San Diego FORWARD
The Regional Plan

Emerging Technologies White Paper
July 2014

A. INTRODUCTION

Technology influences where we work and live, how we communicate with each other, and the personal choices we make. This paper explores emerging technologies as they affect and influence transportation infrastructure for consideration in San Diego Forward: The Regional Plan. Additionally, this paper discusses technology trends and how those trends affect our everyday lives.

This paper examines vehicle technology, infrastructure or roadway technology, as well as personal technology, to inform the public and policymakers on investment opportunities, potential policies, and timing, so that as a region we can make informed choices, maximize the positive application of both transportation technologies and general technology trends, and include relevant information and recommendations in San Diego Forward: The Regional Plan that will shape our future.

B. INTELLIGENT TRANSPORTATION SYSTEMS

Intelligent Transportation Systems (ITS) is the application of technology to transportation systems including vehicles, roadways, intersections, transit, traveler information, bike and pedestrian networks, and payment systems with the goal to maximize efficiency of those services while increasing vehicle- and person-throughput, reducing congestion, and providing quality information to the commuting public and to people traveling at all times of the day. The application of ITS technologies can influence transportation choices across all modes of travel.

SANDAG has had a regional ITS Program in place for some time, which provides a solid foundation from which to incorporate emerging technological advances. The SANDAG ITS program focuses on the following areas of emphasis.

- <u>Planning</u> – Both long range and project level planning, including Performance Monitoring and Management
- <u>Implementation</u> – Implementation of stand-alone projects and as integrated into a larger capital improvement
- <u>Deployment</u> – Development, improvement, expansion and upgrade of ITS investment areas
- <u>Operations</u> – Facilitation of the integration of new ITS systems into on-going operations and maintenance

ITS Planning / Transportation System Performance Monitoring and Management

A fundamental emerging technological need that remains constant during regional transportation planning cycles is determining whether the region is maximizing the benefits of transportation project improvements. To assess and realize the progress and transportation performance benefits of existing and planned project investments requires the application of a comprehensive and sound statistical evidence gathering and analytical process to determine facts, trends, quality of services, and optimal system efficiency. Under transportation system management, this is achieved through transportation system performance monitoring and management.

ITS planning places emphasis on improving data collection, analysis, and management in two key areas: (1) transportation performance monitoring, and (2) transportation system performance management.

Transportation Performance Monitoring

Getting the most out of our transportation investments requires observing the system's performance, to (1) provide current and on-going information on how well the transportation system is performing; (2) identify opportunities for near-term improvements; and (3) assess the impacts of future improvements. Priority activities for improving performance monitoring are focused on continued development for enhancing the region's ability to automate the data collection, data analysis, and data management systems for all modal networks regardless of data collection technology. Transportation System Performance Monitoring is guided by the following principles:

- Improved Traveler Information – Focus on the region's ability to provide better information on speeds, travel times, travel options, or congestion-related information to the traveling public.

- Improved Performance Monitoring and Reporting – Focus on enhancing support for on-going or new efforts that support and align with local, regional, and federal performance monitoring and reporting programs and initiatives.

    - Transportation performance monitoring needs to be automated and uniformed across networks. This will reduce costs and provide more frequent data collection and allow for data collection, analysis, and reporting to be consistent year to year.
    - Transportation performance monitoring needs to reflect the multimodal nature of our transportation system by focusing on all modes of travel.
    - Data availability, accuracy, and management should be carried out to supplement and support on-going performance management and operations efforts including the development of decision support systems and real-time proactive corridor management approach.

Implementation and Project Delivery: Deployment Timeframes

Project delivery follows system engineering principles and accepted project management processes as detailed by the Project Management Institute. Of all the technologies presented in this white paper, only connected or automated vehicles are not currently available as described. All other technologies are available in one form or another, at different maturity levels. San Diego Forward: The Regional Plan will contain funding for emerging technologies, broken down by decade. At this time, all technologies described in this paper, other than connected or automated vehicles, are anticipated for deployment in the short term (next 5 to 10 years), and connected / automated vehicles are anticipated for deployment in the longer term (10 to 30 years).

ITS Operations

SANDAG ITS has deployed several modal programs, systems, and regional communications networks that transition from implementation into pilot or normal operations. These systems require on-going support for operations, administration, and maintenance to ensure that the systems perform as expected and deliver mobility services to the public.

Services such as real time traveler information, 511, and the newly developed 511 mobile application for the Interstate 15 (I-15) corridor require being designed, from the start, as robust systems that function 24 hours a day, seven days a week in order to maintain high usage and credibility by the user. To accomplish this, the ITS team develops support plans, best practices, documentation, and administration strategies while the project transitions from implementation to production. Once proper administration tools and practices are applied, the completed project can be supported by a traditional Information Technology department and thus transferred to the appropriate support team within the regional network of partners for day-to-day operations.

C. EMERGING TRANSPORTATION TECHNOLOGIES

Personal technology has changed the landscape in the last five to ten years and has started to significantly deliver the ability to access the 'virtual' office, classroom, and doctor's office to name just a few. Today's world of universal communication and instant access to information paints a picture of what our future holds.

Advances in technology have the potential to lower travel demand by reducing the need to make as many trips to work, school, or medical appointments. Technology can reduce single occupancy car trips; however, there is also the potential that technologies such as the autonomous vehicle could raise the number of overall vehicle trips by increasing access to self-driving cars. On the other hand, technological advances also have the potential to increase the share of trips made by transit, biking, and walking due to better access to real-time information and services such as car/bike-sharing.

Emerging technologies that are under consideration or have already been developed and are in use in whole or part include the following:

- Emerging Vehicle Technologies
- Zero Emission Vehicle Readiness
- Multi-Modal Management
- Smart Parking
- Mobility Hubs

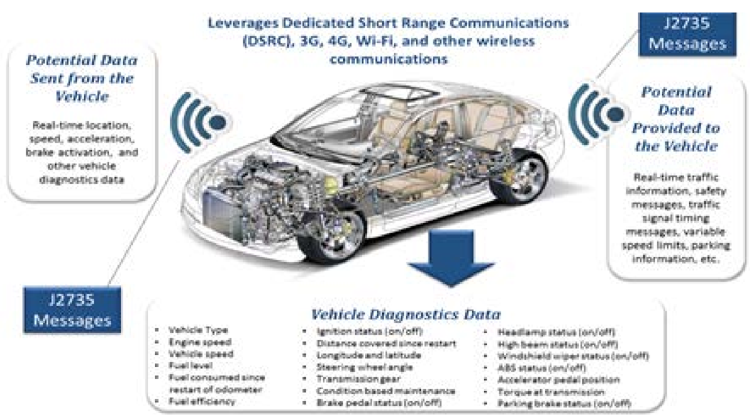
- Unified Transportation Payment
- Other Emerging Technology Trends
- Policies and Investments

D. EMERGING VEHICLE TECHNOLOGIES

Autonomous and Connected Vehicle Technology

One cannot escape the terms "Connected" or "Autonomous" when discussing the future of transportation technologies. Autonomous or Automated Vehicles would operate independently from other vehicles and utilize internal sensors to survey and respond to one's surroundings. Connected Vehicles or vehicles that wirelessly communicate with other connected vehicles and the roadway could operate cooperatively to reduce congestion, decrease fuel consumption and promote increased safety. Ultimately, it is envisioned that fully autonomous vehicles (driverless cars) could replace conventional cars with autonomous cars projected to be available by 2025. It also is projected that autonomous vehicles would reach 50 percent market penetration by 2035, based on current vehicle lifecycle trends. Infrastructure investment to meet this changing vehicle profile could include the development of protected autonomous lanes with barrier separation along with necessary communications network enhancements. Driverless taxis would enable users to request a ride using smartphone applications, without having to search for and walk a great distance to access a vehicle; and such autonomous vehicles enable carsharing companies to seamlessly reposition vehicles to better match demand.

With formal direction now set by the National Highway Traffic Safety Administration (NHTSA) on both *connected* and *autonomous* vehicles, this section of the Emerging Technologies Whitepaper seeks to provide the reader with information used in answering the question "*how real is it?*"



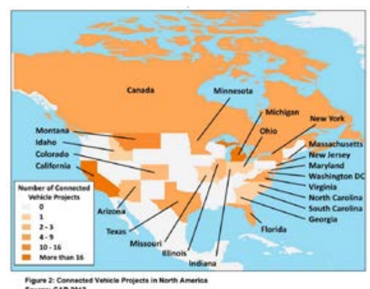
The NHTSA, under the United States Department of Transportation (U.S. DOT), was established by the Highway Safety Act of 1970, as the successor to the National Highway Safety Bureau, to carry out safety programs under the National Traffic and Motor Vehicle Safety Act of 1966 and the Highway Safety Act of 1966. In their announcement confirming that connected vehicles did indeed provide the postulated safety benefits put forward by almost ten years of Research and Development, NHTSA commented that "America is at a historic turning point for automotive travel. Motor vehicles and drivers' relationships with them are likely to change significantly in the next ten to twenty years, perhaps more than they have changed in the last one hundred years. Recent and continuing advances in automotive technology and current research on and testing of exciting vehicle innovations have created completely new possibilities for improving highway safety, increasing environmental benefits, expanding mobility, and creating new economic opportunities for jobs and investment. The United States is on the threshold of a period of dramatic change in the capabilities of, and expectations for, the vehicles we drive. In fact, many are inspired by the vision that the vehicles will do the driving for us.

Although this statement focuses on the enormous safety potential of these new technologies, they offer an even wider range of possible benefits. Vehicle control systems that automatically accelerate and brake with the flow of traffic can conserve fuel more efficiently than the average driver. By eliminating a large number of vehicle crashes, highly effective crash avoidance technologies can reduce fuel consumption by also eliminating the traffic congestion that crashes cause every day on our roads. Reductions in fuel consumption, of course, yield corresponding reductions in greenhouse gas emissions. To the extent vehicles can communicate with each other and with the highway infrastructure, the potential for safer and more efficient driving will be increased even more. Drivers—or vehicles themselves—will be able to make more intelligent route selections based on weather and traffic data received by the vehicle in real time. Mobility for those with a range of disabilities will be greatly enhanced if the basic driving functions can be safely performed by the vehicle itself, opening new windows for millions of people.

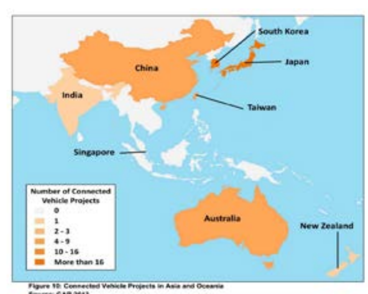
Preventing significant numbers of crashes will, in addition to relieving the enormous emotional toll on families, also greatly reduce the enormous related societal costs—lives lost, hospital stays, days of work missed, and property damage—that total in the hundreds of billions of dollars each year. Moreover, these dramatic changes will offer significant new opportunities for investments in the underlying technologies and employment in the various industries that develop, manufacture, and maintain them." [1]

Definitions

For the remainder of this white paper, a **Connected Vehicle** is defined as a vehicle that has specific wireless communications technology providing additional safety features to both the vehicle and driver; with 360-degree situational awareness to address crash situations – including those, for example, in which a driver needs to decide if it is safe to pass on a two-lane road (potential head-on collision), make a left turn across the path of oncoming traffic, or in which a vehicle approaching at an intersection appears to be on a collision course. In those situations, Vehicle-to-Vehicle (V2V) communications can detect threats hundreds of yards from other vehicles that cannot be seen, often in situations in which on-board sensors alone cannot detect the threat. [2]

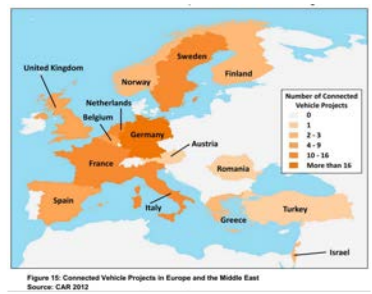


Connected Vehicle Projects in North America[20]



Connected Vehicle Projects in Asia and Oceania[20]

Autonomous Vehicles are those in which at least some aspects of safety-critical control function (e.g., steering, throttle, or braking) occur without direct driver input. Vehicles that provide safety warnings to drivers (forward crash warning, for example) but do not perform a control function are, in this context, not considered automated, even though the technology necessary to provide that warning involves varying degrees of automation (e.g., the necessary data are received and processed, and the warning is given, without driver input). Automated vehicles may use on-board sensors, cameras, global positioning system (GPS), and telecommunications to obtain information in order to make their own judgments regarding safety-critical situations and act appropriately by effectuating control at some level. Accordingly, for purposes of this discussion, vehicles equipped with V2V technology that provide only safety warnings are not automated vehicles, even though such warnings by themselves can have significant safety benefits and can provide very valuable information to augment active on-board safety control technologies. In fact, the realization of the full potential benefits and broad-scale implementation of the highest level of automation may conceivably rely on V2V technology as an important input to ensure that the vehicle has full awareness of its surroundings. [1]



Connected Vehicle Projects in Europe[20]

Current State of these Emerging Technologies

To understand the global nature of the transportation industry, one needs only look at the nations that are currently engaged in connected and autonomous vehicle research. A brief summary of the work being undertaken or completed by the Federal Governments of the United States, European Union, United Kingdom, Japan, Taiwan, Korea, and Australia is provided.

There are multiple Original Equipment Manufacturers (OEM) working together across the continents pictured above to further define the approach for implementing connected and autonomous vehicle programs. One of the earliest examples of these pre-competitive teams can be found in 2005, when the "Crash Avoidance Metrics Partnership" (CAMP) formed as a consortia of seven OEMs, charged with working together to provide input to the U.S. Federal Government on issues from technology to policy. [3]

The SANDAG Board of Directors was informed at the 2014 Board Retreat by Jim Pisz of Toyota that the development timeline for OEMs is between five and seven years. To date, the global automotive industry has completed more than ten calendar years of in-vehicle-development, communications protocol standardization, human factors research, application analysis and testing, and finally field testing of the entire connected technology ecosystem.

To better understand the impetus behind the current national interest in connected and autonomous vehicles, one may look to the remarks made to the "House Committee on Transportation and Infrastructure Subcommittee on Highways and Transit," by the Director of the University of Michigan's "Transportation Research Institute" (UMTRI). UMTRI, located in Ann Arbor, are uniquely positioned to encapsulate the international perspective on connected and autonomous vehicles. They work closely with the "Big Four" OEMs through industry directed grant funding [4]; have recently completed the world's largest field operational test of over 3,000 connected vehicles (funded by the U.S. DOT Research and Innovative Technology Administration [RITA]); and most recently have provided crucial support to the implementation of a "fake city center" in downtown Detroit for the 2014 International World Congress on Intelligent Transportation Systems. Here they will demonstrate the capabilities of multiple manufacturers' autonomous vehicles to over 10,000 transportation professionals from around the globe.

In his submission to the House Committee, the UMTRI Director, Mr. Peter Sweatman, stated that the OEMs continue to work collaboratively with governments, standards bodies, and other OEMs. The desire to do so was driven by the fact that;

"*Historically, the auto industry has focused much of its safety effort on mitigating the impacts of a crash after it happens, and these efforts have been very successful at reducing traffic fatalities and injuries. Significant efforts have also been made to influence driver behavior, but the number of these preventable tragedies each year is still far too high, at approximately 33,000. The next giant leap in reducing the number of fatalities and injuries on our nation's roads is to prevent crashes before they happen.*"[5]

Furthermore, KPMG's 2012 Report on the "Self-Driving Cars: The Next Revolution" expanded on Dr. Sweatman's comments by identifying that an additional benefit of having a National fleet of vehicles capable of avoiding accidents could mean that "*vehicles could also be significantly lighter and more energy efficient than their human-operated counterparts as they no longer need all the heavy safety features, such as reinforced steel bodies, crumple zones and airbags. (A 20% reduction in weight corresponds to a 20 percent increase in efficiency)*."[6]

The Safety Pilot, a $14.9 million dollar Federal Highway Administration's Research and Innovative Technology Administration-funded project executed between 2011 and 2013, was conducted by the University of Michigan Transportation Research Institute. The "Safety Pilot's" stated intention was to aid the NHTSA in its determination of the effectiveness of the safety applications in real-world tests using the general population to provide feedback. The recent regulatory decision announcement, made by the NHTSA [2], indicates that under the highest levels of technical scrutiny, connected vehicle technologies have corroborated their safety benefit hypothesis.

The reader may draw from these very short paragraphs that struggle to do justice to the thousands of smaller steps that took over a decade to perform and demonstrate within the context of a full NHTSA analysis approach that would be used in the determination of whether to proceed with a regulatory recommendation to Congress or merely to add a lesser self-regulation standards guideline to the New Car Assessment Program (NCAP). That NHTSA has made the decision to proceed with the more formal regulation recommendation to Congress was summarized by NHTSA Administrator David Friedman when he stated "Decades from now, it's likely we'll look back at this time period as one in which the historical arc of transportation safety considerably changed for the better, similar to the introduction of standards for seat belts, airbags, and electronic stability control technology."[2]

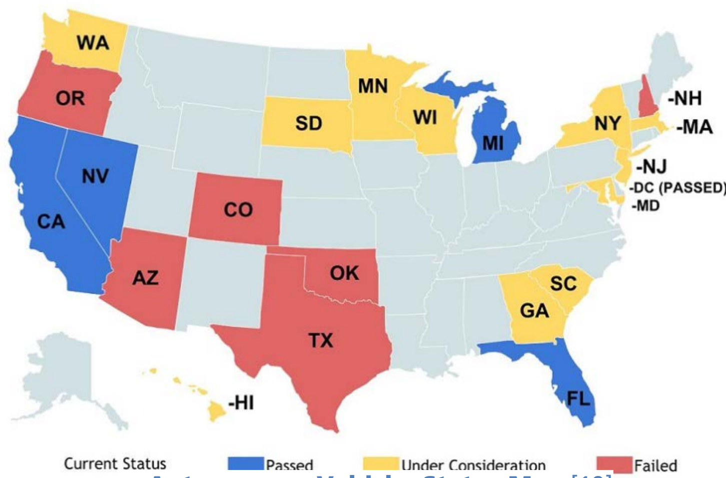
Parallel to the national level "Safety Pilot" test, the Center for Automotive Research (CAR) conducted a scan on international best practices in connected and automated vehicle technologies and has registered 85 entries for Asia, 159 for Europe, and 149 for North America [7]. This report provides a summary of many of the larger projects across both Europe and Asia. Most notable of these is the European Commission-funded CAR2X project, and the scan also found that academic institutions in more than ten states across the nation have either completed or were undertaking additional research regarding particular aspects of the connected vehicle application ecosystem. Although not stated, it is intimated in this report that the federal expansion of the University Transportation Center funding [8], administered from RITA, has had the desired effect of engaging with the next generation of professionals who are likely to engage in a highly connected transportation safety, mobility and the environment vision of the future through ITS "software" to optimize our existing infrastructure.

Following the successful outcomes of the CAMP consortia 'pre-competitive' role to advance the state of transportation, they have now moved on to initiate and complete the work required to take vehicles that are connected and make them autonomous. Their preliminary program of development was recently presented at the SAE 2014 Government/Industry Meeting "Technical Session" (Code: G101)[9]. Based on the work that CAMP has undertaken and successfully completed in connected vehicle technologies, it may be conservatively estimated that similar collaboration and success will be experienced in delivering autonomous vehicle technologies.

Public Acceptance

The advent of the autonomous vehicle is more recent in practicality. Although it could be argued that San Diego is the birthplace of the current connected and autonomous programs, after congress mandated that the "Automated Highway System" test be conducted on San Diego's then fledgling I-15 Reversible Lanes network back in 1997; others would say that the Defense Advanced Research Projects Agency (DARPA) seeded the thoughts of achievability with their "DARPA Grand Challenge" that ran between 2004 and 2007.

An autonomous fleet of vehicles has already been widely demonstrated to hold the promise of better utilizing the capacity of our existing infrastructure. Perhaps not right immediately, but as the 1.9 million vehicles in two to three decades when the penetration rates of these technologies is high enough for technologies such as Cooperative Adaptive Cruise Control [10].



Autonomous Vehicle: Status Map [19]

The SANDAG Board does not stand alone in its interest in delivering safer, more mobile and measurable environmental benefits to the region through the deployment of these two classes of emerging technologies. To date, 23 states have passed or are sitting in consideration of legislation to regulate the "testing" of autonomous vehicles. With the passage of Senate Bill No. 1298 (SB 1298), the California Department of Motor Vehicles (DMV) Vehicle Code was modified thusly "*This bill would authorize the operation of an autonomous vehicle, as defined, on public roads for testing purposes, by a driver who possesses the proper class of license for the type of vehicle being operated if specified requirements are met, including that the driver be seated in the driver's seat, monitoring the safe operation of the autonomous vehicle, and capable of taking over immediate manual control of the autonomous vehicle in the event of an autonomous technology failure or other emergency.*" [11]

The DMV continues to garner public comment on the subject, with SB1298 requiring DMV to adopt regulations no later than January 1, 2015. To date, the DMV has conducted four "public comment" hearings to solicit feedback on the regulatory text. The current regulation addresses many of the insurance requirements, driver requirements, and vehicle requirements. It does however exclude heavy vehicles from testing (e.g., buses, trucks), which may prove to be at odds with the federal program for connected vehicles which is focused on the attributes of professional drivers and regulatory environment as being desirable as first deployable scenarios.

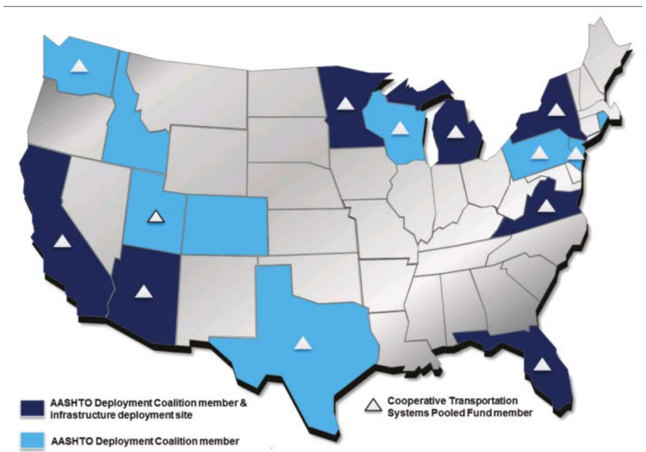
San Diego Regional Discussion

The San Diego region, now in its third decade of recognition as a national and international market leader in the use of ITS solutions to manage traffic congestion, has at times been seen as an incubator for emerging technologies. Our region's cohesiveness at all layers, the Board's commitment to investigate emerging technologies, and our regional partnerships that have delivered results, is nationally recognized. [12]

The discussion above presents a picture of the connected and autonomous technologies that may easily misconstrue the overall program as highly mature, and potentially even full of practice-ready solutions. This is not the case, and people intimately involved recognize the difficulties of the next five to ten years in continuing to mature and ever broadening set of scenarios that must reach automotive grade engineering, and be proven to be practice-ready through the six federally funded "Affiliated Test Bed" sites.

SANDAG recognizes that the pull for this technology will come partly from the bottom up. Traffic engineers who struggle with insufficient detection technologies, built upon 30-year old technology are prone to undervaluing the need to track the performance. [13] This white paper will not serve to provide the level of detail that these bottom-up decision makers will require in the future, but more information on these matters can be found by viewing a partnership between the U.S. DOT's Office of Operations and the American Association of State Highway and Transportation Officials (AASHTO) that seeks to resolve this gap.

The AASHTO "Footprint Analysis" will provide greater insight into the connected vehicle field infrastructure that may be deployed through the development of approximately ten engineering design concepts. These concepts will likely include illustrations of typical deployments at signalized intersections, urban freeways, rural roadways, international border crossings, and other locations intended to provide agencies with a better understanding of the type of systems and equipment that may be implemented. The design concepts will not serve as the plans, or specifications that agencies will ultimately require as they begin actual deployment



State Participants in Connected Vehicle Infrastructure Planning and Deployment [21]

To be completed in October 2015, this will provide a concept for a national connected vehicle field infrastructure footprint that includes:

- Prioritized applications for state and local agencies including the data, communications, security, roadside equipment, and information service needs of each agency
- A set of design concepts and deployment gaps for approximately ten of the highest priority applications, with sufficient engineering detail to describe an operational system
- A range of scenarios that illustrate how different government entities—state, county, or municipal—would approach deployment

- A preliminary national footprint for Connected Vehicle field infrastructure created by expanding the deployment scenarios

- An initial strategy for coordinated, phased deployment based on the scenarios and national footprint, high- lighting interoperability and institutional challenges and opportunities

- A set of deployment cost estimates including equipment, operations and maintenance, and training and staff development

National Affiliated Test Bed Locations

Critical to the maturing of AASHTO's deployment concepts will be the rapid and equal maturing of mobility and the environmental applications. The Federal Highway Administration's Research and Innovative Technology Administration has established two research programs each charged with developing ten high-priority concepts, validating the achievability of these with practitioner input, simulating the application effectiveness in the scenarios detailed in the AASHTO document, and then working with the existing six research institution-based "Affiliated Test Bed" to evaluate the program outcomes in the real-world [14].

These programs are:

- The Dynamic Mobility Applications Program: seeks to identify, develop, and deploy applications that leverage the full potential of connected vehicles, travelers and infrastructure to enhance current operational practices and transform future surface transportation systems management; [15] and

- The Applications for the Environment: Real Time Information Synthesis (AERIS) Program: has the objective to generate and acquire environmentally-relevant real-time transportation data, and use these data to create actionable information that support and facilitate "green" transportation choices by transportation system users and operators.

An important note to capture at this point is that as the global automotive community moves towards a more connected vehicle environment, the future of ITS solutions will also move towards using more transportation software that should be managed as a renewable resource able to provide adaptable strategic solutions.

As such, San Diego businesses found within the "Information Communications and Technology" (ICT) traded cluster [16] could receive a boost. This shift within our region positions ICT to grow significantly as a local transportation technology incubator, as businesses build around the local incumbents already setting the stage to take advantage of this global shift (e.g., "Qualcomm" paid

$3.1 billion in a Merger & Acquisition for Atheros). Atheros owned the rights to the wireless technology that underpins the Connected Vehicle program (namely Dedicated Short Range Communications or DSRC [17]; and "DENSO": one of the world's largest suppliers of advanced automotive technology systems and components, whose North American Research and Development Laboratories are recognized Nationally as a "Connected Vehicle Qualified Product," and their Vice President serves as the Chair of ITS America's "Connected Vehicle Committee"). To date, ICT traded cluster demonstrates significant employment here in the region, and although dropping slightly in the latest SANDAG study, the desirable cluster attributes are seen as delivering a vibrant economy.

Application of Connected Vehicle Technology to Public Transit

The overarching goal of the Transit Connected Vehicle for Mobility program is to improve public transportation by increasing transit productivity, efficiency, and accessibility; mitigating congestion in an integrated transportation environment; and providing travelers with better transportation information and transit services. Transit-oriented connected vehicle mobility applications support dynamic system operations and management, enable a convenient and quality travel experience, and provide an information-rich environment to meet the needs of travelers and system operators across all modes.

The following three mobility applications have been selected by the federal transit administration as high-priority applications and are collectively identified as the Integrated Dynamic Transit Operations "bundle."

- **Connection Protection (T-CONNECT):** Enables public transportation providers and travelers to communicate to improve the probability of successful transit transfers.
- **Dynamic Transit Operations (T-DISP)**: Advances the concept of demand-responsive transportation services utilizing the GPS and mapping capabilities of personal mobile devices to enable a traveler to input a desired destination and time of departure tagged with their current location when requesting transit service.
- **Dynamic Ridesharing (D-RIDE)**: Makes use of in-vehicle and hand-held devices to allow dynamic ride-matching, thereby reducing congestion, pollution, and travel costs to the individual with a low initial investment.

Alternative Fuel Vehicles

Technology advances, market trends, consumer behavior, and government politics could lead to significant changes in California's fuel mix by 2020. Currently, petroleum comprises 92 percent of California's transportation energy sources, but several state policies and regulations to improve vehicle efficiency, reduce petroleum dependence, and expand the use of alternative fuels will alter this landscape. Chart 1 demonstrates how California's

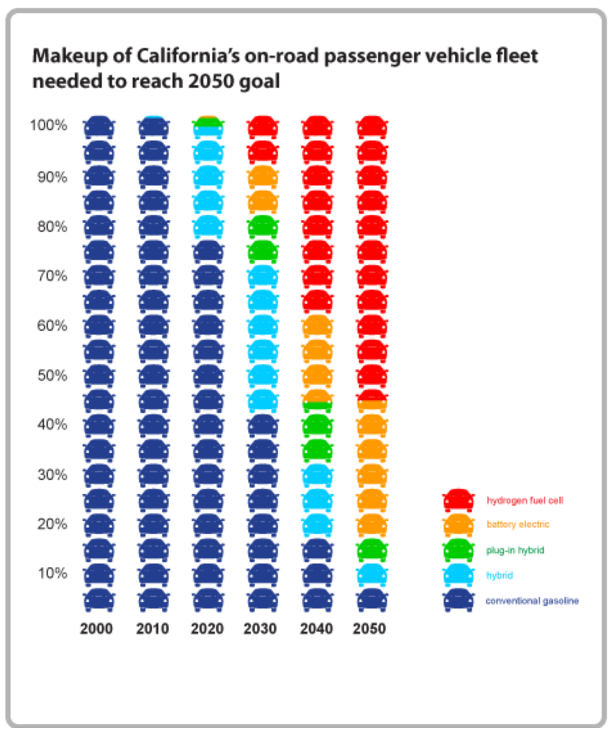


Chart 1. California On-Road Passenger Vehicle Fleet

on-road passenger vehicle fleet is planned to change overtime. The state goal is for 95 percent of vehicles on California roadways to be powered by alternative fuels by 2050. Car, SUV and pick-up drivers will be using vehicles powered from natural gas, electricity, biofuels and hydrogen fuel cells.

Chart 2[1] displays the largest greenhouse gas (GHG) reduction measures identified in the California Air Resources Board (CARB) Assembly Bill 32 Climate Change Scoping Plan. Alternative fuel and high efficiency vehicles are expected to account for 87 percent of the transportation sector's GHG reductions statewide. In order for the state to meet its clean vehicle goals, regional planning and actions are necessary to incorporate alternative fuel infrastructure where little to none exist today.

The deployment of alternative fuel infrastructure (e.g., fueling stations and electric vehicle [EV] chargers) will need to become a consideration when planning the region's transportation network. Recognizing this, the SANDAG Board included several recommended actions in the 2050 Regional Transportation Plan/Sustainable Communities Strategy (2050 RTP/SCS) (adopted in 2011) to begin planning for an increase in alternative fuel vehicles. Specifically, SCS Actions 21, 22 and 24 addressed alternative fuels, the transportation network, and the need for adequate infrastructure.

SCS Action 21 Support planning and infrastructure development for alternative fueling stations and plug-in EV chargers.

SCS Action 22 Develop or facilitate a regional approach to long-term planning for alternative fuel infrastructure that includes the continued development of public-private strategic alliances.

SCS Action 24 Integrate alternative fuel considerations into the development of the regional transportation network by, for example, integrating infrastructure for EV charging into regional park-and-ride lots and transit stations.

Aside from plug-in EVs and chargers, for which the San Diego region is recognized as a national leader, the region currently has very few alternative fuel stations. Currently there are 3 stations that offer biodiesel, 8 with compressed natural gas, 1 providing liquefied natural gas, and 14 with propane in San Diego County.

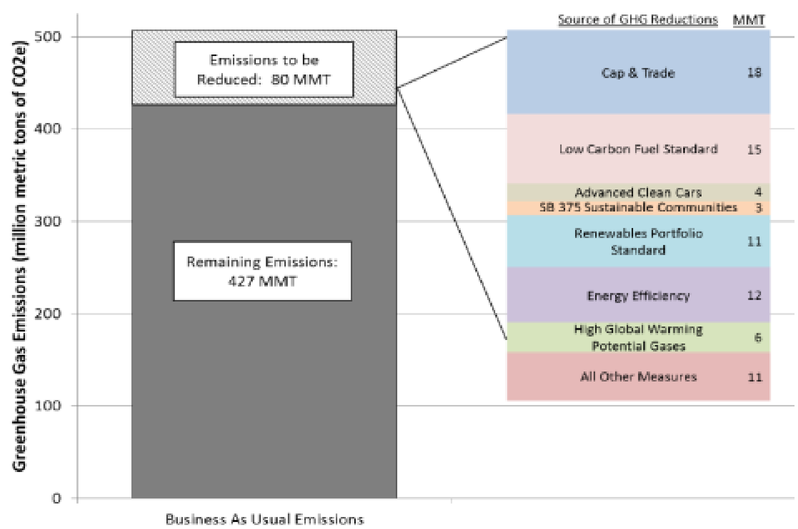


Chart 2. Statewide 2020 Greenhouse Gas Emissions and Sources of GHG Reductions

As automakers offer greater numbers of vehicles powered by a variety of fuels, infrastructure must keep up to enable this market growth. For example, Honda, Toyota, General Motors, Daimler,

[1] Note: The Draft 2013 Scoping Plan Update slightly modifies the GHG reductions associated with the strategies in this chart. It will be updated when CARB releases the revised figure in spring 2014.

Hyundai, and Nissan have stated that they plan to bring hydrogen fuel cell vehicles to market in the 2015-2017 timeframe. Currently there are nine hydrogen fueling stations that are operational and open to the public in California. Support to increase alternative fuel infrastructure in the region would enable local drivers to purchase new and emerging vehicle technologies, receive state rebates, and reduce dependence on petroleum. It also could result in the most significant reduction in GHG emissions from the transportation sector.

Federal Department of Energy grants and California Energy Commission grants are available to offset costs for both alternative fuel vehicles and fueling stations. California's Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP), established in 2007 and reauthorized in 2013, will invest $1.5 billion between 2009 and 2024 to support development and deployment of zero- and low-emission vehicles and low-carbon fuels. Utilization of the ARFVTP can help local businesses, public agencies, and universities receive a fair share of state funding.

E. ZERO EMISSION VEHICLE READINESS

With California investing $1.5 billion between 2009 and 2024 to support development and deployment of zero- and low-emission vehicles and low-carbon fuels, it can be expected that some or all of future autonomous vehicles will be powered by alternative fuels. Although fuel type will have no impact on the autonomous functions of a vehicle, access to fuel will need to be considered for these future cars, trucks and SUVs to utilize the region's roadways.

It is projected that by 2025, there will be 1.5 million zero-emission vehicles (ZEV) on California roads, creating the need for major infrastructure deployment of EV chargers and hydrogen fueling stations. Strategies to support ZEV readiness could include deploying EV charging stations at residential, commercial, public sites, and along highway corridors.

With this in mind, Washington and Oregon have created the "West Coast Electric Highway," a network of DC fast charging stations for PEVs located every 25 to 50 miles along Interstate 5 (I-5). The creators of this concept would like the Electric Highway to span the I-5 from British Columbia through California to Baja California, Mexico.

New and innovative technologies are available today that could address corridor electrification while mitigating impacts to the electric grid, GHG emissions, and economic costs for charger installations and access to adequate power. For instance, there are EV supply equipment options that can be combined with energy storage and solar canopies to create EV charging stations powered completely by the sun.

One design of this combination is having a solar canopy that provides shade for one parking space and enough solar electricity for a Level 2 charger. Another design could utilize a larger solar canopy that provides shade for eight parking spaces and enough electricity for a DC fast charger. Because the batteries are included, these EV chargers can be operated 100 percent off the electric grid and by multiple drivers every day. The San Diego County Regional Airport Authority demonstrated this technology combination in its cell phone lot in November 2013. This type of wireless charging coupled with a renewable power supply and battery storage could be utilized at park-and-rides, rest areas and other readily accessible sites along the region's freeways.

SANDAG's Role

Integrating infrastructure considerations into regional transportation planning, could encourage cohesiveness among regional plans, and provide guidance on high priority locations for infrastructure such as airports, near public transportation, and alongside major routes and freeways.

Through the California Energy Commission's ARFVTP, SANDAG received a $200,000 grant in 2012 to work with local governments and stakeholders to prepare a regional readiness plan for electric vehicles. Subsequently, SANDAG has received a $300,000 grant to expand the EV planning effort and develop a regional readiness plan for all alternative fuels. The San Diego Regional EV Readiness Plan was accepted by the SANDAG Board in January 2014, and the alternative fuel readiness plan is anticipated to be completed in summer 2016.

In addition to alternative fuel planning, SANDAG could partner with local public and/or private stakeholders to bring additional ARFVTP funds to the San Diego region for infrastructure. Electricity, natural gas, propane, biofuels and hydrogen are the fuels automakers are using in next generation vehicles. Planning for this infrastructure will grow in importance as more vehicles are introduced to the market.

Solar Roadways

An area of emerging technology that has developed over the last several years is the concept of utilizing the public ride-of-way for energy generation, storage, and as a distribution system. The concept uses existing transportation right-of-way as a facility to generate energy via wind, solar, or even geo-thermal production. The Federal Highway Administration (FHWA) is leading the research and development on several fronts, including using the actual roadway as a solar array, transmission medium, and storage platform. One such pilot project that is underway at the writing of this paper includes a pilot project that uses solar panels constructed as the road material. These solar roadways collect, store and distribute electricity that can be used for road applications or can be put back into the grid as an offset for future energy consumption.

Although this is a new area of research, the potential benefits could hold promise, up to and including wireless or inductive charging of plug-in electric vehicles. One potential strategy the region could invest in is transit electric vehicles and placing re-charging stations at major transit stops and/or layovers. This would allow the region to test infrastructure charging on a limited or pilot basis, and prove that the concept has merit prior to deploying it on a larger scale for passenger vehicles.

F. MULTI-MODAL SYSTEM MANAGEMENT

It is well known that this region's ground transportation network includes the collection of our freeways, arterials, local roads, transit systems, bike paths, and sidewalks. Although these elements can be identified separately, they are inter-reliant and require a comprehensive management approach to provide the foundation for managing and operating the transportation system as a unified and comprehensive network regardless of modal networks and jurisdictional/institutional boundaries.

Expanding the Regional Communications Network, a high speed inter-governmental data network, will support the San Diego region with defining, designing, and deploying specific projects (tactics).

It will also improve mobility by assessing travel conditions and providing options and feedback to the public. Expanding the Regional Communications Network would:

- Deploy Dedicated Short-Range Communications (DSRC) to support future Vehicle Infrastructure Integration (VII);
- Provide enhanced data collection for regional arterials, bike paths, and pedestrian facilities for performance monitoring; and
- Enhance the California Freeway Performance Measurement System (PeMS) to support both transit and arterial performance.

An emerging technology within Multi-modal System Management is the development and implementation of real-time multi-modal modeling and simulation applications. These applications are designed to simulate and evaluate traffic patterns and multiple/cross jurisdictional operational strategies simultaneously and produce results in minutes. The benefits from this technology include having the ability to forecast traffic patterns and recommend operational changes to minimize delays and congestion. The forecasting and real-time analysis allows transportation system managers to take proactive measures such as: modifying traffic signal timing and ramp meters, providing travelers with enhanced transit information or route information, and travel options during recurring congestion or during incidents; as well as analyzing and developing new transportation system management strategies and multi-modal action plans. Other benefits of Multi-modal System Management include:

- Improve Situational Awareness: Operators will realize a more comprehensive and accurate understanding of underlying operational conditions considering all networks and modes in a corridor or system.
- Enhance Response and Control: Operating agencies within a corridor or system will improve management practices and coordinate decision-making, resulting in enhanced management and response for minimizing congestion levels.
- Better Inform Travelers: Travelers will have actionable multi-modal information resulting in more personally efficient mode, time of trip start, and route decisions.
- Improve Corridor or System Performance: Optimizing networks at the corridor and system level will result in an improvement to multi-modal corridor performance, particularly in high travel demand and/or reduced capacity conditions.
- Establish and develop institutional and organizational commitments for assuring that a corridor or system is managed and operated in a multi-modal performance-based approach.

The region is working to demonstrate the benefits of this concept through the Integrated Corridor Management (ICM) Program. Specifically, under the I-15 ICM project, SANDAG has been working with its local partners (the Cities of San Diego, Poway, Caltrans, Escondido, and the Metropolitan Transit System) to maximize the use of modal networks across the I-15 corridor to improve travel times and corridor reliability. The I-15 ICM project focuses maximizing the operations and management of the I-15 corridor with ramp meters, arterial signals, and the BRT system. This project includes integration of all transportation modal management systems currently used to operate the freeway, arterial, and transit systems along the I-15 Express Lanes corridor. Key benefits expected through the I-15 ICM project include:

- Improved corridor travel times, throughput, and reliability by allowing the implementation of coordinated, multi-agency, and modal response plans

- Improved efficiency of the transportation system by allowing all transportation modes to be managed and operated in a way in which they work together

- Enhanced real-time traveler information to include travel options and modes

- Pro-active management/prevention of congestion impacts by predicting traffic breakdowns and providing coordinated real-time response plans.

The I-I5 ICM project began operations in February of 2014, and its findings and corresponding ICM applications will serve as the foundation for pursuing similar deployments along other regional corridors as part of SANDAG ICM program. Our commitment of an ICM program is a fundamental and core component of our Multi-modal System Management approach.

G. SMART PARKING

The application of the Smart Parking concept is to utilize existing or emerging technologies to deliver a parking inventory management system that provides the ability to disseminate real-time parking availability information to the public, and use such information to maximize the use of parking facilities. This concept can be achieved by collecting, analyzing, and reporting parking data to attain a better understanding of how transit parking facilities are being used as a means for providing enhanced traveler information and for better managing the availability of parking in parking facilities, or particular parking spaces. The concept is a key transportation system management strategy as it places emphasis on better tracking the use of existing transit parking facilities and future transit parking facilities being considered in the San Diego Forward: The Regional Plan, and therefore providing the foundation for developing operational, management, or institutional strategies to best maximize the use and efficiency of such facilities.

The core concept of smart parking is to monitor and collect information about available parking spaces and provide such information to travelers either before they start a trip or at key decisions points along their trip. With such information, travelers can make informed decisions which all revolve around knowing if a parking space is available at a selected destination, including for example, when to start their trip, what transit service route to take, or what travel route to take.

The overall goals of smart parking can include:

- Reduce unnecessary trips for finding a parking space. This can result in time savings to travelers and reduction in fuel consumption. Any reduction in time spent driving around looking for a space can provide benefits in reducing overall transportation emissions.

- Provide travelers with improved traveler information. The ability to provide real-time parking information will supplement readily available transit data including transit route arrival and departure times and thus enhance the convenience and reliability of transit use.

- Improve parking management capabilities through the delivery of actual parking utilization data. Understanding how to maximize the use of existing and future parking infrastructure at a minimum requires the deployment of parking infrastructure monitoring systems. The information collected through such system can be used to assess the demand of the facility and implement parking management strategies that optimize the use of the parking facility.

- Improve financial sustainability of parking operations. The ability to monitor the use of parking demand will provide the ability to gather and assess historical trends on utilization which can serve as background data for development of parking management demand based parking fee business models.

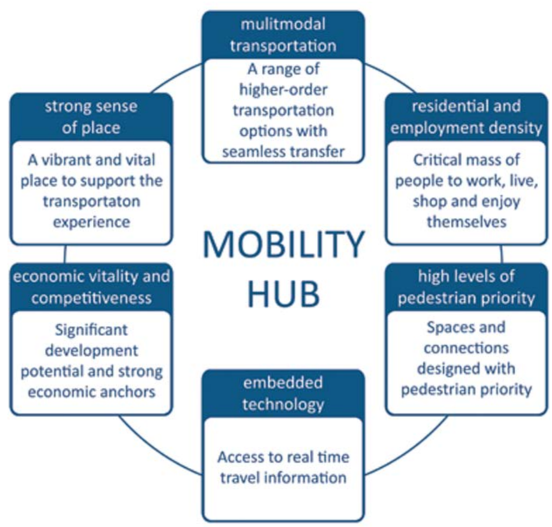
Like all transportation system management strategies, the application of Smart Parking concepts could be considered as part of and logical extension of basic transit station design efforts to assure that the initial infrastructure platform is in place and allow for the next natural step of determining how to best utilize and maximize the use of the region's transportation infrastructure.

H. MOBILITY HUBS

Mobility Hubs are transportation centers located at major transit stations that can provide an integrated suite of mobility options, amenities, and urban design enhancements that bridge the distance between transit and an individual's origin or destination. They can include, but are not limited to, bikeshare, carshare, neighborhood electric vehicles, bike parking and support services, dynamic parking strategies, real-time traveler information, way finding, real-time ridesharing, and improved bicycle and pedestrian connectivity.

The Greater Toronto and Hamilton Area Regional Transportation Plan, "The Big Move," calls mobility hubs much more than a transit station, but a seamless part of the landscape. A strategically located center of activity combining opportunities for work, play, and life that are connected to other centers with key aspects as illustrated in the Mobility Hub graphic below.

Mobility hubs can concentrate transit with first and last mile modes of transportation, integrated into a community which includes retail, shopping, restaurants, and entertainment, all part of a wider connection to service of the region at large through commuter rail, light rail or bus rapid transit.



The Big Move Mobility Hubs

Some of these first / last mile solutions could include shared use vehicles such as bikes, electrified cars, or other single-person conveyances.[2]

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[2] The Big Move, The Regional Transportation Plan of Greater Toronto and Hamilton. 2008, updated 2014, Metrolinx. http://www.metrolinx.com/en/

I. UNIFIED TRANSPORTATION PAYMENT

A unified or universal transportation account combines all forms of public transportation payment including transit fares, municipal parking, and toll collection into a single user-friendly interface. The goal is to influence mode shift from a single occupancy commute to a transit ride by incentivizing the user through the use of rewards, toll discounts, or gamification – a method of challenging the user where points are earned for reach a goal.

This is a single platform that links and coordinates all multi-modal transportation-related activities (parking, tolls, smart cards, transit passes, bank issued IDs, transponders, smartphone, license plates, etc.) in one open payment account system, making for a seamless and convenient commuting experience. Such a platform could facilitate mobility on demand, and reduce the friction that sometimes prevents commuters from periodic use of travel alternatives, thus enabling users to select the mode of travel that best fits their needs for a particular trip, through a convenient and common payment system. The platform could evolve to support the distribution and use of incentives, enabling a user to amass reward credits, based on usage of a particular travel mode (e.g., bikeshare) and used at a later time for a trip on public transit.

A Universal Transportation Account can be at the heart of a connected city concept where the transportation user is in constant connection with the transportation network and is given the best options for traveling based on criteria that are most important to that user whether that is cost, convenience, speed, or environmental impact.

J. CURRENT AND EMERGING TECHNOLOGIES FOR TRANSIT AND ACTIVE TRANSPORTATION

Transit Signal Priority

Transit Signal Priority (TSP) uses GPS along with bus route schedules and real-time performance data to request priority treatment at particular intersections, as necessary. For example, if a transit vehicle is running behind schedule, the TSP system will request priority treatment at equipped intersections to speed up the service. The benefits of TSP include a more reliable transit trip by giving the transit vehicle an extended green light or a truncated red light at the intersection. (Nasar, 2013) [22].

Transit / Pedestrian Collision Warning

Fatal collisions between buses and pedestrians have seen a sharp uptick in the last decade. While the causes for such an increase are varied, one primary source of the trend is the rise of a phenomenon known as "distracted walking," which occurs when pedestrians are distracted from the primary task of walking by such devices as iPods, cell phones, and other forms of electronics.

GPS signals and onboard gyroscopes and accelerometers can be integrated to analyze the bus motion during turning. These sensors together with various sensor technologies such as laser detectors, sound detectors, and conventional cameras, will be evaluated to provide better detection and distance estimation of nearby pedestrians.

Bicycle Assist Technologies

Bicycle assist technologies, such as bike electrification or particular bike-lift systems, could make this alternative mode of transportation more accessible to all populations, and particularly older populations and very young populations, given the hilly terrain of the San Diego region.

Electric bikes include a range of technologies from full-time powered bikes using batteries and electric motors to assistive technologies that can be employed under certain conditions, such as climbing hills. Different than electric bikes, bike-lift systems are seen as measures to make certain streets or roads more accessible to all types of self-powered bicycles. For example, a bike-lift system is installed as part of a steep roadway and the bicyclist attaches their bike to the conveyance for the duration of the lift to make hill-climbing easier. These bicycle assist technologies can help provide greater access to a wide variety of localized land uses, as well as to transit station areas that can help facilitate longer-distance multi-modal trips.

K. OTHER EMERGING TECHNOLOGY TRENDS

This section explores other emerging technologies, technologies that as the transportation planning agency, SANDAG and the region typically do not have responsibility for delivering. However, this category of emerging technologies could have an impact on transportation demand, travel choices, and system accessibility.

Virtual Office

Over the last decade, technologies and tools have advanced to make teleworking a viable reality. Continued advances in communication, virtual reality, and possibly 3D printing will make remote working even more of a reality. A possible future could have teams of workers collaborating in much greater ways beyond sharing files and video conferencing; able to physically interact with objects over distances. Advancements in this area could further reduce travel demand and lessen the need for additional transportation infrastructure.

Parking Guidance

Major advances in parking guidance and parking management systems have been made over the past several years. Valuable time and energy is expended in finding available parking in urban cores. One category of emerging technology combines real-time parking inventory data with personal technology such as smart phones to guide transportation users to available parking. Using sensors, new meters, and real-time park data feeds will help derive efficiencies, reduce time and wasted fuel spent idling or circling city blocks to find an available space. One study has indicated an increase in parking utilization during peak hours and decrease of up to 56 percent vehicle carbon emissions by people that are able to quickly and efficiently locate, reserve, and secure a parking spot.[3]

Traveler Information

Traveler information systems have advanced significantly in the last several years and include real-time and predicative data delivered directly to a user's smart phone or tablet in an easy to read

[3] Source: Park Assist, 2014, http://www.parkassist.com/

format – typical with an interactive map. Emerging technology in this field could have greater depth of information, customized to alert travelers both prior to start of commute or while in route to increase travel reliability and reduce overall congestion. SANDAG completed a Border Wait Times Study and market assessment to identify commercially available ITS technologies capable of automatically measuring, monitoring, and reporting border crossing wait times of commercial vehicles. Strategize and expand on the previous study to deploy ITS technologies that can be used to measure, monitor, and report border wait times at U.S./Mexico border crossings and provide real-time information updates to travelers. Available data could be much more than mode or route choices, and include personal options such as cost, availability, travel times, and energy consumption.

Shared-use Mobility

Shared-use mobility is a convenient alternative for closing first mile/last mile gaps and providing commuters who use alternative transportation with a reliable option to make other trips. The "shared" in shared-use mobility refers to shared ownership of the service or program versus individual ownership (i.e., individual car or bike ownership.) Examples of shared use mobility include carsharing, bikesharing, real-time ridesharing, Transportation Network Companies (like Uber, Lyft, and Sidecar) that provide on-demand ride services that users can request by using smartphone applications, scooter share, shared electric vehicles, and shuttle services.

Personal / Wearable Technology

This emerging technology category has seen significant growth in the last few years with advent of smart phones, tablet computers, and most recently with the Google Glass® project. The increased computing power combined with ever-present high-speed data communication and information is now more than ever delivering readily-available traveler information, virtual or enhanced reality, and services that could impact travel demand. SANDAG and local government role could consist of supporting open data access, promoting telework options, or encouraging development of travel specific applications and programs.

L. POLICIES AND INVESTMENTS

The following are potential policy or investment scenarios that could capitalize on emerging technologies in a manner that reduce travel demand and energy consumption, all while promoting the safety of the transportation network.

Transportation Demand Management

Managed by SANDAG, iCommute is the Transportation Demand Management (TDM) program for the San Diego region. TDM refers to programs and strategies that manage and reduce traffic congestion by encouraging the use of transportation alternatives rather than driving alone, such as walking, biking, taking transit, carpooling, vanpooling, working flexible schedules, and teleworking. These programs reduce overall vehicle miles traveled, make more efficient use of the existing transportation network, and maximize movement of people and goods. An individual traveler's mode choice - be it auto, carpool, vanpool, transit, walking, or biking - is significantly influenced by how communities are designed and developed. Smart growth development can reduce the need for vehicle travel for daily trips, and available parking supply and/or pricing can encourage the use of alternative modes of transportation.

Inclusion of TDM in the local planning and development process offers a broad range of economic, environmental, and public health benefits. TDM:

- *Maximizes returns on infrastructure investments* – TDM reduces the need for new or widened roads, which are costly to construct and maintain. Additionally, TDM is a cost-effective way to build capacity in a community's transportation system by expanding use of alternative modes (carpools, vanpools, transit, biking, walking, and teleworking).

- *Reduces parking demand* – TDM, when incorporated into development, reduces single occupant vehicle (SOV) trips and parking demand, decreasing the cost and burden for jurisdictions and developers to provide more parking capacity.

- *Helps meet environmental and air quality goals* – TDM improves air quality by encouraging commute alternatives to the SOV, which in turn reduces traffic congestion and corresponding vehicle-related emissions. TDM also can help to preserve green space by reducing the amount of land needed for roads and parking facilities, encouraging more efficient land use patterns, and decreasing storm water management costs.

- *Is adaptable and dynamic* – TDM can be customized for specific events, neighborhoods, corridors, worksites, and timeframes. Unlike new infrastructure, TDM programs can easily adapt and respond to economic and population changes

Technology plays a key role in delivering TDM solutions including car and vanpool ride matching software, mode choice driven by traveler information, parking reservation and guidance systems, reservation and payment for shared-use vehicles, just to name a few. As technology continues to grow and evolve, more innovative means of offsetting travel demand can be deployed with less cost and impact as compared to traditional capacity increasing capital infrastructure projects.

Active Transportation

One of the commitments from the 2050 RTP/SCS calls for planning a broad Active Transportation program, including a regional bike network, Safe Routes to School and Safe Routes to Transit. In April 2013, staff presented to the Transportation Committee a proposed framework for this program. The strategy proposed to identify active transportation components associated with SANDAG transit and freeway corridor projects for consideration in the Regional Plan. This approach would help to maximize investments in transit and highway infrastructure, by enhancing safety, and improving bicycle and pedestrian access to transit. The Unconstrained Active Transportation program includes the Regional Bike Plan projects, regional programs, local bike projects, local pedestrian/safety/traffic calming projects, Safe Routes to School, Safe Routes to Transit, and retrofit projects for Safe Routes to Transit and highway interchanges.

Emerging technologies can play a role in promoting Active Transportation including SANDAG complete streets initiatives. This can begin with enhanced detection at the intersection for pedestrians, bicycles, or other forms of non-motorized transportation. Given advanced detection, specialized signal treatments can be added such as queue-jumping for pedestrians or cyclists.

Open Data

In the last several years there has been a concerted effort to move government-developed proprietary management system to an open data platform. The reasoning behind this move is two-fold. First, open data standards promotes competition for transportation technology systems allowing those system to more seamlessly and easily upgrade as those system reach end-of-life. Second, by adopting open-data standards, agencies such as SANDAG move from the application development role into a data management role allowing the private industry to use the wealth of available information to provide robust publically available applications. One good example of this trend is in the General Transit Feed System, developed by Google, which is quickly replacing multiple transit agencies proprietary systems for public time tables publishing allowing third-parties including Google to reach a wider audience all while providing world-class applications.

In January 2014, the Transportation Research Board hosted a transportation open data conference titled "TransportationCamp DC 2014" in hopes of stimulating the development of programs and applications by the private industry for the benefit of the traveling public.

SANDAG and the region could adopt Open Data Principles geared around these concepts which could include the following as provided by the Government Open Data Consortium[4]:

- Data Completeness
- Primary Data from Direct Sources
- Data Timeliness
- Data Accessibility
- Machine Processable Data
- Data Availability
- Non-Proprietary Data
- Data without Licensing

Parking Management Toolbox

The goal of the Parking Management Toolbox is to provide a resource to local jurisdictions that will evaluate the effectiveness of a wide range of parking management strategies for addressing specific challenges in varied community types and special uses. The toolbox will feature a range of case studies that provide best practices for managing parking in a variety of urban and suburban settings. The toolbox will ultimately be developed into an interactive, web-based resource that will assist interested jurisdictions with designing customized parking management strategies.

The draft Parking Management Toolbox is expected to be completed by the summer of 2014 and will delineate the design and structure of a future website that translates the document into an interactive, web-based tool. The web-based tool is expected to be deployed by December 2014.

The toolbox could be leveraged to develop regional and sub-regional parking policies that maximize available locations' utilization. Technology can be used to offer access to available parking and, if payment is part of the transaction, can be managed as part of a universal transportation account.

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