

Pre- and Postconstruction Analysis of the Interstate 15 (Devore) Concrete Pavement Reconstruction Project

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Abstract: This case study presents an innovative fast-track reconstruction approach applied to a heavily trafficked Long Life Pavement Rehabilitation Strategy (LLPRS) project on Interstate-15 (I-15) in Devore in southern California. A 4.5-km stretch of badly damaged concrete truck lanes was rebuilt in only two 210-hour (about 9 days) one-roadbed continuous closures, using counterflow traffic and 24-hour operations. The same project would have taken 10 months using traditional nighttime closures. This "Rapid Rehab" project adopted state-of-the-practice technologies to accelerate construction, to mitigate traffic disruptions, and to propagate project information. As a result, traffic demand through the construction work zone was reduced by 20 percent, and the maximum peak-hour delay was reduced by 50 percent. Web surveys showed dramatic changes in public perception to the Rapid Rehab approach from initial reluctance and objection to support. Advantages of using this method of fast-track accelerated reconstruction included: a shorter period of disruption for the traveling public, 30-year life expectancy for the new pavement, improved safety for motorists and workers, and a 25 percent reduction in construction costs (\$6 million savings) when compared to traditional repeated nighttime closures.				
Keywords: Fast-track construction; Highway reconstruction; Public outreach; Public opinion; Project evaluation; "Rapid Rehabilitation," Surveys; Traffic control.				
Proposals for implementation: Continue use of the approach described in this report for planning, designing and executing long-life reconstruction projects. Monitor and document results from at least several more projects with different scenarios to develop databases and knowledge which will lead to future cost savings.				
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EXECUTIVE SUMMARY

This case study introduces an innovative fast-track reconstruction approach implemented in 2004 on the Interstate-15 (I-15) Devore Urban Highway Reconstruction Project in Southern California. The University of California Pavement Research Center (UCPRC) was engaged by Caltrans District 8 to support (a) its project planning based on preconstruction analysis and (b) its implementation of the project based on contractor performance monitoring and traffic-impact evaluation. This report discusses the preconstruction analysis process and presents the results of the postconstruction analysis.

State-of-the-practice technologies and a “Rapid Rehab” strategy were chosen for this project in order to accelerate construction, to mitigate traffic disruptions, and to propagate information about the project, in which concrete truck lanes were rebuilt along a 4.5 km (2.8 mi) stretch of I-15 using two nine-day extended closures with twenty-four hour per day, seven-day per week construction operations. According to the preconstruction estimated project schedule, this project would have taken ten months using traditional nighttime closures. Instead, the reconstruction took about nineteen days, with extended closure of each roadbed lasting roughly nine days.

The I-15 Devore Project combined conventional construction materials and operations with state-of-the-practice technologies to expedite construction and to minimize adverse traffic impacts for the traveling public. The technologies and innovations adopted for this groundbreaking Rapid Rehab project included: (1) Automated Work Zone Information Systems (AWIS) to update travelers with real-time work-zone travel information; (2) the Quickchange Moveable Barrier (QMB) System (by Barrier Systems, Inc.), which provided a dynamic lane configuration to minimize traffic disruption; (3) a rapid-strength concrete mix that made it possible to open the project to traffic twelve hours after the concrete was placed with a slip-form paver; (4) Web-based information systems for disseminating project updates and surveying public perception of the project; (5) incentive/disincentive provisions to encourage the contractor to complete the closures on time; and (6) a multifaceted, extensive outreach program to gain public support for the project.

Engineers on the project used *CA4PRS (Construction Analysis for Pavement Rehabilitation Strategies)* software, in conjunction with traffic simulation models, to arrive at the most economical rehabilitation closure scenario, estimated construction schedule, and traffic management plan. Postconstruction data validated the preconstruction schedule analysis and the simulation estimates of productivity and traffic delays.

As a result of AWIS extensive public outreach and implementation, a 20 percent reduction in traffic demand through the construction work zone (CWZ) was achieved, thereby reducing the maximum peak-hour delay by about 50 percent (to 45 minutes from the expected 90 minutes). Surveys taken on the project's Web site showed that public perception of the Rapid Rehab approach shifted dramatically from before the project began to after it was completed: initial reluctance and objection changed to majority support. The advantages of using this method of Rapid Rehab, accelerated reconstruction included a significantly shorter period of disruption for the traveling public, new pavement with a thirty-year life expectancy, improved safety for motorists and workers, and an estimated 25 percent (\$6 million) reduction in construction costs compared to traditional repeated nighttime closures.

The results and lessons learned from this project can be applied to other freeway reconstruction and rehabilitation projects on high traffic volume routes.

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1. INTRODUCTION

1.1 California Long-Life Pavement Rehabilitation

More than 90 percent of California's 80,000 lane-km (55,000 lane-km of asphalt, 25,000 lane-km of concrete) state highway system was built between 1955 and 1970. Now, thirty-five years later, California faces large-scale highway deterioration, as this generation of pavements has far exceeded its original twenty-year design life while it has also been subjected to traffic demands undreamed of at the time of its construction. The resulting pavement degradation adversely affects road users by increasing vehicle operating costs, and by lowering ride quality and safety. For road maintenance crews, the roadway degradation increases the time spent performing maintenance work on these major highways. Even partial rehabilitation of these pavements has the inevitable impact of expensive traffic delays (Leather 1987). Major rehabilitation of highways in heavily trafficked corridors also frequently creates difficulties for businesses that depend on traffic flowing freely through their commercial areas.

For all these reasons, transportation agencies often face conflicts between the priorities of commuters, commercial truck traffic, and general road users whose routes are impacted by closures when planning and designing reconstruction projects. In response, the California Department of Transportation (Caltrans) launched the Long-life Pavement Rehabilitation Strategies (LLPRS) program in 1998 to provide long-lasting (thirty or more years design life) pavement with lower maintenance to reduce the need for future repair projects and, ultimately, to save public resources for future generations.

Approximately 2,800 lane-km were tentatively selected as initial LLPRS candidate projects to be rehabilitated over a period of ten years. These projects were selected based on a preliminary life-cycle cost analysis and evaluation of the agency's future cash flow. LLPRS candidate projects were selected from among highways that experience minimum volume demands of 150,000 Average Daily Traffic (ADT) or 15,000 Average Daily Truck Traffic and which have poor pavement structural condition and ride quality. Most of the candidate sections are portland cement concrete (PCC) pavements on interstate freeways in urban networks; 80 percent of the projects are within the Los Angeles Basin and 15 percent are in the San Francisco Bay Area (Caltrans 1998).

1.2 Need for Fast-Track Construction

From 1999 to 2001, about 30 percent of the highway construction projects in the United States were undertaken in urban areas (WisDOT 2005). Typically, such urban highway construction projects cause a serious traffic disruption for the communities that use the freeways, resulting in major inconveniences for the traveling public and commercial enterprises. It is estimated that the annual costs to road users, businesses, and transportation agencies caused by highway construction traffic delays total \$43 billion, \$21 billion of which is in extra fuel consumption (Edwards 1998). The California Trucking Association has estimated that early opening of a freeway has the impact of saving their commercial operators more than \$250 per truck trip or in trucking costs (Carr 1994). Consequently, most state highway agencies are under increased pressure to achieve the earliest possible completion of construction in urban highway rehabilitation. The Federal Highway Administration (FHWA) and the Transportation Research Board (TRB) have recommended experimenting with new, expeditious rehabilitation approaches that have the potential to reduce construction time (Herbsman and Glagola 1998).

In implementing urban highway projects for its LLPRS program, Caltrans focused on: (a) minimizing traffic disruptions and road user cost (RUC), (b) providing a safe construction work environment for work crews and road users, and (c) reducing impacts on adjoining communities and affected businesses. To lessen the impact of closures, Caltrans has experimented with innovative pavement rehabilitation strategies that use accelerated construction approaches—such round-the-clock operations during multiple (repeated) extended closures during weekends or weekdays. The concept of the 55-hour extended weekend closure (Friday, 10 P.M. through Monday, 5 A.M.) was validated on a concrete LLPRS demonstration project for the first time in 2000—on Interstate-10 (I-10) in Pomona (Lee et al. 2002); the concept was validated for the first time on an asphalt LLPRS demonstration project in 2003—on Interstate-710 (I-710) in Long Beach (Lee et al. 2005a).

1.3 Study Objectives and Approach

The I-15 Devore Project was Caltrans' first large-scale project where a continuous lane closure was used with so-called "Rapid Rehab" fast-track construction methods and state-of-the-practice technologies. This report describes these approaches used on this project and their consequences. The report's main objectives are: (a) to summarize the innovations and technologies used for fast-track reconstruction and to show how they expedite reconstruction and mitigate traffic disruption; (b) to validate preconstruction analysis results with the as-built construction and traffic data gathered during construction; and (c) to describe the lessons learned regarding the construction process, traffic, and project management.

The research described in this report was divided into two phases: the Phase I study that was conducted before construction and the Phase II study that was conducted during and after construction. The main objective for the Phase I study, a preconstruction analysis of the I-15 Devore Project, was to integrate pavement design and materials selection with construction logistics and traffic operations (Lee et al. 2005b and 2005d). The preconstruction analysis was validated with on-site measurement of construction productivity and traffic performance during the construction of the project (Lee et al. 2005c).

The Phase II post-construction evaluation documents the technical ideas and the lessons learned from the I-15 Devore Project from the strategic perspectives of construction process, traffic control, and project management. During construction Caltrans implemented innovations and technologies: (1) to accelerate the construction process and schedule, (2) to mitigate traffic disruptions and to measure traffic performance, (3) to increase traffic diversion from the construction work zone by providing road users with automated real-time travel information, (4) to disseminate project information through multifaceted outreach programs to increase public support for the Rapid Rehab strategy, and (5) to capture the change in public perception through the use of web-based surveys. The background and process of each innovation are briefly introduced and their benefits are assessed.

2. I-15 DEVORE PROJECT

2.1 Project Overview

In October 2004, a 4.5-km section of Interstate 15 (I-15) near Devore, California, that had badly deteriorated concrete truck lanes was reconstructed with a new structure section that included 150-mm thick asphalt concrete (AC) base and 290 mm thick concrete slabs. Two continuous closures were used to complete the construction. During each closure the roadbed in one direction was closed and traffic was shifted to the remaining open roadbed. A temporary barrier separated the traffic flows in each direction. Each closure took approximately 215 hours (nine days), using around-the-clock (twenty-hour-per-day/seven day-per-week) operations.

During each closure, the closed roadbed's outer truck lane was removed and reconstructed, and damaged slabs on its inner truck lane were removed and replaced.

The I-15 Devore corridor is one of California's most heavily traveled routes, carrying an ADT of approximately 110,000 vehicles, with a peak hourly volume of 5,500 vehicles traveling in each direction during weekday commute hours (Figure 1). On average, about 10 percent of the vehicles using the corridor are heavy trucks. In contrast to typical California urban freeways, which have high traffic volumes during rush-hour weekday peak periods and lower traffic volumes on weekends, the I 15 Devore corridor has consistently high weekday commuter peaks and even higher leisure traffic volume on weekends. The two highest peak-traffic volumes are northbound (NB) on Friday afternoon and southbound (SB) on Sunday afternoon, when leisure travelers in the Los Angeles area go to and from Las Vegas and resort locations along the Colorado River.

The existing pavement cross section was a typical 1970s-era Caltrans design; i.e., 230 mm of non-doweled, plain-jointed concrete slabs over 100–150 mm of cement-treated base on aggregate base. The scope of the reconstruction included removal of the damaged concrete pavement and replacement of it with a new cross section of 290-mm doweled slabs of Type III portland concrete cement (PCC)—which has a high early-strength gain that meets Caltrans rapid-strength concrete (RSC) specifications—over a 150-mm AC (AR-8000 binder) base. This new structural section would be placed on top of the remaining recompacted aggregate base or native subgrade. As part of the long-life pavement design, to reduce truck loading stresses on the outer edge of the slab, the reconstruction required the new outer truck-lane pavement to be 600 mm wider than the existing configuration. The existing AC shoulders were also

planned for rehabilitation within the same closure period; they were to be cold-planed (milled) to a depth of approximately 60 to 75 mm and overlaid with new asphalt concrete.

2.2 Construction Staging Plan

The construction staging plan split the project into two segments (see Figure 2). Segment 1 consisted of a 2.5 km stretch with four lanes in each direction between the Sierra Avenue and Glen Helen Parkway interchanges. Segment 2 consisted of a 2.0-km stretch from the Glen Helen Parkway interchange to the I-215 system interchange with three lanes in each direction. A progressive staging plan was used to maintain the minimum length of construction work zone (CWZ) closures, as described next. Segment 2 was closed for about three days at the outset of the project, allowing significant reconstruction progress to be made before Segment 1 was closed to traffic. Segment 2 was then reopened in the middle of the closure period while Segment 1 was still under construction.

The northbound (NB) roadbed was closed first and traffic was switched to the southbound (SB) roadbed through median crossovers at the ends of Segments 1 and 2, forming a counterflow traffic system. Construction occurred on the two truck lanes while the two inside lanes were used for access by construction trucks and other equipment. The two directions of traffic shared the SB traffic roadbed as “counterflow traffic,” separated by a Quickchange Moveable Barrier (QMB) that provided dynamic lane configuration depending on the commuter direction (Figure 3).

2.3 Evaluation of Preconstruction Alternatives

The preconstruction analysis sought the most economical reconstruction closure scenario that would also integrate these competing concerns: construction schedule, traffic impact, and agency cost. Four construction closure scenarios were compared: 72-hour weekday, 55-hour weekend, one-roadbed continuous (24-hours per day, seven days per week), and 10-hour nighttime. The analysis concluded that the so-called “continuous/extended closure scenario” would be the most economical. The preconstruction analysis indicated that the extended closure scenario would have about 80 percent less total closure time, about 30 percent less road-user cost due to traffic delay, and about 25 percent less agency cost for construction and traffic control (Table 1) than traditional 10 hour nighttime closures.

Rehabilitation constructability comparing pavement design and material alternatives were reviewed with the *CA4PRS* (Construction Analysis for Pavement Rehabilitation Strategies) model from the perspective of production scheduling and traffic inconvenience (Figure 4). As a result, Caltrans decided to use (1) rapid strength concrete (RSC) with a twelve-hour curing time rather than fast-setting hydraulic cement

concrete (FSHCC) with a four-hour curing time, (2) a new 150-mm asphalt concrete (AC) base rather than a 150-mm lean concrete base (LCB), and (3) a 4.7-m widened lane rather than 3.7-m regular lane tied to a new concrete shoulder on the outer truck lane.

Caltrans decided to use RSC after they confirmed that it would pay off in the long run because it provides better long-term performance than FSHCC. They based this decision on the experience of the I-10 Pomona Project, where it was found that the eight-hour time advantage of FSHCC was offset by higher concrete slump and material stickiness, the need for more delivery trucks and a smaller paving machine, and the restriction to single-lane paving. The *CA4PRS* production estimate indicated that use of either of these materials would result in approximately the same overall completion time and that the time saved by using extended closures would be evened out by the lower paving-operation productivity with FSHCC.

One of the pavement design preferences for Caltrans concrete LLPRS projects in Caltrans District 8 includes the use of an approximately 290-mm thickness of PCC and a 150-mm LCB that are separated with a 25-mm AC bond breaker. However, during the design of this project, Caltrans evaluated other base types primarily to look at their constructability and to find ways to reduce construction time without significantly affecting long-life pavement design. It was determined that instead of using LCB, an AC base could be placed in two lifts of 75 mm, thus eliminating the need for both an AC bond breaker and an additional operation. One of the benefits of placing PCC on the top of an AC base would be that two separate subcontractors with separate materials production and supplies could be employed, and this would shorten the overall reconstruction schedule.

As a result of high project bids in the first round of construction bidding, the initial rehabilitation scope was altered. Whereas the initial scope included reconstruction of both inner and outer truck lanes, the revised project included reconstruction of only the outer truck lane and targeted (about 10 percent) slab replacement on the inner truck lane. The project delay from the spring to fall 2004 resulted in a significant 5 percent increase in traffic volume; as a consequence it was estimated that road-user cost increased by 90 percent (from \$5 million to \$9.5 million) and the maximum expected peak-hour queue delay increased from seventy-five to ninety minutes.

2.4 Dynamic Response to Challenges

Notwithstanding the advantages of the extended closure scenario, Caltrans initially pursued the 72-hour weekday closure scheme, the second most economical scenario, to balance the time value (road-user delay cost) of weekday commuters and weekend leisure travelers. More specifically, Caltrans initially had

greater concerns about the 150 minutes of expected maximum peak-hour construction delays on weekends than the expected 90-minute construction delays on weekdays.

About five weeks before implementing the 72-hour weekday closures, Caltrans held a public meeting to elicit consensus on them. A public information officer put the meeting together with resident engineers and representatives from the Caltrans District 8 divisions of Design, Construction, and Traffic. Local residents attending the meeting strongly objected to the Caltrans scheme that favored weekend, leisure travelers over daily commuters. The residents' consensus was that construction should be done either by conventional nighttime closures, 55-hour weekend closures, or a combination of the two. Some residents advocated canceling the project if Caltrans did not show a willingness to change the construction scheme from continuous weekday to nighttime or weekend closures.

Caltrans responded by implementing an accelerated construction closure scheme with around-the-clock operations, also known as "extended closures." To achieve the goal of minimizing traffic impact on daily commutes, the following Traffic Management Plan (TMP) strategies were pursued: (a) increasing roadway capacity through the CWZ by utilizing dynamic lane configuration with the Quickchange Moveable Barrier (QMB); (b) deploying a comprehensive public outreach effort to convince commuters to actively participate in strategy communications; and, (c) introducing a real-time work zone information system to encourage motorists to divert to neighboring detour routes in the vicinity of the CWZ. Details about how effectively these TMP strategies were implemented on this project are discussed in the following sections.

3. INNOVATION AND TECHNOLOGY IMPLEMENTATION

3.1 State-of-the-Practice Features

The \$16 million I-15 Devore Project combined conventional construction materials and methods to expedite construction and to minimize adverse traffic impacts by using state-of-the-practice innovations and technologies such as:

- A project command center equipped with closed circuit television (CCTV) for team coordination and for monitoring construction progress and traffic impact (see Section 3.2);
- A contract with incentives and disincentives (I/Ds) based on schedule designed to motivate the contractor to complete closures on time or ahead of schedule (see Section 3.3);
- Internet-based information systems on the project Web site for disseminating project updates and surveying public perception (see Sections 6.4 and 7.3);
- A multifaceted, comprehensive outreach program to gain public support in reducing traffic demand during construction through diversions and commuting mode changes (see Sections 6.2 and 6.3);
- A free commuter bus service, using fourteen buses, to promote ridesharing at a cost of \$65,000, which increased ridership by 40 percent (see Section 4.1);
- An Automated Work Zone Information System (AWIS) to update travelers with real-time construction work zone (CWZ) travel information (see Section 4.3);
- A \$300,000 California Highway Patrol (CHP) Construction Zone Enhanced Enforcement Program that issued a total of 1,034 traffic citations during one month of construction (see Section 4.4); and
- A \$100,000 Freeway Service Patrol tow truck service program to facilitate traffic flow through the CWZ, which resulted in the rapid removal of 1,243 disabled vehicles (see Section 4.4).

3.2 Command Center Coordination

One of the keys to the successful execution of the I-15 Devore Project was the coordination and teamwork between Caltrans District units during the planning, design, and construction phases. This involved the Design, Traffic Operations, Construction, Maintenance, and Public Affairs divisions in Caltrans District 8. In addition to internal teamwork, department-level coordination with other agencies, such as the CHP and local and city governments, proved to be one of the biggest factors that contributed to the success of the project. Establishment of a Project Command Center that would organize and monitor daily construction progress and traffic impact was carried forward from the approach taken by

previous LLPRS demonstration projects. The I-15 Devore Project's innovation was to locate the Command Center in the district office, directly across from the Traffic Management Center (TMC), rather than to put it on site, as was done in the previous projects. This innovative choice helped centralize command operations.

One of the key functions of the Project Command Center was to coordinate the meetings that were held each morning during the extended closures; the center provided a single location where information could be discussed and action items could be addressed immediately. The other advantage of locating the Project Command Center adjacent to the TMC was the access it provided to the TMC's closed circuit television (CCTV) traffic system. This networked into the Project Command Center so impacts on the traveling public and construction activities could be monitored directly (Figure 5). This made it possible for Caltrans to provide instantaneous, real-time updates on the status of construction operations and traffic conditions when the Public Affairs Office received a call from the public or from the media.

3.3 Incentives/Disincentives Provisions

Because of high traffic volume on this freeway and the public's desire for early completion of the reconstruction, three different levels of time-related provisions were specified in the contract to ensure on-time completion of the closures:

1. I/D requirements for the extended closures,
2. A late-opening penalty for the segment with a three-lane section, and
3. Cost-plus-time (A+B) contracting for the entire project.

Two types of I/D provisions were specified for the extended closures: primary incentives for the total number of closures and secondary incentives for the total closure days. Assessment of I/D was based on road-user cost (RUC) utilizing the *CA4PRS* schedule analysis in conjunction with a traffic-delay analysis that included macro- and microscopic simulations (Lee et al. 2005d). The *CA4PRS* schedule analysis provided a baseline for a reasonable schedule for completion of the project. The incentives were limited by the realities of the budget for the project and were capped at a value of \$600,000.

The contractor was eligible for a "closure incentive bonus" of \$300,000 if the extended closure was completed in a time period less than or equal to two time segments of 111 hours each; alternatively, the contractor would be subject to an unlimited "closure disincentive penalty" if the closure took longer than three 111-hour time segments. In addition to this I/D clause, the contractor was eligible to receive a daily incentive bonus of \$75,000 if the entire major reconstruction was completed in fewer than nineteen days

(a total of 456 hours), and was subject to a daily disincentive penalty (without a limit) if the reconstruction took longer.

A late lane-opening penalty of \$5,900 per fifteen-minute period without limitation was established for Segment 2 (CWZ bottleneck) if the traffic roadbed was not completely opened by 5 A.M. Friday to accommodate the highest weekday commuter and weekend leisure traffic volumes.

3.4 Real-Time CWZ Travel Information

As part of the up-front, multifaceted, public outreach program, Automated Work Zone Information System (AWIS) real-time travel- and detour-estimated travel time information were provided for roadway users on permanent and temporary changeable message signs (CMS), as well as on the project Web site's traffic roadmap. The AWIS real-time travel information allowed road users to find alternate routes around the CWZ or to time trips to coincide with construction schedules.

The project Web site instantaneously updated traffic snapshots every thirty seconds and provided a virtual tour through the CWZ using a video-streaming feature and ten traffic cameras installed along the I-15 Corridor that automatically changed their positions at five-second intervals. With the ability to refer to the project Web site to check traffic conditions through the CWZ corridor, travelers had several flexible alternate information sources on which to base their travel decisions, giving them the option of changing their departure times, using other modes of travel, taking a detour route, or even canceling their planned trip.

4. WORK-ZONE TRAFFIC OPERATIONS

4.1 Free Shuttle Services and Truck Permits

To lessen congestion-causing traffic during the closures, Caltrans' strategy included drawing upon local resources and using regulatory tactics.

Over the course of the construction period a free shuttle service from the high desert area to Ontario (about 100 km, or 62 mi.) was provided to help alleviate the inconvenience for affected communities. Caltrans teamed up with the Victor Valley Transit Authority (VVTA) to temporarily provide more shuttle buses for those who commute south of Devore. Specifically, Caltrans used state transportation funds (\$65,000) in working with the VVTA to provide additional commuter shuttle service from the high desert to the south (San Bernardino and Los Angeles), with eight trips in the morning and six return trips in the afternoon. This program was effective in mitigating the traffic disruption during the closures, and its effectiveness raised public opinion of the I-15 Devore Project. The additional commuter shuttle service lines resulted in a 40 percent increase in ridership.

Once the final construction staging plan was set up in the beginning of October 2004, new permits for oversize truckloads through I-15 were put on hold (and diverted to freeway detours). This policy restricting oversized trucks was implemented to avoid having heavy trucks get stuck on the narrow, single NB lane when the roadway was configured with three open SB lanes during morning peak-hours for the first extended closure. Trucks that had permits after the restriction went into effect were detoured to I-10 and I-215 during the period of construction. Overall, controlling oversize trucks improved traffic flow through the CWZ, although this restriction could not completely block heavy trucks that had a valid permit issued before the restriction was implemented.

4.2 Dynamic Lane Configuration with the QMB

Using the Quickchange Moveable Barrier (QMB) to establish a dynamic lane configuration helped to balance traffic impacts to commuters and to weekend travelers. Repositioning the QMB and adding a temporary lane from the AC rehabilitated shoulder better accommodated peak directional traffic. The lane reconfiguration was accomplished with a specialized transformer (barrier shifting machine) that traveled along the traffic roadbed at 15 km per hour, picking up the concrete barrier and shifting it to the next lane. Only thirty minutes were required to move the 4.5-km barrier segment, and it was done twice a day without a major disruption to live traffic.

In the morning (4 A.M. to 9 A.M., Segment 1 [which had five lanes on the traffic roadbed during construction] was temporarily configured with three SB lanes by two NB lanes [3 x 2]). In the afternoon the configuration was reversed to two SB lanes by three NB lanes (2 x 3), as shown in Figure 2. This process was repeated for the reconstruction of the SB direction.

The project budget allocated \$1.5 million for a three-month rental of the QMB system, a cost item not needed for traditional lane closures. Caltrans assessed that road-user time savings from the QMB operation paid off the added expense of the QMB rental.

4.3 Implementation of AWIS

The I-15 Devore Project was the first time the AWIS technology had been used on a California LLPRS project, and the system played a useful role in informing motorists of real-time travel and detour route information. AWIS travel-estimate information was posted for roadway users on permanent and temporary changeable message signs (CMSs), as well as on the traffic roadmap on the project Web site (Figure 6). The AWIS monitored traffic data (count and speed) in several locations using Remote Traffic Microwave Sensor (RTMS) traffic surveillance units, which are roadside radar devices that were situated about 1.5 km apart. The traffic data was relayed wirelessly to a vendor's server in St. Paul, Minnesota, where it was processed through an algorithm to estimate travel times through the CWZ. The real-time travel information was then displayed on portable and permanent CMSs that were strategically located at key decision making points for the traveling public. Figure 6 illustrates the basic operation concept of the I-15 Devore AWIS.

The CMSs displayed the estimated travel time between two known points (the junction with SR-210 on the south and the junction with I-215 on the north) in increments of ten minutes. This format was chosen because it proved easier for the public to understand than "overall delay time."

4.3.1 AWIS System Configuration

The I-15 Devore AWIS consisted of three major components: an RTMS to collect data on the speed and occupancy of vehicles, a portable CMS to display travel-time information, and the software on the server to estimate travel time. These components were connected to each other via a wireless communications system. Three RTMSs for the NB direction and two for the SB direction were located at 1.6-km intervals along the CWZ. Additionally, one RTMS was located on I-10 EB to monitor traffic conditions along the

main detour. Three portable CMSs were installed for I-15 NB traffic and one portable CMS was installed for SB traffic to enable travelers to change their routes before entering the CWZ.

The Virtual Transportation Operations Center (VTOC) software on the server computer enabled the operators to monitor, analyze, and integrate traffic data. The software was mainly operated on the vendor's server in St. Paul, Minnesota, and secondarily monitored by traffic engineers at the Caltrans TMC. Engineers at the TMC could override the message on the portable CMSs when they found obvious discrepancies between the travel-time estimates and the actual travel times reported by probe vehicles. The monitored traffic data were transmitted to the server station for the travel-time estimation. The estimated travel times at the server were then retransmitted in real time to both the portable CMSs and the project Web site.

4.3.2 Evaluation of AWIS Performance

There were initial glitches with the AWIS operation—especially in congested (stop-and-go) traffic—for the first half of the project. However, in the second phase (SB construction), the system ran automatically.

While the AWIS operated during construction, Caltrans regularly drove probe vehicles in round-trips along the I-15 CWZ corridor and recorded their travel times. At the Caltrans TMC, both the estimated travel times from the AWIS and the measured actual travel times of the probe vehicles were noted in a log for comparison. This was done to validate the accuracy and reliability of the AWIS travel-time estimates.

During the peak and the non-peak hours of the construction periods, the overall data for the AWIS-estimated travel times and the measured travel times compared well with each other (Figure 7). The average measured travel time and the average AWIS-estimated travel time for the peak-hour delay on I-15 SB, which was during the morning commute, were 34.7 minutes and 36.4 minutes, respectively. For the peak-hour delay on I-15 NB, the average measured travel time and the average estimated AWIS travel time were 51.3 minutes and 45.0 minutes, respectively—both of which represented a 50 percent reduction in actual traffic delays compared to initial traffic delay expectations.

4.4 Safety Enhancement at the CWZ

Most highway construction projects in urban areas in California utilize the Construction Zone Enhanced Enforcement Program (COZEEP), a collaborative program of Caltrans and the CHP to improve CWZ safety. On the I-15 Devore Project there were a maximum of fourteen CHP officers available for COZEEP during the extended closures. Half of those officers were utilized on the freeway for

enforcement and speed control; one officer wrote twenty-one tickets on the first day of enforcement, triple the usual total. During peak periods, the others were used as traffic control officers at key intersections on local streets that lacked signals and signs. COZEEP data showed that a total of 1,034 traffic citations, including twelve for trucks, were issued during one month of construction in October. A total of 103 collisions, including forty-three injury (non-fatality) collisions, were reported during the extended closures, which overall is fewer than available statistics show for ten months of nighttime closures, which is the traditional closure strategy.

For rapid removal of disabled vehicles from the CWZ during the extended closures, a tow truck service was provided at a cost of about \$100,000 from the project budget. A total of three tow trucks were put in place at the CWZ: two of them roamed the CWZ, one in each direction on I-15, and one remained on standby. This service effectively reduced severe, accident-caused traffic disruption by quickly clearing accidents and breakdowns within the work zone, e.g., several accidents were cleared within five minutes. The Freeway Service Patrol log indicated that a total of 1,243 service operations were provided—including 1,060 for disabled vehicles—during the extended closures.

5. RECONSTRUCTION PRODUCTIVITY MONITORING STUDY

5.1 Reconstruction Process

Major reconstruction activities during the extended closures included demolition of the existing pavement, paving the AC base, paving the PCC pavement, and cold planing and overlay with AC of the outside shoulder. These four operations proceeded concurrently with a minimal access space between them. A rehabilitation technique known in the *CA4PRS* software as the “concurrent double-lane paving method” was selected because it allowed demolition, AC base paving, and PCC paving to proceed simultaneously. This technique involves the use of a slip-form paver, which was used because two passenger lanes were available to provide access for rebuilding the two truck lanes at once (Lee and Ibbs 2005).

The following activities were performed during the extended closures (about 215 hours):

- Set up QMB on the traffic roadbed
- Traffic break (about one hour) for lane striping on the median crossover
- Fully close construction roadbed and switch traffic to the reversible roadbed
- Saw-cut old PCC slabs
- Cold plane (mill) old outside AC shoulder
- Demolish old PCC pavement
- Excavate cement-treated base and part of aggregate base (AB)
- Grade and compact AB
- Pave new AC base (76-mm thick by two lifts)
- Compact and cool AC base
- Pave new PCC pavement
- Finish and spread the curing compound
- Saw-cut new PCC slab joints
- AC overlay of outside shoulder
- Clean-up the newly constructed pavement
- Stripe new lanes
- Open the construction roadbed to traffic with about a one-hour traffic break
- Remove QMB from the traffic roadbed

5.2 Reconstruction Productivity Measurements

To enhance the productivity database in the *CA4PRS* software for use in future LLPRS projects, the research team monitored the overall progress in all major operations, including tracking the cycle time of hauling and delivery trucks. In the *CA4PRS* preconstruction analysis, truck cycle time was identified as the most critical element in determining the productivity of pavement rehabilitation. The overall progress on the four major reconstruction operations measured during the first extended closure (NB construction) is shown in Table 2.

The minimum cycle time of loading demolition and discharging fresh concrete directly controlled the number of trucks available each hour; this was confirmed by the *CA4PRS* estimate. The measured average cycle time of loading demolished material for the slab removal operation per truck was about seven minutes. The measured average cycle time of discharging concrete was about three minutes. In summary, the average number of hauling trucks turned around per hour for the slab removal operation was seventeen (with two crews), and the average number of concrete delivery trucks for the paving operation was eighteen.

The productivity data, in conjunction with measurement of the cycle time and the number of trucks turned around per hour, were used to verify the accuracy of the *CA4PRS* software preconstruction analysis. The overall as-built performance, as measured by the research team from the perspective of construction process and progress, appeared to follow the estimated production rate in the *CA4PRS* preconstruction analysis. This consistency was attributed to the fact that the number of hauling and delivery trucks turned around per hour for the major reconstruction operations closely matched the assumed resource inputs used in the *CA4PRS* analysis.

5.3 Contractor's Learning Curve

The construction monitoring study revealed a significant “learning curve” effect on the contractor's production rate. A majority of the reconstruction operations during the SB reconstruction (second closure) showed more progress than those of the NB reconstruction (first closure). The operation that showed the greatest effect of the learning curve, with the same labor- and equipment-resource capacity, was the slab removal operation, which showed 28 percent higher productivity in the second closure. As Figure 9 shows, work progressed at 85 m per hour on average with two demolition crews in the first closure (NB construction) and at 105 m per hour in the second closure (SB construction). The concrete paving operation showed a similar learning-curve effect: there was a 22 percent productivity increase from 93 m per hour for NB construction to 114 m per hour for SB construction. AC-base paving showed a 9 percent

productivity increase, from 146 to 159 m per hour. Base excavation (mill) showed the smallest productivity increase, rising 5 percent (from 142 to 145 m per hour).

Considering that slab removal and PCC paving are two key operations for determining productivity performance, the observed learning-curve effect was attributed to better management by the contractor in the second closure, and to the contractor's desire to meet the scheduled completion date in order to avoid the late-opening penalty in the I/Ds provisions.

5.4 Continuous-Lane Reconstruction versus Random-Slab Replacement

Although the project was initially envisioned for continuous lane reconstruction of two truck lanes in each direction, its scope was reduced after the bid because that approach exceeded the project estimate. As a result, 10 percent of the severely damaged slabs on the inner truck lane were rebuilt as random-slab replacements not touching the existing base. The construction monitoring study revealed that the operation of the continuous-lane reconstruction on the outer truck lane showed a higher level of productivity than the random slab-replacement operation in the inner truck lane. For example, slab removal by the continuous-lane reconstruction operation on the SB construction showed productivity about twice that of random-slab removal (90 m/hr versus 37 m/hr). The productivity of random-slab removal was lower because this process involved the use of an excavator, and problems arose because the machine's blade could not get into the space between the slabs. Remediating the problem required drilling eyeholes into the slab, then using a sling hooked on them to lift the slab, which took extra time.

Most of the time, the random slabs on the inner truck lane were paved by the slip-form paver as part of the continuous outer-truck lane operation. Random slabs at the end of Segment 1 were the exceptions, and these were paved manually by extra crews with a paving screed instead of the slip form. These crews worked separately from the main paving crew to make up for project delays and to ensure that the deadline for opening to traffic would be met. This manual paving process is similar to a traditional nighttime paving operation. The continuous lane-paving operation with the slip form had about eleven times greater productivity than the random-slab paving operation with manual equipment (100 m/hr versus 9 m/hr).

6. MULTIFACETED PUBLIC OUTREACH

6.1 Need for Public Outreach

In planning urban highway projects with heavy traffic volumes, one of the most critical elements is determining the most effective way to disseminate project information to the traveling public about the project and of available detour routes (Benz et al. 1998). O'Connor et al. defined this public outreach concept as “the process of two-way communication between the public and transportation agencies by which transportation agencies and other responsible officials inform the public of project information and use feedback from the public as a factor in sound decision making” (O'Connor et al. 2000).

Comprehensive public outreach processes are time-consuming and require the intensive efforts of many resources. However, project schedule delays, costly litigation, and even project cancellation can occur when the public has a strong reluctance or objection to the proposed project (O'Leary et al. 2003). A well-implemented public outreach program has many potential benefits for transportation agencies, such as enhanced public support, decisions that reflect community values, and lower risk of costly litigation (O'Connor et al. 2000). A well-devised and well-implemented public outreach program is essential to meeting the needs of the public and garnering their support, especially for urban highway rehabilitation projects that cause serious traffic disruption during implementation.

6.2 Dynamic Approach to Public Outreach

The multifaceted public outreach efforts of the I-15 Devore Project were implemented to limit the negative impacts of construction closures on the traveling public. These efforts can be classified into two categories: a proactive approach employed before construction and an interactive approach employed during construction.

Due to the public's initially strong objection to the accelerated construction scheme (with its around-the-clock operations during weekdays), major objectives of the proactive public outreach were:

- To educate the public about the project;
- To build consensus for a revised scheme, renamed the “Rapid Rehab” strategy; and
- To eventually win public support for the strategy.

In the process of proactive public outreach, Caltrans focused on informing daily commuters, travelers, and affected businesses of the accelerated-construction closure scheme and schedule, available detour routes, and the benefits of the Rapid Rehab strategy.

In implementing the interactive approach, the focus shifted to encouraging public participation in forming strategies to substantially reduce traffic demand through the CWZ during peak-hours by diversions to detours, travel mode changes, and travel schedule adjustments. An innovative, state-of-the-practice project Web site was utilized to provide real-time traffic and detour route information to highway users in the target areas. The project Web site was also used to conduct two Web-based community surveys (one before and one during construction) to gain constructive feedback from the public and to examine commuters' perceptions of the Rapid Rehab strategy.

6.3 Proactive Public Outreach

The preconstruction traffic analysis anticipated that a nominal 10 percent reduction in traffic through the CWZ during peak commute hours would still produce maximum traffic delays as long as 90 minutes, while a 20 percent reduction could reduce delays by half, to as little as 45 minutes (Lee et al. 2005d). To achieve the goal of a 20 percent reduction in traffic demand, Caltrans earmarked \$160,000 for the implementation of a proactive public outreach program in the belief that the cost of encouraging public participation in efforts to reduce traffic demand through the CWZ would be paid off by the time value saved by road users. The outreach efforts included use of the media, extensive distribution of outreach materials, establishment of an advisory committee, and holding public meetings. The proactive efforts were dedicated to educating the public about the project and to providing area travelers with the information required either to divert to alternate routes around the CWZ or to time their trips to coincide with construction schedules.

6.3.1 Media Outreach Support

As part of the proactive public outreach program, an intensive media campaign was implemented in the adjoining local communities to inform motorists about the freeway closure scheme, the planned construction schedule, and the available detour routes. Several strategies were developed and effectively used to send outreach messages and to provide reliable project information for travel planning. A series of promotional events were held to pitch I-15 stories to all media formats. Caltrans public information officers provided updates on construction staging, conducted media tours, held press conferences showcasing new technology, and set up photo opportunities and access to behind-the-scenes activities. Quarter-page advertisements were placed in daily and weekly newspapers that reached 1,227,500 readers

in the Southern California region. Altogether, the I-15 Devore Project was covered in more than one-hundred media hits on local TV stations and in nationwide newspapers.

Project information was provided to traffic reporters and to other transportation agency representatives with instructions to access the traffic map on the Internet. The traffic video streamed on the project Web site allowed traffic reporters to obtain for their broadcasts the same real-time traffic conditions available to other Internet users. This new information source was well received and it was used constantly. In addition, a distribution list enabled Caltrans to provide daily updates and critical construction staging plans prior to their implementation.

Radio advertisements during strategic drive times reached both commuters and weekend travelers throughout October 2004. When the extended closures were to take place, advertisements ran one week before the start of construction work and they continued afterward. The radio advertisements repeated the Rapid Rehab theme, informing the public of the benefits of the accelerated construction method, and encouraging participation and support. Public service announcements repeated the project location, suggested avoiding it and using alternate routes during peak commute hours, and promoted safety concerns. These media efforts kept the information fresh, interesting, and newsworthy, and they provided opportunities to repeat the themes of the outreach.

6.3.2 Outreach Materials

The following outreach materials were distributed to local communities, with a special emphasis on the benefits of utilizing the fast-track reconstruction method to complete the project ahead of schedule:

- A comprehensive project brochure that included a graphical detour map.
- Construction flyers, which were distributed to residential communities, truck stops, hospitals, shopping malls, large employers, and gas stations.
- An electronic bulletin, which was sent to the California Trucking Association.
- Twenty-five thousand flyers, which were distributed at a California Trucking Association Trade Show.
- A so-called “fast-fax” construction advisory bulletin, which allowed the public to call or sign up on the project Web site to receive new information via email. Fifteen bulletins were regularly sent electronically to the 485 people registered, disseminating a total of 7,275 messages.
- A project information hot line.
- A project Web site with up-to-date, real-time travel information and detour routes. The Web site still contains information about how the outreach materials were designed.

- Articles were placed in prominent magazines, such as *Westways* (the magazine of the Automobile Club of Southern California), *High Desert Report*, and *Inland Empire*.

6.3.3 Commuter Advisory Committee

To get constructive feedback from daily commuters, Caltrans formed the High Desert Commuter Advisory Committee (HDCAC) to make recommendations about traffic management plans prior to the construction closures. Each of nineteen cities impacted by the I-15 Devore Project appointed a city council member to serve on the forty-person committee. Along with city officials, the committee consisted of one local resident of each city, State Assembly and Senate staff officials, county supervisor staff, and a member of the San Bernardino County Associated Government. County transportation agencies as well as school and fire officials from the affected counties were invited, as were the Public Affairs offices of surrounding Caltrans districts, such as Los Angeles, Orange County, and San Diego. A series of presentations and public service announcements were given at the committee meetings, city council meetings, community events, and county fairs.

Commuter feedback that Caltrans received was often reflected in its changing construction and traffic management plans. For example, during its first NB reconstruction closure, Caltrans originally opened three SB lanes but only one NB lane at the CWZ north segment during morning commute peak hours (utilizing the QMB); this lane configuration was reversed for the evening commute. However, when the committee raised a safety concern about some motorists driving SB as fast as 112 kph (70 mph) despite the 84-kph (50-mph) speed limit in the CWZ—particularly on the median crossover with its downhill slope and sharp double-curvature alignment (with a radius of only 450 m)—Caltrans changed the dynamic lane configuration. The committee’s feedback on this important safety issue led to a shift from 3 x 1 to 2 x 2 lanes for the mornings and evenings in the second closure for SB reconstruction, and the installation of speed advisory systems (automated speed radar and display) at the median crossover.

6.4 Interactive Internet Outreach

The I-15 Devore Project Web site was launched three months before construction started in October 2004. The site provided updated project and real-time traffic information to motorists in the target areas during project implementation, especially daily commuters through the CWZ. The I-15 Devore Project Web site appeared as the first headline on the Caltrans District 8 Home Page and the page linked to the Web sites of neighboring local agencies and the surrounding three Caltrans District offices in Southern California. During the approximately four-month project period implementation, the Web site was updated regularly with the following features: up-to-the-minute information on construction progress, traffic control plans

and detour routes, real-time travel information from the AWIS, press releases and “fast-faxes” for project updates, and Web-based community surveys to help Caltrans gauge changes in public perception of the Rapid Rehab theme (Figure 10).

During the five months before and during the extended closures, the project Web site received nearly 100,000 user sessions (visitor page views), representing a wider participation than any other outreach item. As shown in Figure 11, the user-session numbers on the project Web site increased significantly—to about 40,000—in October 2004, when extended closures were in process. This represented a nearly 300 percent increase in just two months. Because of the useful features available on Web site, the number of user sessions on the Caltrans District 8 Home Page remained high even after project completion. In contrast, the number of user sessions on other Caltrans district home pages in other metropolitan districts reflected no significant variation from August through December 2004. Web-based community surveys indicated that the majority (72 percent) found the project information provided on the Web site to be useful in their trip planning.

To examine the usage patterns of the project Web site, Web server statistics were maintained from August through December 2004. The statistics indicate that the most commonly viewed contents were the real-time traffic map (37,618 requests), the “fast-faxes” (21,133 requests), the schedule (6,150 requests), and the suggested alternate routes (5,023 requests). The statistics also show a unique hourly information retrieval pattern; the heavily peaked request times were 7 A.M. to 9 A.M. and 2 P.M. to 4 P.M. This represents 44.9 percent of all the hourly requests, and supports the fact that the typical user referred to the Web site for commuting purposes, and especially for real-time traffic information. The survey results imply that in future planning of urban highway rehabilitation projects, daily commuters should receive priority treatment as the main target audience for outreach efforts.

7. SUCCESSFUL PROJECT IMPLEMENTATION

7.1 Innovation Payoffs

The innovative fast-track (accelerated) reconstruction strategy known in California as “Rapid Rehab,” is the latest effort by Caltrans to devise accelerated construction techniques that compress construction schedules without increasing maximum peak-hour delays. The benefits of “Rapid Rehab” when compared with traditional repeated nighttime closures include:

1. Faster construction and project delivery (three weeks versus an estimated ten months using the traditional nighttime closure method);
2. A shorter period of traffic disruption for commuters and the traveling public;
3. Longer pavement life span (pavements are expected to last thirty-plus years instead of the average twenty);
4. Improved safety for workers and motorists (through the use of QMB to separate traffic from the work zone);
5. An estimated twenty-five percent lower construction cost (a \$6 million saving on materials that was mainly due to the selection of RSC instead of FSHCC, which costs roughly twice as much and is commonly used as a paving material in nighttime construction), and
6. A reduction in road-user time costs (estimated at \$2 million).

Caltrans concluded that the direct cost increase for the implementation of the innovative additional features was eventually paid off by the value of the time saved by road users and by improvements in public perception of the accelerated-construction approach. Caltrans’ responsiveness to public concerns received much praise from both the public and politicians, and proved instrumental in saving the project and in setting high standards for what can be accomplished using the Rapid Rehab approach.

7.2 Mitigated Traffic Disruption

A traffic monitoring study was also conducted in parallel with the AWIS implementation to quantitatively evaluate the impact of the extended closures on the highway network traffic. The research team measured traffic volumes and speeds before and during construction using several types of traffic surveillance devices, including Remote Traffic Microwave Sensors (RTMS). The overall impact of reconstruction closures on traffic delays was “acceptable” according to a traffic measurement study. This was also confirmed by two Web-based surveys conducted before and after construction. The maximum peak-hour

delay, although infrequent, reached about seventy minutes on weekends for NB travelers and forty-five minutes on weekdays for SB travelers.

A traffic monitoring study comparing the before- and during-construction traffic volumes revealed an approximately 20 percent reduction in actual traffic demand through the CWZ during construction; this was a 10 percent greater reduction than predicted by the initial traffic management plan. More specifically, the daily traffic-demand (volume) reductions measured were 16 percent on I-15 NB and 19 percent on I-15 SB, with a similar trend appearing even during peak hours on weekdays and weekends.

Traffic measurement statistics confirmed that the majority of the traffic diverted used the major freeway detour routes, i.e., use of I-10 EB as the I-15 NB detour showed a 10-percent daily traffic volume increase, and use of I-215 SB as the I-15 SB main detour showed about a 15-percent daily volume increase (see Table 3). These demand reductions through the I-15 CWZ resulted in less inconvenience to motorists than had been anticipated.

7.3 Assessment of Travelers' Reactions

7.3.1 Pre- and Postconstruction Web-Based Community Surveys

To evaluate changes in public perception of this Rapid Rehab project and of how effectively a comprehensive, public dynamic outreach program had been implemented, two Web-based community surveys were undertaken and posted on the project Web site at www.dot.ca.gov/dist8/i15devore/commuter_survey_during_construction.htm.

Among about 400 survey respondents, 90 percent were regular commuters who used the I-15 corridor for one-to-two-hour, one-way trips and the remaining 10 percent were leisure travelers. These percentages do not represent the typical combination of motorists who use the corridor, particularly on weekends when leisure travelers represent a far higher percentage of the total. The survey responses indicate that commuters were much more interested in the traffic conditions in the CWZ than leisure travelers were. The fact that a far greater number of commuters than leisure travelers responded to the survey supports the idea that when urban highway rehabilitation projects are planned, daily commuters should be treated as the major target audience of outreach efforts.

Prior to the extended closures, a preconstruction survey was conducted to examine commuter perceptions of Rapid Rehab strategies and what the public felt it could bear in potential traffic delays. Some of the survey questions addressed:

- Frequency of use of I-15 through Devore
- Trip departure and arrival times
- Trip origins and destinations
- Expected tolerance on travel time during construction

During- and after-construction surveys were performed to investigate the public's actual traffic-delay experience, and to compare changes in public perception of the project with the before-construction survey. Some of questions in the during- and after-construction surveys addressed:

- Willingness to adjust trip departure time to avoid traffic congestion during construction;
- Trip route changes during construction,
- Alternative modes of travel during construction,
- Actual travel times experienced during the lane closures, and
- Accuracy of the travel-time message signs.

The following three sections demonstrate how efficiently the public outreach efforts were perceived on the basis of the before- and after-construction Web survey results.

7.3.2 Commuting Mode Changes

From a traffic management perspective, the key to the project's success would be in convincing motorists to use alternate routes and to adjust their commuting modes to avoid traffic disruption during construction. Before construction began large employers and affected businesses (e.g., airports, postal services, and package service companies) were informed with fliers, in public meetings, and through intensive media outreach. While project planners hoped that a dynamic effort to raise public awareness could result in a 20 percent reduction in peak-hour traffic demand, it was expected that this would be challenging because of the difficulty in targeting road users, the uniqueness of the I-15 Devore Corridor, and the lack of available detour routes near the CWZ.

A traffic monitoring study was conducted to evaluate the impact of the extended closures by comparing traffic conditions before and during construction. The resultant data show that the 20-percent reduction in traffic demand during peak-hours through the CWZ was achieved by the combination of no-shows, diversions, and travel-mode changes.

Questions about travel patterns were posted to measure the difference between how many travelers considered changes in their trip schedules, routes, and modes before construction, and how many made

those changes during and after construction. The surveys revealed that the traffic-volume reduction was attributed to a comprehensive, proactive, and interactive public outreach program. Encouraged by Caltrans' extensive public outreach efforts, commuters changed their daily commuting modes and travel routes during the extended closures. The before-construction survey showed that 61 percent of respondents would not change their travel patterns even if the I-15 CWZ Corridor was congested. In actuality, only 24 percent of respondents to the during- and after-construction surveys indicated that they did not change their travel plans, while 40 percent adjusted their departure times and 32 percent took detours during the extended closures (Figure 12).

7.3.3 Traffic Delay Evaluation

The traffic monitoring study showed that the maximum peak delay was measured at about 75 minutes on weekends (NB) and 45 minutes on weekdays (SB) during the extended closures. The preconstruction survey indicated that 94 percent of respondents felt that a less-than-thirty-minute delay through the CWZ would be acceptable. In the during-construction and postconstruction surveys, travelers reported experiencing the following delays during the extended closures: 27 percent reported delays longer than sixty minutes, 20 percent reported forty-five minute delays, and 53 percent reported delays of thirty-minutes or less. Overall, the actual travel times they experienced matched the AWIS-estimated travel-time information. The during-construction and postconstruction surveys showed that the overall impact of the closures on traffic was "tolerable."

Survey respondents gave a positive evaluation to the accuracy of the AWIS travel-time estimate. Twenty-four percent responded that the AWIS travel-time estimates were accurate all the time and 67 percent commented that they were accurate at least part of the time. The majority (73 percent) of the respondents noted that they utilized the Web site's real-time travel information to some degree; 28 percent "mostly liked" the traffic snapshot; 24 percent mostly liked the AWIS travel-time estimate messages; and 21 percent mostly liked the traffic-streaming video. In addition, in the during-construction and postconstruction surveys, 74 percent of respondents expressed a favorable opinion of the QMB operation.

7.3.4 Changes in Public Perception

The surveys were used to capture changes in how the public perceived the Rapid Rehab strategy. Most preconstruction survey respondents were strongly opposed to the accelerated reconstruction method (with its extended closures): 64 percent expressed an initial preference for traditional nighttime or weekend closures and 14 percent requested that the project be cancelled. However, 70 percent of the respondents to the during- and postconstruction survey expressed support for Rapid Rehab strategy and use of

accelerated reconstruction for future projects (Figure 13). This result indicates that the public is willing to bear the inconvenience of long traffic delays through a CWZ for a short period of time if doing so will significantly shorten the time a construction project requires.

The main contributor to this trend change in public perception from negative to positive was the multifaceted comprehensive public outreach program. This conclusion is supported by the survey numbers: 88 percent of respondents were aware of the extended closure prior to construction, and 75 percent of respondents felt that the public awareness campaign for the I-15 Devore Project was sufficient.

8. SUMMARY AND CONCLUSIONS

This report introduces the innovative approaches applied to the fast-track concrete pavement reconstruction of two badly deteriorated truck lanes on the heavily trafficked I-15 freeway at Devore, California. Two extended closures and around-the-clock operations (24 hours day/7 days per week) for expediting reconstruction were adopted to minimize public inconvenience due to lane closures during construction. The reconstruction of the 4.5-km stretch was completed on time in just 215 hours (about nine days) for each direction.

The traffic monitoring study indicated that the goal of a 20 percent reduction in traffic demand was achieved (which was 10 percent more than the initial estimate), and surveys on the project Web site indicated that the public considered the reconstruction's overall impact on traffic to be "tolerable." The southbound (SB) maximum measured peak hour delay during the extended closures was approximately 45 minutes on weekdays; this compared favorably with the 90-minute delay (with a presumed 10 percent reduction in traffic) predicted in the preconstruction traffic-sensitivity analysis. Achievement of the 20 percent traffic-demand reduction through the construction work zone (CWZ) was attributed to the comprehensive Caltrans public outreach program and the department's traffic-control efforts; these included using the Quickchange Moveable Barrier (QMB) and real-time CWZ travel information systems, which used the state-of-practice Automated Work Zone Information System (AWIS) and a project Web site. The AWIS benefited road users by providing interactive real-time travel estimates, both on-site (in the CWZ) and off-site (on project Web site). Travel through the CWZ was further facilitated by the use of the QMB, which allowed for dynamic lane configuration to help accommodate peak-hour traffic.

Created as part of the multifaceted public outreach program, the state-of-practice project Web site played a key role in reducing traffic demand; it served as an interactive tool that provided the traveling public with real-time travel information and helped Caltrans gain constructive public feedback. Caltrans used the project Web site to conduct two Web-based community surveys to compare commuters' expectations of potential traffic delays before construction with their actual experiences during the extended closures; the surveys also allowed Caltrans to study the overall public perception of the fast-track reconstruction method.

The Web surveys revealed dramatic changes in the public's view of the accelerated fast-track reconstruction method from before the project to after its completion; perceptions of the project changed from one with initial objections to one of support. In the preconstruction Web survey, 56 percent of those

responding held a negative view of the concept of extended closures with fast-track reconstruction. Respondents either expressed their preference for conventional nighttime closures or a desire to cancel the project altogether. The during- and postconstruction surveys revealed a dramatic change in public attitude; 70 percent of the responses supported “Rapid Rehab” strategies for future projects, including the future implementation of the one-roadbed continuous construction scheme. This change conveyed the important conclusion that the public is willing to bear the inconvenience of long traffic delays through a CWZ for a short period of time if doing so will significantly shorten the time a construction project requires.

This project provided a unique opportunity to validate, to fine-tune, and to enhance highway analysis tools for urban highway projects with heavy traffic volume. The number of hauling and delivery trucks per hour turned around for the major reconstruction operations were similar to the assumed resource inputs in the *Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS)* model. An approximately five percent deviation between the *CA4PRS* schedule estimate and as-built production performance was due to a learning-curve effect in the contractor’s production rate, which was driven by a desire to meet the scheduled completion date to avoid a late-opening penalty as defined in the incentive/disincentive provisions.

Developing the fast-track (“Rapid Rehab”) approach required the involvement of design, construction, and traffic engineers throughout the planning, design, and construction phases of the project. This resulted in teambuilding, which enabled those involved to arrive at mutually optimal rehabilitation solutions. This postconstruction analysis of the I-15 Project with the validation of the preconstruction estimates provides innovative ideas for transportation agencies and contractors to balance maximizing of rehabilitation productivity with minimizing of traffic delay, while also minimizing total costs and achieving long-life pavement performance. State highway agencies and decision-makers can use the ideas and findings of this case study to frame a comprehensive fast-track project in urban highway rehabilitation with the goals of accelerating construction schedules and minimizing public inconvenience.

9. LIST OF ACRONYMS

The following acronyms are frequently used in this paper:

AC	Asphalt Concrete
ADT	Average Daily Traffic
AWIS	Automated Work Zone Information System
<i>CA4PRS</i>	Construction Analysis for Pavement Rehabilitation Strategies
CHP	California Highway Patrol
CMS	Changeable Message Signs
CWZ	Construction Work Zone
EB	Eastbound
I/D	Incentives/Disincentives
LLPRS	Long-life Pavement Rehabilitation Strategies
NB	Northbound
QMB	Quickchange Moveable Barrier
RTMS	Remote Traffic Microwave Sensor
SB	Southbound
TMC	Traffic Management Center

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Table 1: Comparison of Alternative Closure Scenarios in the Preconstruction Analysis

Closure Scenario (1)	Schedule Comparison		Traffic Delay		Cost Comparison	
	Closure number (2)	Closure hours (3)	Road user cost (\$M) (4)	Max delay (minute) (5)	Agency cost (\$M) (6)	Total cost (\$M) (7)=(4)+(6)
72 hour weekday	8	512	6.6	75	12.6	19.2
55-hour weekend	10	550	12.7	196	15.1	27.8
One-roadbed continuous	2	400	6.1	196	9.9	16.0
10-hour nighttime	220	2,200	10	36	20.4	30.4

Table 2: Truck Number and Cycle Time on Major Operations Measured During Reconstruction

Operation	Average Truck Number per Hour	Average Truck Turn-around Time (minute)	Total Operation Hours per Closure for 210 hours	Hourly Progress (meter)		
				Northbound (NB)	Southbound (SB)	Average
Slab removal	17	62	49	84.8	104.9	95
Base excavation	13	55	29	144.8	142.1	144
AC Base paving	12	107	28	145.5	158.9	153
PCC paving	17.7	42	45	93.1	114.2	102

Table 3: Measured Traffic Volume Change during the Extended Closures Compared with Traffic before Construction

Network	Route	Average	Network	Route
CWZ Corridor	I-15 Northbound	-16%	-17%	With RTMS
	I-15 Southbound	-19%		
Detours Freeways	I-215 Southbound	+15%	+16%	I-15 SB detour
	I-10 Eastbound	+10%	+36%	I-15 NB detour
Detour arterials	Major intersections	+5%	+6%	With rubber tubes



Figure 1: The I-15 Devore Project location.

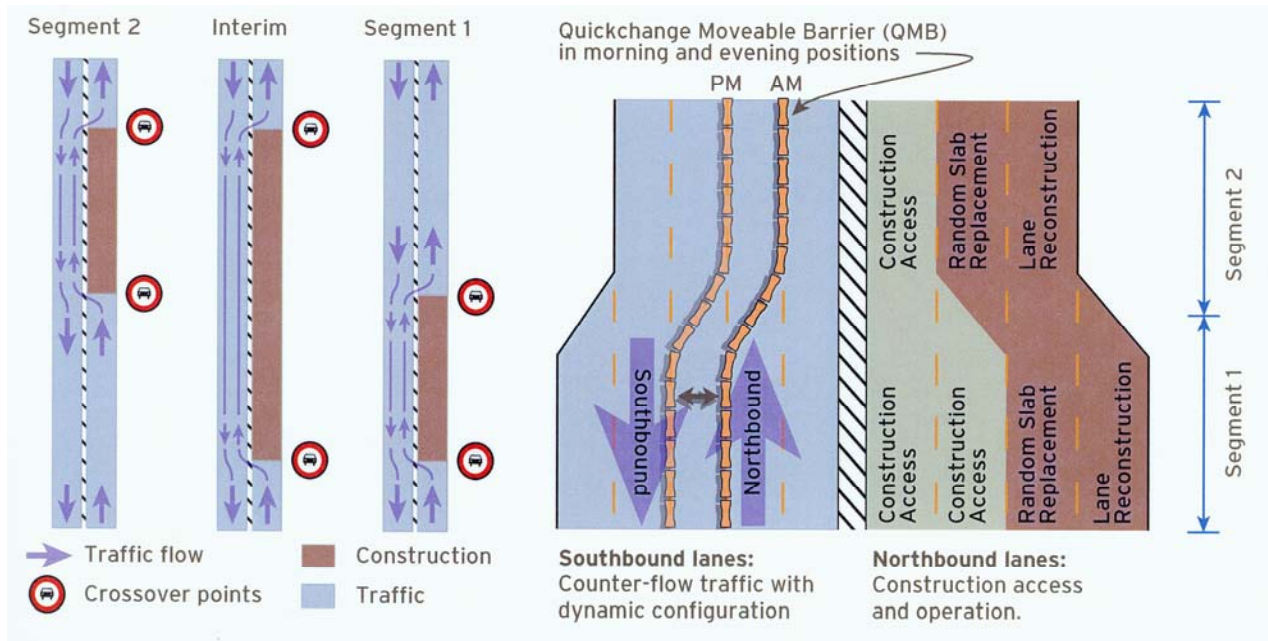


Figure 2: Progressive construction staging plan and lane closure scheme with construction.

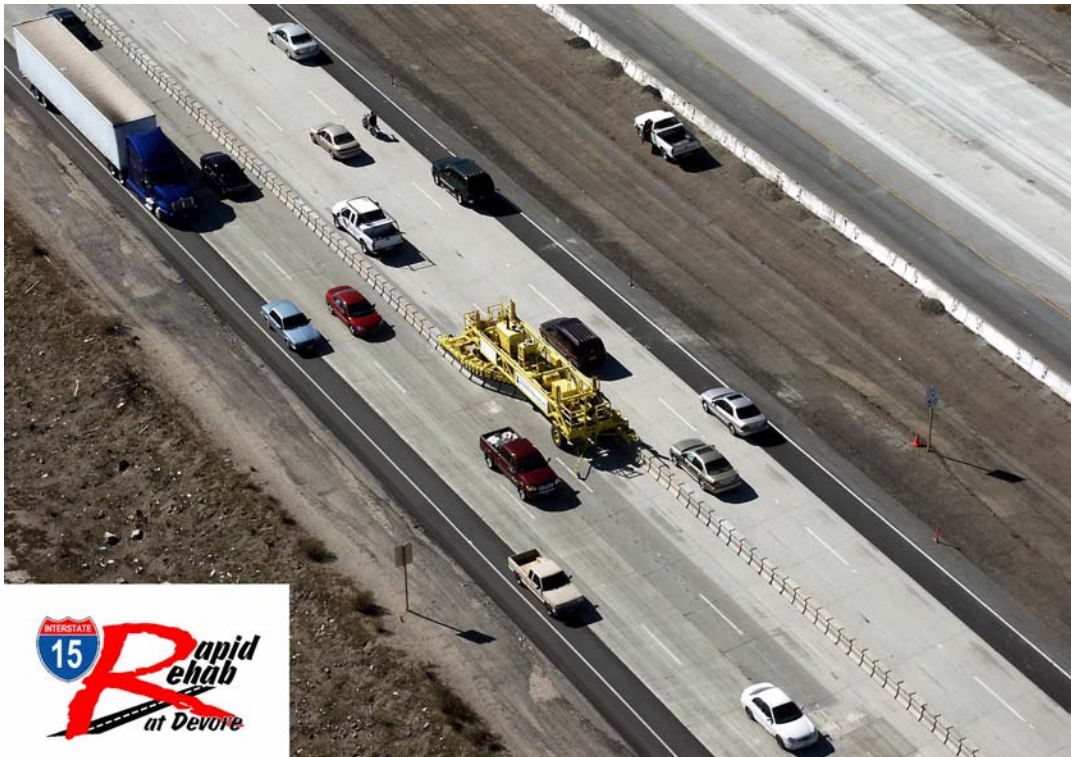


Figure 3: Operation of QMB to provide dynamic lane configuration.

Constructability and Productivity Analysis

File Options Window Help

PCCP Deterministic - I-15 Devore Continuous Closure

Project Identifier: I-15 Devore Continuous Closure Unit: English Metric

Project Details | Scheduling | Resource Profile | Analysis

Construction Window

- Weekend Closure
- Nighttime Closure
- Continuous Closure/Continuous Operation
- Continuous Closure/Shift Operation

Curing Time

- 4-Hours
- 8-Hours
- 12-Hours
- User Defined Hours

Working Method

- Sequential Single Lane (T1)
- Sequential Single Lane (T2)
- Sequential Double Lane (T1+T2)
- Concurrent Single Lane (T1)
- Concurrent Single Lane (T2)
- Concurrent Double Lane (T1+T2)

Section Profile

- 203 mm (8 inches)
- 254 mm (10 inches)
- 305 mm (12 inches)
- User Defined

PCCP (mm):

Treated Base (mm):

Depth (mm):

Additional Demolition

Analyze... Compare...

Lane Widths

T1 Width (m):

T2 Width (m):

Production Details | Production Chart | Gantt Chart

Construction Window:	Continuous Closure/Continuous Concurrent Single Lane (T2)
Working Method:	PCCP: 290.0 mm, New Base: 152.4 mm
Section Profile:	
Curing Time:	12-Hours
Objective (lane-km):	10.50
Maximum Possible (lane-km):	5.34
Maximum Possible (c/l-km):	5.34
Construction Windows Needed To Meet Objective:	1.97

Resource	Allocated	Utilized
Dump Truck (per hour)	10.0	10.0
End Dump Truck (New Base) (per hour)	4.0	2.5
Batch Plant (cu-m/hour)	150.0	48.2
End Dump Truck (PCC) (per hour)	15.0	8.0
Paver Speed (m/min)	2.0	0.6

Figure 4: Input and output screen shots for the CA4PRS analysis.



Figure 5: Monitoring of construction and traffic in the project command center.

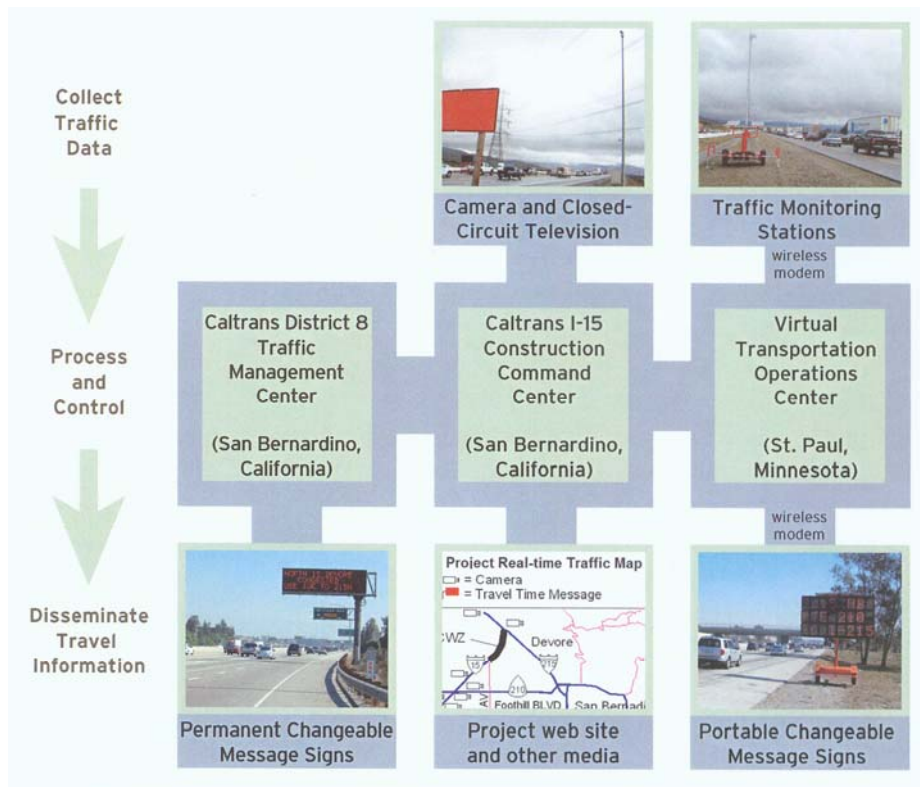


Figure 6: A schematic diagram showing the I-15 Devore AWIS operation.

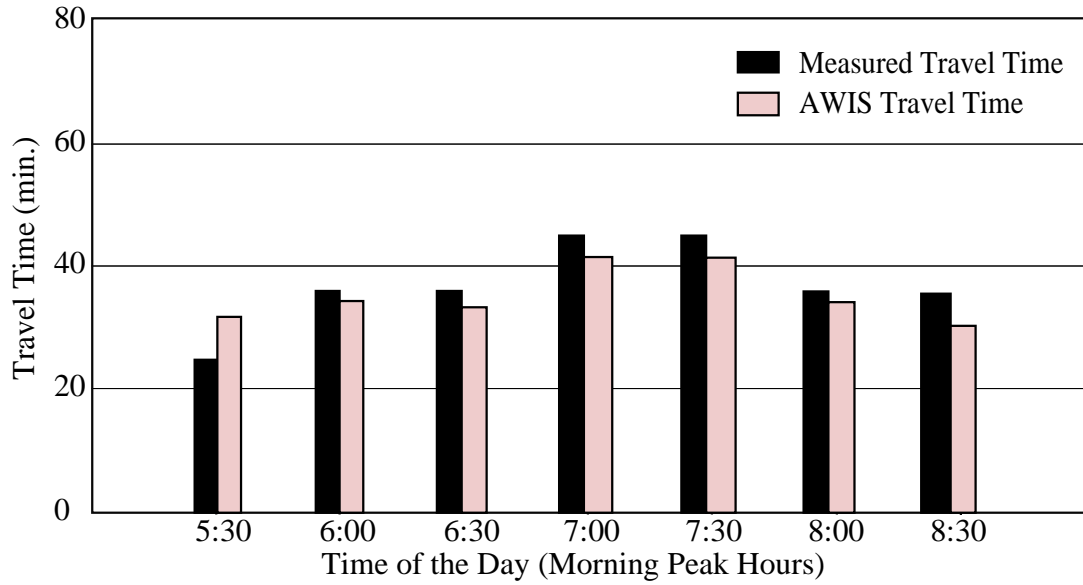


Figure 7: Comparison of measured and AWIS-estimated travel times (I-15 SB, 27 km, October 26, 2004).



Figure 8: Construction and traffic operation during I-15 Devore reconstruction.

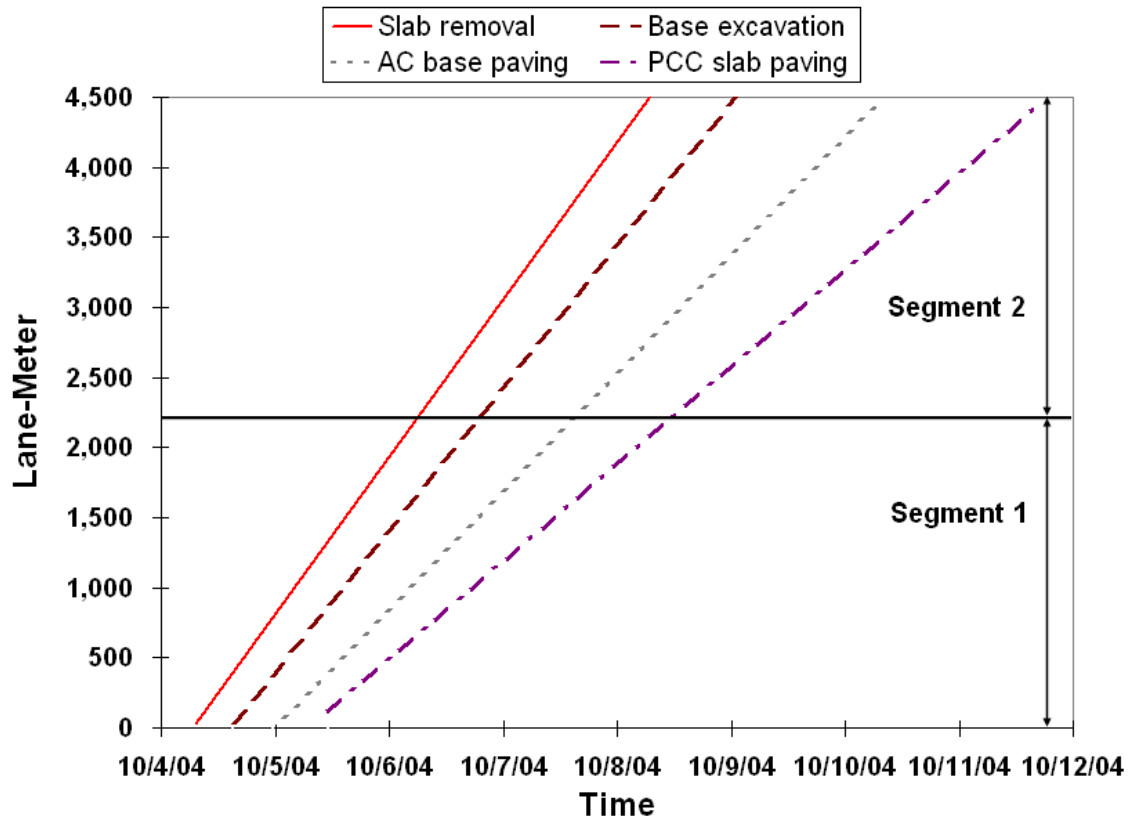


Figure 9: Linear productivity of major operations monitored during northbound construction.

File Edit View Favorites Tools Help

Address http://www.dot.ca.gov/dist8/i15devore/realtime_trafficmap.htm

California Home Monday, May 2, 2005

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I-15 Devore Project

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I-15 Devore Project Real-time Traffic Map

Las Vegas = Camera = Travel Time Message

The map displays the I-15 corridor from Las Vegas in the north to San Diego in the south. Key locations marked include Las Vegas, Devore, Fontana, San Bernardino, and Riverside. Major roads shown include I-15, I-10, I-210, I-215, and SR 138. A legend indicates that white camera icons are placed at various points along the route, and red square icons indicate travel time messages. A thick black line on I-15 near Devore indicates a construction work zone (CWZ). A north arrow is located in the upper left corner of the map area.

LA ← → Palm Spring

San Diego


 Click on the available symbols to display information for that locaion.
 Click here to view real-time streaming cameras

Figure 10: AWIS real-time traffic roadmap on the project Web site (adapted from the original image).

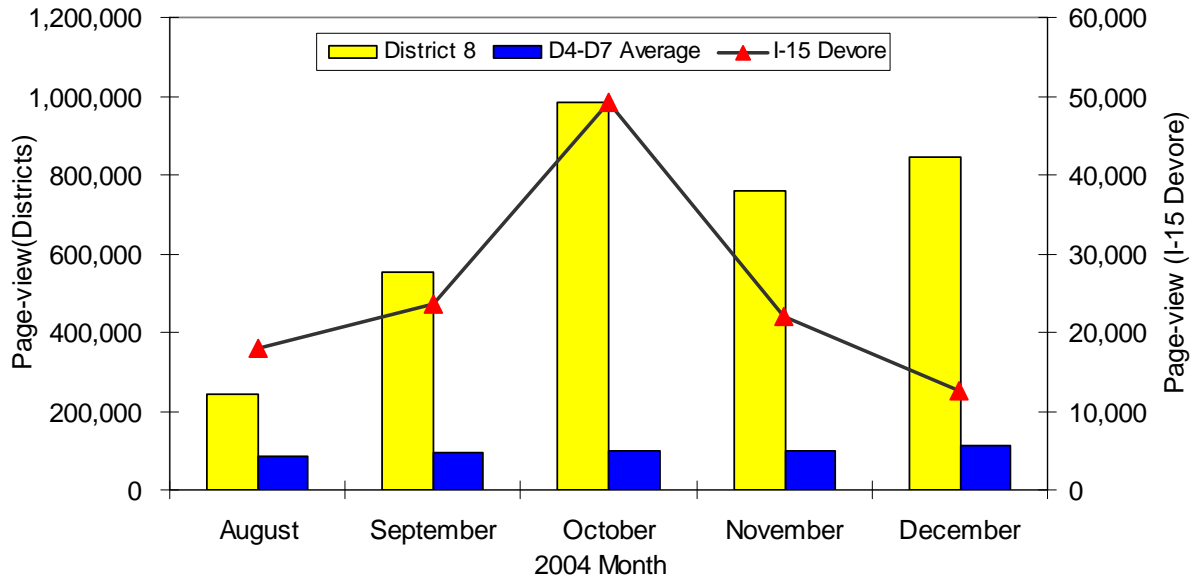


Figure 11: Usage of the project Web site during project implementation.

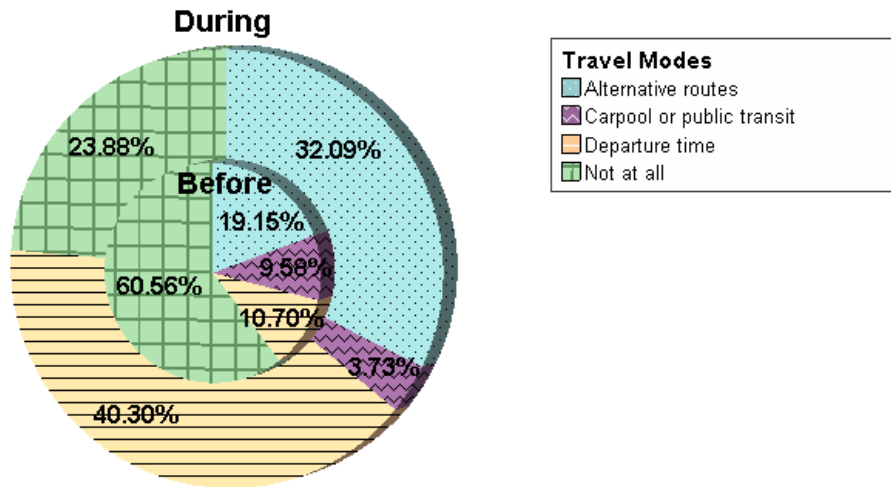
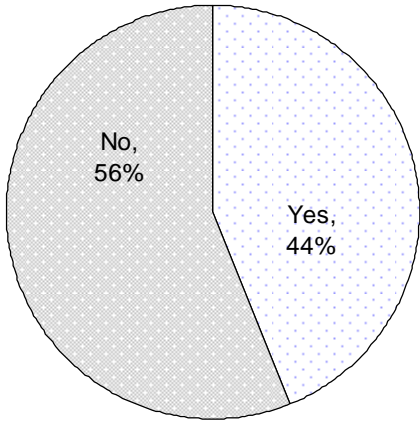
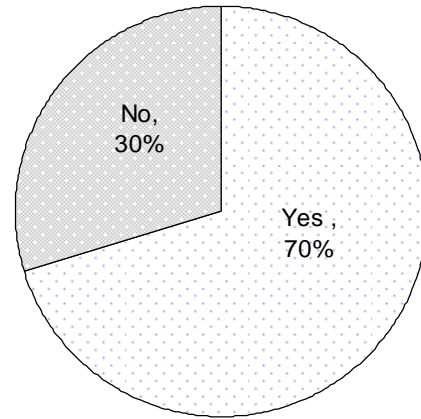


Figure 12: Commuters' travel mode changes in comparison to before- and during-construction.



(a) Before-construction: Do you support the extended continuous closures?



(b) After-construction: Do you support the "Rapid Rehab" approach for future projects?

Figure 13: The change in public perception from strong initial reluctance to support "Rapid Rehab" construction.