REDUCING MOTORIST INCONVENIENCE DUE TO MAINTENANCE OPERATIONS ON HIGH-VOLUME FREEWAYS

C. E. Forbes, J. H. Smith, and W. E. Schaefer, California Division of Highways

In the Los Angeles area about 30 miles are added to the existing 600-mile freeway system each year. While the system grows in size, existing sections grow older; and traffic volumes certainly do not diminish. All of this increases the maintenance work required to keep the system operating, and also increases difficulty of the maintenance task.

Much has been published regarding methods of handling traffic control. In California we are attempting to develop simplified methods that maintenance forces can use to reduce any inconvenience to the motorist. Of course, this is not a new concern to California or to the rest of the country. The increased maintenance work required on our growing freeway system, however, is certainly adding a new dimension to the problem. It is evident that we must step up our efforts to minimize the inconvenience our work creates.

We think of this inconvenience in terms of the delay and frustration accompanying the congestion, which occurs when the maintenance activity reduces capacity below the demand. Lane closures obviously reduce capacity; but an often overlooked feature is the reduction in capacity created by the motorist's interest in the activity itself, called the gawking or gaping effect. Field observation indicates that gawking can reduce freeway capacity by as much as one-third. On a multilane freeway, this factor can be just as important as the occupancy of a traffic lane.

There are several methods for attacking the overall problem. We can eliminate or reduce the need for maintenance in the design of the freeway, minimize the duration or time required for the maintenance operation, schedule the operation to minimize its effect on traffic, or control traffic to minimize the effect of the operation.

DESIGN CONSIDERATIONS

Decisions that determine future maintenance requirements are made routinely during the development of the design of freeways. They range from items such as selection of the type of median barrier to choice of pavement type. Designers have always attempted to include the inconvenience to motorists in this decision process. Few quantitative data are available, however, on the magnitude of the inconvenience or its costs. The increasing maintenance work on high-volume freeways emphasizes the need for better information and better feedback to designers.

DURATION OF OPERATION

More attention is being given to techniques and methods of minimizing the time required to do the maintenance work. AASHO has submitted a problem statement in this

Sponsored by Committee on Maintenance Operations.

area for consideration for inclusion in the National Cooperative Highway Research Program.

SCHEDULING

The other 2 methods of attack on the problem, scheduling operations and controlling traffic, are the subject of this paper. They are simply a part of good work planning. The problem is that time, money, and skills seem to be in as short supply in maintenance as in other phases of highway activity. However, good planning does pay off in minimizing inconvenience, and in some cases it is actually necessary in order to accomplish this work at all.

Proper planning requires that we have a good estimate of both the traffic volumes and the traffic capacity at the work site. Table 1 gives observed rates for some typical operations on Los Angeles freeways. These rates include the gawking effect mentioned earlier. As can be seen, the more interesting the activity is to the motorists, the less the capacity.

The first step in planning the work is to compare the estimated capacity to the demand. Figure 1 shows a curve of the expected demand for a typical freeway section. This curve is used to determine (a) when the work must start and end to avoid congestion; (b) what the delay to motorists will be if congestion cannot be avoided; (c) how many vehicles must be stored; and (d) how many vehicles will be delayed during the lane closure. By knowing the number of vehicles that must be stored, we can make an estimate of the expected length of queue. This will permit better placement of warning devices and provide better information for traffic advisories.

Figure 1 shows an example of a demand-capacity curve for the installation of pavement markers on a section of 8-lane freeway. The operation requires closing 1 lane. Data given in Table 1 indicate that the remaining 3 lanes can be expected to handle 3,600 vph past the work. The heavy line shown in Figure 1 is the cumulative demand plotted from the traffic data shown in the upper left corner. Traffic counts were made on a normal day when no lanes were closed. The slope of the dashed straight lines is the reduced capacity we can expect if we close 1 lane. By moving this slope line up and down with a parallel ruler, we can see how much delay will be incurred by lane closures at different times of the day.

For example, to avoid congestion and delay, work must start after 10:00 a.m. and end at 2:00 p.m. Also, if the work is started at 8:00 a.m., there will be congestion that will last until about 1:00 p.m.; 18,000 vehicles will be delayed. If there are 1.4 people per vehicle, 25,000 people

TABLE 1

CAPACITY RATES FOR SOME TYPICAL OPERATIONS

Type of Operation	Capacity (vph) 1 of 2 Lanes Open	2 of 3 or 4 Lanes Open	3 of 4 Lanes Open
Median barrier or guard-rail repair	1,500	3,200	4,800
Pavement repair, mud-jacking, pavement grooving	1,400	3,000	4,500
Striping, resurfacing, slide removal	1,200	2,600	4,000
Pavement markers	1,100	2,400	3,600
Middle lanes (any reason)	—	2,200	3,400

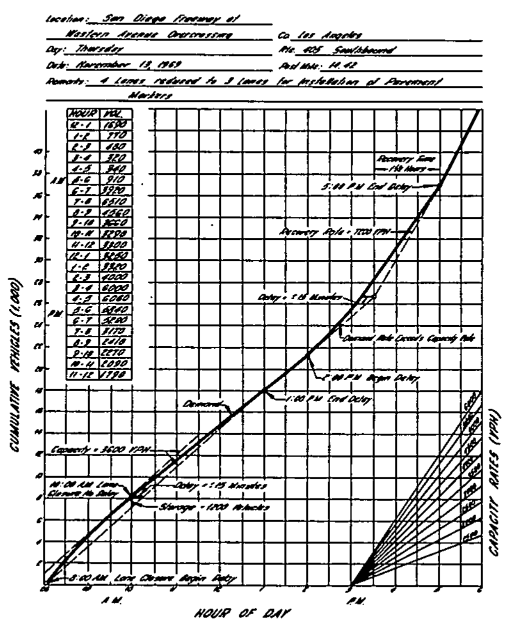


Figure 1. Demand-capacity curve.

will be inconvenienced by the work. If work is started at 8:00 a.m., the maximum delay per vehicle will be approximately 15 min and the maximum storage will be 1,200 vehicles. A storage of 1,200 vehicles or 300 vehicles per lane will produce a 2-mile queue.

If the work period extends beyond 2:00 p.m., the traffic demand rate will exceed the capacity rate and a queue will develop. Increasing traffic will cause congestion to continue long after the lane is reopened, and the reason for the delay will not be apparent to the motorists. For example, if work continues until 3:30 p.m., approximately 6,000 vehicles will suffer delays up to 15 min between 2:00 and 3:30 p.m. It will require another 1½ hours or until 5:00 p.m. for traffic to recover and for congestion to dissipate after the lane is reopened at 3:30 p.m. Another 10,000 vehicles will be delayed as much as 15 min between 3:30 and 5:00 p.m.

In this example, the work would probably be scheduled to avoid delay. This might be called preplanning, and conditions (demand) can be very different from the normal or expected demand when the work crew arrives at the site. In Los Angeles we believe that about 50 percent of the time something will have occurred in the peak period that will reduce capacity near the work area. This means that storage has built up and the peak period flow is not over.

A manual (1) describing a simple field procedure has been developed that permits the foreman to check the traffic demand at the site. A series of 3-min counts are made to estimate the demand and determine if the work can be started without developing congestion. The manual also provides a convenient procedure to measure the delay during the course of the work. If the delay becomes too great, the work can be suspended. For example, if an incident such as an accident occurs upstream and the vehicles are released, the surge in demand can create unexpected congestion at the work site. Monitoring the delay in such cases permits a more knowledgeable decision on suspension of the work.

TRAFFIC CONTROL

Often the maintenance work cannot be scheduled to handle the full demand without delay. Two methods to minimize delay in these instances have been tried and evaluated. One is simply the closing of certain upstream on-ramps to reduce the input into the work area. Another is the use of the median and right shoulders as temporary traffic lanes to increase traffic capacity at the work site. Both methods have been used with some success. An example is the control procedure developed to permit a rather extensive mudjacking operation on Interstate 405 in Los Angeles. The concrete slabs had been poured in 2-lane widths so it was necessary to close 2 lanes and raise them as a unit. It was anticipated that this work would take several months to accomplish.

Figure 2 shows the location. This section of freeway has 4 lanes in each direction with a 22-ft median with barrier fence and 10-ft paved outside shoulders. The northbound lanes in the area of the work are on a 3 percent uphill grade and operation is affected by slow-moving trucks.

One-way traffic demands in the work area between 9:00 a.m. and 2:00 p.m. ranged between 4,000 and 6,000 vph. The 2-lane capacity for this type of operation was estimated to be about 3,000 to 3,600 vehicles per hour depending on the grade, number of trucks, and amount of gawking. It was evident that serious congestion would develop if 2 lanes were closed, particularly in the southbound directions where traffic volumes were heaviest. Figure 3 shows a demand-capacity curve that was constructed for southbound traffic. This indicated that, if there were no diversion, we could expect delays of at least 1 hour. Of course, it was realized that in the actual case delays would never reach this because traffic would divert at off-ramps if the situation were that bad. By closing several upstream on-ramps at Valley Vista Drive and Mulholland Drive, it was estimated that the delay would be cut in half. When the shoulder lane was used, delay was virtually eliminated.

The most desirable solution is to reduce the traffic demand to less than the capacity of the road at the work site by closing upstream on-ramps. This will prevent congestion and the resultant hazards.

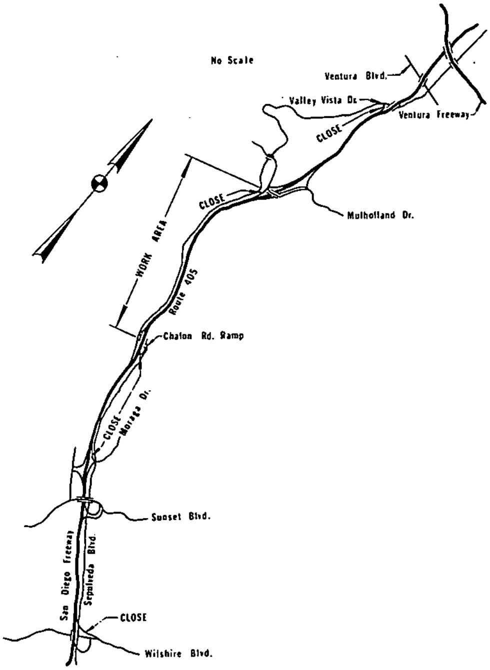


Figure 2. Location of mudjacking operation.

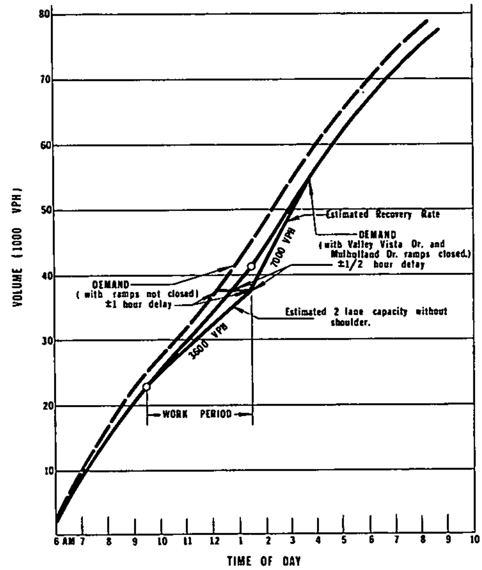


Figure 3. Demand-capacity curve for mudjacking operation.

In this instance that involved closing 2 northbound lanes, it was proposed to close on-ramps at Wilshire Boulevard, Morago Drive, and Chalon Road (Fig. 2). This would divert an average of about 600 vph to the alternate route, Sepulveda Boulevard. It was estimated that Sepulveda Boulevard could handle the diverted traffic, and the additional travel time required would be only about 2 min longer than the freeway trip under normal conditions. In fact, however, diverted motorists would actually break even or save time because the freeway trip would involve some delay.

When work was performed in the southbound lanes, it was proposed to close on-ramps at Valley Vista Drive and Mulholland (Rimerton) Drive. This would divert an average of about 400 vph onto Sepulveda Boulevard. It was not practical to close additional southbound on-ramps in advance of the major freeway interchange because this would delay many motorists not destined for the work area.

Even with the 2 southbound ramps closed, the estimated demand exceeded the 2-lane capacity past the work. So, the second part of the traffic control plan was to use the shoulder as a traffic lane where it was reasonably safe to do so. When lanes 1 and 2 were closed, the right shoulder was used; and when lanes 3 and 4 were closed, the median shoulder was used.

The paved width of shoulder available for traffic was always at least 8 ft with the exception that at one location the lateral clearance to a median sign and guardrail envelope was only 7½ ft. Delineation of shoulders is good because they are asphalt and the normal traveled way is portland cement concrete. The use of the median shoulder required vehicles to cross and drive to the left of a double yellow line. However, when signed, this is legal in California.

The use of the shoulder was permissive rather than mandatory. Cones and striping were not used to force traffic onto the shoulder. Three canvas signs were used to advise motorists of conditions. Figures 4 and 5 show a typical layout. The signs were either mounted on a stand or clamped to a pole on the median fence.

Another way to handle the operation would have been to simply force traffic into the shoulder. For example, when the median shoulder was being used, the left or lane 1 would be forced to the shoulder, lane 2 would be forced to lane 1, and so on. This

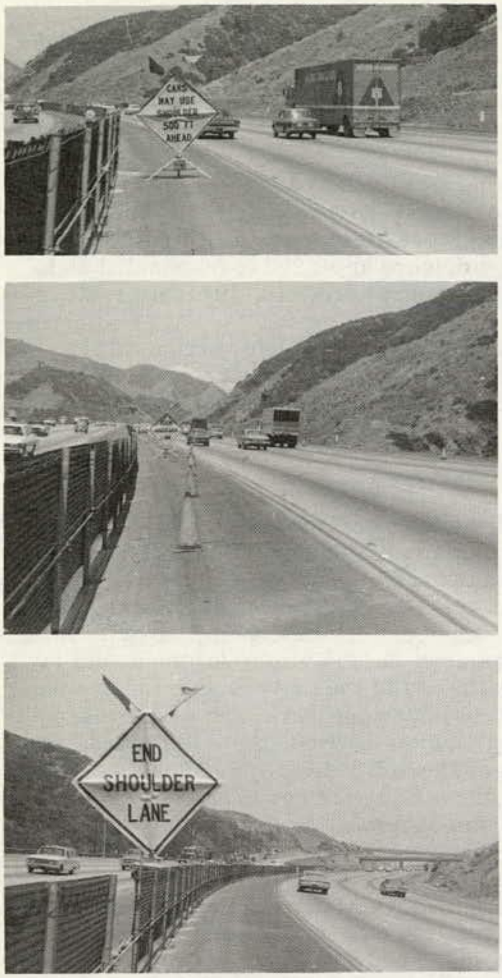


Figure 4. Median shoulder signs.

Figure 5. Outside shoulder signs.

method would probably give the greatest capacity. But on a short-term basis, this is difficult to do. It is also confusing to motorists and puts people on the shoulder whether they want to be there or not, and many times whether they need to be there or not.

The method used takes advantage of the driver's natural desire to minimize his own travel time. As congestion develops, the shoulder is used. If there is no congestion, the shoulder will not be used. As congestion develops in the merging area, cars upstream will move to the shoulder to avoid it. This increases capacity and prevents the queue from extending more than a short distance. In other words, there has to be some congestion before the system works. It was not the intent to eliminate congestion. It was intended only to hold it to a manageable amount so the end of the queue would be in a location where proper warning could be furnished. Also, the presence of some slowing would mean that vehicles entering the shoulder would do so at a somewhat reduced speed. This was considered important, in view of the generally substandard conditions along either the left or the right shoulder.

Ramp Control

The ramp closures successfully reduced traffic demands with little adverse effect to diverted drivers. In the northbound direction when the westbound Wilshire Boulevard, Morago Drive, and Chalon Road on-ramps were all closed, traffic demands were reduced from about 4,000 to about 3,400 vph. Two lanes were adequate, and the use of the shoulder was not required. This, of course, was the best solution. Delays to diverted motorists were nominal (1 to 2 min). Actually, if we compare travel times with probable travel times had no control at all been undertaken, there was no delay. (This, of course, was not apparent to the motorists.)

Ramps were closed simply by placing small barricades across the ramp entrance. For the ramps coming directly off Sepulveda Boulevard, no alternate route information was furnished (unless vehicles turned around they were already on the alternate route). While we are not aware of any complaints, many drivers appeared to be puzzled as to what to do. Based on experience with other ramp-control projects, alternate route information should have been provided.

When the alternate route was not readily discernible, routing information was believed essential. Therefore, information was provided when the westbound Wilshire Boulevard on-ramp and southbound Sepulveda Boulevard on-ramp were closed. Figure 6 shows the layout at these locations.

Use of Shoulders to Increase Capacity

The use of the shoulder did increase capacity at the work site. The amount of the increase depended on many factors. The most important, as noted, is that traffic demand had to exceed capacity in order to force maximum utilization of the shoulder. Very few cars used the shoulder when there was no congestion. However, as soon as congestion developed, use of the shoulder increased. Other factors influencing capacity include (a) whether the median or the right shoulder was used, (b) the grade, (c) the actual layout of the shoulder lane, and (d) possibly the familiarity of the drivers with the system.

On the downhill side, where trucks were not an important factor and where there was constant pressure of a backlog of cars supplying the section, the 2 left lanes, plus median shoulder, handled maximum flow rates of about 5,200 vph. For short periods of time, the median shoulder was handling maximum flow rates of about 1,300 vph. The maximum capacity of the outside shoulder was somewhat less, about 900 vph.

On a day when the shoulder could not be used, the 2 lanes could only handle an average flow rate of about 3,500 vph. Demands were about 5,000 vph. Delays quickly reached about 20 min. The queue extended about 2½ miles back to the Ventura Freeway and remained at this point for several hours. It stayed at this point because so many drivers seeing the congestion and hearing the "sigalert" exited at ramps in the interchange area. When the shoulder was used, delays were nominal (1 to 3 min), and the end of the queue was in an area where adequate warning could be provided.

On the uphill side, slow-moving vehicles had a significant effect. When the right shoulder was used, trucks would frequently be 2 abreast (in the shoulder and right lane) because the shoulder was not designated for trucks (although trucks frequently used the shoulder). This did not occur when the left shoulder was being used. Thus, capacity was greater when the left shoulder was used than when the right shoulder was used.

Figure 6. Ramp closures and alternate route signs.

Traffic demands were lower in the northbound direction, and there were not many periods when there was a constant backlog of traffic. Therefore, it was difficult to determine the actual capacities. Short-term rates for the 2 lanes, plus shoulder, did reach about 4,300 vph with the left shoulder and about 4,000 vph with the right shoulder. Two-lane capacity without the shoulder was only about 3,200 to 3,400 vph.

Operation in the uphill (northbound) direction, when demands were very close to capacity, was quite interesting and illustrated the benefits of the method even under this condition. When there was a demand rate of 3,200 to 3,400 vph and there were no trucks, the 2 lanes had adequate capacity and very few vehicles used the shoulder. When there were some slow trucks in the stream, some congestion developed and enough vehicles used the shoulder to prevent a significant queue from developing. Then, as soon as the trucks passed, free flow resumed almost immediately. Without the use of the shoulder, there would have been a constant queue because the queue buildup caused by trucks could not be dissipated in the relatively short periods between trucks.

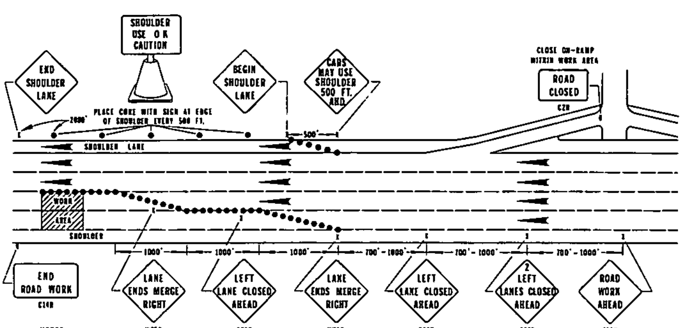
One general problem with the method was that the congestion started in the lanes farthest away from the shoulder; i.e., the lane drops are always on the opposite side from the shoulder. This means that the congestion has to spread to the lane adjacent to the shoulder before it becomes advantageous for a driver in that lane to move to the shoulder. Thus, the start of the shoulder lane has to be well upstream of the actual work area (generally at the start of the transition area). If the shoulder lane starts close to the work area, it will not be used because at that point there will not be enough delay to make it worthwhile for a driver to go to the shoulder.

Figure 7 shows a typical layout developed from this study. If shoulder lanes are used, the lane should extend the entire length of the work area. Capacity is not increased by very much if vehicles are required to merge within the limits of the lane restriction. The beginning of the lane should be delineated by a short transition of cones from the edge of pavement to the outside edge of the shoulder.

The end of the use of the shoulder lane should be well past the work area (1,000 to 2,000 ft). Traffic in the main lanes then has a chance to move over leaving room for traffic in the shoulder to merge back in. The end of the lane should be marked both to meet legal requirements and simply to get traffic off the shoulder. Much to our surprise, when we did not mark the end, some cars stayed on the shoulder for several miles.

There is no question that driving on the shoulder, particularly the median shoulder, is not as safe as driving in a normal-width lane. Some small sports cars traveled at fairly high speeds on the shoulder.

The shoulder lane was used over a 3-month period. During this period, 2 minor (property damage only) accidents were observed. However, it is difficult to determine



NOTES:

1. Signing for median shoulder lane is same as above but on opposite side.
2. Provide at least 1000' – 2000' between work area and END SHOULDER LANE sign to allow traffic to merge. Do not use shoulder if traffic must merge within the work area.
3. Shoulder lane signs should be covered when shoulder lane is blocked by a stalled vehicle.
4. Do not use shoulder lane when paved width is less than 8' or where there are obstructions such as rolled gutter, drainage structures, restrictions on lateral clearance, or where there are on-ramps within the work area.

Figure 7. Signing for shoulder lane closures on metropolitan freeways.

if they would have occurred anyway. One accident occurred because a car in lane 1 swerved to the median shoulder to avoid hitting a car in front of him. He was hit by a car on the shoulder. Whether the driver of the first car swerved instinctively or was unaware that the shoulder was being used or would have hit the fence in any case, we do not know.

In this instance, it is believed that the benefits in terms of reduced accident-causing congestion outweighed the somewhat increased hazard of using the shoulder. This would be especially true if care is used in selecting shoulders that can be used as the traveled way and in marking them as thoroughly as possible. One important feature is to place cones and signs at short intervals at the edge of the shoulder lane as a reminder that it is being used as a traveled way. If a pedestal type of sign is placed on the shoulder, it should be protected by cones (Fig. 4).

CONCLUSIONS

These scheduling and control techniques were very successful in reducing the congestion and delay due to the work project. It is estimated that motorist delay was reduced by 50,000 vehicle-hours during a 3-month period when lanes were closed for mudjacking on the San Diego Freeway.

The results of the control techniques were particularly impressive. For example, on one day when there was a 4-hour closure and the shoulder was not used in the southbound direction, there was very severe congestion. The total delay was about 4,000 vehicle-hours. On another day when the shoulder was used and there were the same traffic demands and a 4-hour closure, total delay was only about 400 vehicle-hours. We think the second operation was also much safer. This means motorist delay was reduced by about 3,600 vehicle-hours. For a frame of reference, the most successful ramp control project (on a daily peak-period basis) in Los Angeles reduces motorist delay by only about 900 vehicle-hours per day.

Of course, placing barricades and signs for this type of work requires additional time and lengthens the setup time. This may decrease the time actually available for production. On the other hand, the use of these procedures could lengthen the work period because higher volumes could be handled.

The experience in Los Angeles indicates that there is a considerable payoff in controlling traffic for maintenance operations. It is interesting to note that many years ago the safety or traffic function was a part of the Maintenance Department in California. It now appears that maintenance personnel must again be involved in traffic engineering.

REFERENCE

1. Kermode, R. H. A Field Procedure for Determining Effects of Lane Closures. Freeway Operation Department, California Division of Highways, Rept. 69-3, May 1969.