TRANSPORTATION RESEARCH
CIRCULAR
Number 462 September 1996

1994 Northridge Earthquake

TRANSPORTATION RESEARCH BOARD / NATIONAL RESEARCH COUNCIL

TRANSPORTATION RESEARCH
CIRCULAR

Number 462, September 1996
ISSN 0097-8515

1994 NORTHRIDGE EARTHQUAKE

Subscriber category
IVA highway operations, capacity, and traffic control

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

FOREWORD

It is rare in the field of transportation planning and operations that we have actual research data on a significant unanticipated event that seriously disrupted the transportation system affecting millions of people and businesses. The event was the Northridge Earthquake on January 17, 1994 in the greater Los Angeles area. The Northridge quake severed two of the busiest interstate freeways in the world. The immediate actions by Caltrans to mitigate the effects of the damaged facilities permitted the transportation system to continue to function. Within days after the quake, Caltrans, with the cooperation of federal and local agencies, initiated a comprehensive study of the impacts of the disruption and the changes in commuter travel behavior. The Transportation System Management Committee in cooperation with the Freeway Operations Committee sponsored a session at the January 1995 Transportation Research Board Annual Meeting in which five papers on the earthquake response and research were presented. These papers are published in this TRB Circular. The TSM Committee appreciates the cooperation of the authors and Caltrans in making this publication possible.

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THE 1994 NORTHRIDGE EARTHQUAKE — A TRANSPORTATION IMPACT OVERVIEW

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ABSTRACT

The January 1994 Northridge earthquake caused extensive damage throughout the Los Angeles area, closing highways for several months that carried some of the highest daily traffic volumes in the world. Although catastrophic travel conditions were widely predicted, except for the first few days after the quake, excessive delays were not experienced and the transportation system continued to function throughout the reconstruction period. Detours were quickly established to take traffic around the closed freeway sections, utilizing city streets and sections of freeways that were not damaged by the quake. New carpool lanes were established to encourage ridesharing in an effort to reduce vehicular demand. Rail and bus enhancements were also implemented. This report discusses the impacts of the freeway closures, the effectiveness of the various mitigation measures, and how commuter behavior changed in the corridors that were most directly affected. On the affected corridors in which convenient local street detours were available (I-10 and SR-118), motorists appeared content to continue driving. On the corridors where alternate routes were few or nonexistent (I-5 and SR-14), rail ridership increased substantially. Bus utilization did not appear to have a major effect in any of the corridors. Users of the newly established carpool lanes experienced some time savings, but interestingly, overall carpool volumes did not appear to be much higher than pre-quake volumes, indicating that few new carpools were formed to take advantage of the lanes.

INTRODUCTION

The magnitude 6.8 earthquake that occurred in Southern California on the morning of January 17, 1994 resulted in widespread damage throughout the Los Angeles area. Of the variety of structure types that sustained major damage, the collapse of several highway facilities were among the most visible to the rest of the world. Substantial disruptions to areawide travel occurred during the first few days after the quake, but the catastrophic traffic conditions that were widely predicted never materialized. Although unfortunate, the prolonged closures of several major transportation links provided a unique opportunity to examine motorist response to traffic disruptions of this magnitude and whether certain traffic management strategies are more effective than others under these circumstances.

This report describes the types of traffic management and mitigation measures that were implemented, how motorists responded to the commute choices that were available to them, and the traffic conditions that resulted. Recommendations on the types of actions and measures which worked well and could be successfully applied to similar situations in other areas are presented.

BACKGROUND

Setting

The freeway system in and around the Los Angeles area of Southern California is considered to be the most extensive, if not necessarily the most modern, in the world. The area is criss-crossed by 27 freeways totaling 615 miles. The freeway system is further supplemented within the Los Angeles basin by a comprehensive local roadway network, which for the most part is on a grid system.

The Los Angeles basin area is physically separated from central and northern California by the San Gabriel and San Bernardino Mountain ranges. Access over the mountains is provided via Interstate 5, which runs the length of the state from the Oregon to Mexican borders, and also by State Route 14, providing access to the Antelope Valley communities of Lancaster and Palmdale. Except for these two freeways, there are no other convenient major public roadways that provide access over the mountains.

Public transit service in the Los Angeles area is provided primarily by the Los Angeles County Metropolitan Transportation Authority, with additional service available from a number of other operators. The Metrolink commuter rail system, in operation since 1992, provides train service connecting Ventura, Los Angeles, San Bernardino, and Riverside Counties.

Pre-Quake Traffic Management Facilities

The freeway system and state highway system is operated by the State of California Department of Transportation (Caltrans) out of their Los Angeles

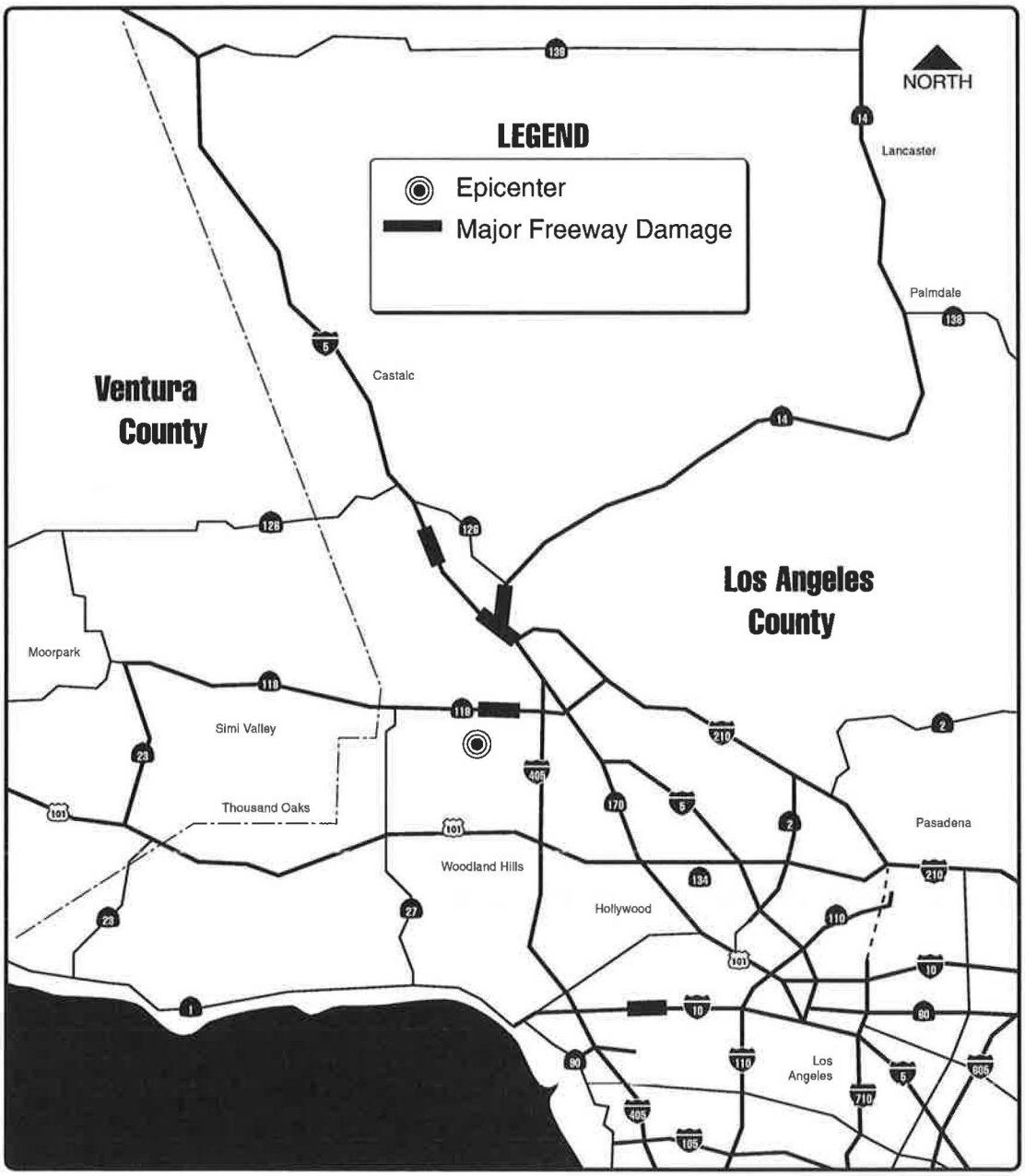

FIGURE 1 Location map.

"District 7" office. Traffic management activities are coordinated through the Traffic Management Center (TMC) in the Caltrans office in downtown Los Angeles. The TMC is staffed 24 hours a day, every day of the year by Caltrans traffic operations and maintenance and California Highway Patrol personnel. Extensive traffic monitoring and management capabilities were already in place on most of the major freeways well before the quake, including loops capable of monitoring speeds and flows, closed-circuit television cameras, and meters at most on-ramps. Permanently mounted overhead changeable message signs were also already in place approaching key freeway junctions. Emergency response Traffic Management Teams also are deployed out of the downtown Los Angeles Caltrans office, providing the capability to fine-tune the traffic management response to individual incidents or closures.

The City of Los Angeles operates its Automated Traffic Surveillance and Control System, which was constructed in 1984. The system, consisting of a network of traffic signals that can automatically adjust signal timing in response to real-time traffic conditions, video

surveillance of key intersections, and changeable message signs, is housed in the city's Department of Transportation headquarters a short distance from the Caltrans TMC in downtown Los Angeles.

DAMAGED FACILITIES

Major damage affecting transportation facilities was confined to four major highways and interchanges (see Figure 1). The Santa Monica Freeway section of Interstate 10, connecting the westerly cities of Santa Monica, Beverly Hills and Culver City with downtown Los Angeles, suffered major damage at two overcrossings. Two of the connectors at the 5/14 interchange in Sylmar collapsed, severing the only freeway link over the mountains to Lancaster and Palmdale, as well as causing damage to the through-movement on Interstate 5. Except for the extensive damage at the interchange, Route 14 to the north was unaffected. Interstate 5, however, also suffered damage at several locations north of the 5/14 interchange, effectively closing the only other major highway link over the mountains. State Highway 118 in Granada Hills was closed when the eastbound roadway collapsed at two locations. Additional damage at other locations resulted in the closure of the entire section of Route 118 from I-405 to I-210 (about 4 miles) in both directions. At all of these locations, closures were immediate and total, with no freeway traffic able to pass through the damaged zones.

At a fifth location, State Route 1 (the Pacific Coast Highway), closures occurred during the first few weeks after the quake. However, repairs on Route 1 were completed by mid-February. Minor damage also occurred at many other highway locations. However, except for the locations described above, none of the closures lasted more than a few weeks.

The local street network was, for the most part, not significantly affected by the quake. Temporary closures were implemented at freeway overcrossings where major damage occurred and at locations where the structural integrity of nearby buildings was in question. This is similar to the experience after the 1989 Loma Preita earthquake in Northern California, where the only sustained damage to transportation facilities was on freeways. Outside of Los Angeles County there was relatively little damage to any roadways. In Orange County to the southeast of Los Angeles, the highway network remained relatively unscathed, although some damage occurred to other types of structures. Airports were also unaffected.

INITIAL RESPONSE

The primary effort within the first hours after the quake consisted of assessing the extent of damage to the roadway system and the provision of basic detours around the affected areas. This function was performed by all available and qualified personnel, but was handled mainly by Caltrans maintenance, construction, and structures staff. Traffic operations TMTs were dispatched to provide assistance in diverting traffic around the closures. Coordination of these efforts, as well as the dissemination of traffic closure information to the public, was handled through the TMC.

Power outages were widespread immediately after the quake, disabling traffic signals on the street system and hindering communications throughout the region. Electrical service to the Caltrans TMC was out, but backup generators and telephones continued to work.

The earthquake occurred very early on a Monday morning, when most of the population was still at home. Furthermore, that Monday was also Martin Luther King's birthday, a national holiday, and thus, many work trips would not have occurred anyway. As expected, areawide traffic volumes were substantially lower than normal in the first few days following the quake, which aided the recovery effort. By the week after the quake, however, workers began returning to their jobs and volumes increased dramatically, although overall volumes were still lower than normal. By mid-March, traffic conditions had generally stabilized throughout the area such that there were only minor day to day variations in peak period travel time.

Early rough estimates indicated that repairs would take from six months to a year. Interstate 5 was expected to reopen in August, Interstate 10 would reopen the month after, and State Route 118 and the 5/14 interchange would reopen towards the end of the year. Incentive clauses were incorporated into the repair contracts in order to encourage contractors to complete the work as quickly as possible. Nevertheless, throughout the reconstruction period, there was considerable uncertainty as to when each of the freeways could be reopened.

Once a determination was made as to which facilities would remain closed for extended periods, the task confronting traffic operations personnel was essentially the same as the underlying problem to congestion problems of any size: *how to best balance capacity and demand.*

MITIGATION MEASURES IMPLEMENTED

Initially, motorists that were originating or were destined for areas outside of the Los Angeles basin were

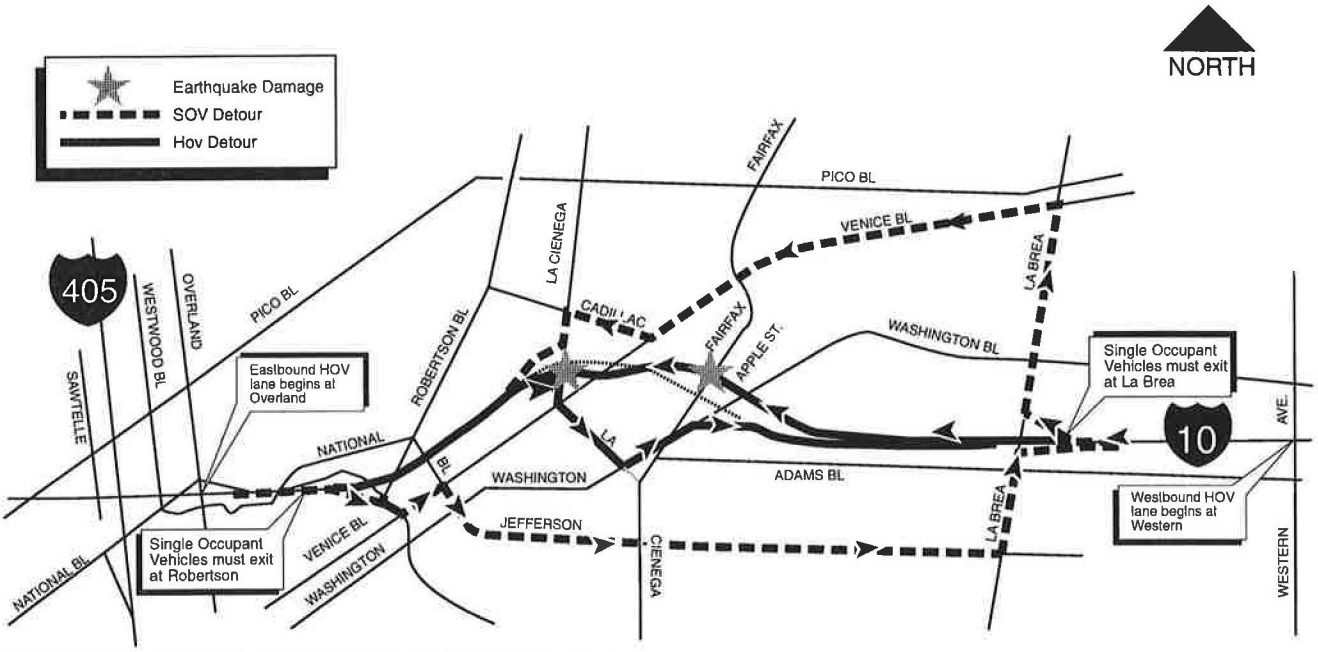

FIGURE 2 Detours implemented on Interstate 10.

encouraged to circumvent the area completely. Recommended routes were Route 101 to the west and Interstate 15 to the east. Use of these long distance detours added as much as 50 miles and several hours to trips. Although this was reasonable and would probably have been acceptable for a relatively short period of time, it was obvious that additional measures would be needed to handle traffic through the duration of the reconstruction period.

Capacity Increasing Measures

Alternate Routes & Detours

The use of local street detours was the mitigation measure that was implemented immediately after the quake and was the measure that ultimately proved to be the most effective. The Los Angeles Department of Transportation estimates that signals were re-timed at 300 intersections, and 1,000 directional signs and 7,500 parking signs were installed on the detour routes.

Interstate 10: Separate detours were implemented for High Occupancy Vehicle (HOV) and single occupant vehicles (see Figure 2). A two-or-more definition was instituted for the HOV detour. HOVs were given preferential treatment by allowing them to stay on the freeway as far as the interchange closest to the closure site and to reenter the freeway immediately past the closure. Single occupant vehicles, on the other hand, were required to exit the freeway two interchanges upstream of the closure and reentered the freeway further downstream of the closures than HOVs. Moreover, once on local streets, the HOV detour utilized streets that were significantly closer to the freeway than the streets utilized by the single occupant vehicles. As a result, the single occupant vehicle detour was about 5 miles longer than the HOV detour. In each direction on the freeway leading up to the detour off-ramps, one lane was designated as an HOV lane to permit HOVs to bypass some of the freeway congestion. This detour scheme was implemented on January 25th, and was revised on February 1st to increase efficiency.

5/14 Interchange: Southbound traffic through the interchange was diverted onto local streets, which were initially converted to one-way operation during peak periods. Northbound traffic through the interchange used the undamaged truck lanes, which were modified to provide two mixed flow and one HOV lane. HOV lanes were opened on the southbound and northbound approaches to the interchange from State Route 14. By the end of January, the southbound local street detours were restriped to provide additional capacity without having to resort to one-way operation.

Interstate 5: A detour utilizing the Old Road, a high capacity local street paralleling the freeway, was implemented by January 29. All traffic was taken off of the freeway, onto the Old Road which accommodated two lanes in each direction, and then directly back onto the freeway downstream of the closure.

State Route 118: Initially, detours were established on local streets, which was relatively easily

accommodated by the comprehensive street network in the area. Signal timing and phasing changes, lane restriping, and detour signing were implemented to support this detour. By February 21st, repairs had been sufficiently completed on the westbound roadway to allow it to be reopened to traffic. The roadway was then striped to provide three lanes in each direction, with a concrete barrier separating the two directions of traffic.

Other Traffic Management Activities

In the week after the quake, Caltrans personnel established a list of strategies that made up the earthquake relief Traffic Management Plan (TMP). These strategies were refined and implemented rapidly in the following weeks. Tow trucks, which had been assigned as part of the Freeway Service Patrol program to some of the routes that were damaged, were re-deployed to patrol the detour routes. Highway Patrol enforcement was also increased through the COZEEP (Construction Zone Enhanced Enforcement Program) to provide traffic control support to expedite repair operations. Peak period helicopter service was leased from the Los Angeles Police Department to provide more rapid and accurate traffic surveillance capabilities. A public awareness campaign was instituted, focusing on providing information on alternative transportation options. Communications equipment, such as cellular phones, pagers, and two-way radios, were leased to facilitate contacts with field units.

EpiCenter: An Earthquake Planning and Implementation Center was constructed and field instrumentation was installed where traffic surveillance and motorist information systems were critically needed but were not available. This included the installation of changeable message signs, highway advisory radio systems, closed-circuit television cameras, vehicle detector systems, and a video image processing system—all operated from the EpiCenter at the Caltrans district office. Satellite linkups were installed to permit communications with equipment at remote sites where conventional linkups could not be implemented quickly enough.

Demand Reduction Measures

Transit Enhancements

Six of the bus transit systems operating in Los Angeles County added new emergency service, which consisted of the implementation of new routes and extension and revision of the schedules of existing service. Most of the bus service changes were implemented on routes on or near Interstate 10. Metrolink added extra trains and line extensions into the Antelope Valley to provide additional capacity for commuters isolated by the closures of Interstate 5 and Route 14. Within the first week, seven new trains were added, and service began operating out of new stations in Lancaster and Palmdale. Numerous shuttles were also put in service to connect Metrolink and Amtrak lines with major employment centers.

Park & Ride Lots

Three new park and ride lots were created at strategic locations in order to encourage the formation of carpools or use of transit. These lots were either newly constructed or made use of leased space on existing lots, and were located in the vicinity of the 5/14 interchange.

TRAFFIC CONDITIONS DURING THE RECONSTRUCTION PERIOD

Fortunately, because of the distance separating the damaged facilities and because of their geographical locations, the effects of each of the closures were generally independent of each other. The closure of the through-movement on Interstate 5 was, of course, closely inter-related with the closure of the 5/14 interchange. The Interstate 10 and State Route 118 closures, however, operated independently of each other and from the Interstate 5 and 5/14 interchange closures. Thus, there was no compounding effect which would have substantially exacerbated the already serious impacts of the individual closures.

Interstate 10

The two-way average daily traffic (ADT) on Interstate 10 prior to the quake was approximately 310,000 at the point of the closure. Based on an average vehicle occupancy of 1.4 persons per vehicle, this translates to 434,000 people typically using the freeway on any given weekday, all of whom had to make decisions about how their trips would be made during the reconstruction period. The closure of the Santa Monica Freeway has been the most thoroughly studied of the closures to date, and in many respects, provided the most diverse spectrum of opportunities for commuters to choose from during the reconstruction period. Motorists could:

1. Continue to drive their automobiles and use the freeway, and then divert to the primary designated detour route.
2. Continue to drive, but divert to parallel freeways, such as the recently opened Interstate 105 (the Century Freeway) located about 8 miles to the south.

3. Continue to drive, but divert to other city streets or arterials that were not officially designated as alternate routes.

4. Form a carpool to take advantage of the new HOV lane and HOV detour.

5. Shift to transit, utilizing existing bus routes or one of the new routes implemented in response to the quake.

6. Change the time of day of travel.

7. Eliminate trips altogether.

Not unexpectedly, daily volumes dropped drastically in the first few weeks until the primary detours were established. ADTs were down by about two-thirds within the first week. Once the detours opened, volumes began climbing steadily, stabilizing at about 130,000, which accounts for 42 percent of the pre-quake ADT.

Extensive traffic counts were performed on parallel local arterials and freeways and a home interview survey was conducted in order to determine where the remaining trips had diverted to. Of the 310,000 daily vehicle trips that occurred on this section of Interstate 10 prior to the quake, 47,000 (about 15 percent) were eliminated altogether during the reconstruction period. Distribution of vehicle and person-trips are summarized in Table 1.

TABLE 1 CHANGES IN TRAVEL ROUTE OR MODE ON I-10

	Vehicles	People
Pre-Quake	310,000	434,000
Reconstruction		
Primary I-10 Detour	130,000	208,000
I-105	5,000	7,000
Other streets	128,000	155,000
Transit		2,000
Telecommuting		2,000
Trip eliminated		60,000
Reconstruction totals	263,000	434,000

Non-HOVs using the primary mixed flow detour during the peak commute periods experienced average delays of only 10 minutes compared to pre-quake travel times. Travel times on the HOV detour were even less, ranging from 3 to 5 minutes more than pre-quake travel times. In fact, once back on the freeway downstream of the closure, travel conditions were better than prior to the quake, since the output of the detours was approximately one-half of the pre-quake demand. As a result, in many cases the total trip travel time for HOVs was less than prior to the quake.

The number of vehicles that diverted to local streets other than the designated primary detour was virtually the same as the number that used the primary detour. Use of the most easily accessible alternate freeway, Interstate 105, was minimal, representing less than 2 percent of the total pre-quake vehicle trips. The low increase in volume was probably directly related to the high levels of delay on the north-south freeways that would have been used to take motorists from Interstate 10 to Interstate 105. Both Interstate 405 (the San Diego Freeway) and Interstate 110 (the Harbor Freeway) are heavily congested during peak periods.

Transit Utilization

Because of the relative ease of use of the local street detours and the comparatively minor delay associated with their use, increases in transit ridership in the Interstate 10 corridor were minimal. Daily boardings increased by about 2,000 passengers immediately after the quake, and then stayed at virtually the same level throughout the reconstruction period. By mid-March, transit operators began consolidating some of the new lines because ridership levels were not sufficient to justify the operating costs.

Effect on Ridesharing

Of particular interest on Interstate 10 was whether or not there would be a noticeable increase in ridesharing in response to the availability of the HOV detour. Prior to the quake, the number of vehicles carrying two or more occupants during the peak hour ranged from 1,000 to 1,400 vehicles. During the reconstruction period, HOV volumes ranged from 1,000 to 1,300 vehicles, although HOVs represented a much larger proportion of the total traffic flow because of the lower overall volume. After the reopening of Interstate 10 on April 12th, peak hour HOV volumes ranged from 1,200 to 1,500.

Thus, although it appears that there was an increase in ridesharing as a result of the HOV detour strategy, the increase was relatively minor. Several factors may have contributed to this. The time savings offered to users of the HOV lane and HOV detour may not have been large enough to instigate a significant change in travel mode. Moreover, the time saved on the HOV detour may not have been large enough to offset the additional time it would have taken to form a carpool each day. In addition, the amount of time savings may have been relatively small in relation to what the total trip times were. Nevertheless, the implementation of the

HOV detour was clearly successful in reducing overall person-delay in the corridor.

Interstate 5 and the 5/14 Interchange

The closures of Interstate 5 and the 5/14 interchange presented a substantially different set of travel options to commuters. At this time, however, the home interview survey and traffic performance data are still being analyzed and only preliminary conclusions can be made.

With few, if any, alternative roadways to use instead of the closed freeways, motorists had a much smaller set of choices to select from compared to Interstate 10. Motorists could:

1. Continue to drive on the freeway in single-occupant autos.
2. Form carpools to take advantage of the State Route 14 HOV lanes.
3. Shift to one of the new Metrolink rail lines.
4. Change the time of day of travel.
5. Eliminate trips altogether.

Travel patterns on Interstate 5 and State Route 14 are highly directional. The primary flow during the morning commute period is southbound, heading towards the Los Angeles basin, and is reversed in the afternoon commute period. In the off-peak direction during commute periods, and during most other times of the day, demands are low enough that virtually no recurrent congestion occurred in spite of the reduced freeway capacity.

Conditions on Interstate 5

The capacity of the two lanes in each direction on the Old Road was generally adequate to handle all but the peak period demands. Peak period travel times were extremely variable during the first month after the quake, with motorists experiencing individual delays as high as one hour. By early March, conditions had generally stabilized, with 10 to 15 minutes of delay in the southbound morning peak and 5 to 10 minutes in the northbound afternoon peak. Vehicles using the detour at times other than the peak period experienced no congestion at all, and use of the detour at those times added only about 2 minutes to trips.

Conditions on State Route 14

The combined capacity of the freeway lanes and improved parallel local streets was also adequate to handle traffic demands, except during the commute periods. Peak period individual delays in the days following the quake were as high as 40 minutes. By early February, after the detours had been improved, delays through the interchange decreased significantly, stabilizing at about 10 minutes in the southbound morning peak and about 20 minutes in the northbound afternoon peak. During the off-peak, there was no congestion on State Route 14 or on the local street detours. At these times of the day, use of the detour added virtually no time to trips.

Time savings for users of the HOV lanes ranged from 5 to 20 minutes during peak periods. HOV lane volumes were approximately 1,500 vehicles during the peak hour. Violation rates varied widely, ranging from 1 to 14 percent dependent on the level of Highway Patrol enforcement.

Transit Utilization

Prior to the quake, the northerly terminus of Metrolink service was at the Santa Clarita station near the 5/14 interchange. Daily ridership was about 1,000 boardings per day. The extensions into Lancaster and Palmdale opened on Friday, January 21st. By the following Tuesday, daily ridership peaked at almost 22,000 boardings, fueling hopes that the rail line would relieve much of the expected freeway congestion and that these ridership levels could be sustained over a long term period. A week later, however, ridership had dropped off to about 13,000, steadily declining through the reconstruction period as shown in Figure 3.

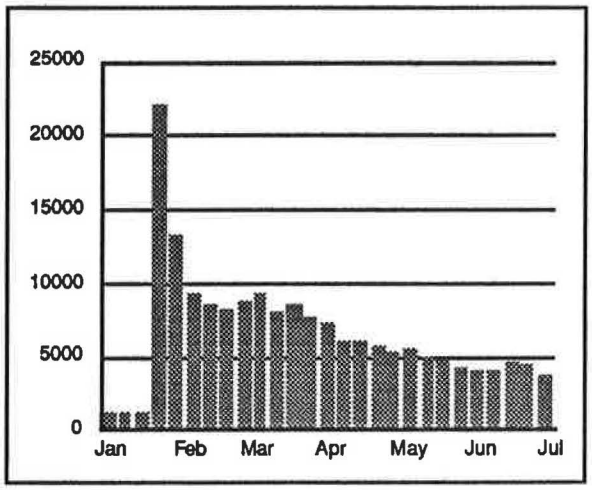

FIGURE 3 Ridership on the Santa Clarita Metrolink line during reconstruction.

By the time the through-movement on Interstate 5 opened in mid-May, daily boardings were less than 5,000. Just before the major connectors at the 5/14 reopened in early July, ridership was at about 4,300 per day. In spite of the inability to sustain the very high ridership levels immediately following the quake, the Metrolink extensions still proved vital in reducing demand on the freeway.

State Route 118

The two-way average daily traffic volume on State Route 118 immediately to the east of the closure was about 123,000 prior to the quake. Until the freeway detour was opened on February 21st, all traffic was being diverted onto the local street detours. As a result, daily volumes on the adjacent freeway sections were less than 50 percent of the pre-quake volume. Some of the local streets were carrying as much as an additional 30,000 vehicles per day. Peak period delays using the designated local street detours were as high as 30 minutes.

Once the freeway detour opened with three lanes in each direction, virtually all delay was eliminated. Daily freeway volumes are still slightly below pre-quake levels, with the local street system absorbing the difference.

Impacts to Truck Travel

The closures of Interstate 5 and State Route 14 raised considerable concern with respect to impacts to commercial truck traffic and commodities movements. Truck intercept surveys were conducted in May at truck inspection facilities at entry points to the Los Angeles area. Telephone surveys were conducted during May and June with 300 shipping companies in the Los Angeles basin. At this time, the survey data is still being analyzed. However, these preliminary conclusions can be made:

- Between 30 to 50 percent of the truck trips into the Los Angeles area were canceled immediately following the quake.
- Until the detours were firmly established, long distance detours via State Routes 58 and 138 and Interstate 15 were used by about one-fourth of the truckers to enter and leave the area. Truck rerouting was the most common action taken by shippers in response to the closures.
- Once the detours were in place, truck volumes returned to pre-quake levels and virtually all trucks returned to their normal routes.
- Rescheduling of shipments was employed by almost one-half of the firms surveyed, with one-fourth reporting less frequent deliveries and pickups.
- Estimated increases in operating costs were estimated to be about 8 percent. A more detailed review of the economic impacts on these firms is currently being conducted by the University of California, Irvine.

Cost of Delay

Motorist delay costs associated with the closure of Interstate 10 are conservatively estimated to be about $990,000 per weekday. Delays due to closures at the 5/14 interchange were about $436,000 per weekday. This correlates very closely with the independent estimate by the Governor's Office of Planning and Research and with the early-completion incentives offered to the repair contractors. These estimates do not include the economic impact of disruption to commercial traffic movements, loss of business due to trips being eliminated, and loss of jobs.

Delay cost estimates were developed by establishing screenlines across the affected corridors, determining the daily volume of traffic that crossed the screenline prior to the quake, and then calculating the aggregate increase in delay based on data collected on the detour routes. Costs were based on standard factors established by the State of California.

FINDINGS AND RECOMMENDATIONS

A. Providing immediate transportation solutions takes precedence over the opportunity to change motorist behavior.

Although the opportunity clearly presents itself to use disasters affecting transportation facilities as an opportunity to make long term changes in driver behavior by establishing new HOV lanes or new and increased use of transit, undeniable political realities must be considered. Whether it is truly feasible to provide "less" vehicular capacity than can actually be provided in order to encourage a modal shift needs to be carefully considered in the context of whether the alternative measures will be able to provide congestion relief, whether they will be adequately used, and whether the benefits of sustained mode shifts compensate any long term negative perceptions that may develop.

B. Stabilization of traffic conditions can take several weeks to several months.

Large fluctuations in traffic conditions can be expected during the initial period following the disaster. Depending on the magnitude of impacts to the system, it may take weeks or months before conditions stabilize into a regular pattern. Consequently, it may not be feasible, nor would it be necessarily cost effective, to attempt to develop the initial traffic mitigation strategies on a real-time basis. A more efficient approach would be to develop large-scale strategies based on known pre-disaster travel patterns, and then make adjustments based on data collected over a reasonable period of time.

C. Where sufficient alternate routes existed, motorists continued driving; where convenient detours were not available, transit options became much more attractive.

The difference in response to the Interstate 10 closure compared to the Interstate 5 and 5/14 closures indicate that where alternate routes are available, motorists were content to continue driving. Increases in bus ridership in the Interstate 10 corridor were very minor. The magnitude of the time savings offered to HOV lane users was probably insufficient to generate any substantive degree of modal shift. Moreover, the closures were not sustained over a long enough period to elicit major mode shifts.

The dramatic increase in Metrolink ridership in the Interstate 5 and State Route 14 corridors immediately following the quake clearly point to the importance of providing transit options on corridors where alternate routes are limited or unavailable. However, once the freeway detours were opened and overall traffic conditions stabilized, ridership decreased sharply. What this means with respect to the long term viability of transit in the Los Angeles area will be the subject of much debate in the future. Whether this experience can realistically be applied to other areas is another important question that cannot be answered at this time.

D. A review is needed of isolated communities that are currently served by a single transportation facility.

Although the detours that were established were successful in providing access to the Antelope Valley, traffic handling could have been substantially more difficult had there been more damage to the highway system or if the Metrolink extensions were not feasible. A review is needed to determine to what extent additional capacity is needed over the San Gabriel and San Bernardino Mountains, if nothing else, to be able to respond to emergencies such as this one. This review could be expanded to include a search for other similarly isolated communities and to provide an estimate of what the economic impacts of prolonged closures might be.

E. Availability of accurate transportation data is critical in developing emergency response.

A database of information should be developed in anticipation of such disasters, integrating data from all transportation providers. Data concerning traffic volumes, travel times, origin & destination information, and transit ridership & schedules should be compiled and stored at a single accessible location. Computer modeling may be useful for this purpose.

After the disaster, a comprehensive data collection effort should begin immediately in order to provide timely and accurate information to the public, to develop mitigation measures, and to determine delay costs with which repair contract incentive clauses my be based.

F. Emergency response procedures need to be expanded to handle major disasters.

"Standard" emergency response measures were already in place and worked well. These include the availability of emergency response teams, widespread use of communications devices such as cellular phones & pagers, and fully-equipped remote field offices. A variety of interagency agreements were already in place which expedited the work between transportation providers.

However, the magnitude of this disaster revealed several areas that require improvement. Detailed procedures should be established in advance to determine how personnel from other locations can be transferred rapidly to the disaster site. These procedures should include a quick approval process for renting or leasing equipment. Media relation training should be given to key staff who will be on the front lines of the recovery effort. Hiring of public relations consultant firms can be extremely beneficial in satisfying the insatiable thirst for disaster information, freeing up personnel to expedite recovery work. Earthquake drills involving all agencies could also be expanded.

G. Areas with well-developed traffic management centers are able to accommodate sudden changes easily.

Properly equipped and well-staffed traffic management centers are an invaluable tool in dealing with transportation emergencies of this magnitude. The availability of devices such as closed-circuit television cameras and roadway detection loops were critical in being able to monitor freeway conditions quickly and frequently. This resulted in more accurate information being given to the public, either via the freeway changeable message signs or through the media. However, the availability of traffic management equipment is by no means a substitute for engineers with the necessary training and experience to develop appropriate operational solutions quickly.

THE 1994 NORTHRIDGE EARTHQUAKE — TRAFFIC MANAGEMENT STRATEGIES

Albert Yee, Kim Nystrom and Stephen K. Leung, Caltrans

ABSTRACT

In the days immediately following the January 17, 1994 Northridge earthquake in Southern California, a team of Caltrans traffic operations engineers was established to formulate possible traffic management strategies that could provide congestion relief during the reconstruction period. The proposals that were quickly developed became the earthquake relief Traffic Management Plan (TMP). Strategies included installation of motorist information and vehicle detection systems in the field and an Emergency Detour Management Center to control this equipment, a comprehensive public awareness campaign, short term traffic control measures, acquisition of communications equipment, helicopter surveillance, traffic data collection, tow service in the affected corridors, increased Highway Patrol support, and new park & ride lots. The rapid implementation of the TMP, and the successful part it played in dealing with what could have been a major transportation disaster was due in large part to unparalleled cooperation and assistance from the Federal Highway Administration. This report describes the various elements of the TMP and how they were implemented.

INTRODUCTION

The magnitude 6.8 earthquake that occurred in Southern California on the morning of January 17, 1994 resulted in widespread damage throughout the Los Angeles area. Numerous highways were closed initially, but sustained closures affected only four facilities: Interstate 10, Interstate 5, the 5/14 interchange, and State Route 118. Unfortunately, these facilities were vitally important to the movement of people and goods into and out of the region and any prolonged closures could have had devastating economic effects. It was clear from the outset that innovative mitigation measures would be required to accommodate the area's transportation needs through the reconstruction period. This report describes the types of traffic management strategies that were devised, and the process with which they were implemented.

DAMAGED FACILITIES

The Santa Monica Freeway section of Interstate 10, connecting the westerly cities of Santa Monica, Beverly Hills and Culver City with downtown Los Angeles, suffered major damage at two overcrossings. Two of the connectors at the 5/14 interchange in Sylmar collapsed, severing the only freeway link over the mountains to Lancaster and Palmdale, as well as causing damage to the through-movement on Interstate 5. Interstate 5 also suffered damage at several locations north of the 5/14 interchange, effectively closing the only other major highway link over the mountains. State Highway 118 in Granada Hills was closed when the eastbound roadway collapsed at two locations. Additional damage at other locations resulted in the closure of the entire section of Route 118 from I-405 to I-210 (about 4 miles) in both directions. At all of these locations, closures were immediate and total, with no freeway traffic able to pass through the damaged zones.

STRATEGIES IMPLEMENTED

A team of California Department of Transportation (Caltrans) traffic operations engineers was assembled to develop a transportation management plan (TMP) to handle traffic until the damaged freeways were reopened. This team worked under the guidance of a TMP Task Force Chairman, who was the single point of contact for the plan and was responsible for coordinating its development and driving its implementation. A Federal Highway Administration (FHWA) emergency TMP coordinator was also actively involved in the scoping of the proposed work and was on hand to expedite approval of each strategy. Preliminary proposals were developed within the first week after the quake. This list was refined in the ensuing weeks, during which time some proposals were eliminated and others were added. The measures which were actually implemented are described below. All were financed completely through federal emergency relief funds.

Emergency Detour Management Center and Field Instrumentation ($12.64 million)

A "Design/Build" contract was executed to install traffic surveillance and motorist information equipment in areas that were affected by the freeway closures but were not covered by existing Traffic Operations System equipment. This contract with National Engineering Technology was scoped, prepared and executed in three days.

Field instrumentation consisted of the following:

- 8 changeable message signs;
- 9 highway advisory radio installations;
- 7 closed-circuit television locations;
- 2 closed-circuit television communication links;
- 20 vehicle detector system locations; and
- 2 video image processing locations.

An Emergency Detour Management Center (later renamed the Earthquake Planning and Implementation Center, or "EpiCenter") was built in the Caltrans district office in downtown Los Angeles to control and monitor the newly installed field equipment. Satellite and cellular telephone hookups were employed where conventional communication strategies were not viable.

The Emergency Center supplemented the traffic management efforts in the pre-existing Caltrans Traffic Management Center (TMC) by focusing on the highways and detours in the affected areas. The TMC continued to provide the freeway surveillance and control functions for the rest of the region, as well as perform incident management and coordination with the Highway Patrol. Furthermore, the computer system in the TMC was not able to handle the additional processing load that the new field instrumentation would introduce.

Public Awareness Campaign ($2.42 million)

A multi-faceted action plan was developed through a partnership effort by Caltrans, the California Business, Transportation & Housing Agency, the Los Angeles County Metropolitan Transportation Agency (LACMTA), and the Mayor's office of the City of Los Angeles.

Ridesharing and transportation demand management efforts were incorporated into a unified Commuter Action Plan, which was to cover the initial six-week period after the quake. This plan was to provide accurate information on alternative transportation options in targeted quake-affected areas through the use of newspaper inserts, and radio and television public service announcements. Estimated cost was $1.60 million, which included surveys and an evaluation of the effort. Pacific/West Communications Group was selected to perform this work.

Additional outreach and publicity after the initial six-week period was needed to inform the public about the freeway recovery plan and schedule. This effort included newspaper inserts & brochures, lane closure information in newspapers, and development of an information hotline. Estimated cost was $819,000. The firm of Frank Wilson & Associates, Inc. was selected to perform this work.

In addition to these efforts, a 1-800-COMMUTE telephone number was established by Caltrans and the Mayor's office. The service provided bilingual information on transit routes and schedules, ridesharing options, and highway conditions.

Detours & Traffic Control ($1.24 million)

Much of the early response and repair effort was provided through maintenance force accounts and by Caltrans maintenance personnel. This involved creation of short term and long term detours around the damaged areas and providing traffic control support in response to the rapidly changing conditions.

Emergency Communications Equipment ($0.14 million)

The ability to communicate with field staff who were assessing damage to the highway system or managing traffic was critical in developing appropriate mitigation measures and to provide accurate and timely information to the public. Equipment such as cellular phones, pagers, two-way radios and stop watches were leased or, in some cases, purchased.

Helicopter Surveillance ($0.19 million)

Funding was expanded for an existing interagency agreement between Caltrans and the City of Los Angeles to provide helicopter service. The helicopters were used for (1) damage assessment by engineers and governmental officials, (2) traffic management, such as coordination of field traffic management teams, and (3) traffic surveillance, such as evaluation of detour routes. Actual usage only was charged to the contract.

Traffic Performance Data Acquisition & Analysis ($1.60 million)

The closure of major freeways provided a unique opportunity to observe motorist response and changes in travel behavior. A study was developed to perform regular and comprehensive collection of traffic performance data, as well as conduct home interview, trucking, and transit surveys. The study was proposed to extend through the reconstruction period and into the recovery period to determine if there were any long term transportation

TABLE 1 COST ESTIMATES FOR CALTRANS TRAFFIC MANAGEMENT STRATEGIES ($ millions)

Field instrumentation and Emergency Detour Management Center	$ 12.64 M
Local detours & signing	$ 1.24 M
Emergency communications eqpt	$ 0.14 M
Park & ride lots	$ 0.56 M
Public Awareness Campaign	$ 2.42 M
Enhanced CHP enforcement	$ 0.38 M
Helicopter surveillance	$ 0.19 M
Repair TMC computer damage	$ 0.10 M
Traffic data acquisition & analysis	$ 1.60 M
Enhanced tow service	$ 2.24 M
TOTAL	$ 21.51 M

effects caused by the closures. Barton-Aschman and Associates, Inc. was selected to perform this study.

Enhanced Tow Service ($2.24 million)

Prior to the quake, peak period tow service was provided on numerous freeways in the area by the Freeway Service Patrol (FSP) program, which is funded by the LACMTA and Caltrans. The program contracts with private towing operators to continuously patrol predefined "beats" and clear stalls and other road hazards blocking the traveled way. In response to the freeway closures, trucks assigned to beats in which the freeway was closed were redeployed to patrol the detour routes. Service was also expanded to provide increased coverage in the vicinity of the major closures. The cost estimate was based on operation of the expanded service for one year. Since most of the freeways were reopened much sooner than that, the actual expenditures were considerably lower.

Construction Zone Enhanced Enforcement ($0.38 million)

Increased California Highway Patrol (CHP) coverage was provided in construction zones and detour routes to enhance safety in the work areas where repairs were underway. An existing interagency agreement—the Construction Zone Enhanced Enforcement Program (COZEEP)—between Caltrans and CHP was supplemented to fund the increased patrols.

Park & Ride Lots ($0.56 million)

Three new park & ride lots were established in the vicinity of the 5/14 interchange to encourage ridesharing and the use of the new Metrolink rail extensions. Approximately 900 new parking spaces were created. One existing parking lot was leased, another lot was leased and then paved and striped, and the third was constructed on Caltrans property. Funds were also included to provide security at these lots.

COSTS

In an April 20, 1989 memo from the Federal Highway Administration entitled "Federal-aid Participation in Traffic Management Improvements in Urban Areas", conceptual approval for Federal-aid funding was granted for a wide range of traffic management strategies. Caltrans requested that the proposed relief measures be considered eligible for emergency funding as provided in Section 125, USC Title 23.

Initial cost estimates were broadly sketched out with the best information available at the time, with all strategies at first totaling more than $110 million. After

more detailed analyses were conducted and a more comprehensive assessment was made of what was actually needed, this figure dropped considerably. The final tally was approximately $22 million (see Table 1). Separate Damage Assessment Reports were filed for each of these measures, which included more detailed cost estimates and justifications. These reports were reviewed by the FHWA TMP coordinator and approved for federal emergency relief funding.

The earthquake relief TMP played a crucial role in handling traffic through the reconstruction period and in expediting the recovery. Other key elements in this effort were the long term detours that were established at each of the major closures which were developed in cooperation with local agencies, the expansion of bus and rail service in the affected corridors, and the incentives that were offered to contractors for early completion of repair work.

THE EFFECTS OF THE JANUARY 17, 1994 NORTHRIDGE EARTHQUAKE ON TRAVEL BEHAVIOR IN THE SANTA MONICA FREEWAY (I-10) CORRIDOR

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Norm Steinman, Barton-Aschman and Associates

ABSTRACT

On January 17, 1994, the Northridge Earthquake shook the greater Los Angeles area with a power of 6.8 on the Richter scale. In addition to other damage, the earthquake destroyed the La Cienega, Venice, Washington and Fairfax over crossings of the I-10 (Santa Monica Freeway) disrupting travel patterns along one of Los Angeles' most heavily traveled corridors. Two primary detours, HOV and all purpose, were established along the Santa Monica Freeway corridor in each direction to divert traffic around the damaged sections. Within days of the earthquake, Caltrans began gathering data to study these traffic effects of the earthquake's damage. Traffic volumes, travel times and auto occupancy rates were monitored and telephone interviews were conducted on households directly affected by the closure.

Of the 434,000 person trips made each weekday on this segment of I-10 prior to the earthquake, 208,000 remained on I-10, and used the primary detours; 159,000 trips shifted to city streets; 7,000 shifted to the recently completed I-105 freeway; 2,000 shifted mode to transit; and, 58,000 trips were eliminated altogether.

On an average weekday during the freeway reconstruction period, trips using the HOV detour averaged six minutes longer than before the earthquake, and the all purpose detour averaged 12 minutes longer. These numbers varied by time of day and direction of travel. The greatest delay, 17 minutes, was recorded eastbound during the p.m. peak period.

BACKGROUND

On January 17, 1994, the Northridge Earthquake destroyed the bridges carrying the I-10 (Santa Monica Freeway) over Washington Boulevard, Venice Boulevard, La Cienega Boulevard and Fairfax Avenue. This section of Interstate 10 is 5.6 km. (3.5 miles) east of the I-405 along a 15.1 km. (9.4 mile) long section joining I-405 (San Diego Freeway) on the west and I-110 (Harbor Freeway) on the east. The Los Angeles Central Business District (CBD) is immediately northeast of the I-10/I-110 interchange.

The 1993 traffic volumes along I-10 just east of the break were 294,000 vehicles (7 day average) and 310,000 vehicles (5 day average). The route had five lanes in each direction east of the break, and four lanes in each direction to the west. The peak period traffic was split roughly 50 percent in each direction. The a.m. peak was two to three hours long with an average speed of 43 kph (27 mph) for the period of congestion over the 15.13 km (9.4 mile) area. The p.m. peak was three hours in each direction with an average speed of 50 kph (31 mph).

The Detours

After the earthquake, Caltrans and the City of Los Angeles Department of Transportation (LADOT), in conjunction with the California Highway Patrol, the Los Angeles County Metropolitan Transportation Authority (LACMTA) and other affected local agencies, took immediate steps to restore traffic capacity within the I-10 (Santa Monica Freeway) corridor. Two detours, HOV and all purpose, were established along the corridor in each direction to divert traffic around the damaged sections. These primary detours were initially established within a week after the earthquake. On February 1, 1994, both sets of detours were shortened and improved.

Westbound Detours

Westbound HOV traffic exited the freeway via the Washington Boulevard off-ramp as before; then, followed Apple Street, a little used frontage road, across Washington and Venice Boulevards at signalized intersections. Finally, the westbound HOV traffic reentered the freeway ingeniously using the temporarily unused eastbound ramps to move under the I-10 (under reconstruction), and over Ballona Creek. This HOV bypass required only 0.8 km. (0.5 miles) of city streets!

The mixed flow traffic exited the freeway at La Brea Avenue, as before, then used Venice Boulevard, Cadillac Avenue, briefly crossing La Cienega Boulevard to reenter the freeway at that westbound on ramp. The

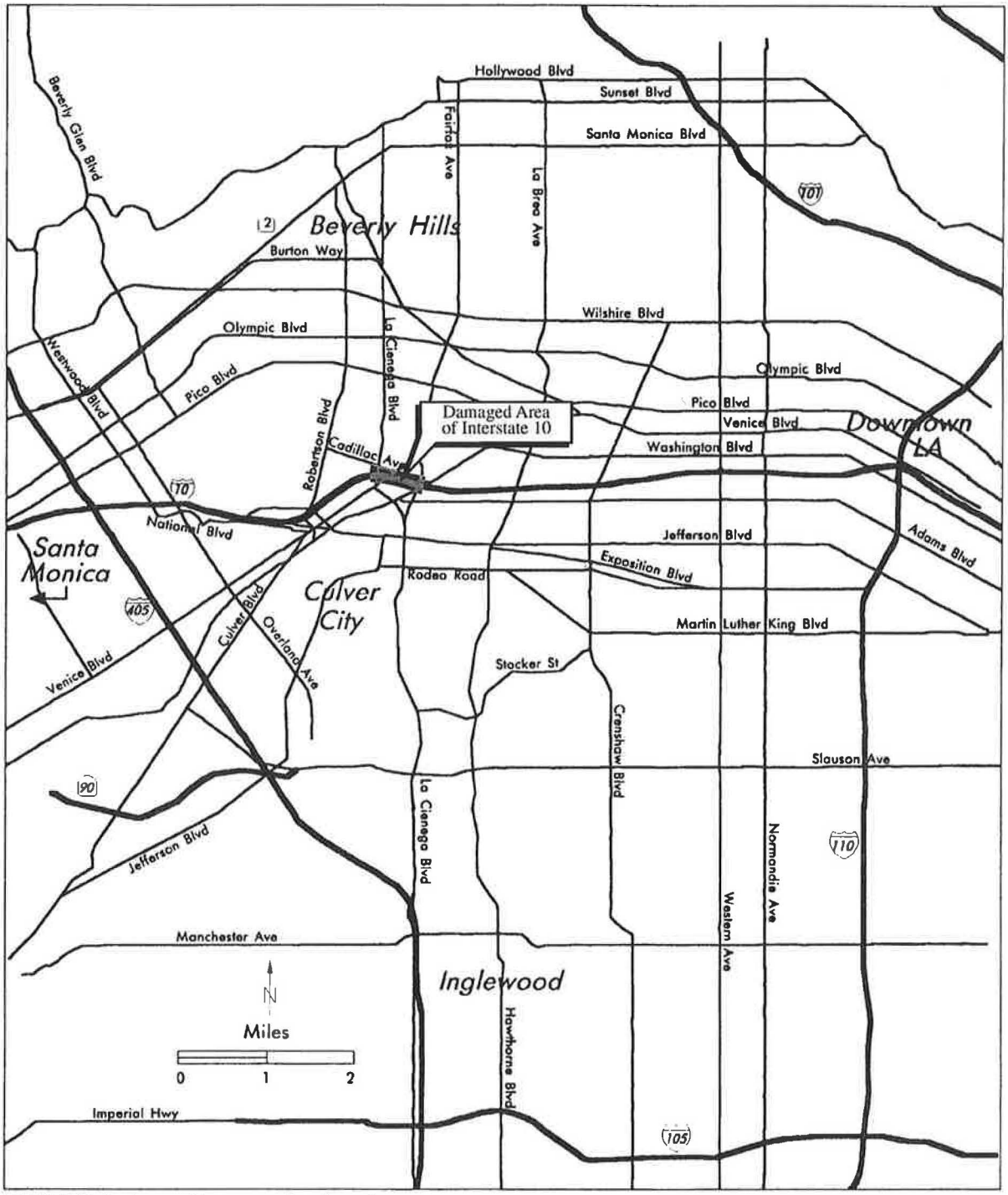


FIGURE 1 Areawide network of roadways.

TABLE 1 AVERAGE ADDITIONAL TRAVEL TIME DELAYS ON I-10 PRIMARY DETOURS DURING MARCH, 1994

Periods of Delay	I-10 Mixed-Flow and HOV Detours			
	EB HOV	EB SOV	WB HOV	WB SOV
AM Peak Period	3	8	4	11
Midday	5	9	3	11
PM Peak Period	15	17	3	10
Evening	8	9	3	9
Weekday Average	8	12	4	11
Weekend	7	8	4	8

Notes:

- *Delay is calculated based on an assumed pre-quake speed of 45 miles per hour.*
- *Westbound detour travel time runs performed from Crenshaw Boulevard Over-crossing to the vicinity of Robertson Boulevard.*
- *Eastbound travel time runs performed from the I-405 to the Washington Boulevard on-ramp.*

Source: Caltrans travel time runs prior to March 3; Wiltec runs after March 3.

westbound mixed flow bypass used 4.8 km. (3 miles) of city streets.

Eastbound Detours

The eastbound HOV lane was not as neat and tidy as the westbound. It had to share very scarce roadway space with local traffic. HOV traffic exited the freeway at La Cienega Boulevard, used La Cienega Boulevard to Washington Boulevard, and reentered I-10 at the eastbound on ramp. The eastbound HOV detour used 1.3 km. (0.8 miles) of city streets.

The eastbound mixed flow traffic exited the freeway at Robertson Boulevard, traversing Venice Boulevard to National Boulevard, then to Jefferson Blvd., and followed Jefferson Boulevard to La Brea Avenue where it reentered the freeway. The eastbound mixed flow detour used about 4.8 km. (3 miles) of city streets.

Delay on the Detours

The average delay experienced along these four detours are summarized in Table 1. As you can see, the delay is not closely related to congestion (Eastbound p.m. peak period excepted). Most of the delay is associated with travel on city streets with their slower speed limits and intersection delays.

HOME INTERVIEW SURVEY

Applied Management and Planning Group (AMPG), a sub-consultant to Barton-Aschman and Associates, conducted a telephone survey of households within the I-10 corridor to examine changes in travel characteristics brought about by the January 17, 1994 earthquake. Respondents in the 792 household sample were asked if they or someone in their households was a regular user of the damaged section of I-10 prior to the earthquake. If respondents answered yes, they were then asked a series of questions concerning trips made before the earthquake, during reconstruction, and after reopening. In addition to I-10 trip information, basic questions were asked regarding household size, auto ownership and so forth. A follow up survey was conducted in October 1994. Four hundred of the original 792 households were contacted and asked to clarify their response to trip discontinuation, changing trip origin & destination and changing trip start times. The follow up survey results are shown in Figure 3.

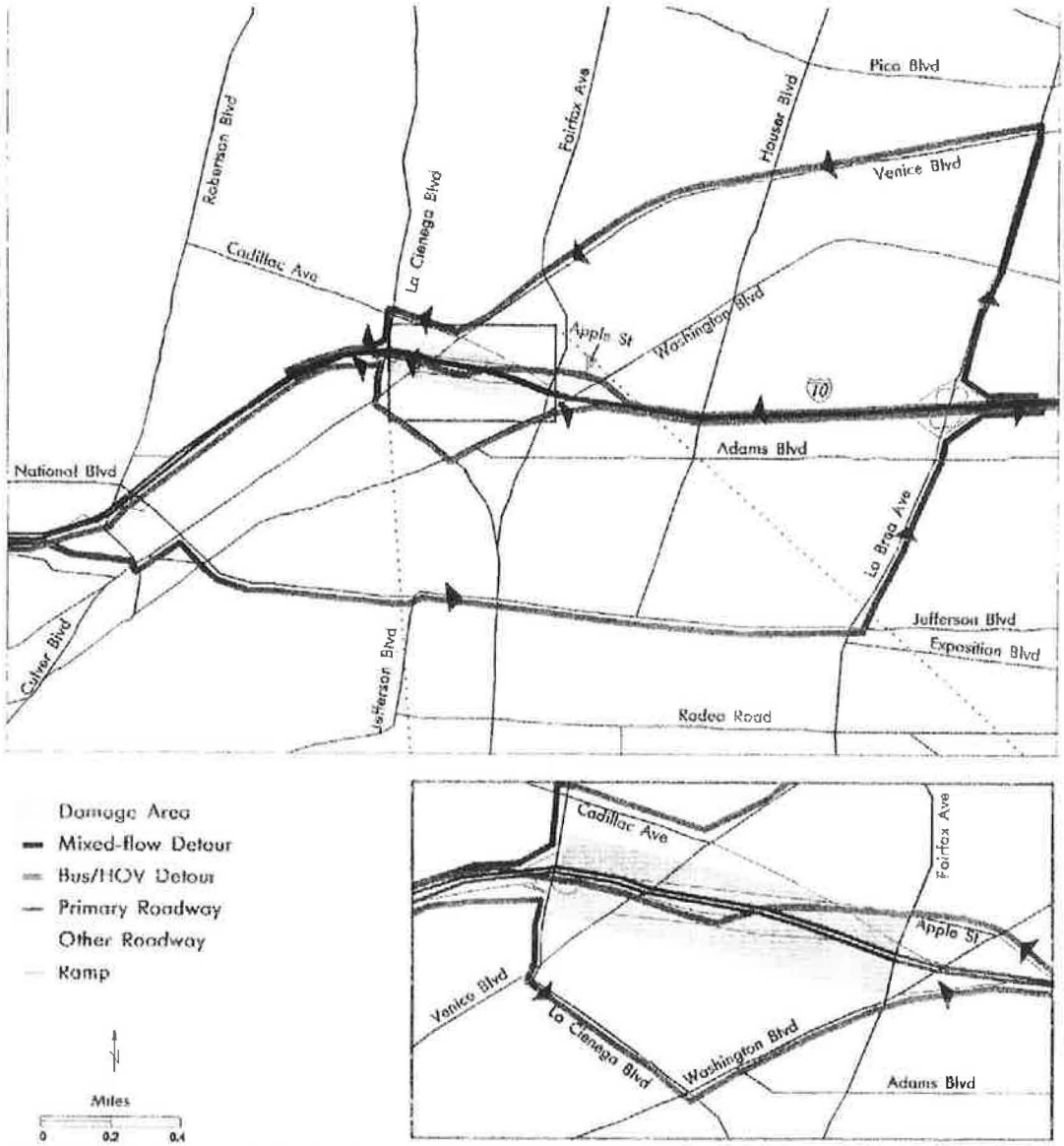


FIGURE 2 Primary HOV and mixed-flow detours in effect from February 1, 1994 until the reopening of I-10 on April 12, 1994.

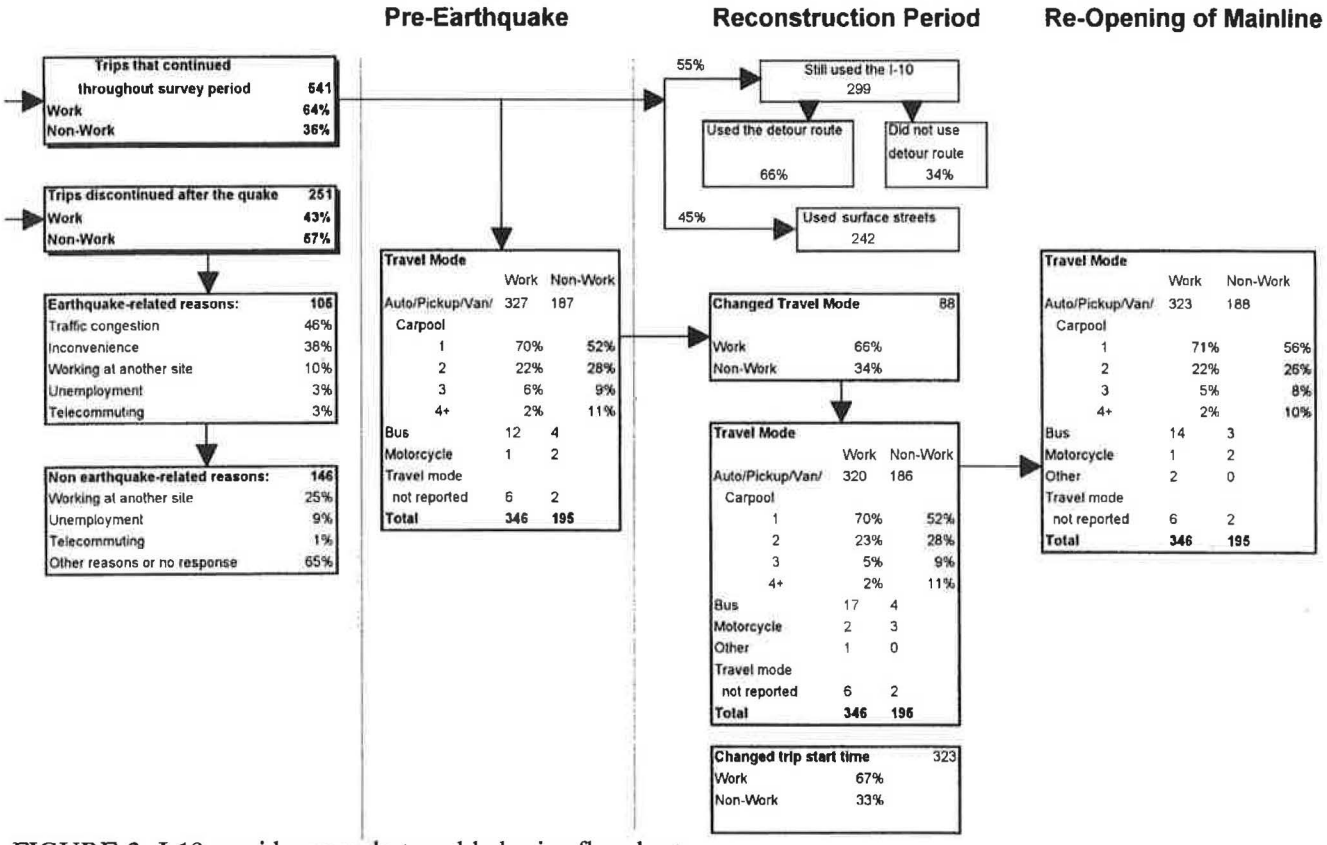


FIGURE 3 I-10 corridor sample travel behavior flowchart.

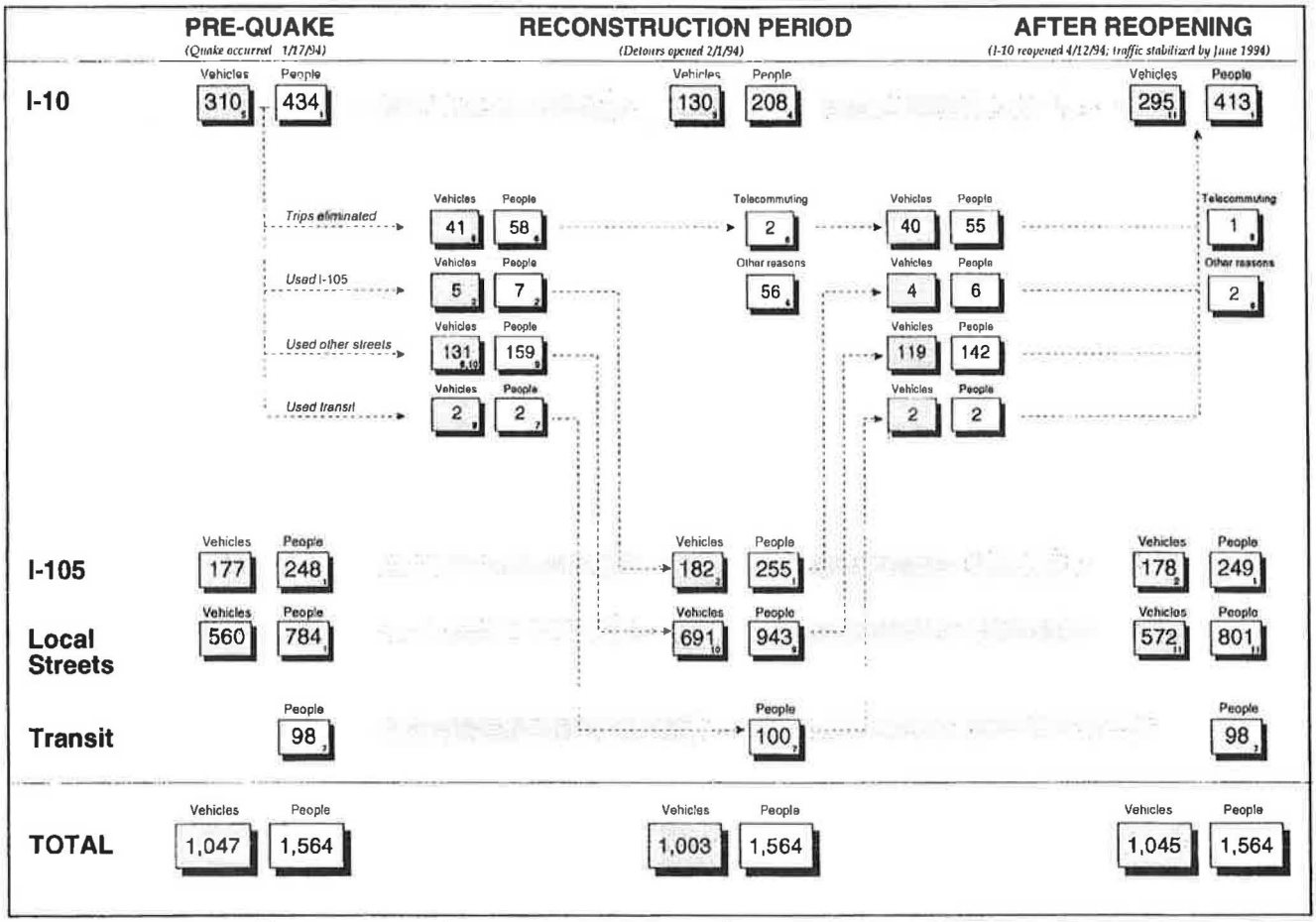


FIGURE 4 I-10 corridor travel behavior flowchart (daily trips in thousands).

Sources of Information for I-10 Corridor Travel Behavior Trends

Footnotes:

1. Daily average vehicle occupancy for all trip purposes combined is 1.4 persons per vehicle for Los Angeles County, based on the *1991 Regional Home Interview Survey*, Southern California Association of Governments (SCAG).
2. Note: Traffic volumes on the newly opened I-105 continued to grow during the period of analysis. The January, 1994 (pre-quake) volumes of 177,000 grew to approximately 210,000 by June 1994. First source for the change in I-105 volumes associated with the diversion from I-10 is the *Home Interview Survey* of I-10 users conducted by Applied Management & Planning Group. The second source is the weekly traffic volumes recorded on I-105 by Caltrans in April, 1994 before and after the reopening of I-10.
3. Average of weekday vehicle counts for I-10 mixed flow and HOV detour from Caltrans and Wiltec field counts.
4. Vehicle occupancies for the I-10 mixed-flow and HOV detours were calculated from the weekly vehicle classification counts. Vehicles in the mixed-flow detour averaged approximately 1.10 to 1.15 persons per vehicle. Vehicles in the HOV detour averaged approximately 2.10 to 2.30 persons per vehicle. A composite I-10 detour vehicle occupancy of 1.6 persons per vehicle is used in this analysis.
5. The 310,000 is a five-day AADT count as derived from the 1993 Caltrans Traffic Count Book. This count location is between La Brea and Venice/La Cienega. A 294,000 AADT seven-day average corresponds to this count at the same location.
6. Source: *Home Interview Survey* of I-10 corridor travelers (AMPG), which indicates that 13.3 percent of I-10 pre-quake users eliminated or modified trips for earthquake related reasons. Less than one percent of total respondents indicated that they telecommuted following the earthquake.
7. 1994 Weekly transit ridership data from LACMTA, City of Los Angeles, Culver City Transit, and Santa Monica Municipal Bus Lines. A second source for the shift to transit is the *Home Interview Survey* of I-10 corridor travelers.
8. Based on the *Home Interview Survey*, between one and two percent of pre-quake I-10 users shifted from driving alone to ridesharing or transit. This led to the assumption that approximately 2,000 I-10 pre-quake vehicle trips were eliminated by shifts to transit and 1,000 vehicle trips by shifts to carpooling.
9. Assumes a vehicle occupancy of 1.21 persons per vehicle for trips diverted from I-10 to arterials, based on assuming that carpools generally used the I-10 HOV primary detour to gain a time savings, while other vehicles were shifted to arterials.
10. As discussed in Chapter 4, a screenline count in the I-10 corridor during the freeway reconstruction in March 1994 identified 107,000 additional vehicles on six major arterials, two of which (Jefferson and Venice) were on the primary mixed-flow detour, carrying 52,000 of the additional vehicles. The remaining four arterials were carrying 55,000 additional vehicles. Assumption: an additional 76,000 vehicles used other city streets not included in the screenline counts for a total of 121,000 daily vehicle trips diverted to arterials.
11. I-10 daily counts just east of I-405 remain approximately 10 percent below 1993 pre-quake counts for comparable months, while I-110 counts just west of the I-10 returned to pre-quake levels in June 1994. Based on this and other information, it was assumed that approximately five percent of pre-quake I-10 trips have not reappeared on I-10 in the vicinity of where the damage occurred.
12. Estimate of total corridor trips from *emme/2* model simulation. Traffic counts on freeways and primary I-10 detours: Caltrans prior to March 3; Wiltec after March 3. Arterial traffic counts from the City of Los Angeles (ATSAC) and County of Los Angeles.

FIGURE 5 Sources of information for I-10 corridor travel behavior trends.

Pre-quake daily vehicle volumes	I-10 Mainline 310,000[2]	Parallel Arterials 560,000[3]	I-105 177,000	Transit Riders N/A	Total Trips Made 1,047,000
Daily vehicle volumes during reconstruction	I-10 Primary Detours 130,000	Parallel Arterials 691,000	I-105 182,000[4]	Transit Riders N/A	Total 1,003,000[5]
Conversion to person trips[5]	208,000[6]	943,000[6]	255,000	100,000	1,506,000
Average delays for weekdays (in minutes)	9[7]	6[8]	0	6	--
Daily person hours of delay	31,200	93,900	0	10,000	135,100
Daily truck traffic estimates	5,200[9]	27,520[10]	7,280[10]	N/A	40,000
Daily truck hours of delay	780	2,752	0	N/A	3,532

Person-hours/truck-hours of delay	Trucks 3,532	Persons 135,100
Value of vehicle time for persons and trucks (cost per hour)	$19.20[11]	$6.00[11]
Cost of delay	$68,000	$811,000
Excess fuel used: total vehicle hours of delay x $1.10 per gallon	100,000 hours x $1.10 = $110,000[12]	
Cost of the I-10 closure for an average weekday	$990,000	

1. *Based upon travel simulation utilizing the City of Los Angeles Framework Model.*
2. *Source: Derived from the 1993 Traffic Volumes, Caltrans for the I-10 between La Brea and Venice/La Cienega.*
3. *The emme/2 model simulation results validated by counts from the City of Los Angeles ATSAC, County of Los Angeles and Wiltec.*
4. *Volumes on the newly opened I-105 Freeway have continued to grow from the time of the earthquake and surpassed 200,000 daily vehicle trips soon after it occurred. The volume of 182,000 represents the relative change in volume assumed to be associated with the damage on I-10. Source: Home Interview Survey of I-10 travelers and Caltrans traffic count trends during March and April 1994.*
5. *Based on the Home Interview Survey of I-10 travelers, approximately 15 to 16 percent of I-10 pre-quake trips either shifted to other travel modes or were eliminated or modified during the reconstruction period on I-10.*
6. *Conversion of vehicles to persons based on daily occupancy factor of 1.4 persons per vehicle from the 1991 Regional Home Interview Survey, except for arterial streets where a daily occupancy of 1.36 is used to reflect additional drive-alone trips diverted from I-10. For I-10 primary detours: 1.6 persons per vehicle from field counts of vehicle occupancies during March.*
7. *Approximation based on factoring from delays recorded from travel time runs performed on I-10 traffic detours.*
8. *Based on a composite average delay for all time periods during weekdays from field travel time runs; March 1994.*
9. *Based on field vehicle mix counts in March 1994.*
10. *Derived from Caltrans pre-quake information on percent trucks.*
11. *California Department of Transportation Policy and Procedure Circular P78-5 Revised February 26, 1990.*
12. *From the Economic Benefits of Reopening I-10, Governor's Office of Planning and Research, State of California.*

FIGURE 6 I-10 corridor: cost of daily areawide delay during reconstruction.

THE JANUARY 17, 1994 NORTHRIDGE EARTHQUAKE IMPACTS ON THE INTERSTATE-5 AND THE STATE ROUTE-14 COMMUTE BEHAVIOR IN LOS ANGELES COUNTY

Steve Tabaie and Stephen K. Leung, Caltrans
Larry W. Wesemann, Barton-Aschman and Associates

Southern California was struck by a 6.8 magnitude earthquake (measured on the Richter scale) on January 17, 1994 (Northridge Earthquake) which caused extensive damage to some of the region's freeway system. The Golden State Freeway (Interstate 5), the Antelope Valley Freeway (State Route 14), and their Interchange in and around the City of Santa Clarita were significantly damaged.

Although the Northridge earthquake caused damage to several freeways in southern California, this report focuses only on the impact of the quake on the traffic on I-5 and SR-14.

Two of the four connector structures between I-5 and SR-14 collapsed (southbound SR-14 to northbound and southbound I-5), while there was considerable damage to the other two connectors (northbound I-5 to northbound SR-14 and southbound I-5 to northbound SR-14). I-5 collapsed on top of the Old Road at Gavin Canyon Undercrossing. I-5 was completely shut off between Roxford Street and Lyons Avenue. Detours were quickly established practically within hours of the earthquake. Work on the damaged (or destroyed) freeway segments was initiated within a few days. Traffic volumes, occupancy counts, and travel time runs were frequently conducted to capture the changes to pre-quake conditions as repair work progressed. Various surveys were also taken to ascertain commute behavioral changes. The results indicated that the majority of people were satisfied with the available detour routes. Those who utilized the established temporary High Occupancy Vehicle (HOV) lane on SR-14 (one lane each direction) saved as much as 9 minutes compared to those on the mixed flow lanes during the morning peak period (southbound) commute.

About seven percent of the I-5 pre-quake trips were discontinued through the two corridors (I-5 and SR-14 corridors) after the quake because of increased traffic congestion, inconvenience, telecommuting, and change in work location. Approximately nine percent of the SR-14 pre-quake trips were also discontinued through the damaged sections due to the same reasons.

Metrolink ridership on the Santa Clarita line increased significantly (from 1,000 boardings per weekday pre-earthquake to 22,000 per weekday in late January, 1994). This, however, decreased to about 4,000 boardings per day in July.

INTRODUCTION

The purpose of this paper is to give the reader an overview of how commute characteristics and driver behaviors were impacted by the earthquake for I-5 and SR-14. The results of traffic data collection and various surveys performed will also be discussed.

Early Monday morning on January 17, 1994 Southern California was shaken by a 6.8 magnitude (Richter scale) earthquake. The EpiCenter of the earthquake was determined to be in Northridge in west San Fernando Valley. There were very few injuries and one fatality on the freeways resulting from the earthquake. This was due to the early morning hour of the quake as well as the fact that all local, state, and federal agencies were closed in observation of Martin Luther King Birthday. However, the quake caused substantial structural damage of varying magnitude to most of the regions's freeways including the I-5 and the SR-14 (see Figure 1).

Caltrans estimated the total State Highway reconstruction cost at $308 million. Actual expenditure on the major damaged facilities was about $250 million, including approximately $90 million for the I-5 and SR-14 corridors.

Caltrans, in concert with the following federal, state, and local agencies 1) initiated an accelerated rebuilding program using federal emergency funding and emergency contracting procedures; 2) established a multimodal action plan featuring primary and secondary detour routes, temporary HOV lane on SR-14, and additional transit services; and 3) created a coordinated program to provide the public with information about detour routes, road closures, and available services.

- U.S. Department of Transportation, Federal Highway Administration (FHWA);
- California Highway Patrol (CHP);
- City of Los Angeles, Department of Transportation (LADOT);

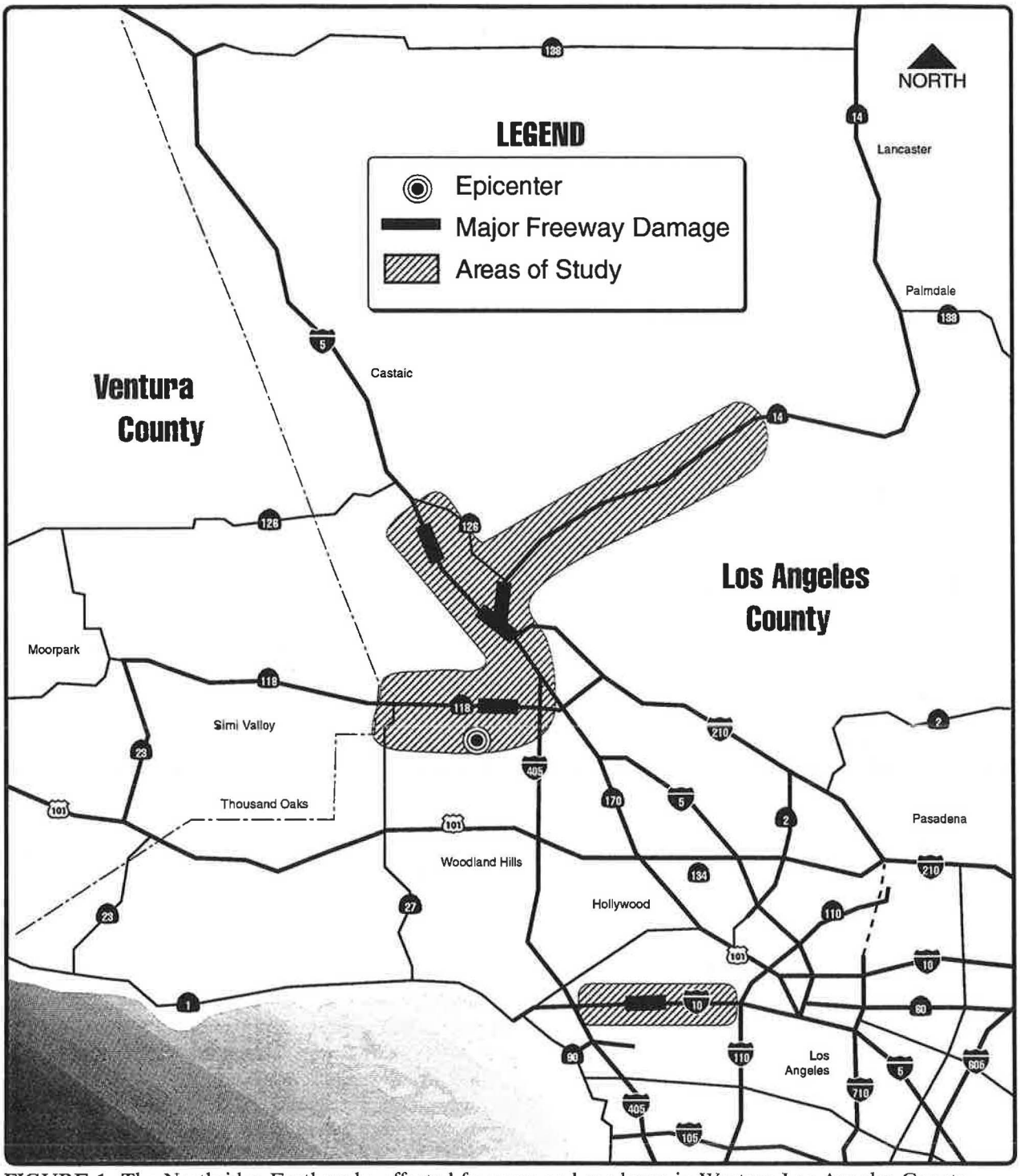


FIGURE 1 The Northridge Earthquake affected freeways and roadways in Western Los Angeles County.

- Los Angeles County Metropolitan Transportation Authority (LACMTA);
- Southern California Regional Rail Authority (SCRRA);
- Antelope Valley Transit Authority (AVTA);
- City of Simi Valley Transit (SVT); and
- City of Santa Clarita, Santa Clarita Transit (SCT).

The $14.8 million contract (which included a $150,000 per day bonus/penalty) to rebuild the Gavin Canyon bridges on I-5 was awarded on January 29. The contract was scheduled to be completed within 130 calendar days. The freeway opened four months after the earthquake struck, 33 days ahead of schedule. Southbound lanes were opened on May 17, and the northbound lanes on May 18.

A $19.6 million contract was awarded on March 18 to rebuild two of the four bridges, (S/B to S/B and N/B to N/B), in the I-5/SR-14 interchange. Work began on March 19 on reconstruction of the southbound SR-14 ramp to the southbound I-5, and northbound I-5 ramp to northbound SR-14. This project was scheduled to be completed within 132 calendar days (on July 28) and had a bonus/penalty of $100,000 per day. These two connectors were restored to their original (pre-quake) configurations and were opened to traffic on July 8, 1994 after the morning peak period.

The project to reconstruct the other two southbound to northbound connectors (S/B I-5 to N/B SR-14, and S/B SR-14 to N/B I-5) was awarded on July 8, 1994. This project was scheduled to be completed in 120 calendar days, and had an Incentive/Disincentive figure of $20,000 per day. These two connectors were opened to traffic on November 4, 1994.

BACKGROUND

Interstate 5 is the only primary north-south regional route that connects the Los Angeles Basin and the San Fernando Valley with points north of the San Gabriel Mountains. State Route 14 connects the cities of Lancaster and Palmdale with the San Fernando Valley and the rest of the Los Angeles Basin (see Figure 1). These two freeways converge at the I-5/SR-14 interchange, where they were mostly destroyed or damaged by the earthquake. Pre-earthquake traffic volume on I-5 south of the interchange (Sylmar, Roxford Street Interchange) was about 220,000 vehicles on an average weekday, while it was about 127,000 vehicles for SR-14 at San Fernando Road interchange (Junction of Route 126).

DETOUR INSTALLATION

Surface Streets

Since the I-5 was closed between Lyons Avenue and Roxford Street, Caltrans with cooperation from Los Angeles County and the City of Los Angeles established detour routes in a matter of hours. The southbound I-5 traffic was forced off at Lyons Avenue, to San Fernando Road, to Sierra Highway, to San Fernando Road, to Sepulveda Boulevard, and got back on at Roxford Avenue on-ramp. Foothill Boulevard was used as the main detour route for the northbound traffic.

San Fernando Road carried about 3,500 vehicles between 7:00 to 8:00 a.m. in the southbound direction, while the northbound volume was insignificant. Foothill Boulevard carried about 1,100 vehicles between 7:00 to 8:00 a.m. in the southbound direction, while the afternoon volume was 1,600 vehicles from 4:00 to 5:00 p.m.

The Old Road

The Old Road detour around the damaged bridges of I-5 at Gavin Canyon opened to traffic on January 29, eleven days after the earthquake. Caltrans crews and the contractor worked together to create the 4.8-km (3-mile) detour from Calgrove Boulevard to the I-5 truck stop just north of the I-5/SR-14 interchange. The construction cost was $3.2 million; another $3 million was spent removing the damaged structures at two locations and shoring up another structure.

This detour provided two mixed flow lanes in each direction which turned out to alleviate considerable amount of congestion. Data collected on the I-5 detour south of SR-14 revealed that the northbound volume was about 3500 vehicle on the mainline detour. The total detour corridor volume (including the SOV and HOV truck lanes, Foothill Blvd, and San Fernando Road) for the northbound direction was about 10,500 vehicle (from 3:00 to 4:00 p.m.). This was 102 percent of the pre-earthquake volume for the same location. The southbound I-5 mainline detour volume was counted to be about 3200 vehicle (from 7:00 to 8:00 a.m.). The total detour corridor volume for the southbound direction was about 12,000 vehicle between 7:00 to 8:00 a.m. This was about 88 percent of the pre-earthquake volume.

Truck Lane

On January 28, ten days after the earthquake, two lanes of the SR-14 opened for southbound traffic connecting to the southbound I-5. Caltrans restriped the southbound truck bypass to provide one mixed flow lane and one HOV lane. Later it was restriped for two mixed flow lanes.

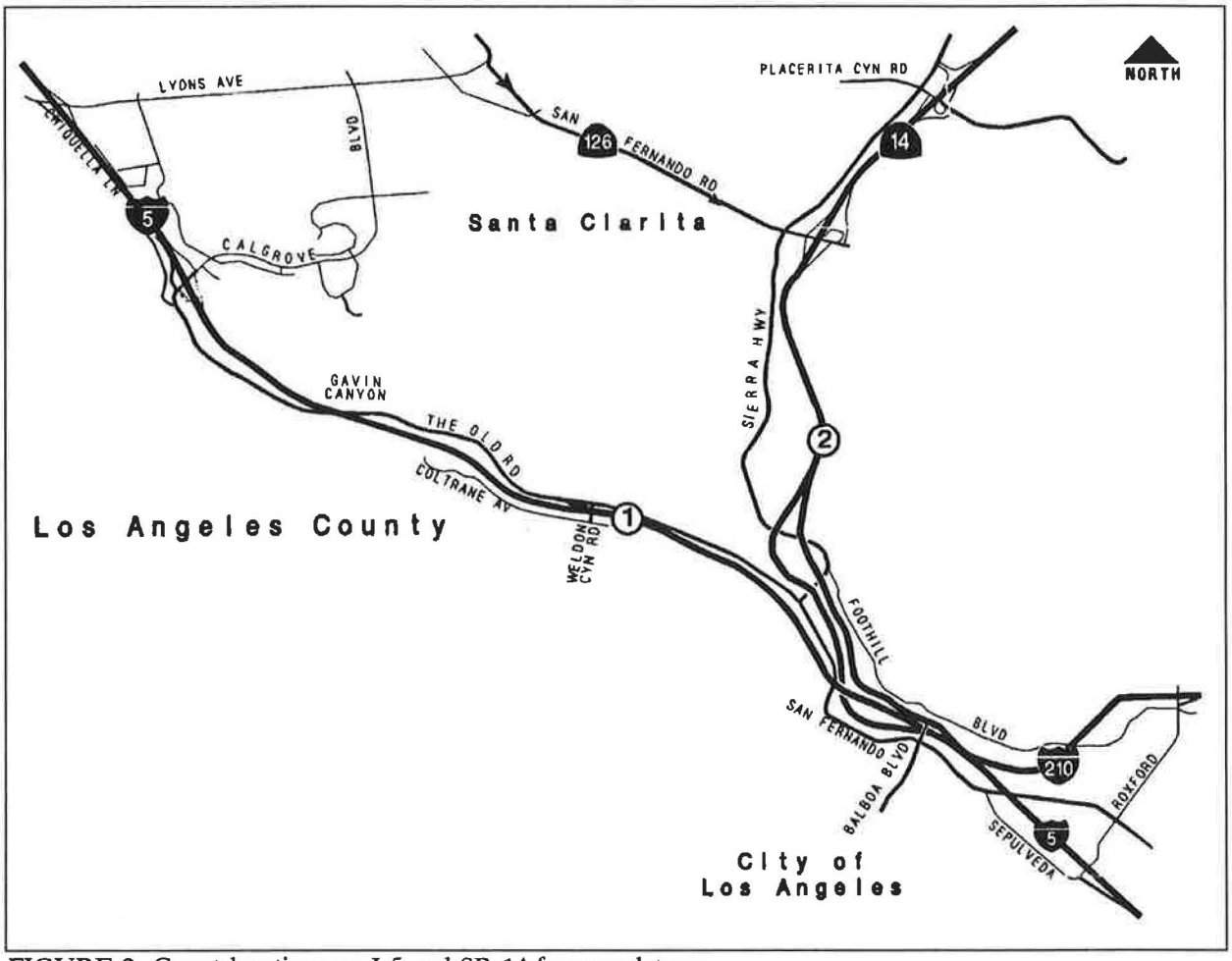


FIGURE 2 Count locations on I-5 and SR-14 freeway detours.

HOV Lane

A temporary HOV lane was installed on southbound SR-14. The northbound I-5 truck lanes were used as the connector to the northbound SR-14 freeway. Consequently, a northbound HOV lane was established using the right shoulder area of the truck lanes.

These preferential (HOV) lanes proved to be very useful. The Average Hourly Volume for the southbound HOV lane (counted between 6:00 a.m. to 9:00 a.m.) was about 1800 vehicle, while it was about 1450 vehicle for the northbound HOV lane (counted between 3:00 to 6:00 p.m.). The peak-hour volume was approximately from 7:00 a.m. to 8:00 a.m. for the southbound direction, while it was from 3:00 to 4:00 p.m. for the northbound direction. The count locations were north of I-5, at merge/diverge point for the detours on the truck lanes.

I-5 AND SR-14 TRAVEL CHARACTERISTICS

Traffic pattern changed, after the earthquake, not only on I-5 and SR-14, but also on the other freeways in the area such as SR-170, I-210, and I-405. Hence, the changes in the traffic characteristics were periodically (weekly at first and then biweekly) monitored by reviewing the peak-period traffic data collected on the detour route. Peak-period data included traffic volume counts (for mixed-flow and HOV detour lanes), types of vehicles, and travel times on the detour route.

I-5 Peak-Period Traffic Volumes

Traffic volumes on the I-5 detour route were counted during the morning (6:00 a.m. to 9:00 a.m.) and evening

(3:00 to 6:00 p.m.) peak periods at the Weldon Canyon Road overcrossing (see Figure 2). Vehicle mix surveys were also conducted to determine the percentage of trucks and buses on the I-5 detour route.

Peak period traffic volume steadily rose after the earthquake. In the last two weeks of January, some commuters may have avoided making the peak-period trips on the detour route by utilizing transit. Others may have switched to carpools and therefore produced fewer vehicle trips for the same number of travelling persons in the corridor. On the other hand, traffic volumes during peak-periods may have increased in the following weeks in February and March as commuters became more and more familiar with the detour route and stabilized later in April and May before I-5 was re-opened on May 17 and 18. The increasing familiarity included accepting the operating conditions on the detour route, or switching to alternate routes or modes.

SR-14 Peak-Period Traffic Volumes

Traffic volumes on the SR-14 detour route were collected during the morning (6:00 to 9:00 a.m.) and evening (3:00 to 6:00 p.m.) peak periods (see Figure 2). Vehicle mix surveys (used to calculate the percentage of the trucks and buses in all lanes and the categories of vehicle in the HOV lanes) were conducted to ascertain the post-earthquake peak-period traffic characteristics.

Peak-hour traffic volumes steadily rose in the weeks after the earthquake on the SR-14 detour route. The average morning peak-period hourly volume (southbound) was approximately 1,000 to 3,000 vehicles in the mixed-flow detour; while between 1,000 to 2,200 vehicles traveled in the HOV detour. In the afternoon peak direction (northbound), about 2,500 to 4,500 vehicles were traveling in the mixed-flow detour; while 900 to 1,500 vehicles traveled in the HOV detour.

I-5 Truck Travel

The earthquake-damaged section of the I-5 was used by a high volume of trucks making long-haul trips in the region. Pre-earthquake truck traffic was about 13 percent of the total traffic volume on I-5 south of the SR-14 interchange. After the earthquake, some truck traffic was diverted from the damaged area of I-5 to other inter-regional routes such as I-15 and US-101. Trucks travelling from SR-99 in the Central Valley were diverted on SR-58 through Tehachapi to I-15 and then to I-10. Truck counts revealed that some truck drivers used SR-138 as a detour route across the Antelope Valley to I-15.

After the earthquake and before the opening of the Old Road detour, truck traffic on I-5 had decreased by approximately 30 percent of the pre-earthquake levels. The establishment of the Old Road detour at the end of January provided two mixed flow lanes in each direction, (where there had been four lanes per direction prior to the earthquake on I-5 freeway). By late February, truck volumes on the I-5 detour route returned to their pre-earthquake levels.

SR-14 Truck Travel

Truck travel on SR-14 was not as significant as on I-5. While the trucks traveling on I-5 north of San Fernando Valley were making primarily long-distance (interregional or interstate) trips, this was not the case on SR-14. Trucks could travel on I-5 through southern California, as well as north through California and on to Canada or could connect to other east-west interstate routes. SR-14, on the other hand, provides a roadway connection only between the Antelope Valley and the San Fernando Valley.

Post-earthquake truck volume on SR-14 showed a similar pattern to that on I-5. By late February, volumes had largely returned to pre-earthquake levels. Data collected indicated that trucks traveling on SR-14 mixed-flow lanes during the peak travel periods in February and March represented between 2 percent and 8 percent of all vehicles.

ALTERNATE MODES OF TRANSPORTATION

Transit

Post-quake traffic capacity was significantly reduced (due to damaged structures) on I-5 and SR-14. This reduced capacity resulted in longer-than-usual delays for persons traveling on those freeways and their detour routes. Consequently, many persons sought other modes of travel (e.g., carpooling, buses transit, and Metrolink commuter trains).

The following transit operators in Southern California modified their services and expanded their people-carrying capacities to respond to changes in demand in the I-5 and SR-14 corridors: Los Angeles County Transportation Authority (LACMTA), the City of Los Angeles Department of Transportation (LADOT), the Southern California Regional Rail Authority (SCRRA), the Antelope Valley Transit

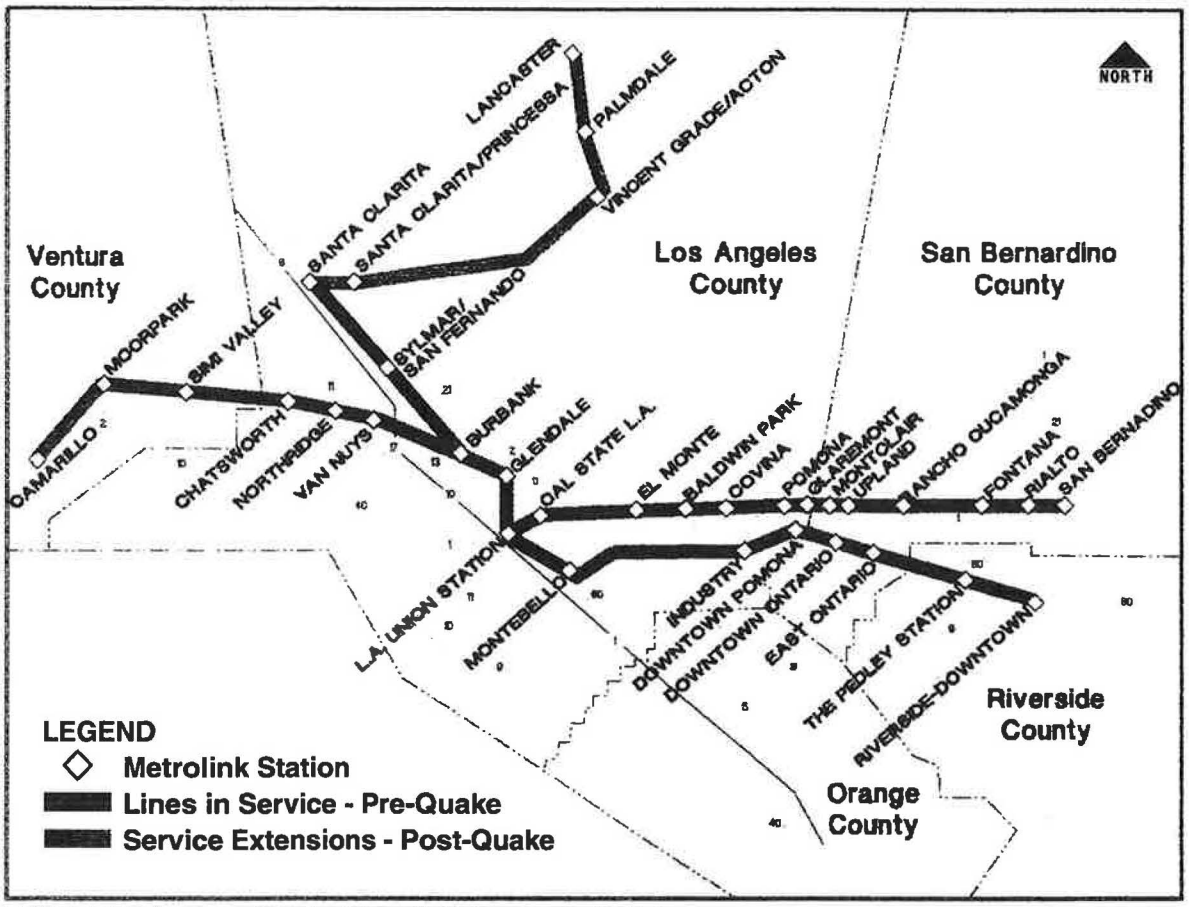


FIGURE 3 Post-earthquake Metrolink Commuter Rail System.

Authority (AVTA), the Santa Clarita Transit (SCT), and the San Fernando Valley Transit (SVT).

There were some service interruptions on and after the day of the earthquake. However, services were restored by the transit operators within a few days.

Service modification for the Metrolink Commuter Rail consisted of implementing new trains, extending the line to Palmdale and Lancaster, and adding four new stations north of Santa Clarita, (see Figure 3). Some bus ridership shifted to Metrolink trains after the extension of the Santa Clarita line.

Metrolink

According to the Southern California Regional Rail Authority (SCRRA), ridership on Metrolink's Santa Clarita line, which averaged 1,000 boardings per day before the earthquake, reached a high of 22,000 riders on January 25, 1994. Based on ridership information reported weekly (last reported on July 5), the Santa Clarita Metrolink ridership went down to about 3,600 passengers (which included some riderships from the new extension to Palmdale and Lancaster, see Figure 3); while the Ventura County trains carried approximately 2,500 boardings on July 5, 1994.

In order to begin operating the new Orange County service that was inaugurated on March 28, Metrolink borrowed cars and locomotives from the GO Transit System of Toronto, Canada. Twelve of those double-decker cars and five locomotives were put in service late in March on the Santa Clarita line.

Systemwide ridership on Metrolink, which was averaging about 9,500 boardings per day before the earthquake, reached a high of 31,280 boardings on January 25, 1994. Average daily ridership on the entire Metrolink system went down to 16,600 boardings per day for the last week of June 1994.

SURVEYS

Household

Home telephone interviews were conducted in May, and again in October 1994. There were two main areas targeted for the surveys; the Santa Clarita area (I-5), and the Palmdale/ Lancaster area (SR-14). The survey sample for each of the areas was 300. Approximately 300 respondents were using the I-5 and SR-14 prior to the earthquake, and were affected by the established detour routes. The survey results indicated the only significant travel mode shift was to Metrolink. The most significant finding from the first survey was that about 13 percent of the work trips and 28 percent of the non-work trips made on I-5 were discontinued due to the quake. The corresponding figures for the SR-14 were 9 percent and 10 percent, respectively.

These figures were significantly lower during the second survey. Namely, 4 percent of the work trips and 12 percent of the non-work trips made on I-5 were discontinued due to the quake. The corresponding numbers for the SR-14 were 5 percent and 13 percent, respectively.

The surveys also revealed that the majority of the trips were work trips which generally took place in the morning. During the time that I-5 was closed, more respondents started their trips between 4:00 a.m. and 6:00 a.m., while fewer made trips between 6:00 a.m. and 7:00 a.m.

I-5 Home-Interview Survey

The May survey results indicated that 68 percent (75 percent for the October survey) of those responded were making work related trips, while the rest were non-work related. The number for persons driving alone before the earthquake went down by 2 percent after the earthquake. The two, the three, and the four-and-more persons occupancy did not change. One percent reported using transit buses before and after the quake. One percent reported using the Metrolink prior to the earthquake, while 3 percent reported riding the trains post-earthquake.

The average duration of trips increased substantially after the earthquake. The post-quake work trip duration was 74 minutes, 26 minutes longer than that of pre-quake. The increase in non-work trip time was greater than that of work trips. The post-quake non-work trip time was 81 minutes, 32 minutes longer than pre-quake level.

Seventeen percent of the respondents (during the May survey) eliminated their trips (work and non-work trips) due to the earthquake, while 4 percent eliminated their trips for other reasons. These figures dropped to 6 percent and 2 percent during the second survey. Figure 4 shows the breakdown of the survey result for I-5.

Of the 232 respondents that continued their trips after the earthquake, 155 (67 percent) changed their trip start time, and started their trip 44 minutes (average) earlier.

SR-14 Home-Interview Survey

The May survey result indicated that 77 percent (79 percent for the October survey) of those responded were making work related trips, while the rest were non-work related. The number for those driving alone decreased by 2 percent, while the two and the three vehicle occupancy increased by 1 percent. The four-and-more vehicle occupancy did not change. Two percent of respondents rode the transit buses before and after the earthquake. The survey showed that no one used the Metrolink trains prior to the earthquake, while 2 percent reported riding the trains post-earthquake.

Ten percent of those surveyed in May eliminated their trips due to the earthquake, while 4 percent eliminated their trips due to other reasons. These figures dropped to 7 percent and 3 percent during the October survey. Figure 4 shows the breakdown of the survey results for SR-14.

CONCLUSIONS

Although the Northridge earthquake caused considerable damage to the Southern California Freeway System, and cataclysmic travel conditions were widely anticipated, with the exception of the first few days after the earthquake, excessive delays were not experienced and the system operated throughout the reconstruction period.

The Old Road detour for I-5 and the HOV and the mixed-flow detours on the SR-14 truck bypass lanes provided approximately 60 percent of the I-5 and SR-14 pre-quake capacity. These detours were efficiently designed, established in record time, and were well advertised by Caltrans and other local agencies.

Shortly after the earthquake, Caltrans initiated emergency measures to suspend normal contacting procedures. This allowed Caltrans to bid, award, approve and execute contracts the same day. In order to ensure the continuing and expeditious traffic data collection, and to prepare and publish various reports, Caltrans brought on board Barton-Aschman and Associates, Inc.

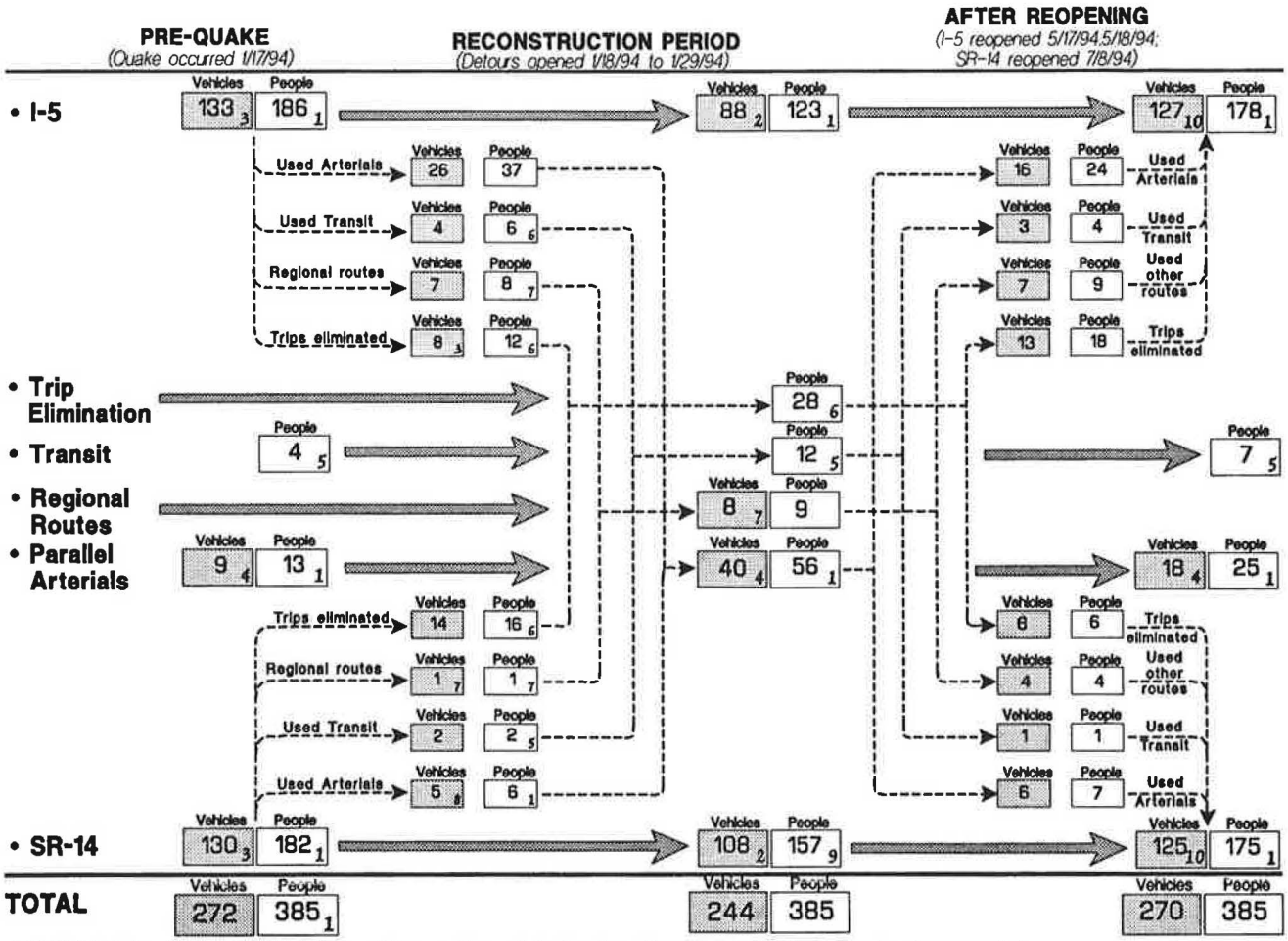


FIGURE 4a I-5 and SR-14 corridors: Travel behavior flowchart (daily trips in thousands).

The expansion of Metrolink service was well received by the local community; especially, the period of time immediately following the earthquake. The fast reconstruction of the mainline I-5 and the main connectors at the I-5/SR-14 interchange resulted in prompt return back to pre-quake travel patterns for the single drivers who had shifted to Metrolink.

The majority of the travelers were pleased with the implementation of the detours in the I-5 and SR-14 corridors.

Findings

Because few alternate detour routes were available in the damaged area of I-5, SR-14 and their interchange (compared to other damaged freeways), Metrolink ridership increased significantly.

A considerable number of people using the established detours shifted their trip hours by starting earlier in the morning.

Some trips (mostly non-work trips) were eliminated due to the quake.

Need for Future Papers

There are different types of surveys, which fall outside the scope of this paper, that could be studied. One suggested topic would be to capture the effects of the Northridge earthquake on retail businesses.

Sources of Information for Travel Behavior Trends in the I-5 and SR-14 Corridors

Footnotes

1. Daily average vehicle occupancy for all trip purposes combined is 1.4 persons per vehicle for Los Angeles County based on the *1991 Regional Home Interview Survey*, Southern California Association of Governments.
2. Average weekday vehicle counts for I-5 and SR-14 detours from Caltrans and Wiltec field counts.
3. Source: Derived from the 1993 Traffic Volumes Count Book, Caltrans; for the I-5 between Calgrove Boulevard and the junction with SR-14. For the SR-14, between SR-126/San Fernando Road and the junction with I-5.
4. Pre-quake arterial counts from LADOT, Traffic Surveys. Post-quake data from Caltrans District 07.
5. Pre-quake, post-quake, and recovery transit patronage from Transit Operators: Los Angeles County Metropolitan Transportation Authority, Southern California Regional Rail Authority, City of Los Angeles (LADOT), Antelope Valley Transit Authority, and Santa Clarita Transit.
6. Source: Based on the *Home Interview Surveys for the I-5 and SR-14 Corridors*. For the I-5, approximately 7 percent of pre-quake trips were not made through the damaged portion of I-5 due to trip elimination or changes in trip origins or destinations. For the SR-14, approximately 9 percent of pre-quake trips were not made through the damaged I-5/SR-14 interchange after the earthquake. Approximately 3 percent of all I-5 and SR-14 trips shifted to transit.
7. A combination of approximately 3,000 vehicles that formerly transitioned between I-5 and SR-14 using interchange ramps before the earthquake and interregional trips such as truck traffic utilizing other regional routes to enter the Los Angeles Basin. Source: 1994 Truck Intercept Survey and Caltrans' ramp count data.
8. Assumes that the growth in arterial volumes after the earthquake is split between trips attracted from I-5 and SR-14. In addition, some shift of trips from I-5 to SR-14 occurred including carpools from Santa Clarita being attracted to the SR-14 carpool lanes.
9. Based on field observations, the SR-14 mixed-flow and HOV detours had a composite vehicle occupancy of 1.45 persons per vehicle during March 1994.
10. Based on post-recovery traffic counts from Caltrans for August and September 1994.

FIGURE 4b Sources of information for travel behavior trends in the I-5 and SR-14 corridors.

THE EFFORTS AND EFFECTS OF FREEWAY SERVICE PATROL IN THE 1994 NORTHRIDGE EARTHQUAKE RECOVERY

Chao Wei, Peter Hsu, and Stephen K. Leung, Caltrans

ABSTRACT

Since its inception in July 1991, the Los Angeles County Metro Freeway Service Patrol (FSP) with its 144 roving tow trucks has proved to be a valuable traffic management tool in reducing motorists' delay by early detection and clearance of minor incidents. During the recovery period after the January 17, 1994 Northridge earthquake, the FSP again made major contributions to relieve the non-recurrent congestion in Los Angeles.

The Northridge earthquake caused significant damages to some of the region's freeways in Los Angeles County, including the heavily traveled Santa Monica Freeway (I-10) and the Golden State Freeway (I-5)—the main corridor connecting southern and northern California. Miles of traffic backup and hours of traffic delay were experienced by the motorists. This is compounded by the post-earthquake restriping of freeways and detours to maximize the roadways capacity leaving little or no shoulder for disabled vehicles. Any incidents, however minor, could have magnified the already congested traffic delay.

This paper describes the efforts of the FSP in deploying the tow trucks to the earthquake-affected freeways and local detour areas in assisting the motorists during the earthquake recovery. The strategies of the deployment, the operations of the roving tow truck and the management are discussed. In addition, statistics of the post-earthquake assists are presented to show the effects of the FSP in the detection and response to the incidents in the earthquake-affected areas. Comparisons of the pre-earthquake and post-earthquake and after-reopening assists are performed to characterize the earthquake detour areas incidents. Conclusions of the efforts and effects are also presented.

This paper is useful to the incident and traffic management project managers and administrators.
Keywords: Freeway Service Patrol, Incident Management, Northridge Earthquake.

BACKGROUND

The January 17, 1994 Northridge earthquake caused many damages to the regional freeways in Los Angeles County. A 4-mile section of Santa Monica Freeway (Interstate 10), the world's busiest freeway, was closed after the earthquake due to the collapse of two bridges. An 8 mile section of the Golden State Freeway (Interstate 5), the main corridor connecting southern and northern California, was also closed due to the collapse of the Galvin Canyon bridge and the interchange of I-5 and State Route (SR) 14.

California Department of Transportation (Caltrans), with cooperation from other governmental agencies, quickly provided freeways, highways, and local surface streets detours for these closures. However, the closure of freeways had a significant effect on the commute traffic. Miles of traffic backup resulted and substantial traffic delay was experienced by the motorists in the early stage of earthquake recovery, especially when most of the detour roadways were restriped to maximize capacity leaving little or no shoulder for the disabled vehicles. Any incidents, however minor, could have magnified the already congested traffic and resulted in extended traffic delay to the motorists. These incidents, if not removed quickly, could have also resulted in more incidents—secondary accidents. Early detection and timely clearance of incidents have a significant effect on the delay reduction as well as accident reduction on the earthquake detour routes.

Since its inception in July 1991, the Los Angeles County Metro Freeway Service Patrol (FSP) with its 144 roving tow trucks has proved to be a valuable traffic management tool in reducing motorists' delay by early detection and clearance of minor incidents. During the recovery period after the January 17, 1994 earthquake, FSP again made major contributions to relieve the non-recurrent congestion in earthquake detour areas.

This paper describes the efforts of the FSP during the Northridge earthquake recovery by providing roving tow trucks to the earthquake-affected freeways, highways and local streets detour areas to assist stranded motorists and provide tow service to the disabled vehicles. The strategies of the earthquake deployment, the operations of the roving tow truck and the management are discussed. In addition, the statistics of the post-earthquake incidents and their characteristics from January to May, 1994 are presented for the major damaged freeway detour areas (I-10, I-5, SR-14 and SR-118) to show the effects of the FSP during the Northridge earthquake recovery. Comparisons and analysis of incident characteristics for the pre- and post-earthquake and after-reopening by the end of May 1994

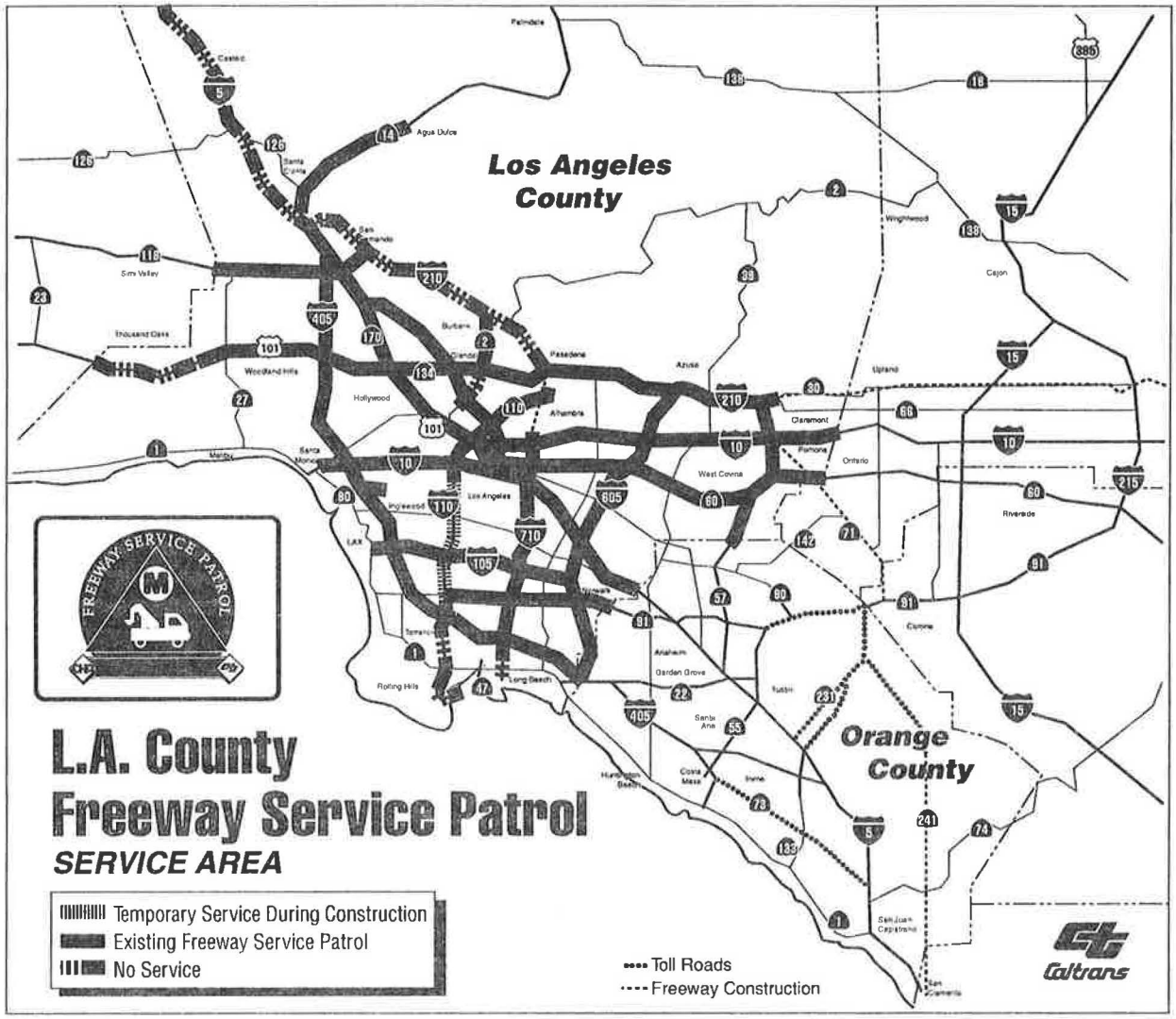


FIGURE 1 Freeway service patrol area map.

are performed. Conclusions of the efforts and effects are also presented.

THE LOS ANGELES COUNTY METRO FREEWAY SERVICE PATROL

The FSP was initiated in July 1991, the first such program in California. It is a joint venture of Caltrans, California Highway Patrol (CHP), and Los Angeles County Metropolitan Transportation Authority (MTA). The FSP program is intended to reduce the non-recurrent congestion on freeways during the peak commute hours by quickly removing the disabled vehicles from freeways, or providing quick fixing items, such as refilling a gallon of gasoline, changing a flat tire, repairing a leaking hose and recharging a dead battery.

Before the January 17, 1994 Northridge earthquake, the FSP had 144 tow trucks patrolling 40 beats (a beat is sections of freeways) covering 381.3 centerline miles of freeways in Los Angeles County as shown in Figure 1. More than 550,000 incidents had been assisted by the FSP with an average annual assist of 220,000. The 144 tow trucks are from 20 private contractors, which can tow the vehicles with a gross weight up to 6,000 pounds. The FSP program has been very successful since its inception. More than 90 percent of returned survey letters rated the service as excellent and commended the program as a wise expenditure of the tax-payers' dollars. The 93/94 fiscal year budget is $24 million. The

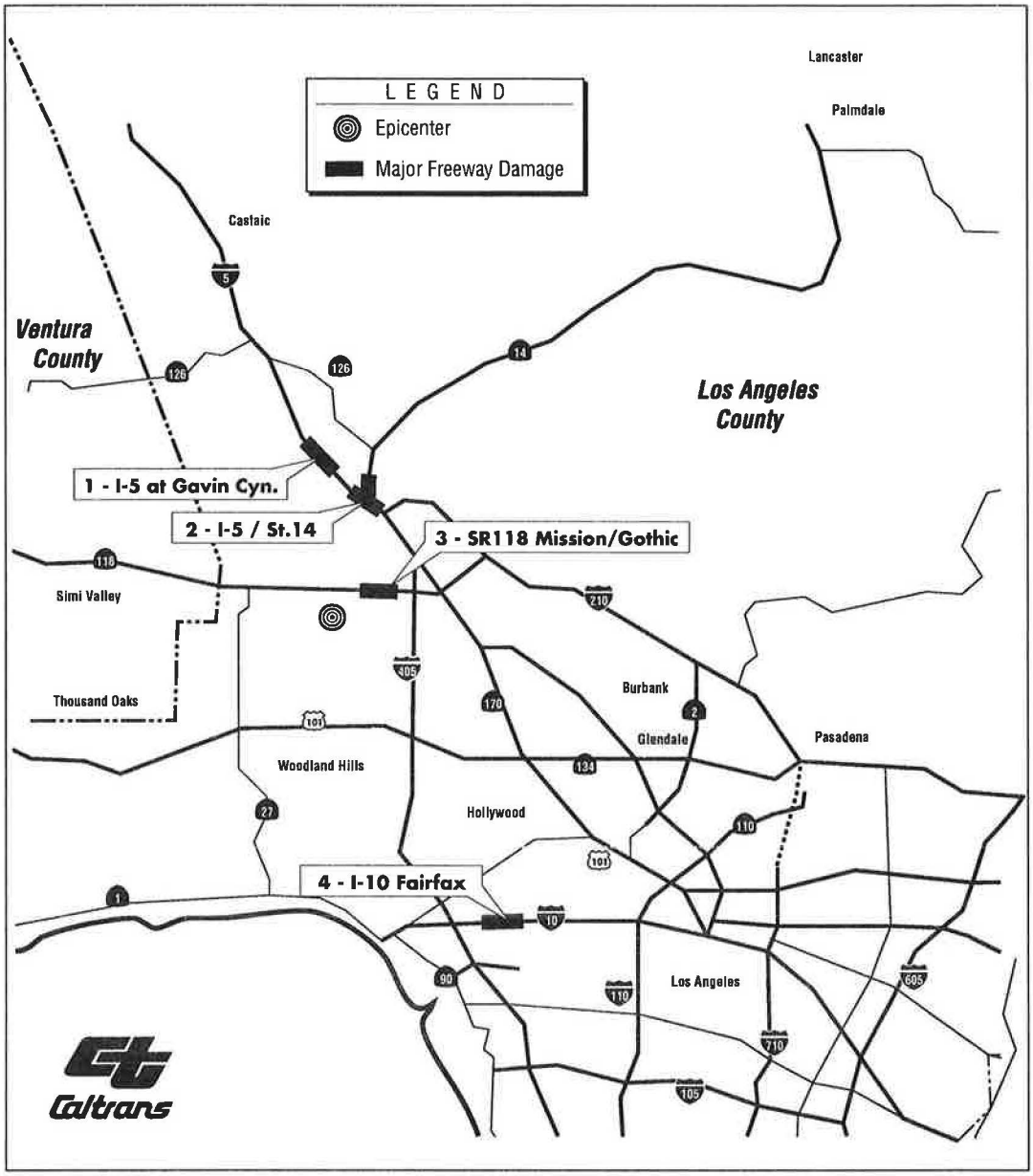


FIGURE 2 The Northridge Earthquake affected freeways and roadways.

program is the largest one in the nation in terms of the number of tow trucks according to a survey by *The Urban Transportation Monitor* (Ref: This Week's Survey Results: Freeway Service Patrols. *The Urban Transportation Monitor*, Vol. 6, Numbers 16 and 17, September, 1992).

THE DAMAGED FREEWAYS BY THE NORTHRIDGE EARTHQUAKE

Figure 2 shows the locations of the major freeways which were damaged during the January 17, 1994 Northridge earthquake. They included I-5 (the Golden

TABLE 1 LIST OF NEW BEATS IN THE EARTHQUAKE DEPLOYMENT

BEAT	FWY	LIMITS	CENTERLINE MILES	# OF TRUCK		AM SHIFT	PM SHIFT
				HEAVY DUTY	REGULAR		
41	5/14	Roxford St. to San Fernando Rd.	4.5	-------	4	5:00 AM to 9:30 AM	2:30 PM to 7:30 PM
42	5	Lyons Ave. to Roxford St.	8.1	1	3	5:00 AM to 8:00 PM,	Monday-Friday
				1	2	8:00 AM to 8:00 PM,	Saturday
				1	2	10:00 AM to 8:00 PM,	Sunday

TABLE 2 LIST OF EXISTING BEATS WITH EARTHQUAKE EXTENDED SERVICES

BEAT	FWY	LIMITS	CENTERLINE MILES	# OF TRUCKS	AM SHIFT	PM SHIFT
7	101	Reseda Boulevard to Route 101/134 Interchange	9.6	5		
				(4)	(6:00 AM to 10:00 AM)	(3:00 PM to 7:00 PM)
10	405	Devonshire St. to Mulhulland Dr.	9.2	4	6:00 AM to 11:00 AM	3:00 PM to 7:30 PM
				(3)	(6:00 AM to 10:00 AM)	(3:00 PM to 7:00 PM)
17	10	Bundy Dr. to Vermont Ave.	9.3	5	6:00 AM to 11:00 AM	2:30 PM to 7:30 PM
				(4)	(6:30 AM to 10:00 AM)	(2:30 PM to 7:00 PM)
33	118	Rocky Peak Road to Route 210 at Maclay St.	16.8			3:00 PM to 7:30 PM
				(4)	(6:00 AM to 9:00 AM)	(3:30 PM to 6:30 PM)
34	5	Roxford St. to Hollywood Way	10.3	5	5:30 AM to 10:00 AM	3:00 PM to 7:30 PM
				(4)	(5:30 AM to 9:00 AM)	(3:00 PM to 7:00 PM)

: Shaded areas are either trucks or hours modified to suit the needs of FSP extended service

( ) : Original trucks and shift hours before Northridge Earthquake

---- : No Deployment

State Freeway), I-10 (the Santa Monica Freeway), SR-14 (the Antelope Valley Freeway), and SR-118 (the Simi Valley Freeway). Three of the four damaged freeways are located in the north-western portion of Los Angeles County, about 20 miles away from Downtown Los Angeles. The Santa Monica freeway is west of Downtown Los Angeles.

The closed sections on I-5 and SR-14 are in mountainous terrains. There are few nearby alternate parallel arterial streets. Special detour plans for the closed sections of I-5 and SR-14 were implemented by Caltrans and other agencies to use the local streets, highways and undamaged freeways as detour routes. Traffic normally using the closed sections of the urbanized I-10 and SR-118 can use the parallel arterial streets as alternative.

The closed section of I-5 is a 4-lane facility in each direction with pre-earthquake daily traffic volume of about 136,000. I-10 and SR-118 are also a 4-lane facility in each direction with pre-earthquake daily traffic volume of 257,000 and 123,000, respectively. The damaged sections of I-5/SR-14 interchange are a two lane connector from the south-bound (S/B) I-5 to north-bound (N/B) SR-14 and the three lane connector from S/B SR-14 to S/B I-5.

THE FSP EARTHQUAKE DEPLOYMENT

Strategies

The FSP management realized the importance of early incident detection and clearance and the effectiveness of the FSP and decided to provide roving tow truck service to the earthquake affected areas as part of the transportation management strategies implemented in the Northridge Earthquake Traffic Management Plan. Thirteen additional FSP roving tow trucks from the existing FSP contractors were deployed to the earthquake affected freeways, highways, and Local streets detour routes to reduce the incident-related congestion. The deployment included adding extra tow trucks to the existing covered FSP areas and the pre-earthquake un-covered but earthquake-affected areas (I-5). The regular peak commute hour service schedules were extended and additional service hours were also

provided based on the traffic conditions and construction activities.

Deployment and Service Hours

Two new beats were initiated for the I-5 and SR-14 detour areas. They are Beat 41 and Beat 42. Table 1 shows the characteristics of these two beats. Beat 41 covered 4.5 centerline miles from Roxford Street on I-5 to San Fernando Road on SR-14. Four FSP tow trucks patrolled this beat from 5:00 to 9:30 a.m. in the morning shift, and from 2:30 to 7:30 p.m. in the afternoon shift, Monday to Friday. Beat 42 covered 8.1 centerline miles on I-5 from Roxford Street to Lyons Avenue. Three FSP tow trucks patrolled Beat 42 from 5:00 a.m. to 8:00 p.m., Monday to Friday; and two FSP tow trucks patrolled from 8:00 a.m. to 8:00 p.m. on Saturday and from 10:00 a.m. to 8:00 p.m. on Sunday.

Added number of tow trucks and extended service hours on other existing beats are shown in Table 2. One FSP tow truck was added to Beat 17 which includes the closed section of Santa Monica Freeway (I-10). The original patrolling route was modified to cover the traffic detour areas of local arterial streets. The service hours were also extended to cover from 6:00 to 11:00 a.m. in the morning shift and from 2:30 to 7:30 p.m. in the afternoon shift. Beat 33, which includes the closed section of Simi Valley Freeway (SR-118), extended its service hours to cover from 3:00 to 7:30 p.m. in the afternoon shift - half hour early for the starting time and one hour late for the ending time. The original patrolling routes were also modified to cover the detour traffic on the parallel arterial streets. One FSP tow truck was added to Beat 34 which is from Hollywood Way to Roxford Street on I-5. The service hours were extended from 5:30 to 10:00 a.m. and from 3:00 to 7:30 p.m. One additional FSP tow truck was added to each of Beats 7 and 10 together with extended service hours.

Heavy Duty Tow Truck

Before the earthquake, all the FSP tow trucks would only tow a vehicle with a gross weight of up to 6,000 lbs. When the disabled vehicle is more than 6,000 lbs, a rotational tow truck is called out to tow the disabled vehicle.

During the earthquake deployment, a new type of roving tow truck was deployed to Beat 42 on I-5, as listed in Table 1. This new type of roving tow truck is the heavy duty tow truck with the ability to tow up to 80,000 lbs. The purpose is to reduce the response time for calling a rotational tow truck in case of disabled heavy trucks. This is because of the high percentage of trucks using I-5, usually about 15 percent of traffic volume. The percentage of the disabled vehicles that are three or more axles (Big Rig) before the earthquake is more than 5 percent. The deployed heavy duty tow truck gave FSP the additional capability to clear almost all the disabled vehicles with improved response time. During the course of three and half months, the heavy duty tow truck had assisted in 641 incidents.

Construction Activities

Many Caltrans earthquake reconstruction projects were underway to reopen the damaged freeways as soon as possible. These projects involved closing some lanes and portions of the freeway, which could result in traffic congestion when traffic demand exceeds the reduced capacity. In order to prevent further potential congestion and delay, FSP tow trucks were deployed to these areas during the construction period. Two or more tow trucks were deployed on I-5 depending on the day, the time of constructions and the traffic conditions. The service hours were also varied to accommodate the construction activities. Hours were generally from 8:00 p.m. to 5:00 a.m.

Contract Award and Cost

All the FSP tow trucks for the earthquake deployment were from the existing FSP tow truck contractors. The pre-earthquake FSP tow truck contract requires the contractor to have at least 1 backup tow truck and 2 backup drivers for each beat. Most backup trucks have adequate communication equipments to be operational. The backup drivers were also certified FSP drivers, trained by CHP and Caltrans staff. This enabled the tow truck contractors to provide the service immediately for the earthquake deployment. Twelve different tow truck contractors provided the earthquake tow service. During the earthquake deployment, the contract cost for a regular tow truck was from $34.87 to $50.00 per truck

per hour. The heavy duty tow truck contract cost was from $63.63 to $70.00 per truck per hour.

Operations

The FSP tow trucks were equipped with radios and Mobile Data Terminal (MDT), which allowed FSP tow truck drivers to communicate with the dispatchers at Los Angeles Communication Center (LACC) and Caltrans. Dispatchers can talk to the FSP drivers through the radio system, and the MDT enables the driver to send the information about the incident immediately to the Computer Aided Dispatching System (CAD) and this information becomes a record in the CAD available for evaluation and other uses. For those tow trucks without the radio equipment, cellular phones were provided. This also enables the dispatcher to call the tow truck driver to respond to the incident immediately when the dispatcher receives any requests for help.

The FSP tow trucks patroled both directions of the beats of the freeways and detour routes. They were designed to have a uniform headway between the tow trucks. They could take a 15-minute break for each 4-hour shift, but no two tow trucks could take breaks at the same time or at the same location. When the FSP driver encountered a disabled vehicle, the driver usually spent up to 15 minutes attempting to mobilize the disabled vehicle. This may have included changing a flat tire, adding a gallon of gasoline, providing "jump start", temporarily taping cooling system hose and refilling radiators. Otherwise, the driver was instructed to tow the disabled vehicle off the freeway to a designated drop-off location.

CHP and Caltrans FSP field supervisors jointly supervised the operations of FSP tow trucks in the earthquake detour areas. When an FSP tow truck driver was found in violation of the FSP operational policies, the driver or the contractor could have been subjected to penalty.

Management

Caltrans with CHP and MTA jointly managed the FSP program and monitored the tow trucks operations, and contractors' compliance with the contracts. Two committees, the Policy Committee and the Technical Committee, consisted of members from Caltrans, CHP, and MTA and contractors. The committee members made the policy changes, resolved issues arising in daily operations, and explained the contract related service by holding regular meeting. In addition, each agency had its assigned responsibilities. Caltrans was responsible for the fleet management, program evaluation, and required equipment order and supplies. CHP was responsible for the tow truck dispatching, safety and operational enforcement, complaint investigations, and tow truck inspections. MTA was responsible for the funding, contract administration, meeting coordination and billing. CHP and Caltrans are jointly responsible for the FSP tow truck driver training.

Caltrans fleet managers, with the aid of Automatic Vehicle Locator (AVL) and the MDT information in the CAD, monitored the locations of the trucks, the sign-on, sign-off and break time of the FSP tow truck drivers. Whenever it was needed, the Caltrans fleet managers dispatched the FSP tow truck driver to the incident scene as well. Good communications, careful planning, close coordination, and timely decision making from all three agencies' management contributed to the responsiveness and effectiveness of the earthquake deployment.

THE STATISTICS OF EARTHQUAKE DETOUR ASSISTS

Whenever the FSP tow truck driver made an assist, the driver recorded the assist conditions on a pre-formatted card, namely scantron card. The recorded conditions include the type of incidents (out of gas, flat tire, over-heat, accident, etc.), locations of the incidents (freeway lanes, right or left shoulder, etc.), type of vehicles (automobile, van, Big Rig, etc.), whether tow was needed, how the incident was detected. The cards were then returned to Caltrans for evaluation. The statistics presented in this section are from these returned cards for the post-earthquake assists. The purpose is to show the effects of the FSP assists during the Northridge recovery. Statistics for Beats 17, 33, 34, 41 and 42, which are in the major freeway damaged areas and represent more than 90 percent of assists, are used for this study. For Beat 17, data was collected from after earthquake to the reopening of I-10 on April 12, 1994. For beats 33 and 41, data was collected from after earthquake to the end of May, 1994. For Beats 34 and 42, data was collected from after earthquake to the reopening of I-5 on May 18, 1994.

Figure 3 shows the total monthly and accumulative earthquake assists for Beats 17 (I-10), 33 (SR-118), 34 (I-5), 41 (I-5/SR-14) and 42 (I-5). Beat 42 had the highest number of incidents because of few parallel arterial streets available as alternate routes. Interestingly, Beat 17 (I-10), the most traveled freeway before the earthquake, had the lowest number of

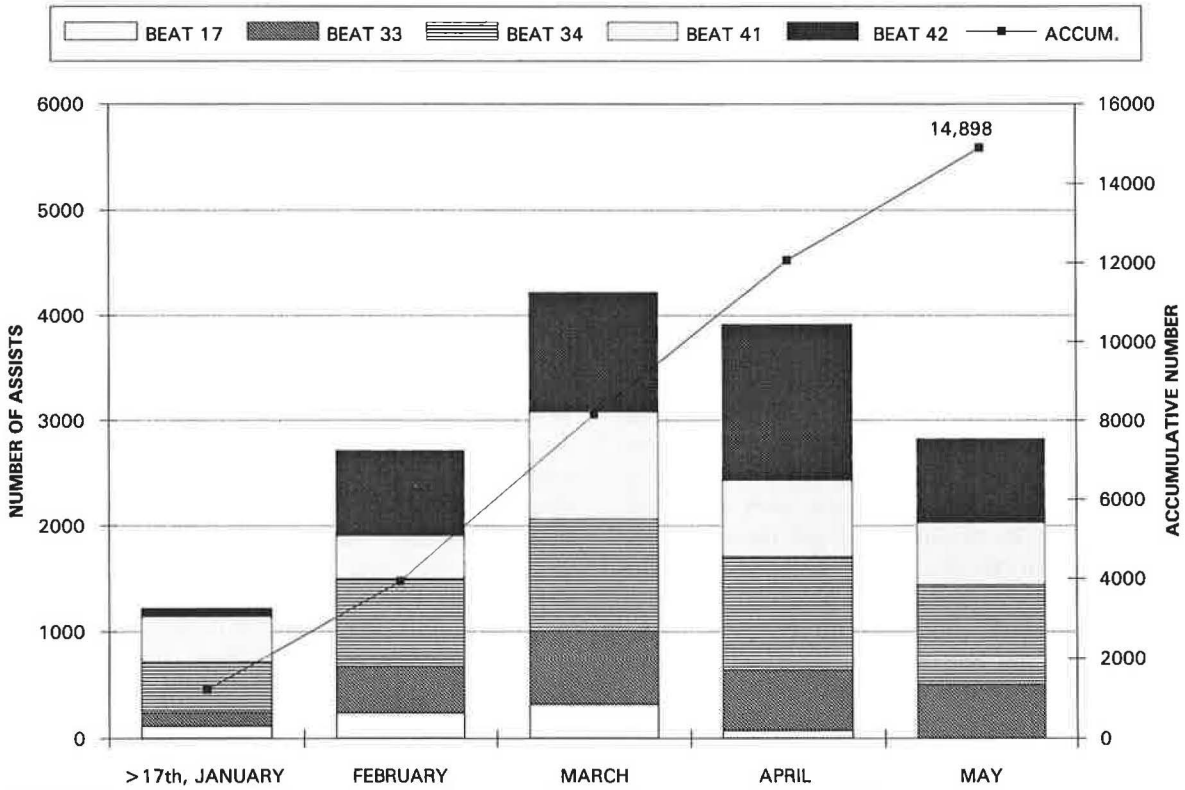


FIGURE 3 Summary of earthquake detour assists from January—May, 1994.

incidents. Due to the urbanized setting, motorists were able to use the arterial streets parallel to the freeway as alternate routes. Similar low assist results were found on Beat 33 (SR-118). The total accumulative assists for these four beats by the end of May, 1994 was 14,898.

Figure 4 (a) shows the percentage of assists for each type of disabled vehicles. Fifty-three percent of assists are automobiles, 14 percent are vans, and 6 percent are Big Rigs—a three or more axles vehicle. Figure 4 (b) shows the percentage of assists for each type of vehicle problems. The mechanical problem led with the highest percentage (23), with accidents at 5 percent, flat tire 13 percent, overheat vehicles 12 percent, and out of gas 8 percent. Figure 4 (c) shows the percentage of assists for each type of locations of disabled vehicles. Twelve percent of assists were located on freeway lanes, and 74 percent on right-shoulders. Figure 4 (d) shows 95 percent of incidents were spotted by FSP drivers, and only 5 percent were dispatched by CHP and Caltrans. In addition, 19 percent of incidents (2830) involved towing, as shown in Figure 4 (e).

COMPARISONS OF PRE- AND POST-EARTHQUAKE ASSISTS

The purpose of the comparisons is to examine the change of the incident characteristics for pre- and post-earthquake. There are two types of detours. One of which is where parallel arterial streets are available, such as Beats 17 (I-10) and 33 (SR-118). The other type of detours is where a few parallel arterial streets are available, such as Beats 34 and 42 (I-5) and Beat 41 (SR-14/I-5). However, Beats 41 and 42 are new and do not have records of pre-earthquake assists, Beats 17 and 34 are selected for the comparisons of the pre- and post-earthquake assists characteristics. A period of two months before and after the earthquake was considered in the comparisons.

Daily Assists

Figure 5 (a) shows the average daily assists for November and December 1993, pre-earthquake

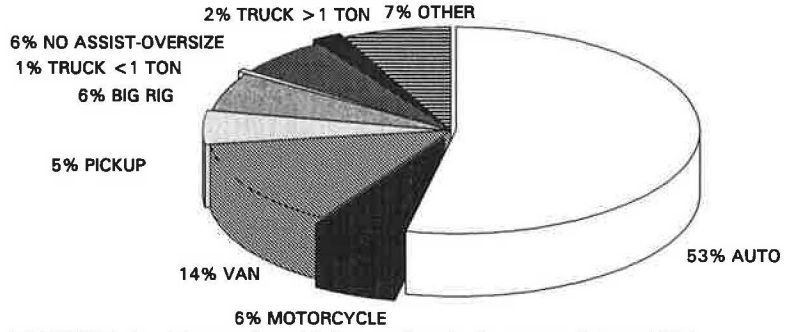


FIGURE 4a Type of vechicles assisted, January—May, 1994.

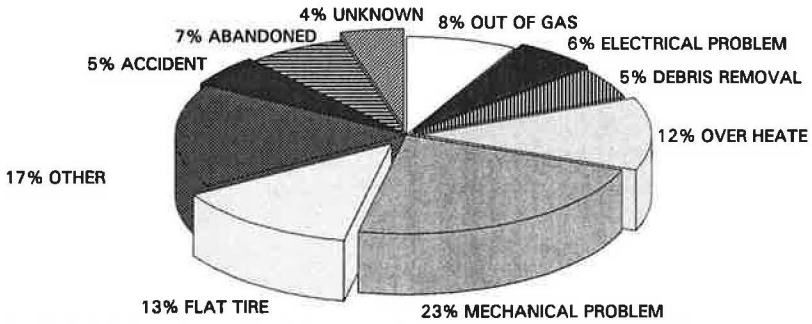


FIGURE 4b Type of vehicle problems, January—May, 1994.

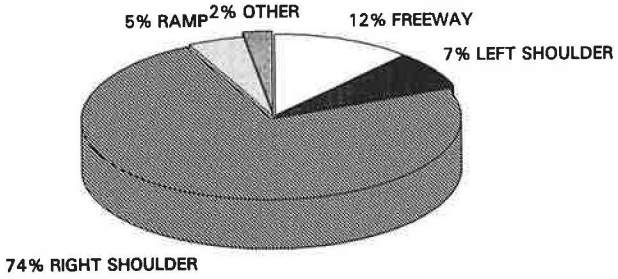


FIGURE 4c Disabled vehicle locations, January—May, 1994.

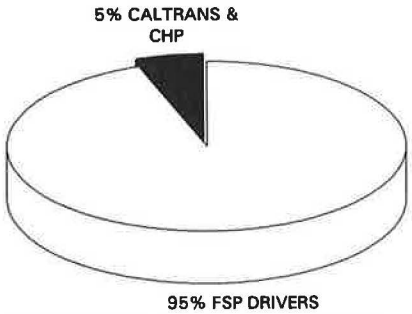


FIGURE 4d Vehicle located by, January—May, 1994.

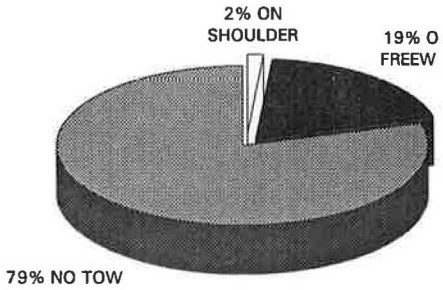


FIGURE 4e Drop locations, January-May, 1994.

January, post-earthquake January 1994, February, and March 1994 for Beats 17 (I-10) and 34 (I-5). After the earthquake, the daily assists for Beat 17 (I-10) are lower than pre-earthquake. This is due to the fact that the motorists used the available parallel arterial streets as an alternate route. However, Beat 34 (I-5) shows an increase of average daily assists after the earthquake, probably because the motorists had fewer parallel streets as by-pass alternatives to the closed freeway section. Furthermore, Beat 34 (I-5) is south of the I-5 detour and congestion often backed up from this point which resulted in more incidents.

Incident Detection

FSP is an effective traffic management tool in early detection of incidents. This tool is very valuable during the earthquake recovery when the detours directed traffic away from freeways and the surveillance system was not available yet. As shown in Figure 5 (b), the percentage of incidents spotted by FSP drivers increases just after the earthquake for Beat 17 (I-10). The percentage for Beat 34 (I-5) also increases slightly in February and March of 1994. Overall, for pre- and post-earthquake, more than 90 percent of incidents were spotted by FSP drivers.

Type of Vehicle Problems

Accidents due to traffic congestion and reduction in capacity are always our concerns in the sense that these accidents may prolong the delay and magnify the traffic backup. Figure 5 (c) shows the percentage of incidents that are involved in accident for the pre- and post-earthquake. For Beat 17 (I-10), the accident percentage increases immediately after the earthquake. For Beat 34 (I-5), the accident percentage increases only in February by 50 percent comparing with November and December, 1993, but drops in March, 1994.

Figure 5 (d) shows the percentage of incidents for another type of vehicle problem: overheat, for pre- and post-earthquake. Long traffic delay often results in overheating problem for the vehicle. This is quite true for Beat 34 (I-5), which is south of and adjacent to the beginning of the detour and was often congested during peak commute hours. However less overheating problems were found for Beat 17 (I-10), which has less traffic volume because many motorists used surface streets as an alternate route.

Type of Disabled Vehicles

Figure 5 (e) shows the percentage of automobile incidents for the pre- and post-earthquake. There is no significant change in automobile incident percentage between pre- and post-earthquake for both Beats 17 (I-10) and 34 (I-5). It seems to suggest that most of the motorists still stay with their own means of commuting after earthquake. Private vehicles are still preferred by Los Angeles commuters.

Figure 5 (f) shows the percentage of Big Rig incidents—a three or more axle vehicle for pre-and post-earthquake. For Beat 17 (I-10), the percentage of Big Rig incidents is zero before the earthquake, but increases to 1 percent in March after the earthquake. For Beat 34 (I-5), the Big Rig percentage increases from 6 percent to 9 percent in February but drops back to 4 percent in March. The increase in February may be resulted from the opening of Old Road detour with 2 lanes in each direction near the end of January. Trucks might then shift to use this Old Road detour and worsened the traffic conditions. After February the traffic volume became more stable.

Locations of Incidents

Figures 5 (g) and (h) show the percentages of incidents located on freeway lanes and on right shoulders, respectively, for pre- and post-earthquake. Both Beats 17 (I-10) and 34 (I-5) have an increase in the percentage of incidents located on the freeway lanes after the earthquake, especially for Beat 34 (I-5), recording an increase of 50 percent. Consequently, both two beats have a decrease in the percentage of incidents located on the right shoulders after the earthquake. These changes may be the results of detours and restriping of roadways to maximize the roadway capacity, therefore eliminating some shoulders.

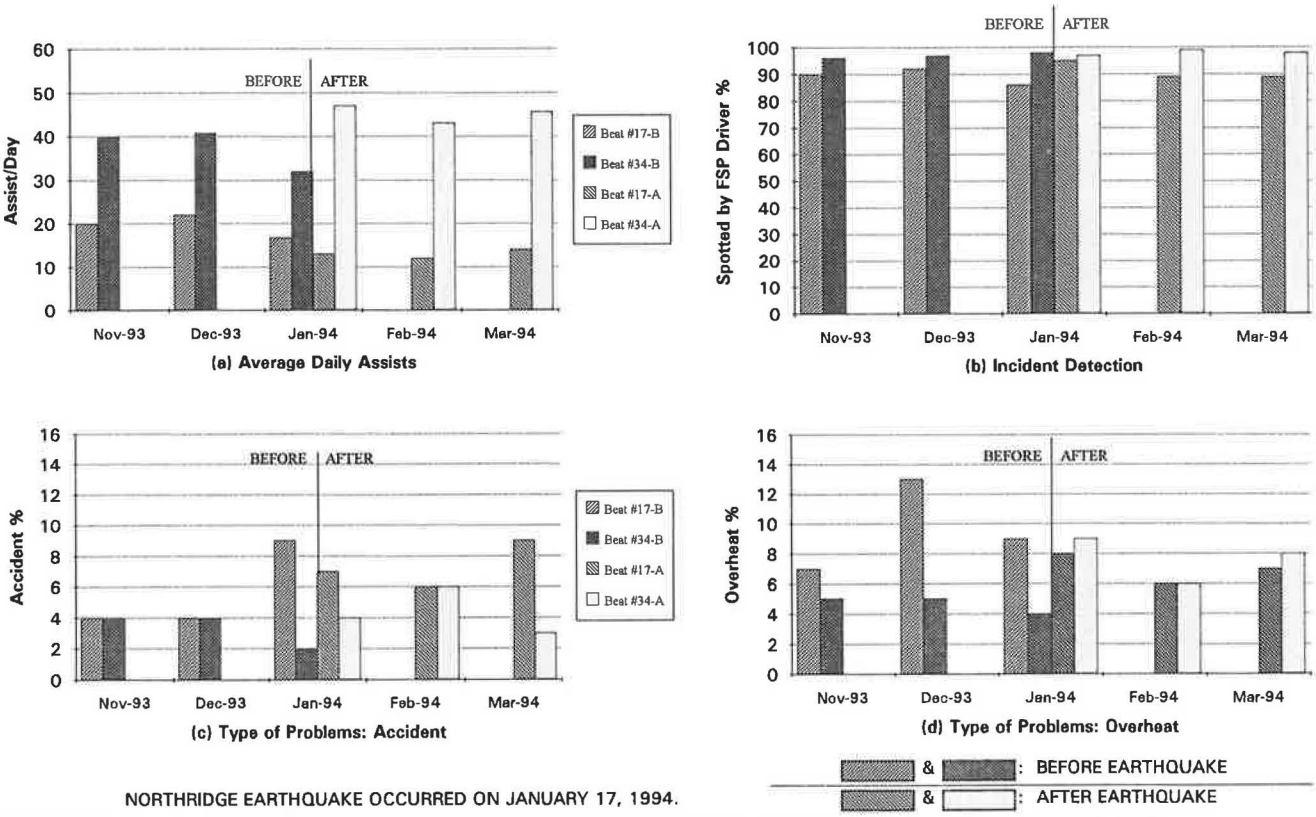


FIGURE 5a—d Comparisons of pre- and post-earthquake assists for Beat 17 (I-10) and Beat 34 (I-5).

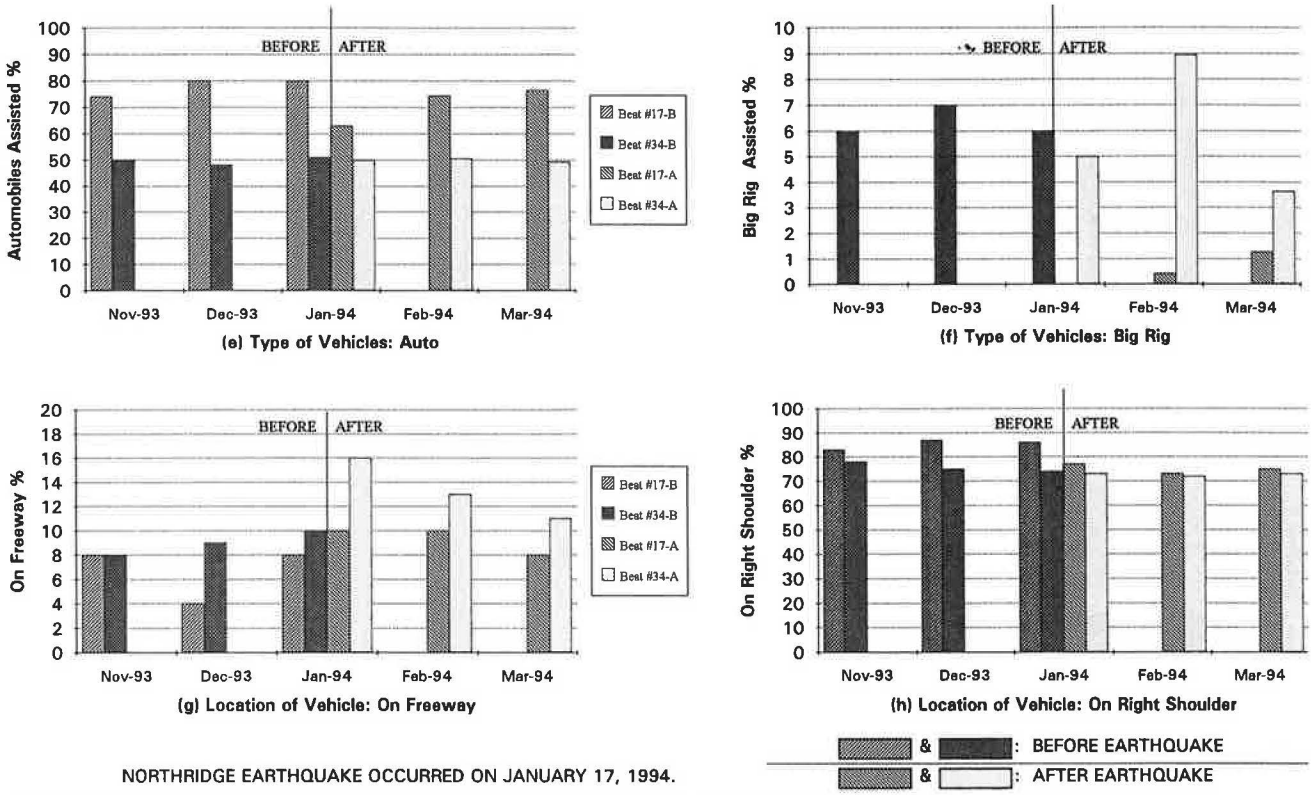
Summary

In summary, after the earthquake, both Beats 17 (I-10) and 34 (I-5) have higher percentages in accidents, Big Rig incidents, and freeway in-lane incidents, but lower incident percentage on right shoulder. For Beat 17 (I-10) with the parallel arterial streets available for the motorists to by-pass the damaged freeway section, the average daily assists and the overheating incident percentage decreased after the earthquake. For Beat 34, the average daily assists and the overheat incident percentage increased after the earthquake. In addition, more than 90 percent of incidents were spotted by FSP drivers.

COMPARISONS OF POST-EARTHQUAKE AND AFTER REOPENING ASSISTS

I-10 (Beat 17) was the first freeway to be reopened on April 12, 1994. I-5 (Beats 34 and 42) was reopened on May 18, 1994. However, the data for June is not available for Beat 34 at the time of this study and thus less than half month data for after reopening are available. Beats 42 was terminated after the reopening of I-5. SR-118 (Beat 33) and interchange of SR-14/I-5 (Beat 42) are still under construction. Therefore, Beat 17 is selected for the study of the effects of freeway reopening on the incident characteristics. Incidents assisted by the FSP in March and May are compared, and in the meantime, pre-earthquake incident characteristics are also compared.

After the reopening of I-10, the daily traffic volume has increased by more than 50 percent (Northridge Earthquake Recovery, Weekly Transportation Report, Numbers 9 and 13, Caltrans District 7, April and May, 1994, *unpublished*). However, the average daily number of incidents after reopening has no significant change comparing March with May, as seen from Figure 6 (a), but is lower than pe-earthquake [Figure 5 (a)]. The percentage of incidents spotted by the FSP drivers decreased after the reopening as seen from Figure 6 (b), probably because the freeway was closely monitored by Caltrans and CHP, and the other effective communi-



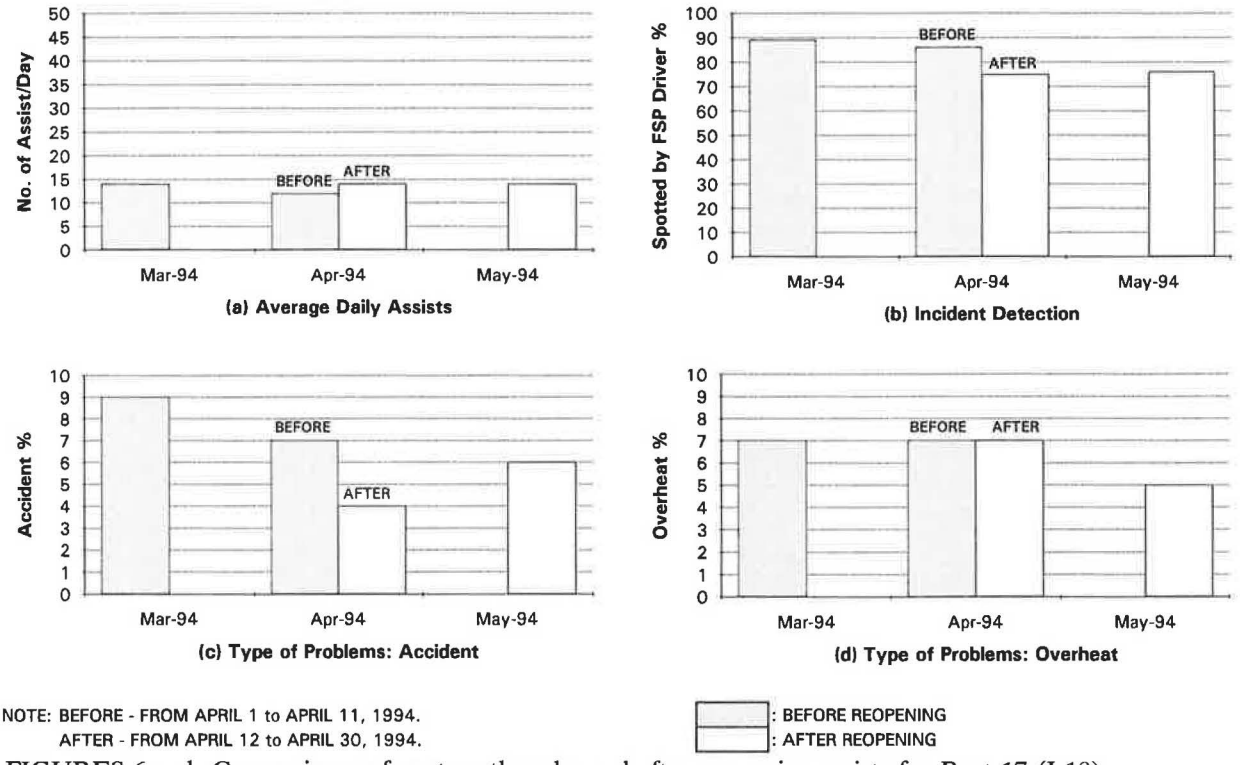
FIGURES 5e—h Comparisons of pre- and post-earthquake assists for Beat 17 (I-10) and Beat 34 (I-5).

cation tools were available for the motorists, such as call boxes. The percentage after reopening is also lower than pre-earthquake [Figure 5 (b)]. The percentage of incidents involved in accident drops by 50 percent in May compared to March, as seen from Figure 6 (c), but is still slightly higher than pre-earthquake [Figure 5 (c)]. Overheating incident percentage decreases in May as seen from Figure 6 (d), which is also lower than pre-earthquake [Figure 5 (d)]. The percentage of automobile incidents is slightly higher in May as shown in Figure 6 (e), but is within the range of pre-earthquake [Figure 5 (e)]. The percentage of Big Rig incidents increases from 1 percent to 2 percent, as shown in Figure 6 (f), which is also higher than pre-earthquake [Figure 5 (f)]. The percentage of incidents located on freeway lanes is the same for March and May as shown in Figure 6 (g), which is also about the same as pre-earthquake [Figure 6 (g)]; however, the percentage of incidents located on right shoulder after reopening increases from 75 percent to 82 percent as shown in Figure 6 (h), which is about the same as pre-earthquake [Figure 5 (h)].

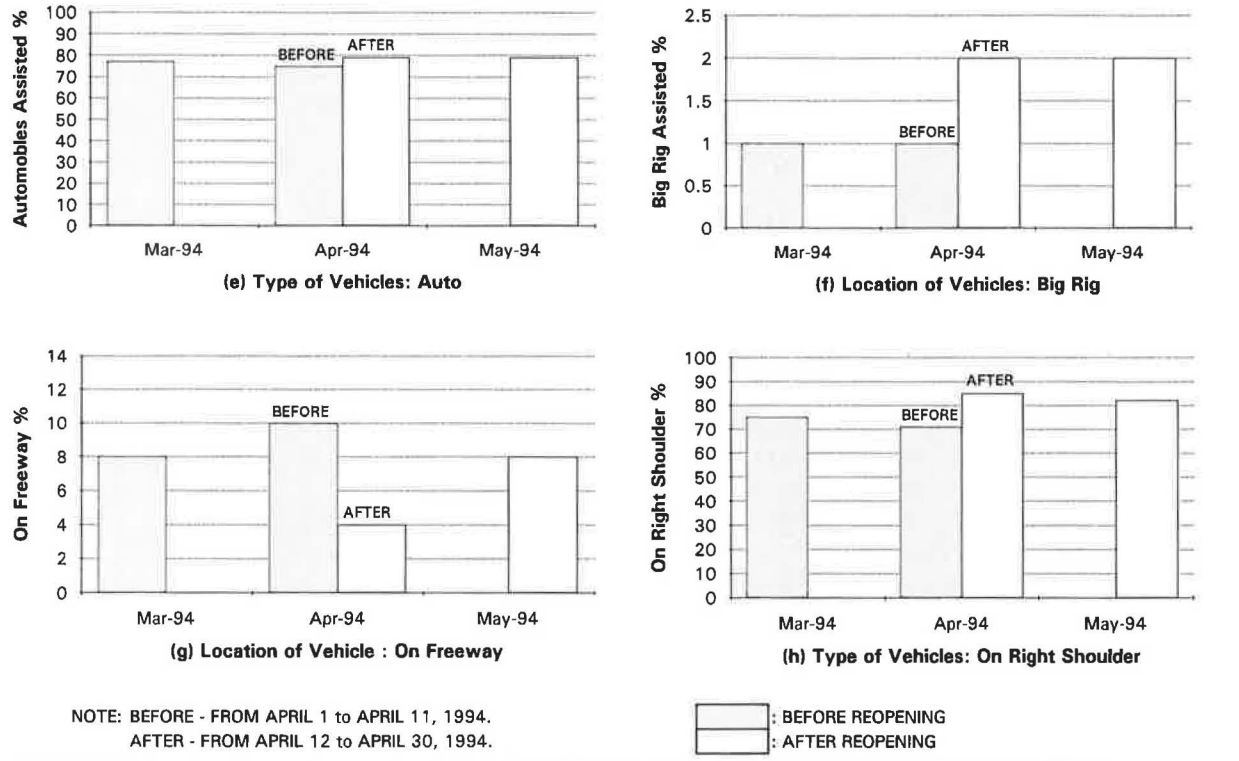
Overall, the comparisons show that the reopening of I-10 has no effect on the average daily number of incidents, although the daily traffic volume has increased by 50 percent, but has reduced the accident percentage. More incidents were found on right shoulders due to the shoulder availability on the freeway. This might have indirectly reduced the accident rate. However, the Big Rig incident percentage has increased. After the reopening, all the incidents characteristics are back to pre-earthquake levels, except the average daily assists and the overheating incident percentage are lower than pre-earthquake.

CONCLUSIONS

The Los Angeles County Metro Freeway Service Patrol (FSP) has responded quickly to the need of assisting motorists after the Northridge earthquake by timely deploying the roving tow trucks to the earthquake affected freeways, highways and local detour streets to reduce the non-recurrent congestion. FSP also deployed a new type of tow truck - heavy duty tow truck - to the I-5 where a high percentage of truck incidents was recorded.



FIGURES 6a—d Comparisons of post-earthquake and after reopening assists for Beat 17 (I-10).



FIGURES 6e—h Comparisons of post-earthquake and after reopening assists for Beat 17 (I-10).

FSP has provided an additional 13 tow trucks (including the heavy duty tow truck) to the earthquake affected areas and covered an additional 12.6 centerline-miles of freeways in addition to the pre-earthquake existing FSP service areas. The FSP service hours for the earthquake affected areas were extended to accommodate the long commute hours for the motorists. Special arrangements to provide tow truck and special service hours were made for the construction activities to reduce the potential of traffic congestion.

During the earthquake recovery period, FSP has detected the incidents earlier with 95 percent of the incidents spotted by the FSP drivers. FSP has assisted in 14,898 incidents for Beats 17, 33, 34, 41 and 42 during the earthquake recovery period from January 18, to the end of May, 1994. FSP also provided tow service to 2830 disabled vehicles (19 percent of assists) for the five beats (17, 33, 34, 41 and 42).

The comparisons of pre- and post-earthquake and reopening incidents show that when there are parallel arterial streets available for motorists, the number of the incidents was lower after the earthquake. This may be due to the fact that the motorists use the arterial streets as alternative routes to avoid potential traffic congestion. But when there are few parallel arterial streets, such as I-5 (Beat 34), the number of incidents and the accident percentage have increased after the earthquake, because the roadway capacity was reduced in the detour areas. In addition, the reopening of the freeway seems to have positive effects in the sense that the percentage of accident incidents was reduced.

The comparisons also reveal that most of the incidents were located on the right shoulder, but the percentage decreased after the earthquake due to the restriping of the roadways to maximize the roadway capacity, but went back to pre-earthquake level after the reopening. In addition, there was an increase of percentage of in-lane incidents after the earthquake. These results provide clear evidence of the need for deploying the roving tow trucks to the earthquake affected areas to quickly clear the incidents in order to reduce the non-recurrent congestion.

In summary, the Los Angeles County Metro Freeway Service Patrol has proved to be an effective traffic management tool in reducing the non-recurrent traffic congestion as well as aiding the motorists during the Northridge earthquake recovery.