Chapter 7

Systems Management: Making Better Use of What We Have

Chapter Contents

TSM investments enhance today's transportation network and ensure that future improvements realize their full potential.

Transportation Systems Management

Reducing traffic congestion, travel times, and air pollution depend on effectively managing the region's transportation system. Known among regional planners as Transportation Systems Management, or TSM, the effort is a core component of the 2050 Regional Transportation Plan (RTP) and its Sustainable Communities Strategy (SCS). Its goal is to smooth the flow of traffic on streets and highways, eliminate bottlenecks, and enhance public transit. TSM investments, detailed in the 2050 RTP, enhance today's transportation network and ensure that future improvements realize their full potential.

Management of our transportation system depends on implementing several techniques and incorporating advanced technologies, such as metering the flow of traffic onto freeways, coordinating traffic signals, tracking public transit vehicles, and keeping travelers informed – all of which helps keep traffic flowing. Transportation planners also are exploring new strategies that employ cutting-edge technology and innovative operating concepts that expand TSM capabilities.

Our region's transportation agencies are working together to implement two of these innovative concepts, known as Integrated Corridor Management (ICM) and the Connected Vehicle Initiative, formally known as IntelliDrive℠. Both can have a significant impact on improving traffic flows. These and other initiatives will help transportation operators manage the transportation system in real time, can improve safety, are highly cost-effective, and offer the public high value for their tax dollars. By managing our transportation system in real time, operators do not have to rely on pre-established plans that estimate the flow of traffic. Instead, they

can rapidly respond to conditions on the ground at any given time.

The returns or benefits (i.e., in savings from shorter travel times, less fuel consumed, and lower emissions) and improved safety from TSM investments outweigh the costs associated with implementing them. Various studies by the U.S. Department of Transportation (U.S. DOT) and recognized academic and transportation institutions cite TSM benefit-cost ratios ranging from 5:1 to as high as 40:1. Adopting plans to explore and implement TSM solutions will improve the productivity of the region's roadways, highways and transit systems in a cost effective manner.

Intelligent Transportation Systems Strategic Plan

SANDAG has been working on updating the Regional Intelligent Transportation Systems (ITS) Strategic Plan with a ten-year forward look at developing and implementing new technology strategies for TSM. Whereas the 2050 RTP has a 40-year horizon, the ITS Strategic Plan looks at a shorter horizon and focuses on system improvements in the coming decade.

The ITS Strategic Plan was developed through the active participation of the regional stakeholders, including the 18 cities, the County of San Diego, Caltrans District 11, the Metropolitan Transit System, and the North County Transit District. The Plan documents the region's priorities for TSM investments and measures for evaluating the value of ITS projects.

The TSM Chapter of the 2050 RTP was developed with outputs from the ITS Strategic Plan, which are reflected in the following discussion of TSM investments areas. The ITS Strategic Plan describes the work plan for the first ten years of the RTP's 40-year horizon and is included as Technical Appendix 21 of the 2050 RTP.

TSM Investment Areas

A diverse range of investments is needed to best manage the region's transportation system. The objectives of the overall investment strategy are to:

- Emphasize management approaches based on the performance of multiple modes of transportation
- Continue providing travelers information as a means to manage demand and provide choices for travel on the transportation system
- Leverage existing management tools and electronic payment systems for multiple modes of transportation
- Actively explore, evaluate, and implement advanced technologies that can benefit the transportation system

These objectives have been applied across six program areas. Some investments, although identified for a particular mode of transportation, do not necessarily limit the benefits to that particular mode. Investments in pervasive technologies, such as real-time modeling, detection devices, and the Connected Vehicle Initiative, have universal benefits that support solutions across different modes and transportation networks.

Multimodal Integration and Performance-Based Management

As reflected in the TSM investment objectives, an important strategy to maximize the efficiency of the existing system is to cohesively manage all modes of transportation. Our region's ground transportation network is comprised of freeways, roads, and the public transit system. These elements can be identified separately, but they are interdependent and must be managed comprehensively to achieve regional mobility and reliability goals.

Improving mobility requires strategies that give the public reliable choices for travel across the transportation network. These strategies also help balance regional priorities for managing our transportation system and the everyday demands on it. This approach, known as Integrated Performance Management (IPM), relies on the incorporation of a number of ITS and operational initiatives. The application of IPM

provides the foundation for managing the entire transportation system based on its overall performance.

Effective integrated performance management relies on the following:

- The application and deployment of performance monitoring tools
- The application of advanced technologies for detection and modeling
- Connections between the management systems for local roads, highways and public transit
- Common and unified transportation policies and procedures

The region is working to demonstrate the benefits of an IPM strategy through the ICM initiative, sponsored by the U.S. DOT. The ICM pilot program focuses on maximizing the management capabilities and efficiency within the I-15 corridor by:

- Managing the flow of traffic onto the interstate (also known as ramp metering)
- Coordinating traffic signals on local streets and freeway interchanges to reduce travel times
- Utilizing managed lanes and congestion pricing to match capacity with demand
- Providing real-time traveler information to promote choices
- Enhancing the Bus Rapid Transit (BRT) system to reduce transit trip times

The I-15 ICM project also includes defining and establishing the institutional commitments to ensure that the corridor is managed and operated based on the combined performance of local roads, I-15, and transit services.

The ICM project has the following objectives:

- Improved Situational Awareness: Operators will have a more comprehensive and accurate understanding of the underlying operational conditions of all transportation networks in the corridor.
- Enhanced Response and Control: Operating agencies within the corridor will work together to improve their management practices and coordinate decision-making, resulting in more effective responses to changing conditions.
- Better Informed Travelers: Travelers will have information they can act on for multiple choices of travel. This will empower them to take more control of their travel decisions, including when to begin a trip and what route to take.
- Improved Corridor Performance: Managing all modes of transportation will improve the overall performance of the corridor, particularly during peak travel times and also when corridor capacity is reduced (e.g., after a traffic accident or during construction).
- All these efforts help reduce congestion and travel times during daily commutes, special events, and emergencies. Achieving these results in other corridors will depend on continued investments in TSM tools. Monitoring the network and performing real-time analysis, with the capability of coordinating traffic across arterials, freeways, and public transit, will help maximize the efficiency of our region's existing transportation system

Performance Monitoring

The collection and analysis of transportation data continues to play a critical role in assessing the performance of the transportation system, changing management tactics, and estimating the benefits of future investments. Limited funding and obstacles to obtaining right of way make building new transportation infrastructure difficult. Greater focus must be placed on using tools that manage traffic flows in real time, in order to better manage traffic conditions.

Mitigating traffic congestion requires sophisticated transportation management software that collects, analyzes, and manages large amounts of real-time information. Real-time data has been used to manage ramp meters, as well as for timing traffic signals on local roadways. These systems dynamically adjust to improve traffic flow based on current conditions. Wider use of these tactics will make the region's entire transportation system more efficient.

SANDAG has identified the following principles of an effective performance monitoring program.

- Data collection, analysis, and management should be automated, uniform year-to-year, and regularly reported to decision-makers and the public.
- The transportation system is multi-faceted and measuring its performance should consider its full complexity, including freeway on-ramps, freeway connectors, principal arterials, public transit, and other features.
- The availability and accuracy of data are critical to operational decisions.
- Periodic public surveys should be conducted to augment automated data.

Several efforts are underway to monitor the performance of our region's transportation system. They include:

- Major Streets and Roads: SANDAG coordinates the annual collection of average daily traffic volumes from Caltrans and from local jurisdictions.

- Freeway System: For most freeways, traffic volumes and speed data are automatically collected by Caltrans through loop detectors embedded under the pavement, as well as through other non-intrusive technologies. About 65 percent of the urban freeway system is automatically monitored by detectors located near freeway on ramps. SANDAG is working to increase this coverage and address data collection needs for connections between freeways and from on/off ramps.

- Transit Service: The Regional Transit Management System (RTMS) is a sophisticated management tool that monitors the performance, in real time, of more than 50 percent of the region's fixed route bus services. The transit operators also use the region's automated fare collection system, known as Compass, to collect data on ridership and payment activities. As these systems are expanded, the region's public transit operators will be able to use them to better manage services and deliver real-time information to customers (e.g., bus speed, mileage, and hours of service).

- Multimodal Performance Measurement System (PeMS): In cooperation with Caltrans, SANDAG is working to enhance the statewide PeMS tool to include real-time data and reporting for arterials and public transit. Historically, PeMS has provided freeway data and performance measures, such as travel times, traffic volumes, and speeds. SANDAG is developing new modules that will provide similar performance statistics for arterials and public transit by incorporating detection data from local streets and real-time performance and passenger count data from public transit vehicles. The completion of the arterial and transit modules will serve as the platform for making PeMS a system for reporting door-to-door travel times, and providing an arterial and corridor-wide performance monitoring framework.

- Transportation Performance Monitoring Reports: SANDAG is involved in several performance monitoring efforts to document, report, and communicate the effectiveness of transportation projects. These efforts include the State of the Commute Report, the *TransNet* Independent Taxpayer Oversight Quarterly Corridor Performance Report, and the RCP Performance Monitoring Report.

Real-Time Modeling/Simulation

Managing our transportation system in real time requires the ability to rapidly analyze data on its current performance and to evaluate solutions to minimize traffic congestion. The ICM project in the San Diego region has this ability. It relies on advancements in processing power, sophisticated algorithms, and the development of software applications that provide real-time multimodal modeling and simulation capabilities. This state-of-the-art solution extrapolates historical data and combines it with real-time data to develop dynamic Decision Support Systems (DSS).

These DSS systems are used to forecast traffic patterns, and then analyze and recommend operational changes to minimize or reduce traffic congestion. This technology allows transportation system managers to modify traffic signal timing and ramp meters; provide travelers with route information and options during recurring congestion or incidents; and

analyze and develop new TSM strategies and action plans.

Initial transportation models show that performance-based management approaches, such as ICM, which integrate freeways, arterials, and public transit, can produce benefit-cost ratios ranging from 7:1 to 25:1. The ICM project for the I-15 corridor is expected to significantly improve peak period road conditions, according to modeling. Projected improvements include a savings of 350,000 person-hours of travel time, an 11 percent increase in reliability for expected travel times along the corridor, and annual reductions of more than 3,000 tons of emissions.

Traveler Information

Keeping travelers informed about road conditions is an important part of reducing traffic congestion and improving safety. Informed travelers can help make the transportation system work better by making more intelligent decisions about when and how to travel. This is especially true during accidents and other incidents. Continued investments in improving traveler information, by making it more accessible through new devices and increasing usability through richer trip planning, will help our region meet the mobility and reliability goals of the 2050 RTP.

From the start of their day, commuters begin deciding how they will travel. They check the weather, listen to news reports, and think about where they need to be and when they need to be there. All of this plays into their final decisions about whether to drive, carpool, or take public transit; what routes to take, and when to leave. Our region's efforts to keep commuters informed empowers them to make intelligent decisions about when and how to travel.

The San Diego Regional 511 program and other traveler information efforts offer commuters real-time information on highway speeds, incidents, travel times, and transit arrival times. San Diego 511 is a central source of regional travel information for a variety of programs, including Compass Card, FasTrak®, iCommute, Roadside Assistance, and public transit. San Diego 511 disseminates information by phone, the internet and on TV. As improvements are made to our region's transportation network through investments in public transit and the expansion of carpool and high occupancy toll lanes, keeping travelers informed of their options will help them plan their trips most efficiently. Travelers, for example, may get information on options to drive to a public transit or rideshare stop during their commute. Information about comparative travel times and the environmental consequences of their travel choices will be available by telephone, the Web, and newer devices such as in-vehicle computers, after-market navigation systems, and smart phone apps.

Transportation System Management initiatives such as ICM and Connected Vehicle will improve the quality, usefulness, and delivery of information to travelers. These initiatives eventually will allow travelers to manage their trips better by, among other things, adjusting their travel speed to avoid red lights and prevent traffic jams. Keeping travelers informed will require more outreach and marketing campaigns in which private industry can play a role. This will help to keep travelers up-to-date as their demand grows for information and new business models are needed to support costs.

Arterial Management

Managing arterial roadways (major streets) can reduce delays and result in quicker trips and lower emissions. Investments in this area have been limited in the past because initiatives to measure and manage the performance of arterial roadways were not cost-effective. However, recent advances in wireless technology are making new investments in collecting traffic data along arterial roadways more economical.

Improving the flow of traffic on arterial roadways is among the most cost-effective strategies for reducing stop-and-go traffic, cutting overall travel times, and lowering fuel consumption and pollution.

Expanding these technologies for the Regional Arterial Network System will help improve the region's traffic signal systems. Improvements to arterial detection and signal interconnect will provide the ability to create a traffic signal system that is dynamic and coordinated throughout the region. This enhanced system will help improve the flow of traffic to and from freeways, and the overall effort will help support the mobility, reliability, and system preservation goals of the 2050 RTP.

Improving the flow of traffic on arterial roadways is among the most cost-effective TSM strategies for reducing stop-and-go traffic, cutting overall travel times, and lowering fuel consumption and pollution. The benefit-cost ratios of adopting strategies to better manage arterial roadways have ranged from 17:1 to 40:1, according to national studies. In the San Diego region, initiatives to synchronize traffic lights near I-805 resulted in a benefit-cost ratio of 11:1. They led to about 154,000 fewer hours of delay annually (a 14 percent decrease), about 5.4 million fewer stops annually (a 6 percent decrease), and 149,000 fewer gallons of fuel consumed per year (a 6 percent decrease). Similar results have been demonstrated across the country for other projects, including the optimization of 700 intersections in the Tysons Corner area of Northern Virginia, where the number of hours of delay was reduced by about 22 percent and stops were reduced by about 6 percent.

Improved data collection, analysis, and management for arterials promote a more comprehensive understanding of how traffic can be better managed across arterials and in conjunction with freeways. Past efforts to re-time traffic signals depended heavily on manual data collection, limiting the ability to easily update timing plans for changes in traffic. The results were timing plans that were soon out of date. Technology used today allows operators to re-time traffic signals more frequently, and even adjust them to accommodate real-time traffic conditions. This newer technology also can help operators coordinate the timing of traffic signals on arterials with the flow of traffic to and from freeways.

The Connected Vehicle platform, discussed later in the Emerging Technologies section of this chapter, is another advanced technology that will further improve the management of arterial roadways. Connected Vehicle promotes strategies such as "Eco Driving," which calculates the optimum speed a driver should use in order to avoid stopping at red lights. This could result in reduced traffic congestion, and lower emissions for arterial roadways.

Investing in arterial TSM solutions, which includes the deployment of Connected Vehicle devices along 2,000 miles of arterial roadways, will improve the ability of operators to monitor performance and better manage the flow of traffic along major streets as well as to and from freeways.

Freeway Management

The freeway system is the backbone of our regional transportation network, and continued TSM investments will help to minimize congestion and reduce bottlenecks. Our region has been progressive in deploying and using various tools to better manage freeway traffic flows. They include traffic detection technologies, closed-circuit television (CCTV) cameras, ramp meters, electronic message signs, and the Advanced Transportation Management System (ATMS), which provides central monitoring and sign control for managing incidents. These tools need to be built upon and improved to better manage our transportation system.

Traffic operators at Caltrans District 11 monitor traffic conditions, post information on highway signs, and coordinate with first responders – a commonly-practiced strategy to effectively manage the freeway system. Other regions that employ an ATMS show decreases in crashes, delays, and response times during incidents. In Espola, New Mexico, a traffic management system deployed for NM-68 resulted in a 27.5 percent decrease in the number of crashes, as well as an 87.5 percent reduction in vehicle delays. In Georgia, the NaviGAtor incident management program reduced the duration of an average incident from 67 minutes to 21 minutes. The result was 7.25 million fewer vehicle hours of delay over one year.

About 65 percent of the urban freeway system in the San Diego region is automatically monitored by detectors located near freeway on-ramps. Increased geographical coverage and additional spot detection technology at freeway connectors, off-ramps, and other locations are needed to improve the ability of operators to monitor freeway traffic and better manage the system. Ramp metering is a highly effective tool that reduces congestion. Our region has a significant number of metered ramps, but the technology is coordinated only with the freeway segment closest to the ramp. Optimizing the flow of freeway traffic requires a broader view that considers upstream and downstream flows, as well as the traffic exiting and entering the freeway from

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Our region has successfully implemented sophisticated management systems for bus and Trolley operations.

arterials. Future ATMS investments will seek to complete a Universal Ramp Metering System that provides operators with the ability to dynamically adjust ramp metering rates to match specific traffic conditions. These ATMS enhancements will help operators better manage connections between arterial roadways and freeways, making both more efficient.

Advising drivers of downstream traffic conditions is a valuable TSM tactic that traditionally is provided through electronic message signs. These signs provide real-time information along critical sections of the freeway network, so that travelers can be advised of current conditions, and make decisions to modify their route or mode of travel. Documented benefits include decreases in crashes where the signs were used to alert drivers of work zones, and decreases in secondary incidents where drivers are advised of an accident or congestion ahead. Some driver frustration also was reduced when travel time or incident information was displayed along a particular route.

Roadway signs and newer technologies, such as smart phones and the Connected Vehicle can improve the timely delivery of this information and incorporate information about the time that drivers can save by taking public transit or carpooling.

Similar to its application on arterials, Connected Vehicle technology can help make traffic flow smoother along freeways by increasing safety and providing drivers with information such as a recommended speed. The Connected Vehicle initiative includes existing underlying technologies to support driving in narrow lanes, safely reduce the distance between vehicles, deliver relevant information to drivers, allow for paying roadway or parking tolls without a transponder, and provides enhanced data collection. All of these aspects will play a significant role in reducing congestion and lowering emissions.

Another innovative TSM concept that will aid the region's mobility and environmental goals is called Active Transportation and Demand Management (ATDM). This concept applies additional management controls to freeway traffic flows by using electronic signs to introduce variable speed limits and dynamic lane usage. These tactics can smooth the flow of traffic and reduce bottlenecks during peak periods or incidents and provide additional capacity through the use of part-time shoulders.

The Freeway Service Patrol (FSP), which provides roadside assistance to stranded motorists during periods of peak traffic congestion, is a more traditional TSM program that mitigates traffic impacts. FSP focuses on quickly removing disabled vehicles from the freeway when traffic can be at its worst. Reducing the distractions and slowdowns caused by disabled vehicles

provides a significant and cost-effective benefit for mobility and safety.

Transit Management – Bus and Rail

Transit management systems help ensure that bus and rail lines are safe and performing optimally. The public transit industry has long used performance-based management techniques. They rely on a variety of rudimentary and sophisticated systems to monitor rubber tire and steel wheel fleet vehicles. These systems also play a critical role in monitoring the safety of public transit drivers and customers, and the system as a whole, through tracking solutions and dedicated voice and data communications.

Our region continues to explore new ways to improve the operation, convenience, and safety of the public transit system. The future application of technologies, such as wireless detection systems, that specifically can identify buses and rail vehicles, real-time simulation software that can predict travel times and passenger loads, and broad solutions such as Connected Vehicle all should be examined for potential benefits.

Our region has successfully implemented sophisticated management systems for bus and Trolley operations, which allow operators to monitor performance and safety and provide customers with real-time information. These systems are essential to the operations of public transit, and future investments will pay for upgrades, life-cycle replacements, and the introduction of new technology. Past investments also include completing the Trolley fiber communications and security network, which supports the management system; CCTV; customer information; and fare collection systems.

Our region's management systems for bus and rail operations allow public transit managers to develop coordinated service schedules; monitor the adherence to schedules; manage duty rosters; and, in the case of light rail, monitor and control critical wayside elements as well as life and safety systems. Investing in the management of public transit covers four key systems. These include the Regional Scheduling System (RSS), which provides tools for maximizing resources for both bus and rail; the Regional Transit Management System (RTMS), which provides automated dispatching and vehicle tracking for buses; Positive Train Control (PTC), which implements automated safety controls for heavy rail services; and the Centralized Train Control System (CTC), which provides a critical safety system for light rail operations. Each of these transit investment areas are discussed further in the following sections.

Regional Scheduling System (RSS)

The RSS helps public transit operators maximize human resources and minimize the need for additional vehicles by efficiently combining bus routes and rail lines with available resources. The RSS also is used to schedule the correct number of personnel, the frequency of buses, and the configuration of trains to meet expected demands. The system also allows transit operators to perform "what-if" scenarios, to compare proposed system changes and then measure the expected outcome of each scenario.

Regional Transit Management System (RTMS)

The RTMS provides public transit agencies with the ability to track buses via the Global Positioning System (GPS). This enables transit managers to measure on-time performance along routes and for individual buses, and therefore better plan bus service, particularly during periods of peak demand. The RTMS has been integrated with the San Diego 511

regional traveler information service enabling patrons to request real-time information on the departure time of buses at stops along a particular transit route. The RTMS helps improve the reliability of bus schedules by automatically tracking vehicles and directing service changes in real time.

The Regional Transit Management System helps improve the reliability of bus schedules by automatically tracking vehicles and directing service changes in real time.

The RTMS also enables transit signal priority, allowing buses to automatically communicate with traffic signals and request priority treatment in the form of shortened red or extended green signals. This priority treatment provides significant benefit to transit operations by reducing transit trip times and improving schedule reliability.

The region is working to expand the RTMS to include contract and suburban routes in the eastern and southern parts of the county. The inclusion of all fixed route buses in the region will enhance performance monitoring and broaden the availability of real-time traveler information to all transit patrons through 511, and increased deployment of electronic message signs at bus stops.

Positive Train Control (PTC)

In October 2008, the President signed the Rail Safety Improvement Act of 2008 into law. The Act clarifies that the mission of the Federal Railroad Administration is to ensure that rail safety is the highest priority. This new law requires all Class I railroads and intercity passenger and commuter railroads to implement a positive train control (PTC) system by December 31, 2015.

A PTC system, as defined in the new law, must prevent train-to-train collisions due to:

- over-speed derailments
- unauthorized incursions by trains into established work zones
- the movement of a train caused by a switch left in the wrong position

The PTC system meets these requirements by using digital communications and GPS technology to monitor train locations and speeds.

The system integrates with the railroad dispatching system, communicating with PTC equipment on the right of way and onboard each train. A train's speed and performance is therefore monitored in real-time. If an engineer fails to operate the train within defined safety parameters in connection with a wayside signal, a speed restriction, maintenance work zones, or a switch position, the PTC system proactively brings the train to a stop before an unsafe condition materializes.

Centralized Train Control (CTC)

The Trolley CTC system delivers many of the same tools for the rail system that the RTMS delivers for bus operations. The tools include on-time performance and vehicle tracking throughout the system. The CTC system monitors train movement, block signaling, and system functionality around the clock. The system monitors and maintains remote control of traction power substations, which electrify the overhead catenary system. The CTC system also integrates tools for CCTV, public announcements, traveler information systems, and critical life-safety monitoring and control systems installed in tunnels and along other segments of the rail system.

Electronic Payment Services

Electronic Payment Services and Systems is a growing investment area in TSM, due to the development of advanced applications such as transit smartcard systems and open road tolling. Both applications make collecting payments for services quicker and more efficient. Electronic Payment Systems also

create opportunities for innovative pricing models. When combined with applications for parking, they can be used to create a Universal Transportation Account (UTA). This type of unified account can help motivate travelers to use the transportation system more efficiently. For example, discounts for parking can be offered when the traveler uses public transit.

The SANDAG Electronic Payment Services area includes three programs: Compass Card for paying transit fares; FasTrak® for tolling; and "Smart Parking," the region's research effort into future applications for parking management and payment. The sections below detail each of these programs and highlight the SANDAG vision for the future in Electronic Payment.

Compass Card

Our region's automated fare collection system, dubbed "Compass Card," was developed and deployed in cooperation with the two regional transit agencies: the North County Transit District (NCTD) and the Metropolitan Transit System (MTS). The Compass Card is a contactless smart card configured to hold transit products such as monthly passes and stored value (i.e., "electronic cash") that can be used to pay fares on a bus or at rail ticket vending machines.

The Compass Card system is used on all urban buses and rail lines in the county. It is fast and easy to use. With a quick "Tap and Ride®," transit users have access to all types of public transportation. It is convenient to use and re-load, with multiple options for purchasing products at agency-operated transit stores, third-party outlets, by phone, and on a secure Web site. Customers also can protect the balances on their cards by obtaining optional "balance protection." The service allows them to receive a replacement card, with the value

or pass restored, if their original card is lost or stolen.

The Compass Card system also provides transit operators with better information about ridership and for analyzing fares. For example, knowing how many transfers a rider makes on his or her way to a destination is crucial to delivering services where they are needed most. The Compass Card system gives operators that capability. The Compass Card system also allows transit agencies to quickly adapt fare structures to meet market conditions. It delivers additional flexibility and agility so agencies can develop and deliver new transit products. The 30-day rolling pass, for example, gives users the flexibility to purchase a pass on their schedule, and not necessarily on the first of the month.

With a quick "Tap and Ride®," transit users have access to all types of public transportation.

FasTrak® - Open Road Tolling

The San Diego region is recognized worldwide for introducing dynamic pricing on high occupancy toll (HOT) lanes on I-15. As a TSM solution, applying open road tolling and HOT lanes balances demand through a performance-based management approach. SANDAG manages this innovative solution through its FasTrak® program.

Regional commuters pay a fee, or toll, through their FasTrak® account to use the I-15 Managed Lanes and State Route 125 (SR 125). Costs vary, from congestion pricing used on I-15 to manage traffic volumes to traditional tolling on SR 125.

Electronic parking systems apply advanced technologies to deliver real-time information about the availability of parking for a particular location or a particular space within a parking facility.

The tolling system maintains customer information, tracks their use of toll roads, and deducts payments from the customer's prepaid account. This is achieved by using transponder Radio Frequency (RF) technology. By using a transponder, customers are able to make toll payments at highway speeds without stopping, eliminating the bottlenecks associated with manually collecting cash at toll booths. The investments made in the I-15 Express Lanes project and the SANDAG FasTrak® program will continue as vital TSM solutions for current and future HOT lanes, in addition to traditional toll facilities. These technologies also can be used to pay for parking and other transportation services.

Smart Parking Systems

Parking continues to grow as an issue in policy discussions about the regional transportation system, in part because there is limited capacity for parking at public transit facilities. Our region needs new ways to monitor how parking facilities are being used, as well as new ways to inform travelers about parking and how to pay for it. Advances in wireless detection technology, meanwhile, have made deploying parking management systems more economical. SANDAG is working with NCTD to pilot the technical, operational, and policy aspects of Smart Parking solutions.

Electronic parking systems apply advanced technologies to deliver real-time information about the availability of parking for a particular location or a particular space within a parking facility. Management information and tools such as pricing are then incorporated. These systems are used to optimize the use of existing parking infrastructure, and to improve the management of supply and demand for parking.

Smart Parking systems have been implemented in the San Francisco Bay Area, in Europe, and in Japanese cities as management tools to more efficiently use parking capacity at transit stations. These systems provide convenient and reliable information and access to transit parking facilities. Providing this type of service helps make transit more competitive than driving alone, research shows.

The continued study and deployment of smart parking management could be further leveraged in coordination with FasTrak® and/or Compass Card to enable SANDAG to explore coordinated pricing for users.

Advanced Technologies

The application of ever improving technology has the ability to help our region achieve its mobility goals, reducing congestion and emissions. Used wisely, technology can increase capacity and maximize the efficiency, utilization, and safety of our current transportation system. Maximizing the potential of TSM requires ongoing research into technologies that improve management capabilities, system operations, and safety. There can be some risks and additional costs in deploying new technologies, but the latest developments warrant a close look to see what they have to offer the San Diego region.

The list of new technologies is extensive, but those available to SANDAG that can have a direct and immediate benefit or bring transformative change to transportation systems management are fairly limited. Still, they are significant. Three technologies in particular have the potential to improve our region's efforts to better manage the transportation system: wireless sensors and detection, real-time modeling and simulation, and the Connected Vehicle initiative. Respectively, these technologies improve performance monitoring and planning information; provide capabilities for proactive management based on predictive data; and introduce a completely new platform for safety, mobility, and environmentally-focused applications.

Wireless Detection

Expanding our region's detection system is a key goal in the effort to improve how the region monitors the performance of our transportation system. Data gathered using a comprehensive sensor and detection program provides a better understanding of how the transportation system is performing. This understanding can then be used to determine which transportation investments can provide the greatest benefits to promote greater mobility. The information also will provide system operators with the data they need to design strategies for better managing the transportation system.

Advances in wireless technology have made comprehensive performance monitoring systems more feasible. The proliferation of wireless technology has resulted in the advent of low-cost sensors and detectors that serve as replacements for traditional methods of collecting data, such as in-pavement loops. The new wave of devices reduces the cost, time, and infrastructure needed to collect data for measuring the performance of transportation systems.

The information captured through this technology helps operators manage and attain an understanding of operational conditions across the transportation system, including along arterial roadways, at parking facilities, and along transit routes and bikeways. The expansion of this technology has given operators the ability to attain a more complete picture of regional and multimodal travel patterns, and to predict volume and speed flows as traffic moves from streets to highways and vice-versa. Improved data, and the expansion of data coverage, also provide the public with a more complete picture.

There are many monitoring systems available, each with its own strengths. Detection technologies that use loops, video, and infra-red sensors are being used in transportation. Wireless solutions involving anonymous probe data using cell phones or Bluetooth devices are in their infancy, but they have gained significant momentum. The benefits and costs associated with implementing each technology should be justified, based on the specific application or project.

Variation between the systems ranges from data quality or accuracy levels to long-term maintenance costs. The level of granularity available from fixed devices exceeds that of probe data because of the lane-level precision that can be gained and because of the number of measurements that are captured. This level of information is needed for systems management, but it may exceed what is needed purely for travelers.

Similar technologies also may help in monitoring emissions. Advances in detection technology are being pursued to determine and directly monitor emissions reductions, as well as other improvements. Using knowledge gained from initiatives such as the "Transportation Air Quality & Congestion

Evaluation" (TRACE) project from the State of Florida's Department of Transportation, advances are being made in small, portable air quality monitors. These air quality monitors, measuring various levels of contaminants that have been identified as contributing to greenhouse gas emissions (e.g. CO, NO, NOx, NO2, PM), are tracked before and after a project's implementation. Therefore, a baseline is established and a tangible measurement of the project benefits is made. These sensors are now economical enough to procure and deploy in sufficient numbers at TSM project sites.

It is important to note that regardless of the various types of technologies available, the overall goal is to achieve a comprehensive view of performance for all modes and transportation networks. Accordingly, a regional focus should be placed on finding a technology solution that provides the greatest benefits from a functional and cost perspective. The advent of low-cost sensors provides opportunities to expand our region's data collection network on arterials and parking facilities. Doing so will help establish a solid foundation for understanding the current and proposed state of the transportation system. Deployment of these detection technologies also provides the information needed to improve system efficiency, safety, and operations. The data also will enrich the quality and extent of the information offered to travelers.

Real-Time Multimodal Modeling and Simulation

Modeling that supports traffic and transportation planning has long been a staple in the transportation field. These models have focused mainly on supporting project development or transportation planning efforts. These efforts have included producing regional travel demand forecast statistics and analysis, as well as project-specific traffic analysis.

An emerging technology within this field is the development of real-time multimodal modeling and simulation applications. These applications are designed to simulate and evaluate traffic flows and multiple operational strategies simultaneously, and to produce recommendations in minutes. Real-time modeling applications complement existing tools by extrapolating historical data and combining it with real-time data to develop dynamic decision support applications. The benefits from this new technology include the ability to forecast traffic patterns and recommend operational changes to minimize delays and congestion. This forecasting and real-time analysis allows transportation system managers to take proactive measures, such as modifying the timing of traffic signals, ramp meters, or speed limits; providing route information and options to travelers during recurring congestion or during incidents; and analyzing and developing new TSM strategies and action plans. The advances in modeling and simulation technology have proven successful in locations such as Madrid, Spain and in Singapore. The deployment of this real-time system locally will allow regional and local operators to improve management of our transportation system.

This technology has been proposed to the U.S. DOT for a demonstration as part of the I-15 ICM project. The technology is planned for development and implementation as part of the I-15 ICM traffic prediction and decision support system. The I-I5 ICM project is planned for completion in 2014, and its findings and corresponding ICM applications will serve as the foundation for pursuing similar deployments along other regional corridors as part of the SANDAG ICM program.

Connected Vehicle

Connected Vehicle is the U.S. DOT program name given to a platform for advanced vehicle communication technologies and applications. It is internationally recognized for significantly improving roadway performance, increasing safety, and providing environmental benefits. Through the development of a ubiquitous high-speed communications network, the Connected Vehicle platform leverages and advances the intelligence of the vehicle itself and the roadway it travels on. Connected Vehicle will enable an entirely new suite of applications that will significantly change the transportation network, performance measurement, and management capabilities.

The U.S. DOT's Joint Program Office has announced that Connected Vehicle is its highest priority program, and it is working with state and local agencies to complete planning and expand pilot deployments. The U.S. DOT envisions broad deployments of Connected Vehicle by 2014 as part of its strategic research plan, which was approved by the ITS Management Council in December 2009. To this end, the U.S. DOT has engaged national and international industry groups to deliver a robust technology environment within which Connected Vehicle will come to fruition on schedule. The Institute of Electrical and Electronics Engineers (IEEE), the Society of Automotive Engineers (SAE), and the American Association of State Highway and Transportation Officials (AASHTO) have worked over the last six years to solidify standards for industry certification. These standards will ensure that robust deployment strategies and plans are available.

The core of the Connected Vehicle platform is the communications network, which addresses safety, traffic management, and traveler information applications by enabling vehicle-to-infrastructure and vehicle-to-vehicle communication. This communications medium between vehicles and roadside devices, such as traffic signals, creates a collective intelligence that can bring vast changes to the planning and operation of transportation systems. These changes improve safety, but they also provide the primary platform for enhancing accessibility, reliability, mobility, and effective systems management. This ubiquitous communications platform will extend to state routes, local streets, buses, bikes, Trolley, and heavy rail systems. It is therefore an important step toward achieving overall goals for regional livability.

Safety

The U.S. DOT, private industry, and educators are strong supporters of Connected Vehicle as a tool to significantly reduce accidents and the number of people killed in highway accidents every year – now totaling about 40,000. In California, more than one million vehicle crashes occur every year, with an economic cost of about $25 billion annually. Of this total number of accidents, 210,000 are injury crashes and 4,000 include fatalities. In the San Diego region, about 25 percent of fatal crashes occur at intersections, while another 25 percent result from vehicles changing lanes or veering off the roadway. The U.S. DOT estimates that Connected

Connected Vehicle is internationally recognized for significantly improving roadway performance, increasing safety, and providing environmental benefits.

Vehicle could reduce annual fatalities by 83 percent, and also significantly reduce the number of crashes not due to driving under the influence of alcohol or drugs.

Human error can be reduced through a variety of improvements to the engineering of a vehicle that increase its overall "intelligence." Vehicles can be made "aware" of other vehicles on the roadway, their speeds, the status of traffic signals they are approaching, and the road conditions ahead. They also can have access to detailed lane-level maps to calculate curve/speed ratios and respond to road hazards.

The initial deployment of Connected Vehicle will likely focus mostly on assistive functions, along with braking and throttle control. But the exchange of information between intelligent vehicles and an intelligent infrastructure will provide a platform for more autonomous functions.

As the technology is deployed, an increasing number of vehicles will become "Connected Vehicle Ready," either when they are manufactured or through after-market installations. Therefore, the penetration of Connected Vehicle into the marketplace, and the level of sophistication of the applications deployed, will work in unison. However, many applications are not dependent on the penetration rate of Connected Vehicle technologies into all vehicles. These include:

- Control Loss Warning: This warns a driver when he or she is about to lose control of the vehicle.
- Red Light Running: The vehicle issues visual, physical, and audible alerts if the driver is at risk of violating a red light or stop sign.
- Curve Speed Warning: The vehicle warns the driver to slow down.
- Road and Travel Conditions Warning: The vehicle is aware of crashes, work zones, slippery road conditions, detours, traffic congestion, weather-related road conditions, parking restrictions, turning restrictions, and other situational elements that may affect the driver. The vehicle issues an audible or visual warning to help a driver avoid these conditions.

As Connected Vehicle is fully deployed – expected sometime between 2018 and 2025 – the numerous applications available to assist a driver increasingly lessen the chances for human error on the road. These applications are expected to become radically more intuitive. Some examples include:

- Electronic Emergency Brake Lights: The vehicle would notify the driver when a vehicle ahead is braking hard.
- Intersection Movement Assist: The vehicle would warn the driver when it is not safe to enter an intersection, for example when something is blocking a driver's view of oncoming traffic.
- Do Not Pass Warning: The aim of this application is to warn the driver if he or she attempts to change lanes and pass when there is a vehicle in the opposing lane within the passing zone.
- Collision Warning and Crash Mitigation: This application would warn the driver of an approaching object (e.g., a stopped vehicle, a slowed vehicle, or a vehicle following too closely), or a vehicle ahead that is suddenly decelerating – whether it is in good or bad weather.
- Blind Spot Warning: The vehicle would warn a driver when he or she tries to change lanes, if there is a car in the blind spot.

- Forward Collision Warning: The vehicle would issue alerts and then warn a driver if he or she fails to apply the brake when a vehicle ahead is stopped or traveling significantly slower.

Mobility

Additionally, the Connected Vehicle platform and the resulting connected intelligent vehicles will enable our transportation system managers to receive and send enhanced decision-quality data to vehicles about the status of the network. This is one of the single greatest opportunities for system managers, across modes and jurisdictional boundaries, to put into effect proactive congestion management strategies that have the potential to deliver a profound impact on the reliability of travel times.

The Connected Vehicle platform provides a connected, data-rich travel environment. The platform will capture real-time data from equipment located onboard all types of vehicles (automobiles, trucks, buses, and bikes) moving within the network. The data will then be available for transportation managers to use in order to optimize our transportation system for peak performance. Drivers, meanwhile, will enjoy unparalleled visibility into the road ahead. To achieve this, the Connected Vehicle platform is used in the following contexts:

- Vehicles as Anonymous Data Probes: Future Connected Vehicle technologies are expected to provide Traffic Management Centers (TMCs) with a richer data set than current wireless devices that are not integrated into vehicles. On Board Equipment (OBE) integrated with a vehicle's electronic systems will be designed to anonymously relay information on vehicle conditions such as traction control or anti-lock braking activation, which are proxies for road surface conditions. The OBE will transmit this data anonymously to Road Side Equipment (RSE), which in turn will relay the information in aggregate form to system operators. The data will be turned into useful information to show operators where roadway maintenance may be needed.

- Ramp Metering: Connected Vehicle technologies of the future could deliver real-time data to optimize the operation of ramp meters in response to changing conditions on the freeway and on nearby surface streets. By ensuring that ramp metering does not merely shift congestion to the arterial network, operators would optimize the capacity of the transportation system. If Connected Vehicle improves the operation of ramp meters by just 5 percent, it will save an estimated 1.2 million gallons of gas nationally every year. The projected savings are valued at $2.8 million, and more than 11,000 tons of CO2 emissions would be avoided, once the system is fully deployed.

- Corridor Management: In the future, transportation agencies could use real-time data to manage corridor-level traffic. Travel demands could be balanced across adjacent or parallel facilities, using strategies such as changing the direction of a reversible lane in response to an incident; changing the timing of ramp metering; and using message boards to encourage motorists to divert to a different route.

- Performance Measurement: Connected Vehicle offers the potential to generate an expanded set of measures for monitoring the status and operation of the transportation system. Connected Vehicle generated data could provide metrics to measure the effectiveness of system

The Connected Vehicle platform will play a significant role in reducing greenhouse gas emissions and improving public health.

operation, including travel time, stops, delays, and travel reliability; condition metrics, including indicators of pavement traction, pavement roughness, precipitation, visibility, and air quality; and demand metrics, such as vehicle counts.

- Traveler information: The ability of the platform to send location-specific data and target it to specific vehicles greatly enhances the information available to travelers. This targeted capability introduces the concept of dynamic in-vehicle signage, augmenting or replacing the regulatory or informational signs used today. It also allows real-time messaging on road conditions, the status of traffic signals, and even recommended speeds to smooth the flow of traffic. Further enhancements of this capability and vehicle intelligence could lead to vehicles automatically taking action based on the messages they receive.

- Tolling: Connected Vehicle also is being promoted as the new platform for a nationwide tolling standard. This standard potentially would reduce costs related to infrastructure deployment and ongoing operation by eliminating transponders, leveraging a common platform, and introducing more competition. The integration of new Connected Vehicle applications with vehicle systems also has the capability to introduce new enforcement and pricing strategies for carpool lanes and HOT lanes by detecting the number of occupants in the vehicle.

Environment

By providing the traveling public with real-time information about traffic congestion and other travel conditions, the Connected Vehicle platform can help reduce emissions. The Connected Vehicle platform, combined with environmental applications, will be targeted specifically at reducing fuel consumption, idling, and vehicle miles traveled while reducing acute congestion. It will play a significant role in reducing greenhouse gas emissions and improving public health, particularly in major metropolitan areas, around ports and freight hubs, and on major highways and corridors.

Applications such as Eco-Driving will possibly be the largest single unifying activity for the 40 percent of travel that occurs here in the San Diego region on Connected Vehicle-ready local streets. The concept of "Green Driving" or "Eco Driving" is where the system informs a driver of the speed he or she should travel in order to avoid red lights and instead catch a "wave" of green lights. This can be achieved with or without high levels of penetration by the Connected Vehicle platform into vehicles. Connected Vehicle is a broad-reaching platform that will have a transformational impact on all modes of the nation's transportation network. Delivering a communications platform to increasingly intelligent vehicles will have a profound impact on the way highways and roadways are planned and used. The U.S. DOT is therefore working toward making Connected Vehicle a required safety feature of all new vehicles. The National Highway Traffic Safety Administration is expected to begin the rule-making process in 2013 to adopt this emerging technology.

The following actions support the Plan's Systems Management Chapter recommendations:

Transportation Systems Management	
Actions	**Responsible Parties**
Multimodal Integration and Performance-Based Management	
1. Implement a regional system to implement and maintain the monitoring of 100 percent of the region's urban freeway lanes, on/off ramps and connectors, and critical arterial networks through the use of automated data collection systems.	Caltrans, SANDAG, and local jurisdictions
2. Expand the monitoring of regional transit service with automated data collection through vehicle location systems and automated passenger counters.	SANDAG, MTS, and NCTD
3. Continue developing enhancements to PeMS to improve transportation system performance reporting and to develop corridor measures that comprehensively examine person throughput across highways, arterials, and transit.	SANDAG
4. Complete the demonstration and evaluation of real-time modeling and decision support systems as part of the I-15 Integrated Corridor Management project and apply improvements to other major corridors.	Caltrans, SANDAG, and local jurisdictions
5. Provide regular system performance reports to the SANDAG Board of Directors, Policy Advisory Committees, and working groups for review and action.	SANDAG
Traveler Information	
6. Continue the delivery of traveler information to the public using data collected through performance monitoring investments and disseminated through public and private channels.	Caltrans, SANDAG, and local jurisdictions
7. Enhance traveler information services to provide multimodal choices that promote sustainable strategies and reduce congestion.	SANDAG, MTS, NCTD, and Caltrans
8. Explore new dissemination options such as in-vehicle devices, mobile applications, and Connected Vehicle, and evaluate non-public subsidies for delivery.	SANDAG
Arterial Management	
9. Develop a plan and initiate phased deployment of additional detection devices and/or service for major arterials throughout the region.	SANDAG and local jurisdictions
10. Develop an ongoing program to enhance traffic flows on arterials and to/from freeways using timing updates and a responsive/adaptive system that consider corridor performance and multi-jurisdictional coordination.	SANDAG, local jurisdictions, and Caltrans
11. Evaluate wireless devices, Connected Vehicle, and innovative applications such as Eco Driving to further improve traffic flows and reduce environmental impacts.	SANDAG
12. Develop a plan and initiate phased deployment of additional detection devices for main lanes, HOV/HOT facilities, on/off ramps, and highway connectors.	Caltrans and SANDAG

Transportation Systems Management (Continued)	
Actions	**Responsible Parties**
Freeway Management	
13. Continue improvement of Caltrans District 11 management systems for monitoring the freeways through detection and traffic cameras; and for making real-time adjustments to ramp metering that consider corridor performance.	Caltrans and SANDAG
14. Evaluate the benefits and devise a deployment plan for additional electronic message signs to convey multimodal traveler information using traditional roadside signage and/or advanced in-vehicle solutions.	SANDAG and Caltrans
15. Continue the partnership with the State to monitor and expand the Freeway Service Patrol (FSP) program, to align it with extended peak commute and weekend hours.	SANDAG
16. Implement an automated FSP vehicle fleet tracking and management system to monitor and report FSP program performance.	SANDAG
Transit Management – Bus and Rail	
17. Program the life-cycle replacement of the Communications/Security, Scheduling, Transit Management, and Centralized Train Control systems and evaluate opportunities for improvements.	MTS and NCTD
18. Continue efforts to develop plans to implement Positive Train Control.	NCTD and SANDAG
19. Evaluate and demonstrate the benefits of new technologies such as wireless detection, real-time modeling, and Connected Vehicle for transit.	SANDAG, MTS, and NCTD
Electronic Payment Services	
20. Program the life cycle replacement of the Compass Card and Fastrak® electronic payment systems.	SANDAG, MTS, and NCTD
21. Continue evaluation of Smart Parking systems, the benefits of parking information, and the impact of pricing models.	SANDAG
22. Evaluate and demonstrate the benefits of the Universal Transportation Account concept and coordinated pricing strategies.	SANDAG
Advanced Technologies	
23. Continue research and demonstration efforts to identify and evaluate new TSM technologies.	SANDAG
24. Develop implementation plans and/or pilot projects for wireless detection and real-time modeling/simulation.	SANDAG, MTS, NCTD, and Caltrans
25. Coordinate with the U.S. DOT on Connected Vehicle development and possible early adoption/deployment in San Diego using local, state, and federal funds.	SANDAG