay Area Metropolitan Transportation Commission (MTC) include an emphasis on emissions reduction, low-cost operational improvements, and traffic congestion on the Bay Bridge. Of additional interest is the idea of a smartphone app that could be employed to perform the following functions:

- Recruit volunteers to download the app
- Identify eligible vehicle models for participation
- Provide free or reduced price to use express lanes as incentives for using the app
- Show benefits to express lane operations or pollution emissions

There is potential synergy with an existing MTC initiative to deploy a smartphone app to verify the eligibility of vehicles using a managed lane.

Key priorities for the San Diego Association of Governments (SANDAG) involve the need to reduce greenhouse gas emissions, and address climate change. Projects of interest include smart infrastructure, next generation ICM projects, CAVs, pedestrian safety, and smart borders. Another element in the 2021 Regional Plan is NextOS, a platform intended to enable more effective use of data for decisions, and to provide traffic information to residents and businesses. The existing I-15 ICM system has capabilities including command and control of signal systems and ramp metering coordination. A microsimulation model together with a decision support system is currently in place. In the next five years, SANDAG hopes to leverage this prior success into a platform for I-905, which is used largely by commercial vehicles.

Alameda-Contra Costa Transit District (AC Transit) is focused more on ADAS for driver assistance than it is on full automation. Regarding automated technology, AC Transit is concerned about adoption, workforce challenges, training, and cybersecurity. The District expressed a need to learn more about the maturity of the products coming to market.

Connectivity is a top priority for AC Transit. Current vehicle location systems have capabilities for 10 to 15 second data for real-time bus location and passenger counts. AC transit is interested in sharing that data with riders and partners. Interest was also expressed about collision avoidance. Regarding a possible pilot, one key issue is integration with existing hardware and software as well as the use of WIFI bandwidth and potential for radio frequency interference.

Santa Clara Valley Transportation Authority (VTA) has an asset in terms of dedicated express lanes. The primary way to provide discounts and exemptions is to use a Fastrak transponder in the vehicle. All vehicles must have a transponder to use the express lanes. To receive a discount the transponder must declare the occupancy of riders in the vehicle. Clean air vehicles must use a transponder registered as a clean air vehicle. A pilot program could use similar mechanisms.

VTA reported a preference for ADAS over full automation. Each driver performs many tasks and partial automation to enhance safety is desirable. AV policy will need to consider labor unions and existing workforce agreements.

One challenge for the industry is managing toll violations and cheaters who game the system. Most operators would like to have automated vehicle occupancy information. Such technology is expensive to install and therefore can only be deployed in strategic locations. In the Bay Area, Caltrans requires continuous access to express lanes; this is very different than controlled access in Southern California. As a result, drivers are able to cheat by getting around the toll readers. Others cheat based on occupancy. They have the transponder and falsely declare three riders in the car because it is free. VTA depends on the California Highway Patrol to pick out those violators.

Action Plans and Next Steps

To achieve significant gains in emissions or safety, it is not enough for vehicles to be connected and automated, they also need to be collaborative. Mechanisms do not yet exist that entice OEMs to share detailed data in real time that would enable applications such as the flow smoothing described herein. Market forces appear to result in continued fragmentation of data.

A more collaborative environment for data exchange will likely require leadership at all levels of government, and include steadfast funding and support for research, development, and CAV pilot demonstrations and deployments.

Moving forward there are key questions that need to be addressed to advance the prospects for collaborative automation. First, is it possible to generate a sufficient quality and quantity of traffic information that can be utilized by multiple brands of partially automated vehicles to enable collaborative integration in mixed traffic flow? Second, can this data be successfully used to enable collaborative automation between different vehicles as part of a demonstration project with 1000+ drivers through a university-led pilot project? Can this technology be used commercially by multiple competing automobile manufacturers willing to buy the same data because it is mutually beneficial?

As a leader in the field, UC Berkeley and the CIRCLES consortium will continue stakeholder engagement as well as the technical work to scale up the technology from the MegaVanderTest where 100 vehicles used the technology for one week, to a larger test consisting of 1000+ vehicles using the technology over six months. A concept of operations needs to be developed specifically for a target road geometry and a California-based partner. This future concept should benefit from lessons learned [12] from previous pilot studies.

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