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Impact of Urban Freeway Rehabilitation on Network Traffic: Measurement and Simulation Study

Authors
Lee, Eul-Bum
Mun, Jin Hyun
Harvey, John T.

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By

Eul-Bum Lee, Jin Hyun Mun, John T. Harvey

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Pavement Research Center
Institute of Transportation Studies
University of California Berkeley / University of California Davis

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EXECUTIVE SUMMARY

This technical memorandum presents an analysis of the impact of urban freeway pavement rehabilitation on freeway traffic on I-710 Long Beach (CA), a freeway with high traffic volume, over eight 55-hour weekend closures. The study included actual traffic measurements and microscopic simulations through a broad traffic network containing a construction work zone (CWZ), neighboring freeways, and detour arterials. As drivers re-routed to the detour routes, the hourly peak traffic demand through the CWZ during construction weekends decreased by 37 percent from historical averages, which is near the Traffic Management Plan (TMP) average estimate of 40 percent. During construction, traffic volume on arterial intersections was increased noticeably (14 percent), and network-level no-show traffic was insignificant (only 1 percent). As the weekend closures were repeated, drivers exhibited a learning effect, with the maximum peak hourly volume through the CWZ decreasing. The microscopic simulation study experienced some calibration limitations due to the large grid network and high traffic volume, but was found to be sufficiently efficient and reliable to warrant use for validation of TMPs for future highway rehabilitation projects.

1.0 INTRODUCTION

The majority of the urban freeway network in California was constructed between 1955 and 1975 with projected design lives of 20 years. Traffic demands on these freeways have continued to grow, and all of these pavements have long exceeded their original design traffic, with many reaching it before 20 years. The resulting poor pavement quality of the deteriorated freeways adversely affects user safety and vehicle operating and highway maintenance costs. This experience has spurred a shift from building new transportation facilities to programs focused on "4-R" projects (Restoration, Resurfacing, Rehabilitation and Reconstruction).(*1*)

1.1 Highway Rehabilitation in California

The California Department of Transportation (Caltrans) launched its Long-life Pavement Rehabilitation Strategies (LLPRS) initiative in 1998 to rebuild approximately 2,800 lane-kilometers out of the 80,000 lane-kilometer state highway network over a 10 year period beginning in 1998.(*2*) Most of the projects currently consist of Portland Cement Concrete (PCC) pavements in urban corridors of Southern California (the Los Angeles basin) and the San Francisco Bay Area. Criteria for LLPRS candidate projects are poor pavement structural condition and ride quality and a minimum of 150,000 Average Daily Traffic (ADT) or 15,000 Average Daily Truck Traffic (ADTT).

The main goals of LLPRS are to provide new pavement with at least 30 years of design life requiring minimal maintenance.(*2*) Construction windows of 55-hours (10 p.m. Friday to 5 a.m. Monday) with 24-hour operations were selected over the typical 8- to 10-hour weeknight closures. The 55-hour weekend closure was selected to minimize traffic delay during pavement rehabilitation since urban freeways typically carry lower traffic volume during weekends than weekdays, and a larger portion of weekend trips are considered to be discretionary travel. The longer weekend closures permit the use of a wider variety of rehabilitation strategies, and were assumed to increase the safety of road users, construction crews, and agency personnel because the number and duration of closures would be significantly less than those of a weeknight closure scenario.(*3*)

In 1999 Caltrans successfully rehabilitated 2.8 lane-km of I-10 in Pomona. This was the first concrete LLPRS demonstration project, and utilized fast-setting hydraulic cement concrete in conjunction with a single 55-hour weekend closure. The 55-hour extended weekend closure turned out to be about 40 percent more productive compared to nighttime closures on the same project.(*4*) The success of the I-10 project led Caltrans to systematically implement LLPRS projects using extended weekend closures on other projects. The I-710 Long Beach project, presented in this paper, was the first asphalt LLPRS project, and used repeated 55-hour weekend closures to rehabilitate and reconstruct 26 lane-km of old PCC with long-life asphalt concrete.

1.2 Research Objectives

The main goal of the traffic case study presented in this paper was to evaluate the impact of rehabilitation work on the high volume urban freeway over the repeated 55-hour weekend closures. The research team measured traffic delay with a number of traffic surveillance devices through the construction work zone (CWZ) on I-710, neighboring freeways, and alternative arterial detours defined in the transportation management plan (TMP) for the project. These closure impacts were determined by evaluating traffic statistics in three cases: "before-construction" (historical), "during-construction" and "after-construction" weekends. The result was a set of traffic statistics, including changes in traffic volume, travel times, travel speeds, etc.

The second objective of the research was to evaluate the TMP developed by Caltrans and to enhance traffic planning skills for future LLPRS projects. This was achieved by comparing predicted outcomes of the TMP, especially traffic demand reduction and detours during closures, with actual data. The behavior of drivers was also examined to determine if there was a "driver learning effect," meaning that travel and detour behavior changed in response to the public outreach campaign, and then further adjusted based on driver observations of actual delay. This was performed by monitoring the peak traffic volume change through the CWZ as a result of re-routing over repeated weekend closures.

The third objective of the research team was to develop a microscopic traffic simulation model to replicate construction closure scenarios on a traffic network, and compare the simulation results to actual data in order to validate the accuracy of the simulation.

2.0 I-710 WEEKEND CONSTRUCTION

Interstate 710, located in Los Angeles County, was built in 1951 with three to four lanes in each direction. I-710 serves as a major route for commuter and commercial traffic between Los Angeles and Long Beach. It is also a gateway to the Ports of Long Beach and Los Angeles, two of the busiest cargo ports in the United States. It was originally built with Portland Cement Concrete (PCC), with a design life of 20 years. Due to the heavy truck traffic carried over its 51-year life, it was extremely deteriorated, with severe faulting and transverse, longitudinal, and corner cracks, and many "shattered slabs" with multiple types of cracking.(*5*)

Rehabilitation of the I-710 Long Beach project consisted of 26.3 lane-km over 4.4 centerline-km with three main lanes in each direction plus median and outside shoulders in both directions. The rehabilitated section lies between the Pacific Coast Highway (PCH) intersection and the San Diego Freeway (I-405) system interchange, as illustrated in Figure 1. The existing pavement structure consisted of 200 mm PCC with 100 mm Cement Treated Base (CTB).

Two types of pavement rehabilitation structure were utilized. The first was utilized for 400-m long segments beneath the freeway overpasses, which did not meet current federal bridge clearance requirements. For these segments, the existing PCC and CTB and part of the subgrade were removed and replaced with 330 mm of new, Full-Depth Asphalt Concrete (FDAC). The FDAC replacement

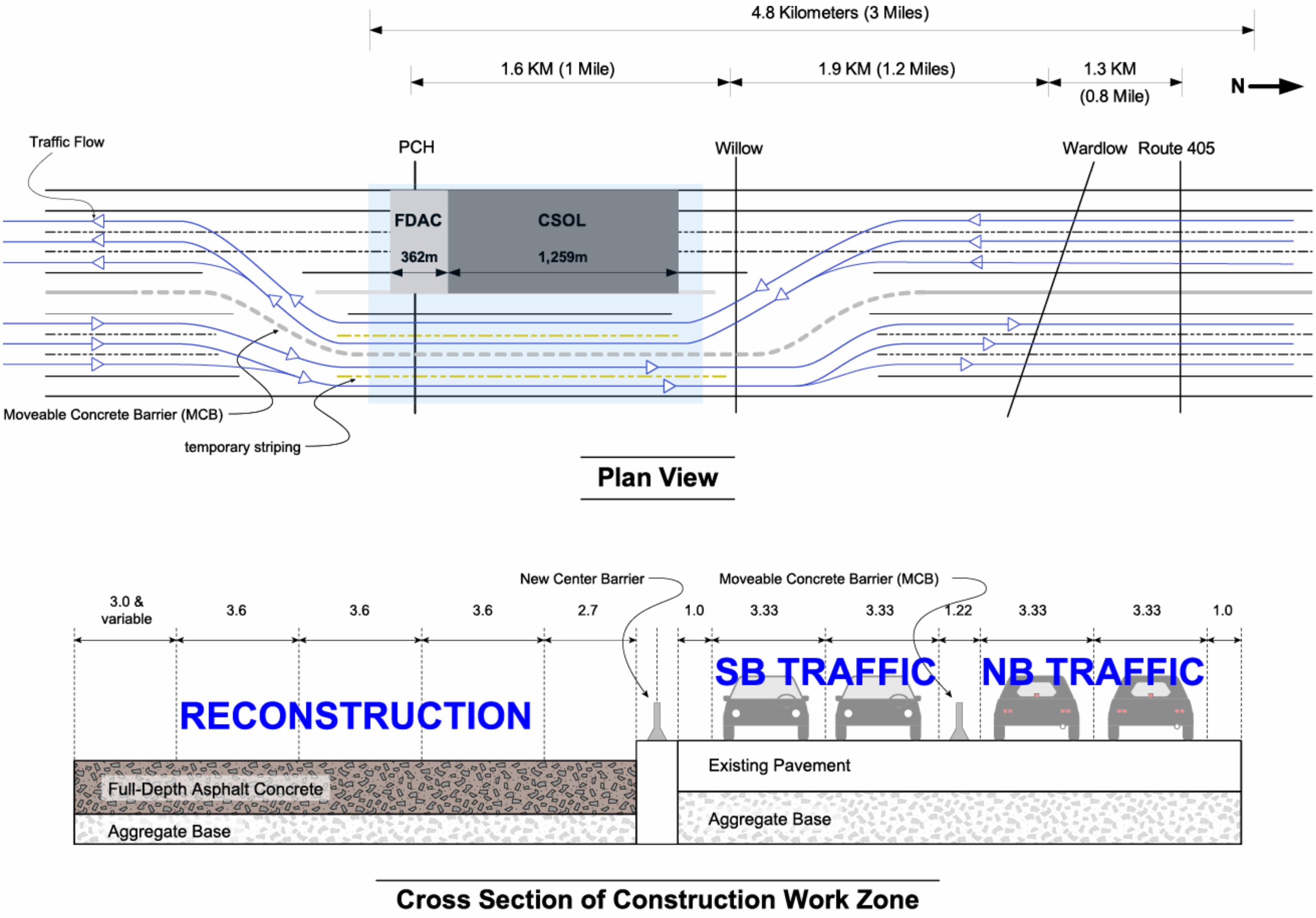

Figure 1. Lane closure tactics for the first 55-hour weekend closure at Pacific Coast Highway.

sections consisted of five layers, and included four different asphalt concrete mix designs (76 mm of rich bottom AR-8000 mix, 152 mm of AR-8000 mix, 76 mm polymer modified PBA-6a mix, and 25 mm of open-graded friction course).

The second rehabilitation structure was utilized between the overpasses, where vertical clearance was not limiting. On these segments, the old PCC pavement was cracked, seated, and overlaid (CSOL) with 230 mm of asphalt concrete. The new cross sections of the CSOL sections consist of four asphalt lifts: 45 mm of AR-8000 mix with a fabric interlayer placed on top of it, 85 mm of AR-8000 mix, 75 mm of PBA-6a mix, and 25 mm of open-graded friction course. Total volumes of materials involved were 11,400 m^3 of PCC pavement removal, 15,000 m^3 of roadway excavation, and 112,700 tonnes of hot mix asphalt concrete paving.

The project contract had an original bidding price of $16.7 million. Construction started in April 2000 and had an initial completion target of fall 2002. The contract amount eventually increased to about $20 million due to several change orders and claims involving asphalt mix design problems, roadway alignment adjustment, and poor subgrade soil conditions. With these changes, the whole project was eventually completed in October, 2003 over eight 55-hour weekend closures. In parallel to the traffic study, the research team monitored and analyzed construction process and progress (productivity), as summarized in the project report.(*6*)

2.1 Rehabilitation Progress

The initial Caltrans plan estimated ten 55-hour weekend closures to complete the project. The contractor eliminated two weekend closures by adding extra resources, and was contractually compensated with $200,000 in incentive pay. The first 55-hour weekend closure was March 28–31, 2003 and all the major rehabilitation work was completed during the eighth weekend closure on June 20–23, 2003. Five non-working weekends were excluded: the Long Beach Grand Prix (car racing), Easter, Memorial Day weekends and two weekends with bad weather. Work remaining after the final weekend closure included the final task of laying down the 25-mm open-graded friction course during weekday nights, which was completed at the end of September, 2003.

2.2 Traffic Control Scheme

The I-710 corridor carries an average daily traffic (ADT) volume of more than 164,000, with 13 percent heavy trucks during weekdays and an ADT of about 122,000 during weekends with about 4 percent heavy trucks. Weekend closure was selected for the rehabilitation work since weekend peak traffic volume of about 4,300 vehicles per hour (vph) in each direction was less than weekday peak traffic (about 5,400 vph). Short, nighttime closures were inappropriate for this project considering the huge volume of demolition hauling and paving delivery materials that had to be handled. It was essential to implement effective Construction Work Zone (CWZ) traffic controls to reduce the impact of construction closures on network traffic.

Caltrans applied a “counter-flow traffic” scheme in which one entire direction of the freeway (the “construction roadbed”) is closed for construction during the weekend, and traffic is switched to the other side of the freeway (the “traffic roadbed”) by using median traffic crossovers at each end of the CWZ. Because the freeway has only three lanes in each direction, the shoulder was temporarily converted into a traffic lane to allow for two lanes in each direction on the traffic roadbed with moveable concrete barriers (MCB) installed between the two lanes. However, significant traffic delay was still expected unless some traffic demand during construction weekends was reduced because the typical weekend peak volume of 4,300 vph still exceeded the expected capacity of the two-lane CWZ (about 3,000 vph).

The freeway section between the PCH and the I-405 junction was completely closed in both directions for about six hours (Friday, 11 p.m. – Saturday, 5 a.m.) at the beginning of the 55-hour weekend closures with traffic detoured to local streets. During this full closure, MCBs were installed, traffic markers (stripes) and reflectors were removed, and the traffic roadbed was re-striped for the 2-by-2 lane configuration. Rehabilitation operations proceeded during the 55-hour closure from 10 p.m. Friday through 5 a.m. Monday. At the end of the 55-hour weekend closure, both directions of the freeway were completely closed again for 6 to 7 hours for MCB removal and the re-striping before re-opening to public traffic on Monday at 5 a.m. Traffic signs and traffic control devices were also installed before the construction started. Comprehensive traffic signs and information dissemination provided detour strategies on adjacent freeways and arterials during the construction weekends as set forth in the TMP.

2.3 Traffic Management Plan

Caltrans has traditionally developed TMPs for highway construction based on previous experience, with limited quantitative reference data. With a large number of upcoming pavement rehabilitation (LLPRS) projects on urban freeway networks in the state, the need to develop systematic and comprehensive TMPs for highway rehabilitation is becoming increasingly critical to minimize traffic inconvenience during construction. In this research, the TMP estimation, especially the estimate of reduced traffic demand during construction mainly resulting from no-show and re-routing traffic to alternative routes, was validated with the actual traffic measurements.

During the period of highway rehabilitation, drivers were expected to respond to the CWZ closure in three ways: no-shows, detours, and no change. The comprehensive TMP included plans to reduce traffic demand during construction by informing drivers of alternative routes and ramp closures by the following means: a Public Awareness Campaign (PAC) to reduce traffic demand; Portable, and Permanent Changeable Message Sign (PCMS) and a Motorist Information System (MIS) to direct drivers to take detours; and Highway Advisory Radio (HAR) messages to disseminate real-time traffic information. In total, 230 roadway guide signs and 26 PCMS's were installed on the traffic network during each weekend closure.(*7*)

With this TMP, Caltrans expected reduced traffic demand during construction and hence a more manageable traffic flow through the CWZ. Individual delays of a maximum of 275 minutes for Northbound (NB) I-710 and 274 minutes for Southbound (SB) I-710 were estimated for weekend closures without TMP implementation. With the reduced traffic demand as a result of TMP implementation, Caltrans District 7 Traffic Operations expected that there would be no delays on SB I-710 and significantly reduced delays on NB I-710, with maximum individual delays of 14 minutes.(*7*)

The alternative north-south parallel detour routes in the TMP consisted of freeways such as I-110 and major arterials including Long Beach Boulevard and Santa Fe Avenue. The TMP estimated that 10 percent peak hour traffic on I-710 NB would be no-shows due to the PAC, and that more than 25 percent of traffic would be diverted through I-110 and arterials as guided by PCMS's. For the southbound (SB) traffic on I-710, the TMP estimated that 10 percent of mainline traffic on I-710 would be no-shows, 15 percent would instead use I-110 or I-605 by way of I-105 and Route 91, and another 20 percent would use I-405. In the case of the I-405 connector to SB I-710, which was blocked during construction, the TMP expected that 10 percent of traffic from I-405 would be no-shows as a result of the PAC. The remaining 90 percent of the traffic from I-405 was estimated to be detoured to surface streets or I-110 and Route 47 by PCMS's.(*7*)

3.0 TRAFFIC MONITORING STUDY

The traffic monitoring study for the I-710 project consisted of the following two elements for the traffic measurement, TMP evaluation, and simulation model:

- time window comparison: before, during, and after construction weekends.
- geographic network comparison: I-710 corridor (CWZ), neighboring freeways, and arterials.

The traffic monitoring tools used for this study were the California Freeway Performance Measurement System (PeMS), Weigh in Motion (WIM) stations, Remote Traffic Microwave Sensors (RTMS), rubber tubes, and tach runs. Figure 2 shows the overall locations of traffic data measurement system element in the study network area (approximately 12 km by 16 km).

PeMS is a real-time database accessible over the Internet and was used for traffic monitoring on the I-710 corridor (outside of the CWZ) and the alternate freeway network. PeMS receives information from Caltrans loop detectors and provides aggregated traffic data and various real-time information such as total flow, average flow, speed, and vehicle mile per hour.(*8*) WIM, which is primarily intended for measurement of truck traffic loads, provides information on volume, speed, and axle spacing of trucks. Heavy truck traffic volume and speed data were counted at Caltrans WIM Stations 59 (NB I-710) and 60 (SB I-710), which are located north of the CWZ.

Temporary measurement systems including RTMS and rubber tube were used to obtain traffic data in areas the existing permanent surveillance system could not cover. RTMS, a lateral scanning system installed at the upstream inlet, the midpoint, and the downstream outlet of the CWZ, measured the traffic volume, vehicle classification, and speed through the CWZ on both direction of I-710.(*9*) Historical data collected from the old loop detector station on the nearby PCH, which was removed during construction, was used to validate RTMS data. In order to measure the diverted traffic from I-710 to alternative arterial routes during construction, portable counters and rubber tubes were installed on I-710 freeway ramps and on major intersections in the local arterial roads. In addition, tach run vehicles were driven through the I-710 corridor before construction and during construction at peak weekend hours to obtain average speed and travel time changes due to the construction.

3.1.1 <u>Time Window Comparison</u>

Traffic was measured using the various traffic monitoring devices over three different time

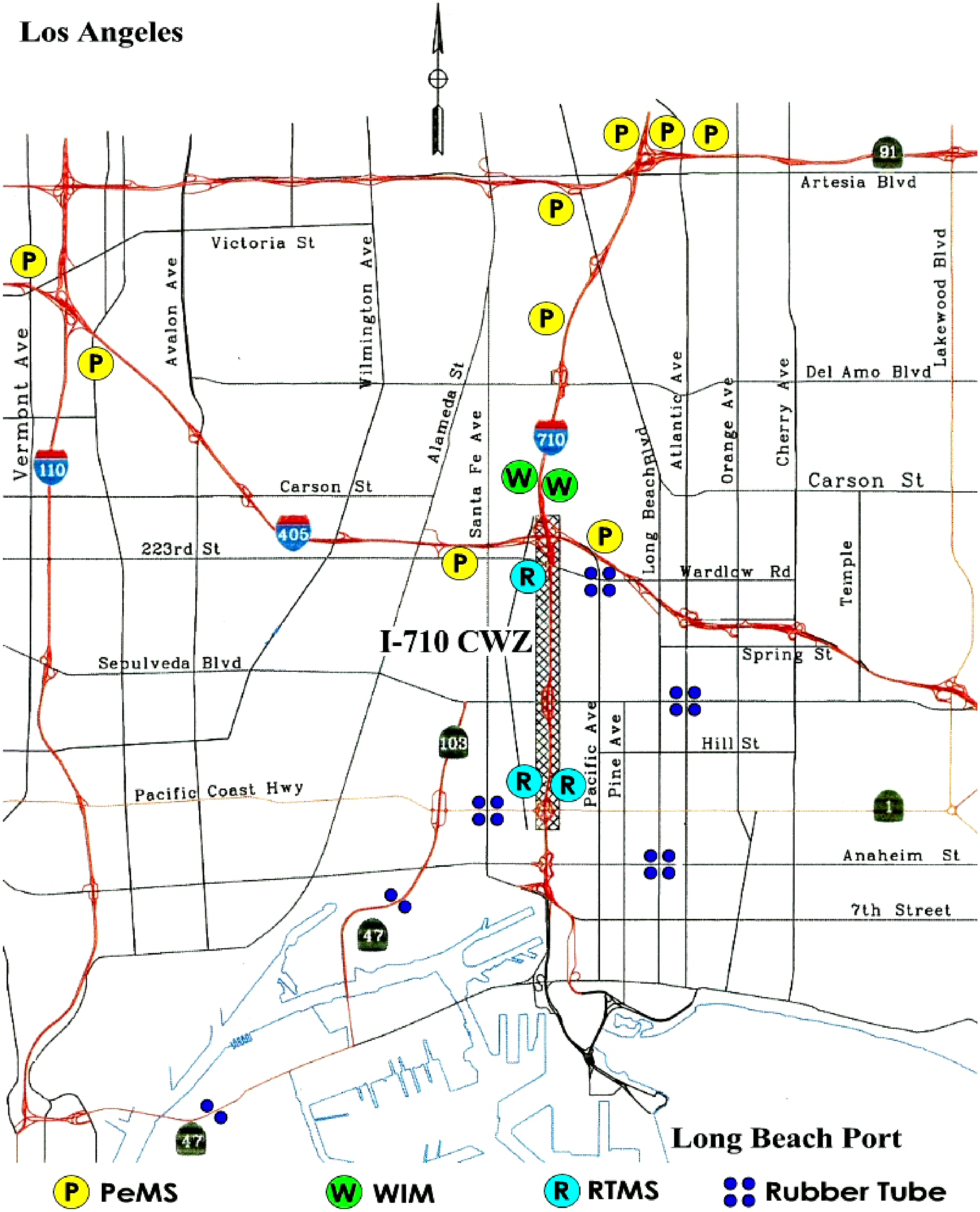

Figure 2. The locations of the traffic surveillance (measurement) system in the I-710 study area.

windows: weekends before construction, weekends during construction, and weekends after construction. The analysis of the data from each time window provided traffic impact data in terms of variables such as changes in traffic count, speed, and travel time. For example, the difference between traffic data from the weekends before construction and the weekends during construction is a direct indicator of the impact of the CWZ closures on traffic. The traffic data from weekends during construction and weekends after construction provides an indication of the changes in traffic conditions as a result of new, smoother pavement after the rehabilitation with any permanent changes in driver behavior, although the latter were expected to be negligible.

3.1.2 Network Comparison

The traffic impact analysis divided the study area into three traffic networks: (1) the I-710 corridor through the CWZ; (2) the adjacent freeway network; and (3) the local detour arterials. The direct traffic impact of the CWZ was indicated by measuring traffic flow through the I-710 main corridor. The weekend-by-weekend changes on traffic flow during construction on the I-710 corridor were compared so that driver dynamic behavior through the CWZ could be analyzed. With adjacent freeway network and detour arterials, the changes in spatial interaction of traffic flow were also monitored to measure a detour pattern.

4.0 TRAFFIC MONITORING RESULTS

4.1 Construction Work Zone (CWZ) Traffic

The comparison of traffic patterns through the I-710 CWZ between before-construction weekdays, before-construction weekends, and during-construction weekends based on RTMS data is illustrated in Figure 3. For I-710 NB, historical weekday peak hour (7–8 a.m.) traffic was about 5,400 vph with a maximum 18 percent trucks while weekend peak traffic (4–5 p.m.) was about 4,300 vph

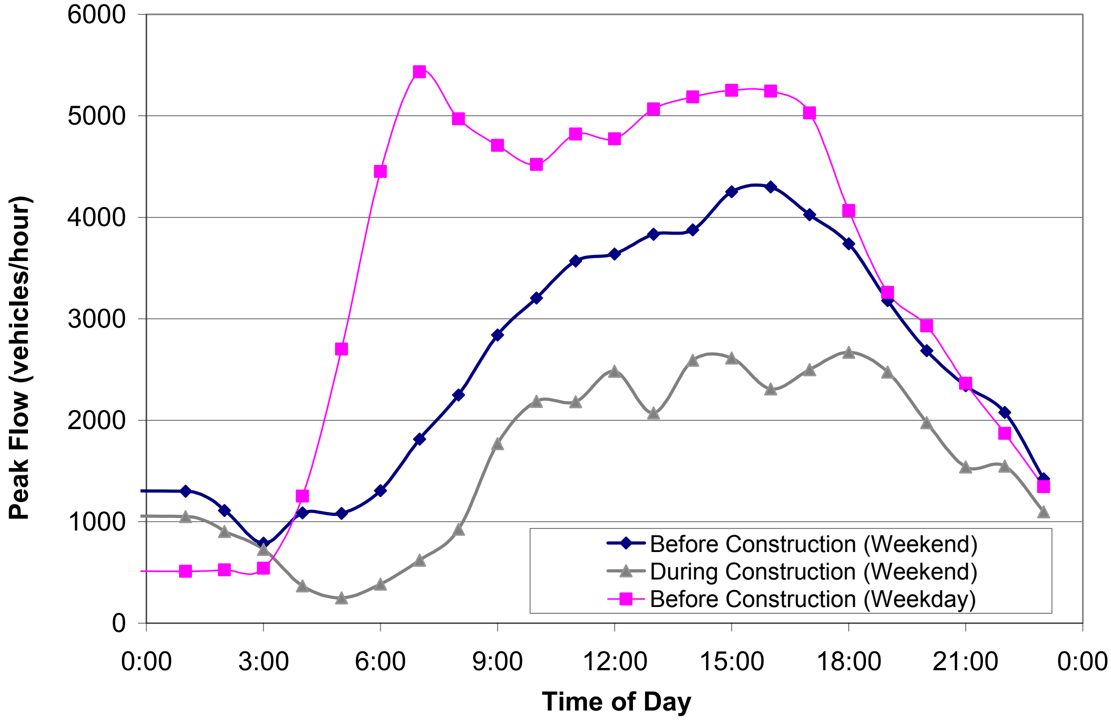

Figure 3. I-710 Northbound traffic flow before and during construction.

with maximum 6 percent trucks before construction. During construction weekends, maximum traffic flow was reduced to 2,733 vph (Saturday, 1–2 p.m.), with trucks making up only 2.3 percent of the flow.

Average Daily Traffic (ADT) on Northbound I-710 through the CWZ decreased by 36.9 percent during construction weekends with a peak hour traffic reduction of 37.2 percent compared with historical weekends, as summarized in Table 1.

Table 1 Comparison of Traffic Management Plan, Measurement, and Simulation through I-710 Construction Work Zone

Measurement		**North Bound**	**South Bound**
Before	ADT (veh./day)	61,255	61,044
	Peak (veh./hr.)	4,299	3,900
During	ADT (veh./day)	38,667	35,544
	Peak (veh./hr.)	2,733	2,503
Reduction (%)	ADT	36.9%	41.7%
	Peak	37.2%	35.8%
Estimated Peak Reduction (%)	Simulation	31.2%	18.9%
	Traffic Management Plan	35.0%	45.0%

After construction, weekend peak traffic rebounded to 4,500 vph on NB I-710 at the PCH, slightly more than maximum historical weekend traffic before construction. Southbound I-710 traffic through the CWZ showed a similar pattern, with an ADT reduction of 41.7 percent and a peak hour traffic reduction of 35.8 percent. It was observed that the main reduction in traffic flow through the CWZ was a result of detours rather than no-shows, as is discussed in Section 4.3.

4.2 I-710 Corridor Traffic

Corridor traffic data on I-710 was also measured at six loop detectors outside the north end of the CWZ boundary. Traffic flow at the north of the CWZ on I-710 indicates that there was no significant decrease or increase of traffic on the Southbound I-710 corridor during construction, and shows a similar traffic pattern to that of a historical weekend day. The Northbound traffic at the north of the CWZ on I-710 during construction was slightly reduced during peak hours.

The weekend truck volume measured from the WIM located at the north of the CWZ during construction was similar to that of historical weekends, implying that some truck traffic rerouted up to the north around the CWZ rather than behave as no-shows.

Travel time and average travel speed through the I-710 corridor was one of the major measurements of the effect on traffic performance due to the CWZ. The average speeds through the CWZ during construction indicated no congestion but were lower than those of before-construction weekends, going from 112 km/h to 80 km/h. The speed limit during construction was 72 km/h. From the measured travel time, it can be seen that there was no significant congestion during construction weekends, and traffic flowed freely even during peak hours. Occasionally during weekend closures, a breakdown in travel speed on I-710 was observed due to stalled cars, but the speed recovered after the stalled cars were towed away.

4.3 Dynamic Driver Behavior

In order to investigate how drivers through the I-710 CWZ changed their patterns during the repeated construction closures, variation in peak weekend traffic volume was monitored and analyzed. As presented in Figure 4, the peak hour pattern on I-710 NB changed as the construction weekends progressed, suggesting that the flow rate during peak hours (2,932 vph on Saturday and 3,162 vph on Sunday) was eventually around the 3,000 vph that was estimated as a maximum flow rate. Tach run data during construction revealed that traffic was flowing freely, but nearly at capacity. It can be concluded that people driving through the CWZ exhibited a learning curve effect based on their effort to minimize wasted travel time as the weekend closures were repeated. Some drivers who avoided I-710 during the first weekends because they were influenced by the public outreach (no-shows or detours), tried to use the I-710 freeway later on, thus increasing traffic through the CWZ.

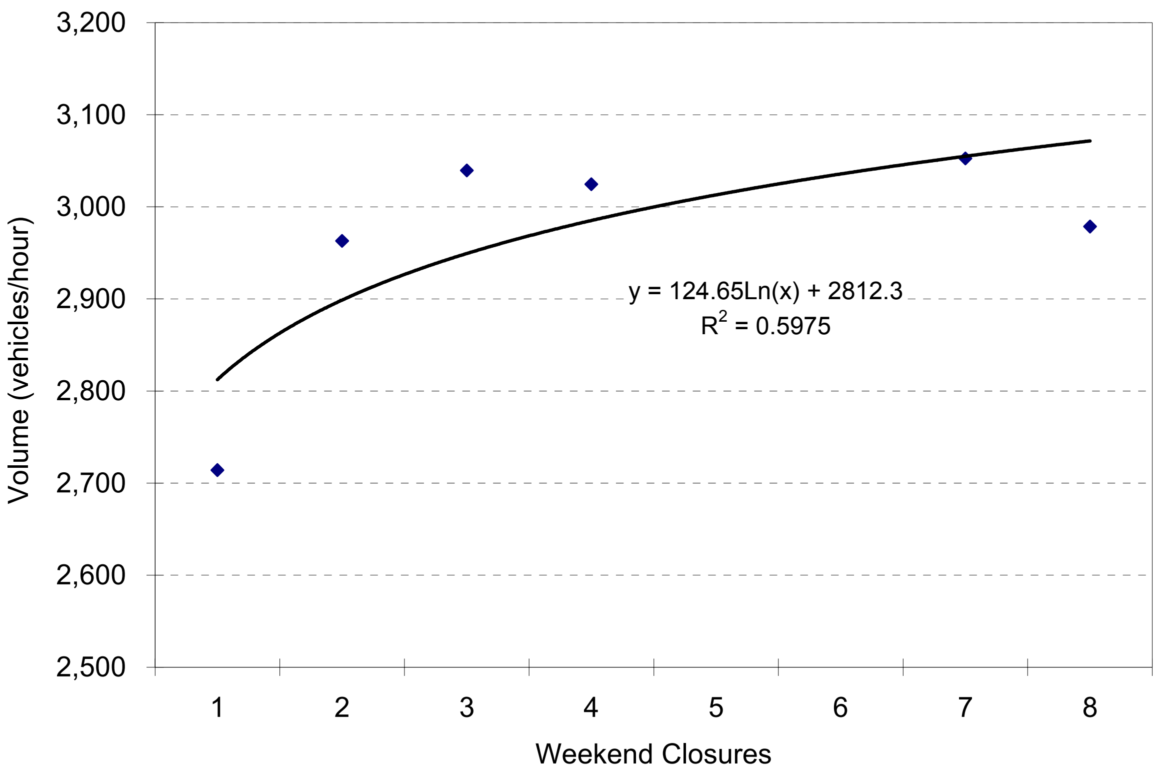

Figure 4. Variation of weekend-by-weekend peak traffic flow (Saturday and Sunday average) on I-710 Northbound through the CWZ with the 2 by 2 lane configuration.

No construction took place during the Long Beach Grand Prix weekend or Easter weekend because more weekend traffic than usual was expected. During the Long Beach Grand Prix weekend, peak hour volume increased by 7 percent compared to historical weekends, while traffic volume during the Easter weekend increased by 3 percent. The data collected during the weekends clearly showed that traffic increased during these times, which further validated the decision to skip those weekends.

4.4 Neighboring Freeways

The selected measurement sites included 11 PeMS loop detector stations distributed over the freeway network in the study area. Overall, the freeway network showed a similar traffic pattern between the before-construction and during-construction weekends, although traffic flow during peak hours around the CWZ during construction weekends decreased slightly. The total traffic volume (the sum of the 11 loop counts) measured across the whole freeway network in the study area during construction weekends (735,854 vehicles per day) decreased by about 1 percent compared to historical weekends (743,543 vehicles). This implies that there was only a small change in total traffic flow on the freeway network around the CWZ, indicating that no-show traffic during construction was almost negligible. This is quite different from the TMP estimation of 10 percent traffic no-shows, although more accurate methods such as cordon line surveys are needed to more precisely measure the variations in total traffic demand.

Traffic on I-405 SB near the CWZ was slightly reduced during the peak hour. I-110, a main parallel freeway showed an approximately 7 percent increase in traffic during construction weekends mainly due to detoured traffic. This increase closely follows the prediction made in the TMP. It can be seen that there was little change in total traffic flow in the freeway network except for localized re-routing around the CWZ on I-710 and I-405, as the main detours to surface roads. This implies that major local arterials were the major detour routes, as confirmed in the following section.

4.5 Detour Arterial Roads

4.5.1 Ramp Counts

During the construction weekends, freeway off-ramps were open, however most on-ramps in the CWZ were closed. All the ramp volumes during construction were reduced since some portions of the ramp volume were already detoured to alternative routes before travelers reached the CWZ. This is also supported by an observed decrease in off-ramp volumes.

The reduction in volume for on-ramps outside the CWZ was not larger than expected. This can be explained by the fact that some of the ramps in the CWZ were closed, and traffic was expected to be distributed throughout the open ramps during construction. This resulted in a small decrease of on-ramp traffic volume (outside the CWZ) which was too small to support a definitive conclusion.

4.5.2 Surface Roads

As expected, traffic volume at the intersections of the major alternative detour routes during construction increased noticeably, which implies that drivers changed their routes to alternative paths as the TMP specified. The TMP expected that the major routes around the CWZ would be Long Beach Boulevard and Atlantic Avenue (north-south arterials parallel to I-710). It seemed that drivers were reluctant to go around the two main arterial detours since they were farther from the CWZ (about 4 km to the east) and added to travel time and distance. But the intersection at Pacific Avenue and Wardlow, which was not included on the TMP as a major alternative route but is located close and parallel to the CWZ, showed the largest traffic increase—156 percent—during construction. This indicates that many drivers used Pacific Avenue as an alternative route even without any information from the TMP. In addition, Pacific Avenue directly connects to ramps for I-405 and I-710.

A noticeable increase (about 14 percent on average) in traffic volume also occurred on the measured major intersections (total of 5 locations) during construction weekends. This difference of spatial interaction in traffic flow mainly resulted from drivers re-routing to get around the CWZ. Much like the I-710 corridor, no significant traffic congestion was observed on the detour arterials, and a free flow of traffic was maintained during construction.

5.0 TRAFFIC SIMULATION STUDY

Microscopic traffic simulation models were developed to see how accurately a microscopic simulation could represent a network-wide urban freeway with high traffic volumes during CWZ closure, and replicate the changes in traffic patterns. In the simulation study, the comparison time windows and network boundaries were the same as in the traffic measurement study scheme. Outcomes generated from the traffic simulation were compared with actual traffic measurement data and the TMP estimation between before construction and during construction weekends on the CWZ, major freeways, and detour arterials.

5.1 Simulation Tools Selection

The selection of the traffic simulation tools used was based on their ability to perform the following tasks:

- Realistically replicate existing traffic conditions in a large network with high traffic volume;
- Predict changes in traffic behavior during construction; and
- Produce a quantitative assessment of the traffic pattern changes.

Based on a preliminary investigation to apply microscopic simulations for LLPRS projects, the research team concluded that PARAMICS (PARAllel MICroscopic Simulation) and MITSIM (MIcroscopic Transportation SImulation Model) were the most efficient tools for the California case studies.(*10, 11*)

PARAMICS is similar to other microscopic simulation software, and provides good geometric descriptions with detailed lane configurations, vehicle types, and vehicle performance as well as traffic data acquisition functions. PARAMICS also has various assignment methods such as all-or-nothing, stochastic, and dynamic feedback assignments.(*12*) MITSIM was chosen because of its advanced assignment function which updates the traffic route of a vehicle based on prior travel time history for each origin-destination pair.(*11*) This assignment function in MITSIM was expected to complement the user interface features of PARAMICS.

5.2 Simulation Network

The I-710 traffic simulation model covered a grid network (12 by 16 km), which was similar to the measurement study boundary (Figure 2). Basic network coding in PARAMICS was performed using overlay files of aerial photos downloaded from Microsoft TerraServer (*13*) as templates to build the model road geometry. Additional information such as the number of lanes and lane configuration was collected by field observation, and the traffic signal plans were provided by traffic engineers in the local cities.

The MITSIM network was initially converted from the PARAMICS network. After the conversion, the geometry and lane configurations in MITSIM were adjusted manually because the conversion software was not perfect. For example, some of the links were misconnected and the lane allocations of on-ramps in particular were incorrect. This necessitated the laborious task of manually checking and adjusting for all geometric information and traffic control elements.

The zone structures in the simulation network used to generate traffic Origin-Destination (OD) demands were built based on a transportation planning model provided by the Southern California Association of Governments (SCAG). The model considers residential populations and the number of workers. The model had a total of 170 zones (127 internal and 43 external) on the simulation network.

Unfortunately, SCAG provided only weekday OD demands as a typical traffic planning model. Because the I-710 construction was to take place during weekends, the weekday OD matrices had to be adjusted for the weekend. This was performed using a conversion factor for each freeway, with a formula based on measured difference in ADT from PeMS between weekdays and those of weekends. Although the origins and destinations of vehicles may vary from weekday to weekend, it was assumed that any difference would not be significant for the purposes of this study. Hourly OD matrices for the 24-hour time frame were generated from the SCAG model and adjusted with an hourly factor based on PeMS counts. The target simulation period was limited to one hour (1 p.m. to 2 p.m.) on Saturdays since this was the time of highest traffic demand during the weekend closures.

5.3 Network Calibration

The purpose of the calibration process was to compare traffic volumes of the major origins to the traffic volumes measured in the OD refinement step. The grid network could have multiple routes for each origin-destination pair, so it was essential to find an appropriate assignment method. PARAMICS provides the three different assignment methods that can be implemented in any combination.(*12*) Vehicles initially choose the best route based on their preference rate (perturbation) when they are released. Some of the "familiar vehicles" update their travel cost in every given period and change their route based on the updated travel cost. Many simulations were run, each with a different assignment method. After observing the routing patterns, the combination of stochastic and dynamic feedback was determined to be the best assignment method. After the network was calibrated, traffic flow was within 10 percent accuracy and travel speed was within 5 percent accuracy for the target freeways compared with the measurement data.

The original traffic demands from SCAG were observed to be slightly overestimated compared to measurements. Adjustment factors were calculated and applied based on the comparison between simulation counts and measurement data on external zones connected to the major freeway. Unfortunately, no module was available in PARAMICS to adjust traffic demand discrepancies based on measurement at the time of this study. An OD matrix estimation package, which generates a new OD matrix by optimization with a given pattern OD matrix and a set of observed traffic counts,(*10*) was released soon after by the developer of PARAMICS and used for the third Caltrans LLPRS project.(*14*)

The calibration method in MITSIM was practically identical to the one in PARAMICS, except for one important difference: MITSIM has an additional assignment method that uses the historical travel time of the previous simulation to modify routes for the next simulation. This assignment method deleted unexpected traffic patterns, particularly merging and diverging areas.(*15*)

5.4 Simulation Results

Results from PARAMICS are presented in the following sections as an example. The majority of results obtained from MITSIM were similar.

5.4.1 <u>I-710 CWZ and Main Corridor</u>

Peak traffic flow for I-710 NB estimated from the simulation during construction weekend decreased by 31.2 percent (37.2 percent in the measurement) and traffic flow for I-710 SB decreased by 18.9 percent (35.8 percent in the measurement) through the CWZ compared with the simulated before-construction weekend (Table 1). This comparison confirmed that the simulation counts through the CWZ were consistent with the measurements during construction. The peak traffic flow in the simulation for both directions through the CWZ was around 1,500 vehicles per hour per lane (vphpl), which was believed to be the capacity of the CWZ. No traffic congestion was observed in the simulation due to lane dropping on the traffic crossovers. The travel speed estimated in the simulation did not show rapid increases or decreases, which indicates that the I-710 corridor including the CWZ, should maintain a free flow of traffic, which is consistent with the measurements.

5.4.2 Neighboring Freeways and Detour Arterials

Neighboring freeways, such as I-405, I-110, and I-605 did not show any significant difference between before- and during-construction weekends in the simulation. This indicated that the vehicles which were expected through the CWZ did not give the first priority to neighboring freeways as alternate routes. The simulation traffic patterns on the freeways during construction were consistent with the actual measurements except that simulation showed no traffic increase on I-110 as a parallel freeway.

The surface arterials designated on the TMP as north-south local detours in parallel to the CWZ during construction, such as Pacific Avenue, Long Beach Boulevard, and Atlantic Avenue, were used as main alternate routes in the simulation. There were some discrepancies between simulation results and actual measurements on surface roads, probably due to the difficulty of calibration in the large network. For example, traffic flow northbound on Pacific Avenue increased by only 27 percent during construction in the simulation while the measurement data indicated about a 156 percent increase.

5.5 Limitations of Microscopic Simulation

The microscopic simulation in this study could replicate traffic patterns at a network level. Simulation results were consistent with actual traffic measurements in general, especially through the CWZ. The difficulty and limitations of calibration in the large grid network, especially for arterial roads, caused some discrepancies between the simulation results and the actual measurement.

The simulation periods were initially expected to be longer than one hour. However, it was difficult to run multi-hour simulation scenarios because unrealistic congestions kept appearing in merging areas when the next hour was added, probably due to the size of the grid network. Despite these problems, the simulation study indicated that simulation can serve to provide useful information to develop efficient TMPs for future urban freeway rehabilitation projects in California.

Lessons learned based on the large network simulation experience, especially the difficulty of calibration, convinced the research team to separate the geographic scope of the simulation network into two levels for similar projects in the future: the corridor study with only the main freeway including a few alternative routes at first, and an expanded larger grid network containing neighboring freeways and arterial roads. This split concept was successfully implemented on the traffic analysis for the I-15 Devore reconstruction project.(*14*)

6.0 CONCLUSIONS

The I-710 Long Beach Caltrans asphalt LLPRS demonstration project was successfully completed without causing serious traffic delay by using eight repeated 55-hour extended weekend closures. This traffic case study compares the TMP with traffic measurements and microscopic simulations to quantify construction closure impact on the urban traffic network. Based on lessons learned from the I-710 Long Beach project, Caltrans is convinced that 55-hour weekend closures are viable and generally offer the most economical construction closure strategy for urban freeway rehabilitation projects. This traffic measurement and simulation study should be useful for other transportation agencies developing and evaluating traffic management plan for highway rehabilitation projects with high traffic volume.

In summary:

- Overall, the I-710 TMP was accurate, efficient, and comprehensive, especially in reducing traffic demand during weekend construction. The traffic measurement data indicated that no congestion occurred during the repeated 55-hour weekend closures, and that traffic flowed freely during weekend construction, as the TMP estimated. Without implementation of the TMP, significant delays would have been expected.

- Some discrepancies existed between the traffic measurements and the TMP. For example, the TMP overestimated the reduction of I-710 southbound traffic during construction, and no-show traffic could not be found in traffic measurements although 10 percent no-shows were expected by the TMP.
- On average, the measured traffic pattern through the I-710 CWZ showed that peak hour traffic decreased by about 37 percent along with a decrease of about 39 percent in Average Daily Traffic (ADT).
- The freeway network showed a similar traffic pattern during construction weekends, meaning that the total reduction across the studied freeway network during construction weekends was only 1 percent.
- Traffic on the arterials increased dramatically. For example, the total counts measured on the arterial intersections increased by more than 14 percent on average during construction weekends, and traffic volume at the intersection of Pacific and Wardlow Avenues increased by about 156 percent. This large increase indicates that drivers were more likely to use alternative parallel routes close to the CWZ, rather than more distant routes, although the nearer routes were surface streets and the distant routes were freeways.
- The maximum traffic volume through the CWZ observed during construction ranged from approximately 1,200 to 1,500 vehicles per hour per lane. This was about the traffic level expected to be reached with 2 by 2 lane traffic and barriers (MCB) for counter-flow traffic control. Drivers exhibited a learning effect with respect to the maximum peak volume through the CWZ as the weekend closures were repeated. After construction was completed, the maximum weekend traffic flow went back to historical levels immediately.

- The estimated traffic reductions from the simulation models during construction were similar to the traffic patterns from the measurements, especially through the I-710 CWZ. However, due to the difficulty of calibration of a large grid network there were some discrepancies between the simulation results and the measurements, especially on arterial roads. Despite the difficulty, the simulation model could be used to develop and evaluate TMPs for future LLPRS projects with more sophisticated calibration skills and efforts.

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