NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 170

MANAGING URBAN FREEWAY MAINTENANCE

TRANSPORTATION RESEARCH BOARD
National Research Council

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SYNTHESIS OF HIGHWAY PRACTICE **170**

MANAGING URBAN FREEWAY MAINTENANCE

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RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
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Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration of the U.S. Department of Transportation.

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of interest to maintenance engineers, traffic engineers, and others interested in the management aspects of maintaining urban freeways. Information is provided on techniques and procedures used by agencies to improve and speed up maintenance procedures, schedule work, and coordinate freeway lane closures.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

Maintenance of aging urban freeways is difficult because of the high volumes of traffic on these facilities. This report of the Transportation Research Board describes techniques and procedures that highway agencies are using, such as reducing work time and scheduling work for off-peak periods, to minimize traffic delays while freeway maintenance is performed.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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TO: CHIEF ADMINISTRATIVE OFFICERS
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FROM: Thomas B. Deen
Executive Director

SUBJECT: National Cooperative Highway Research Program
Synthesis of Highway Practice 170, "Managing Urban Freeway Maintenance"
Final Report on Project 20-5, Topic 16-09 of the FY '84 Program.

I am enclosing one copy of a synthesis report resulting from research conducted by the Transportation Research Board and administered by the National Cooperative Highway Research Program. The Synthesis report was prepared by E. Nels Burns. In accordance with the selective distribution system of the Transportation Research Board, all persons who have selected the Highway transportation mode and the subject areas, Maintenance, and Operations and Traffic Control, will receive copies of this document.

The NCHRP staff has provided a foreword that succinctly summarizes the scope of the work and indicates the personnel who will find the results of particular interest. This will aid in the distribution of the report within your department and in practical application of the research findings on various techniques used by highway agencies to maintain freeways under high traffic conditions.

Enclosure

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MANAGING URBAN FREEWAY MAINTENANCE

SUMMARY

Aging urban freeways require an increasing amount of maintenance in order to keep them functioning properly. However, the high traffic volumes on these freeways make maintenance difficult, primarily because there is little time to perform the work without creating adverse effects on traffic operations. In a survey of 28 agencies responsible for urban freeway maintenance, the work items listed most frequently as causing scheduling difficulty were those associated with bridge maintenance and pavement patching. The primary reasons for this are the need for adequate space for work to be performed and the difficulty in scheduling times when there will be minimal impacts on traffic. Carefully planning for lane or freeway closures and understanding traffic impacts are necessary if the necessary maintenance is to be implemented effectively.

The primary local responsibility for operations management usually rests with the local (district) operations or maintenance engineer, who must develop sound management strategies to plan efficient maintenance programs. This will require coordination or communication with a wide range of groups or agencies, such as active highway contractors; news media; school officials; transit operators; hospital emergency units; state, county, or city agencies that offer emergency services (including police and fire); utilities; airport limousine services; auto clubs; trash collection agencies; trucking associations; major traffic generators; and other private agencies that may be affected.

It is not easy to predetermine all factors that may affect the managing of urban freeway maintenance activities. It is sufficient to say that the internal and external agency coordination is paramount to the success of any scheduling and implementation of normal maintenance activities. Safety of the workers and consideration of the traveling public demand high-quality, cooperative management efforts by all of the involved agencies.

Many agencies have implemented maintenance management systems that can match an agency's resources with its maintenance needs. These systems require development of work productivity performance standards that result in known man-hours for each type of maintenance work required on the freeway. Thus agencies are able to schedule the appropriate number of personnel and the proper equipment to match the amount of work required and the time available.

To meet the work load demands for maintenance, many states have had success in employing contractors to perform various pavement maintenance tasks. The survey indicated that more than 50 percent of the agencies use both their own forces and contractors to perform pavement patching work on their urban freeways. However, there is a considerable amount of lead time needed to determine the limits of the pavement work and to prepare contracts. Time is also necessary to prepare plans, advertise, and award and implement contracts to perform spot work that requires short response times.

Many agencies have developed traffic control standards for lane closures required to perform pavement maintenance work of short duration. In some agencies, the traffic engineering departments have established specialized units that deal with the development or monitoring of traffic control plans in the field. These units have demonstrated that special attention in the area of traffic management helps to deal

with special problems. When trained crews are available in this specialized traffic control area, their use greatly aids in the provision of more uniform traffic control, and safety for workers and the motoring public.

Many agencies are able to perform routine short-term maintenance during off-peak hours of weekdays when there is no need for lengthy disruption of traffic by an extended work period. However, an increasing number of agencies have chosen, or have been forced, to perform a significant amount of maintenance work at night or on weekends to minimize disruption of the heavy traffic found on urban freeways during normal weekday hours. Approximately 50 percent of the survey respondents indicated that they perform some maintenance activities at night or on weekends.

Timely and accurate traffic data are essential when scheduling maintenance work activities (e.g., work on pavement, shoulders, and bridges) that will require the closure of lanes or entire freeways. These data are a critical element in the management effort to schedule and perform maintenance work at times that will minimize the disruption to the ever-increasing traffic on urban freeways.

Good public relations is an essential element of the successful management of urban freeway maintenance activities. Most agencies surveyed have established routines and practices regarding the advance notice of freeway or lane closures that are required for maintenance activities. All agencies indicated that they use press releases to the various news media (radio, television, and newspapers) in advance of and during planned lane or freeway closures.

The area of managing urban freeway maintenance is a dynamic field. It is one that must continue to be addressed openly in seeking innovative ways to effectively match available resources and personnel to maintain urban freeways efficiently and safely while minimizing inconvenience to the motoring public.

CHAPTER ONE

INTRODUCTION

From the late 1950s through most of the 1960s, the majority of urban freeway maintenance was confined to mowing, sweeping, and routine roadway lighting maintenance. During that time, when freeways were in good condition, maintenance personnel were not overburdened and maintenance budgets were not tightly constrained. It was a relatively simple task to handle all maintenance using agency forces, materials, and equipment. It was also a relatively simple task to select daytime hours that avoided the traditional 7 to 9 a.m. and 4 to 6 p.m. peak periods to perform the normal maintenance work required.

Because of high traffic volumes and heavier vehicles, however, urban freeways have aged. Many require a substantial amount of maintenance to preserve the integrity of the system. They have also become more congested, and public-agency resources are much more limited. As a result, considerable demands have been placed on the maintenance management function. Urban freeways are the backbone of metropolitan transportation systems. This makes the managing of urban freeway maintenance activities a critical element to assure efficient movement of persons and goods. The need for efficient budgeting of personnel, material, and equipment to keep urban freeway systems in good repair while minimizing costs and maintaining maximum operational efficiency is essential.

Many urban communities have been successful in using strategies to reduce the high traffic demands during peak hours by implementing aggressive programs to maximize people movement: implementing flexible work hours, using high-occupancy vehicles, increasing transit use, and other efforts. The net effect of this in many urban areas is a lengthened peak-hour commuting period that has increased operating speeds and shortened travel times. But it also has effectively shortened the off-peak periods when maintenance work can be performed without causing adverse effects on traffic operations.

DEFINING THE GENERAL MANAGEMENT TASK

Highway operating agencies have taken a variety of measures to manage their urban freeway maintenance activities effectively. The local maintenance manager of each agency has the primary responsibility of handling these maintenance activities and must perform the following tasks:

- Identify and rank those maintenance activities that must be performed.
- Match available resources (funds, personnel, equipment, and materials) with the most efficient means of implementing the maintenance activities without sacrificing performance, using agency forces or contractors.
- Coordinate the activities both within and outside of the agency to determine the agencies potentially affected by traffic.
- Schedule and implement maintenance activities in such a manner that will provide the safest and quickest repair at the least cost, and minimize roadway occupancy time in implementing these activities.

DEFINING THE MAINTENANCE WORK TASK

In order to define the activities associated with managing urban freeway maintenance, a survey was sent to 30 agencies responsible for maintaining urban freeways. Responses were received from 28 agencies in 18 states and one Canadian province, including several urban districts of state departments of transportation. The respondents represent most of the major urban areas in the United States. The survey asked the agencies to rank maintenance activities by scheduling difficulty. Table 1 presents a summary by priority ranking of the types of maintenance activities that present the most critical scheduling problems.

By far the work items listed most frequently were those associated with bridge maintenance and pavement patching. In the

TABLE 1

ACTIVITIES RANKED BY SCHEDULING DIFFICULTY

Maintenance Activity	Agencies Listing Activity	Weighted Ranking by Priority[a]
Bridge Deck & Joint Repairs	17	79
Pavement Patching	11	62
Sweeping	11	35
Concrete Pavement Repair	6	31
Pavement Markings & Markers	8	25
Resurfacing	4	21
Overhead Electrical	8	19
Asphalt Pavement Repair	4	17
Joint and Crack Sealing	4	17
Guard Rail Repair	7	17
Moving Operations	2	12
Structure Drainage	4	12
Overhead Sign Maintenance	3	11
Attenuator Repairs	5	7

[a] Rating based on rankings by individual agencies with 6 points given for first, 5 points for second, etc. for highest to lowest critical scheduling difficulty.

case of bridge deck repairs, this is because of the need for adequate lateral space for work to be performed and the difficulty in scheduling times when there will be minimal impacts on traffic. In the case of pavement patching, the short-term and moving nature of this activity also creates a scheduling problem. These and other traffic-disrupting maintenance activities make it necessary to plan carefully for lane or freeway closures and to have knowledge of traffic impacts.

Some agencies expressed concerns about the duration of maintenance operation (i.e., moving, short-term, or long-term). Other agencies were very concerned about incident management and nonrecurrent maintenance-related activities (i.e., emergency events, material spills and cleanup, and reconstruction).

This synthesis focuses on the problems of normal maintenance operations performed by agency forces, devotes attention to agency management practices and policies, and shows examples of problems that have been solved by sound strategies and techniques.

CHAPTER TWO

AGENCY COORDINATION AND RESPONSIBILITIES

In recent years, surging traffic demands and an increase in the number of nonrecurrent incidents (accidents, breakdowns, etc.) on urban freeways have prompted most state agencies to place more authority with their local districts or divisions. This is because of the necessity to respond quickly to public concerns and to maintain optimum operational efficiency and safety on the urban freeways. The primary local responsibility for operations management usually rests with the local (district) operations or maintenance engineer, who must develop sound management strategies to plan efficient maintenance programs. It is also important to have a reliable staff that can assist in this planning and field crews that are prepared to respond on short notice to any event that requires quick action. The engineer must deal with the direct functions within the agency and also recognize the need to coordinate with external agencies that may be affected by any disruption to the normal traffic-flow patterns caused by maintenance activities. Required maintenance activities may affect (a) other active highway contractors; (b) news media; (c) school officials; (d) transit operating agencies; (e) hospital emergency units; (f) other state, county, or city agencies that offer emergency services (including police and fire departments); (g) airport limousine services; (h) auto clubs; (i) trash-collection agencies; (j) trucking associations; and (k) other private agencies (e.g., large traffic generators).

DECISIONS CONCERNING CONTRACT MAINTENANCE

The decision concerning the need to contract certain maintenance activities or its desirability is one that involves many complex factors. Synthesis 125 (*1*) indicates that the primary factors influencing decisions of whether to contract maintenance include the following:

- legislation or policy limitations,
- availability of personnel,
- specialized work,
- specialized equipment,
- costs and staff limitations,
- contractor availability,
- peak work loads, and
- responsiveness to operational needs.

Because the maintenance of urban freeways is a critical priority, the decision must be considered very carefully, with all pertinent factors taken into consideration. Table 2 shows the results of a survey conducted in 1983 (*1*) for all highway maintenance activities. The survey indicated that the maintenance activities applicable to urban freeways that were contracted most frequently were maintenance overlays, bridge painting, bridge repairs, and pavement sealing.

TABLE 2 (*1*)
MOST FREQUENTLY AND LEAST FREQUENTLY CONTRACTED ACTIVITIES

Activity	Respondents %	No.
Most Frequent		
Maintenance Overlays	77	58
Bridge Painting	67	50
Bridge Repair	55	41
Pavement Sealing	43	32
Least Frequent		
Seeding and Mulching	7	5
Attenuator Repair	4	3
Sign Cleaning	3	2
Management Functions	1	1

For most agencies the decision process for contract maintenance involves determining whether there is a need to contract and whether contracting is feasible. The need for contracting should be based on the anticipated work load, considering the agency annual work program, and the resources required, considering the availability of those resources. Feasibility should consider whether (a) the activity is suitable for contracting, (b) the agency is capable of managing the contract, and (c) the contractors are available to perform the required work. Table 3 shows how agencies answering the 1983 survey ranked all pertinent factors considered in their contracting decision process (*1*).

INTERNAL COORDINATION

Once the decision is made concerning whether each maintenance activity is to be performed by agency forces or contractor, it is important to develop a maintenance program schedule that is coordinated with other internal agencies that may be involved with or affected by each of the maintenance tasks.

TABLE 3
FACTORS CONSIDERED IN DECIDING TO CONTRACT MAINTENANCE (*1*)

Factor		% Using
Availability of Personnel		91
Specialized Work		89
Specialized Equipment		89
Costs		89
Staff Limitations		77
Availability of Contractors		67
Peak Work Loads		67
Agency Policy		62
Responsiveness		56
Other:	Emergency	1.5
	Quality of Work	1.5
	Labor Relations	1.5

Internal coordination in planning and implementing maintenance programs generally involves working closely with the construction, traffic engineering, and public-information units of the agency. Corridor management teams are units that have been established to coordinate and improve traffic management on specified freeway corridors. There are many of these units functioning in a number of urban areas in several states, including Texas and Florida. Some of these teams are part of the agency, but many are not. Communication among these various players assures that work is coordinated with other related construction and permits development of a schedule that minimizes traffic disruption.

The public and other affected agencies should be informed well in advance about inconveniences that may occur during the maintenance work period. More specific details concerning traffic analyses and public-information programs are included in Chapters 4 and 5.

EXTERNAL AGENCY COORDINATION

The location and nature of the maintenance activity will normally dictate the extent of coordination involved with external agencies. Routine maintenance activities that do not disrupt normal traffic flow, such as mowing or cleaning drainage facilities, can generally be performed during daytime off-peak hours. With careful planning and the use of proper warning devices on the freeway, these activities should not affect the operations of external agencies adversely.

When pavement or shoulder repairs or other traffic-disrupting activities requiring lane or freeway closures are performed, however, they should be planned and coordinated carefully with other internal and external agency activities in the area. A traffic control plan (TCP) should be developed that will cause minimal disruption to traffic during the scheduled work period. It is essential that all affected agencies be notified in advance of the work and provided with the following information:

- The location and nature of the work to be performed.
- Dates and period(s) of time that traffic will be disrupted.
- Specific information regarding delays that may be anticipated and alternative routes that may be used to avoid delays.
- Maps showing location and length of work, with pertinent alternative routes, as necessary.

The degree of detail of this information will vary with the impact of the maintenance activity on normal traffic flow.

When developing TCPs for traffic management, it is important to consider the impacts of freeway or ramp closures on external agencies. Some of the agencies to notify might include: emergency services, local transit operating agencies, trash-collection agencies, and local school officials. Thorough planning will assure that satisfactory alternative routes and schedules can be developed before the maintenance activities are performed. Timely public-information programs are essential to keep these agencies, as well as the motoring public, informed of maintenance activities. Public-information programs are discussed in Chapter 5.

COORDINATION WITH OTHER AGENCIES PERFORMING MAINTENANCE WORK

In some states, there is legislation that limits the function of state agencies within cities and counties. There is sometimes a jurisdictional problem with local utilities as well. Coordination with these external agencies is often very complicated, but it is an essential part of the management effort. A number of agencies have organized multi-agency committees or freeway management teams involving all affected agencies to better coordinate diversified maintenance activities.

As can be seen in Table 4, the agencies report that there are a variety of practices regarding who performs certain maintenance activities: There were no agencies reporting that they performed all work with their own forces, and a number of agencies reported that they are increasing the amount of work performed by contract. It is noteworthy that fewer than one-half of the agencies performing pavement patching and fewer than one-third of those performing drainage maintenance on bridge structures use their own forces. The state of Michigan, for example, is involved with three separate counties that perform urban freeway maintenance work on state highways within the Detroit metropolitan area. A number of other states, including Ohio, have maintenance on urban freeways managed and performed by separate local public agencies.

Coordination is frequently necessary when maintenance agreements for roadway and sign illumination and other electrical devices are in force. In Texas, the law requires that roadway lighting on highways in cities with a population greater than 15,000 be maintained by the city. In Houston, however, the district office of the Texas State Department of Highways and Public Transportation (SDH&PT) maintains all safety-lighting installations.

It is essential to coordinate maintenance by agency forces with contract work as it is in progress. Some agencies find it convenient to schedule the work of their own agency forces within the limits of lane closures scheduled by contractors, thereby also minimizing the further disruption of traffic.

Coordination of maintenance activities with external agencies presents problems that must be worked out if maintenance work is to be accomplished as efficiently and safely as possible. Com-

TABLE 4
PERFORMANCE OF MAINTENANCE ACTIVITIES

Type of Maintenance	Own Forces	Contract	Own Forces & Contract	Other Agency: City or County	Other Agency: Utility
Traffic Surveillance & Control	18	3	6	2	0
Signs & Supports	17	1	10	2	0
Pavement Patching	12	0	14	2	0
Lighting (& Signs)	12	5	12	3	2
Traffic Signals	12	1	8	6	0
Sweeping	11	3	10	3	0
Pavement Marking & Delineation	9	2	17	2	0
Drainage Bridge Structures	8	0	21	3	0
Resurfacing	2	14	12	2	0
Mowing, Weed Control	2	2	2	2	0
Litter	1	1	0	0	0
Winter Maintenance	1	0	0	1	0
Guard Rail	0	0	4	0	0

TABLE 5
SURVEY OF AGENCY SCHEDULING PRACTICES

	Type of Work Zone							
	Moving		Short Term		Long Term		Close Freeway	
	No.	%	No.	%	No.	%	No.	%
Daytime Off Peak	25	89	25	89	15	54	3	11
Nighttime	7	25	10	36	13	46	7	25
Weekend	9	32	12	43	12	43	7	25
No Restrictions	0	0	2	0.7	2	0.7	1	0.3

munication with all active contractors and cognizance of all existing construction work zones is essential when planning maintenance activities.

The success of traffic management strategies for the 1984 Summer Olympic Games, planned and implemented for the Los Angeles area by the California Department of Transportation (Caltrans), is an excellent example of sound management strategies employed for a special event. Maintenance activities, as a part of the overall management strategies, were organized to avoid any conflicts with the Olympics. These same techniques and principles can be employed to accommodate sports events, holiday parades, concerts, and other special events.

It is not easy to predetermine all factors that may affect the managing of urban freeway maintenance activities. It is sufficient to say that the safety of the workers and consideration of the traveling public demand high-quality, cooperative management efforts by all of the involved agencies.

CURRENT AGENCY SCHEDULING PRACTICES

A number of agencies reported on their current practices in managing various maintenance activities. Each agency was surveyed to determine time periods when maintenance is typically performed, and they reported many different practices in the hours and days used for scheduling various types of work activities. Table 5 shows a variety of work zone types and current practices for scheduling maintenance activities. No definition of "short-term" or "long-term" was used in the survey; respondents used their own interpretations.

One easily can see in Table 5 that a majority of the agencies still schedule moving operations and short-term work during daytime off-peak hours. However, they reported an increasing amount of work being scheduled during nighttime and weekend hours because of the reduced number of hours available when work will not have an adverse effect on traffic operations or the safety of workers and motorists.

A number of agencies reported that their work is scheduled during the available off-peak hours and that work continues for as many days as it takes to complete the activity. Other agencies indicated that the available off-peak hours closely conformed to the normal work hours of their maintenance crews.

Several agencies (54 percent) reported that long-term work is performed during off-peak hours, but many of the agencies reported long-term work being scheduled during nighttime (46 percent) or weekend periods (43 percent). Few agencies (11 percent) close their freeways during daytime off-peak hours to perform scheduled maintenance work, but some do close the freeways during nighttime hours (25 percent) or on weekends (25 percent) to perform work.

CHAPTER THREE

EXAMPLES OF EFFECTIVE MANAGEMENT TECHNIQUES

The following examples, gathered from research reports and agency contacts, are offered to demonstrate some of the strategies that have been employed successfully to match available resources with the maintenance demands on urban freeways.

MANAGEMENT OF PAVEMENT-PATCHING PROGRAMS

Pavement-patching operations are among the most difficult to schedule, as noted by the agencies surveyed. Therefore, it is very important that careful planning be accomplished as early as practicable. This planning should consider selecting hours and efficient techniques to perform the work that will minimize delay and occupancy of the work site to ensure the safety of the workers and the motoring public.

A study for the Federal Highway Administration (FHWA) developed improved methods for pavement patching on high-volume roads (*2*). The study recognized the two basic types of pavement deterioration, gradual and rapid. Gradual deterioration is easier to schedule in a normal maintenance work program because of the slower development of the problem and the considerable time available for advance plan preparation. Rapid deterioration demands constant monitoring of facilities and requires management strategies that permit quick response. The study thus concentrated on the management functions required for solving problems associated with rapid deterioration.

The maintenance manager must recognize the most effective techniques to use in pavement repairs and assure that the materials, equipment, and personnel selected match the type of pavement in need of repair. In addition, it is essential that the labor crews be well trained so that pavement repair time and traffic flow disruption are minimized.

In response to this type of problem, the Georgia Department of Transportation created a foreman's academy, a two-week residence program required for all new maintenance foremen. Patching procedures and traffic control are topics included within the courses provided.

It is desirable to make sure that all members of a maintenance crew are familiar with their assignments. This assures the minimum delay time to the motoring public during maintenance operations. The following list of planning events is offered to aid in improving patching operations:

- Coordinate work at several locations to provide a full workday.
- Assign personnel.
- Gather materials on-site or put on order for specific delivery time.
- Have equipment available and running.
- Plan traffic control.
- Make traffic control devices available.
- Determine method of operation.
- Detail total procedure.
- Explain work coordination plan.
- Establish procedure to clean up and vacate site.
- Notify cooperative agencies (police, etc.).

PATCHING PROCEDURES FOR CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

The Illinois Department of Transportation has recently developed quicker and more economical procedures for patching continuously reinforced concrete pavements (CRCP) (*3*). The most common form of distress in these pavements is cracking or deterioration of the pavement surface.

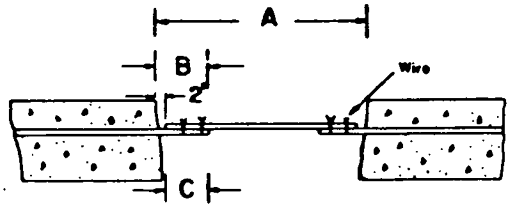
The conventional repair technique required patching a 10-ft section, which was often much larger than the area of deterioration. Two sets of saw cuts were used to prepare three sections of the patch. Full-depth saw cuts were made for removal of the 4-ft center section for working room and partial-depth cuts to the top of the reinforcing were made at each end of the 10-ft section. The concrete was carefully removed to avoid damage to the reinforcing bars. Continuity of the reinforcing was restored by lapping and tying (splicing) new steel onto the exposed 3 ft of existing steel at each end.

Researchers at the University of Illinois developed new methods of splicing (Figure 1), using either a tied or mechanically coupled reinforcement splice. After several tests of these techniques, Illinois has standardized a minimum patch length of 4.5 ft and permits contractors to exercise their option on either splicing method.

The state of Illinois in 1984 placed 1730 new patches on CRCP with an average savings of $500 per patch. Because it is necessary to remove less than one-half of the previous section of concrete pavement, a considerable amount of time savings to the motoring public can be realized using these new techniques.

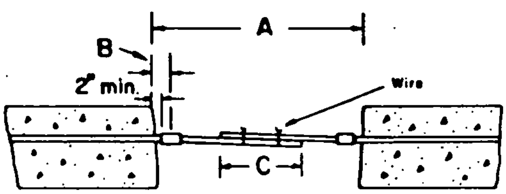
AGENCY POLICIES ON LANE CLOSURES AND TRAFFIC RESTRICTIONS

A number of agencies have issued written policies and procedures on lane, ramp, and full-closure requirements. Some of the agencies using written policies include the Seattle (*4*), Chicago, Los Angeles (*5*), and Detroit districts of their respective state transportation/highway agencies.



	A (minimum)	B	C
No. 5 Bars	4 ft 6 in.	18 in.	16 in.
No. 6 Bars	4 ft 6 in.	22 in.	20 in.

TIED REINFORCEMENT



	A (minimum)	B	C
No. 5 Bars	4 ft 6 in.	6 in.	16 in.
No. 6 Bars	4 ft 6 in.	6 in.	20 in.

MECHANICALLY COUPLED REINFORCEMENT

FIGURE 1 Details of patching technique for CRCP (Illinois) (*3*).

These policies have been issued in order to protect against conflicts in lane or other closures and to avoid traffic restrictions during peak traffic hours. They have been very effective in providing an organized method for maintenance operations to be planned and scheduled in the most efficient manner possible.

Most policies incorporate a list of the freeways within the agency's jurisdiction by section and direction and the hours and days during which single- or multiple-lane closures are permitted. These limitations have been determined from an analysis of congestion and traffic demands on each freeway.

Responsibilities and delegation of authority are typically defined in these policies, along with appropriate sources of reference, such as the *Manual on Uniform Traffic Control Devices* (MUTCD), and the procedures for internal requests and agency approvals.

The following is a summary of guidelines that may be used in developing a policy on lane closures:

- *Purpose of the Policy* Define lane closure applications, including how they affect planning for emergencies or special events.
- *Responsibility* Include the agencies affected.
- *References* List other agency manuals, directives, or policies that are pertinent, such as the MUTCD.
- *Procedures* Include requirements for agencies requesting lane closures, along with request forms and an explanation of the approval process. Encourage advance notice of lane closures. (A sample request form from the Houston district of the Texas SDH&PT is shown in Figure 2.)
- *List of Freeways and Closure Restrictions* Include all freeways by route number (and name, if necessary) with weekday, weekend, or holiday restrictions. (A partial sample list for the Detroit, Michigan, area is shown in Table 6. A map prepared by District 7 of Caltrans designates various sections of the Los Angeles area freeways according to criticality in the event of repairs. Extremely Critical means that lane closures will cause serious delay and congestion. These areas must have a traffic plan. Critical means that lane closures may cause delay and congestion. These areas should have a traffic plan. Unmarked means that lane closure should not cause serious delay. A traffic plan may be prepared. These designations are based on the assumption of a single-lane closure during nonpeak hours.)
- *Communication Requirements* Include the notification of the following external agencies:

  Other active highway contractors,
  News media,
  School officials,
  Transit operating agencies,
  Hospital emergency units,
  Other state, county, or city agencies that offer emergency services,
  Airport limousine services,
  Auto clubs,
  Trash-collection agencies,
  Trucking associations,
  Major traffic generators (e.g., stadiums, theme parks, etc.), and
  Any other private agencies that may be affected.

Each agency has its own procedures for implementing lane and other freeway closures, as well as guidelines for how restrictive any policies must be. However, the use of a written policy on lane closures must be well planned from historical traffic data and analysis of the tolerable degree of congestion that can be permitted during any maintenance operation.

MAINTENANCE MANAGEMENT SYSTEMS

Many agencies have implemented maintenance management systems that can match an agency's resources with its maintenance needs. These systems require development of work productivity performance standards that result in known man-hours for each type of maintenance work required on the freeway. Thus, agencies are able to schedule the appropriate number of personnel and the proper equipment to match the amount of work required and the time available.

To: ☐ DISTRICT MAINTENANCE ENGINEER

☐ DISTRICT CONSTRUCTION ENGINEER

REQUEST FOR APPROVAL OF TRAFFIC CONTROL PLAN

COUNTY ________ HIGHWAY _____ DIRECTION __________ CONT. ________ SEC. _____ MP or JOB _____

LIMITS ____

1. Date scheduled _______________ Time __________ AM, PM thru ____________ AM, PM
2. Nature of work ____

   ____

   ____

3. Has work been coordinated with any other work in the area? ☐ Yes ☐ No ☐ None
   Indivdual contacted: ______________________
4. Individual in responsible charge of this work who will be present: ______________________
5. Number of lanes: 1 2 3 4 5 (Circle) #1 lane always
6. Lane/s closed: 1 2 3 4 5 (Circle) Left Lane
7. Describe Traffic Management Procedures to be used: ______________________

   ____

   ____

   ____
   (Use back of form for additional information and sketch)
8. If freeway, will any ramps require closure? ☐ Yes ☐ No If so, identify:
   Entrances ______________________ Exits ______________________
9. Portable message signs recommended? ☐ Yes ☐ No
10. Is police assistance requested? ☐ Yes ☐ No How many? ☐ Where and how will police be used? ______________________
11. Submitted by ______________________ Date ______________________

☐ Carbon copy Chairman, District Safety Review Team

DISTRICT OFFICE USE ONLY

TRAFFIC CONTROL PLAN APPROVED

____

Dist. Const./Maint. Engineer Date

Freeway Traffic Management Check (Optional)

☐ Recommend approval

☐ Recommend modification
(See reverse)

By ______________________

Copy to:

☐ Public Affairs Officer ____________
Date

☐ Traffic Management for Police Assistance

FIGURE 2 Traffic control request form (Texas).

TABLE 6
LANE CLOSURE RESTRICTIONS (MICHIGAN)

US-10 (JOHN C. LODGE FREEWAY)

No lane closures shall be allowed during the following hours Monday through Friday.

1) Southbound US-10
   a) Telegraph to Southfield
      6 AM to 9 AM
   b) Southfield to Jefferson
      6 AM to 9:30 AM
      3 PM to 8 PM
2) Northbound US-10
   a) Telegraph to Southfield
      3 PM to 8 PM
   b) Southfield to Davison
      6 AM to 9:30 AM
      2:30 PM to 8 PM

During other hours ONE lane may be closed.

I-94 (FORD FREEWAY)

No lane closures shall be allowed during the following hours Monday through Friday.

1) Eastbound I-94
   a) Telegraph to Wyoming
      6 AM to 9 AM
      3 PM to 8 PM
   b) Wyoming to I-75
      6 AM to 9:30 AM
   c) I-75 to I-696
      2:30 PM to 8 PM
2) Westbound I-94
   a) Telegraph to Wyoming
      6 AM to 8:30 AM
      3 PM to 8 PM
   b) Wyoming to I-696
      6 AM to 9:30 AM
      2:30 PM to 8 PM

During other hours ONE lane may be closed.

Some states have carefully studied various maintenance work categories (pavement patching, bridge decks, shoulder repairs, etc.) and have trained specialty crews to perform these work tasks very efficiently. The Georgia DOT has specialty crews in the area of pavement patching, to optimize efficiency in the performance of that task (*2*).

The Metropolitan Toronto Department of Roads and Traffic has developed a *Maintenance Management Manual* that provides information concerning processing of report forms, definition of work activities, and standards used in preparing annual work programs for each maintenance yard (*6*). In addition to policies and forms, this manual also includes examples of work crew sizes for actual work performed and summarizes performance standards and crew sizes covering typical maintenance activities such as pavement patching, mowing, sweeping, and more. An example from the manual is shown in Figure 3.

197 – GENERAL MACHINE SWEEPING

Purpose:	(1) To prevent disease, injuries and annoyances arising from road dirt. (2) To prevent injury to pedestrians and damage to property and vehicles caused by loose objects being thrown up by traffic. (3) To promote safety by removing debris which could cause skidding conditions. (4) To reduce the obscuring of pavement markings and to prolong the life of these markings. (5) To prevent the clogging of structure drains and storm sewers.
Required When:	On Expressways only, throughout the year once every week, weather permitting.
Crew Size:	3
Equipment:	1—2½ ton truck 1—Sweeper 1—Water Truck
Method:	(1) Set out appropriate safety devices and signs. (2) Make one pass per curb. (3) When full, empty Sweeper into truck or onto road. (4) Haul in truck to designated dump site. (5) Follow sweeper with water tank truck.
Average Daily Production:	65-80 Pass Kilometres Driven.

FIGURE 3 Example from Toronto *Maintenance Management Manual.*

PAVEMENT MAINTENANCE SERVICE CONTRACTS

In recent years, the efficient management of personnel has become much more critical. To meet the work load demands for maintenance, many states have had success in employing contractors to perform various pavement maintenance tasks. The results of a survey of agencies (Table 4) indicates that more than 50 percent of the agencies use both their own forces and contractors to perform pavement patching work on their urban freeways.

However, there is a considerable amount of lead time needed to determine the limits of the pavement work and to prepare contracts. Time is also necessary to prepare plans, advertise, award, and implement contracts to perform spot work that requires short response times, such as pothole repair. The Houston district of the Texas DSH&PT has chosen to implement innovative agreements to have contractors provide labor and equipment services for short-term spot-improvement pavement-patching needs (*7*). In early 1985, two $3 million contracts with two-year terms were let to provide these pavement maintenance services. The district furnishes either portland cement concrete or hot- or cold-mix asphalt concrete quick-setting materials from specified supply locations. Each contractor is responsible for one-half of the district's geographic area (as defined by the district office), and the contractors are required to respond to a request for patching services within 6 hr following notification by the engineer. A seven-day work week is required, and work is performed during off-peak periods (day and night) during weekdays and weekends. Contractors are required to submit traffic control plans, which must be approved before any work is begun. Each contractor is also required to have five crews available at all times (seven days per week) to perform the necessary work.

This method requires the assignment of additional technical personnel to provide inspection services for plant material as well as at the work site. If the agency decides it is advantageous to provide materials for the contractor, then it is required to keep an adequate supply of materials on hand to assure timely delivery.

TRAFFIC CONTROL FOR SHORT-TERM MAINTENANCE

Many agencies have developed traffic control standards for lane closures necessary to allow the performance of short-duration pavement maintenance work. These standards may be from the MUTCD or adopted state manuals that comply with the intent of the MUTCD. Other standards have been developed locally that are tailored to typical conditions encountered with these maintenance activities.

In some agencies, however, the traffic engineering departments have established specialized units that deal with the development or monitoring of traffic control plans in the field. The Los Angeles district of Caltrans, for example, has a planned lane closure unit (PLCU) (*5*) that was formed to assist all branches of the district in planning and implementing lane closures. The PLCU has at its disposal 11 portable changeable-message signs (CMS) mounted on trucks, 4 trailer-mounted CMS, and permanent ground-mounted CMS at various locations throughout the district. These signs are used as advance warnings for construction as well as maintenance closures. The PLCU also provides information regarding the optimum time for lane closures and road closures.

The Houston district of the Texas SDH&PT created a traffic management team specifically to assist in "active traffic management" on freeways within the district (*8*). This unit was established following serious accidents involving maintenance workers performing the work in the field. A five-person crew was formed with a supervisor, crew leader, and three additional personnel. This unit has been very effective in developing and monitoring traffic control in the field for the maintenance work performed by district forces as well as contractors. Recently, the priorities for the unit have been modified somewhat, and the district traffic management activities have focused more on incident management activities.

The examples of special units in Los Angeles and Houston to deal with work zones have demonstrated that special attention in the area of traffic management helps to deal with special problems. When trained crews are available in this specialized traffic control area, it greatly aids in the provision of more uniform traffic control, and safety for workers and the motoring public.

The provision of special crews places heavy staffing responsibilities and demands on the agencies, and it is essential that the agency provide adequate personnel to satisfy the demands by contractors. The use of specialty crews also may have the disadvantage of discouraging contractors from having trained personnel on-site to deal with emergencies that must be handled if the response time for the specialty crews is too long.

PROTECTION FOR WORKERS

Safety for workers has become a major concern of maintenance agencies as well as contractors in recent years. The decreased availability of funds and greater maintenance demands, along with the higher traffic volumes, have placed pressure on officials to accomplish the work as quickly as possible, while still providing a safe environment for the workers. Several agencies have instituted public-relations campaigns to alert motorists to the safety aspects of work zones. One example is the "Give 'em a BRAKE" program, which uses media contacts, brochures, and signs at the work site in an effort to get motorists to be more cautious and courteous and to drive more slowly through work zones (*9*). Some agencies have used special law enforcement efforts (including hiring off-duty police officers) to assure motorist compliance with traffic controls or to assist workers when closures are set up.

The Houston district of the Texas SDH&PT was faced with some serious problems as a result of a number of accidents involving their work force during 1980 and 1981 (*8*). The special traffic management agency mentioned previously used special crews to improve safety as well as to handle traffic control in work zones. The traffic control plan request form shown in Figure 2 was also developed to better manage field activities.

A number of ideas have been tested to develop methods of physically separating workers from the traveling public. The use of truck-mounted attenuators to provide protection to both workers and motorists has been increasing since they were first developed in Texas in the mid 1960s (*10*). These devices are attached to the rear of a shadow truck, which is located 25 to 275 ft before the work area. The distance depends on whether the shadow truck is moving or stationary, the prevailing speeds, and the weight of the impacting vehicle to be contained (*10*).

Another type of separation device is one that is anchored on each end by an equipment truck (Figure 4). This device provides 44 ft of work space between the trucks and has been considered for use on an experimental basis by the Texas SDH&PT in Houston for pavement patching.

The California Department of Transportation has considered equipping workers with two-way radios within helmets to improve communications and safety at work sites. Another device developed by one manufacturer (*11*) is a portable concrete median barrier. The barrier consists of 1-m lengths of concrete barrier that are tied together and can be placed using a piece of transporting equipment. The equipment has the ability to move the barrier longitudinally into place at the work site. It also lends itself to daily operations in which a barrier wall must be moved laterally to open closed lanes during peak hours or other periods when traffic demands require normal capacity for the freeway.

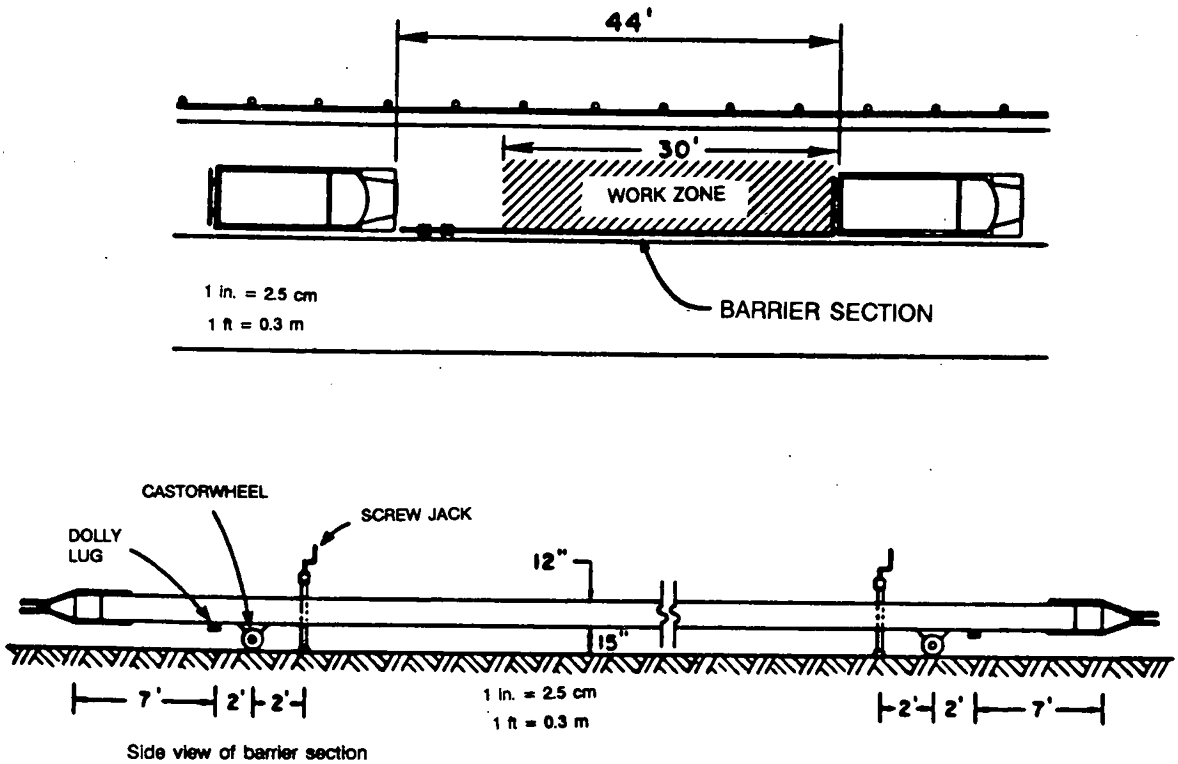


FIGURE 4 Device to separate work zone from traffic (*14*).

The transporter equipment can move the wall up to 16 ft laterally in one pass to open a closed lane. The barrier wall has been used in North Carolina for an Interstate pavement-rehabilitation project and in Oklahoma for several Interstate bridge deck repair projects.

The portable barrier wall is good for maintenance work, because it has the advantage of providing the necessary physical protection for workers and can easily be moved longitudinally or laterally when required for work or traffic conditions. The primary disadvantages are the initial cost of the transporter equipment and the need to plan and schedule applicable work to keep the equipment in use to make investment in the system cost-effective. Although there is continued research needed on providing maximum protection for workers in work zones, this device demonstrates the innovative thinking that can improve worker safety.

NIGHT AND WEEKEND WORK

Many agencies are able to perform routine short-term maintenance during off-peak hours of weekdays when there is no need for lengthy disruption of traffic by an extended work period. However, when extensive pavement repairs or maintenance activities require closing lanes or the entire freeway for longer periods, it may become necessary to schedule maintenance when it can be performed most safely and efficiently. As mentioned previously, an increasing number of agencies have chosen, or have been forced, to perform a significant amount of maintenance work at night or on weekends to minimize disruption of traffic on urban freeways during normal weekday hours.

Some agencies have evaluated work at night using demonstration projects to determine the feasibility and the benefits/costs of night hours. Shepard and Cottrell (*12*) concluded that it is difficult to make a blanket recommendation for nighttime maintenance because of differences in agency policies and the wide disparity in the degree of tolerance of congestion and delay during daytime hours that either the public or the agency is willing to accept. Shepard and Cottrell did conclude, however, that night maintenance work would have to increase because of the heavy demand for reconstruction and maintenance work, as well as the high traffic volumes in urban areas.

The California Department of Transportation studied the feasibility of performing non-emergency maintenance during low-volume traffic hours (*13*). The study led to a policy that prohibits lane closures for planned maintenance work when the loss of traffic capacity would cause significant delay to motorists. In this case, work would be shifted to weekend periods when delays would be less than 15 min or to nighttime. In addition, the study suggested rescheduling of the normal maintenance work week to include Saturdays and Sundays, and, on critical freeways, a gradual move to night work of all maintenance that cannot be completed on weekends.

Night maintenance activities require additional planning because of the increased risk to workers and motorists that is caused by reduced visibility. Another factor is the exposure of workers to drivers under the influence of alcohol or drugs, which appears to be an increasing problem during late-night and early-morning hours. Union contracts are also affected because of changes in work shift schedules.

Night Demonstration Projects in Chicago

The Chicago District of the Illinois Department of Transportation conducted two experimental nighttime projects during 1982 and 1983 (*14, 15*). The 1982 project involved patching 1222 yd^2 of asphalt concrete on the Dan Ryan Expressway, an eight-lane freeway. The cost comparisons with daytime work are presented in Table 7.

TABLE 7
BRIDGE PATCHING COST COMPARISON BY STATE FORCES (*14*)

Item	Standard Operation (one lane closure)	1981 Daylight Operation on Ryan Bridge (one lane closure)	1982 Operation on Bridge (two lane closure)
Traffic Control	Maintenance forces	Maintenance forces	Private contractor ($5.42/sq yd) plus State's ETP forces ($1.62/sq yd)
Labor	3.20 MH/sq yd $32.00/sq yd	1.46 MH/sq yd $14.60/sq yd	1.43 MH/sq yd $14.30/sq yd
Material	$25.50/ton	$25.50/ton	$25.50/ton plus $8.50/ton for storage
	$4.55/sq yd	$4.55/sq yd	$6.30/sq yd
TOTAL	$36.55/sq yd	$19.15/sq yd	$27.64/sq yd

The project showed the following benefits of nighttime scheduling:

- A production rate 57 percent better than the standard production rate.
- A cost savings of $10/$yd^2$ when compared with the standard bridge-patching rate.
- An absentee rate of less than 1 percent.
- An absence of traffic-related injuries.

The project experienced several problems:

- Asphalt mix consistency was difficult to achieve.
- Lighting of the work area and pavement visibility were poor.
- Reflective vests for workers were uncomfortably hot.

Two 1983 projects were also demonstrations: one was a partial-depth patching of the Dan Ryan Bridge in the outer two lanes and the second was a partial-depth patching and skin-patch overlay on the Eisenhower Expressway. The selection of night work was caused by the need for more than one lane to be closed. (During daytime work hours closure of a single lane is all that is allowed.) Work was performed on a four-day work-week schedule.

These two projects corrected some of the problems encountered in the 1982 project. This resulted in the defining of guidelines for scheduling night work on a selective basis during the normal planning process for maintenance work.

The conclusions were as follows:

- Public benefits derived from the night work were sufficient to warrant inclusion of night work in the normal work-planning process.
- Selected portions of five separate freeways were determined to be suitable for night work scheduling.

Recommendations included:

- The decision to use night work should be based on location and need.
- Night work should not become an automatic part of the regular maintenance program. Its use should be reviewed annually.
- There should be judicious use of night work because of the additional strain on budgets, workers, and supervisors.

It was also reported that union work requirements were overcome and appeared to be no problem once the work hours for night shifts were defined. Consideration should be given during the negotiation stage of union contracts so that they do not restrict night work and do permit the cooperation of all affected agencies. One typical adverse comment on night or weekend work is the negative reaction by some personnel who have second jobs or other obligations during evenings or weekends.

As can be seen in Table 5, which summarizes agency responses to questions about maintenance work performed at night or on weekends, approximately 50 percent indicated that they perform some maintenance activities at night or on weekends. It should also be noted in Table 5 that many agencies reported that maintenance involving moving operations and short-term work could be scheduled during daytime off-peak hours, whereas long-term maintenance work was scheduled during night or weekend hours.

As reported by Shepard and Cottrell (*12*), there appears to be a wide disparity in agency policies regarding night and weekend work. Some policies encourage and others discourage night or weekend work. Some agencies have policies prohibiting work during these hours. There also appears to be a wide variation in public and agency tolerance of traffic delays in various geographical areas.

COMPLETE FREEWAY CLOSURES

The need for complete freeway closures to perform maintenance work requires great care in the planning and scheduling

TABLE 8
JULY 1982 CLOSURE ANALYSIS (*16*)

	Activity							
Item	Sweeping	Catch Basin Cleaning	Mud Jacking	Spot Surface Replacement	Cold Patching	Gore Painting	Bridge Scaling	Totals
Actual Total Accomplishment	322.1 pass-miles	63 units 13 crew-day	13 locations	34.5 tons 6 crew-days	36.5 tons 8 crew-days	74 locations	70 locations	
Cost/Unit[a,b]	$496/pass-mile	$2700/crew-day	N.A.[c]	$4259/crew-day	$1733/crew-day	N.A.[c]	N.A.[c]	
Estimated Total Costs under Normal Open Traffic Conditions[a]	$159,762	$35,100	$32,670[d]	$24,966	$12,171	$22,496[d]	$91,017[d]	$378,182
Actual Cost During Closure[a]	$ 97,046[e]	$ 8,357	$16,518	$12,511	$ 5,519	$13,736	$17,756	$171,443
Savings	$ 62,716 39%	$26,743 76%	$16,152 50%	$12,455 50%	$ 6,652 55%	$ 8,760 39%	$73,261 80%	$206,739 55%

[a]Costs include labor additives and overhead.
[b]Based on Manpower Management System.
[c]No previous unit or daily costs have been developed for these activities.
[d]Costs developed using actual costs plus traffic control.
[e]Includes pre-signing costs ($16,445).

of work because of the additional impact on the motoring public. There is also a need for traffic data collection that includes all the highway and street facilities that may be affected. Many other agencies also will be affected, and some of these may have to be included in the planning and scheduling process.

Detroit, Michigan

Maintenance work at night has been a normal activity for the Michigan DOT since 1982, as described in a report by Savas (*16*), but the development of this practice goes back much further. A committee consisting of representatives of the Wayne County Road Commission, the city of Detroit, and the State Highway Department was formed during the middle 1960s to oversee highway activity in the region. Wayne County became the agency responsible for performing urban freeway maintenance in the Detroit metropolitan area, under agreement with the state.

The first complete closure of a freeway in the Detroit area was performed in 1968. During the closure, maintenance work was accomplished with a savings of 40 percent over the cost of maintenance during open conditions. Typical work during the closure included concrete and asphalt patching, sweeping, catch basin cleaning, and guardrail maintenance. Routine use of this traffic control technique was not adopted until 1981, however, when spiraling maintenance costs prompted the consideration of complete closures as a regular practice. Inflation, deteriorating road systems, public demand, and strict traffic regulations were contributing factors.

Among the different plans considered were complete daytime, weekend, and night closures of freeways for maintenance. After considering all factors, it was decided to close predetermined sections of freeway from 10:00 p.m. to 6:00 a.m., Sunday through Friday. Short-term, moving-type, routine maintenance activities (e.g., sweeping, catch basin cleaning, pothole patching, etc.) were performed. Strip maps and news releases were placed in local newspapers and provided to TV and radio stations daily. All other affected agencies were notified. County officials worked out the details with the unions for the shift change.

Twelve sections of freeway 5 to 10 miles in length involving 40 centerline miles of freeway were scheduled for closures. A completion time of six to eight weeks was anticipated, and the work was completed three weeks ahead of schedule, with favorable comments received from the public and news reports. The total net savings from the 1981 closures, when compared with normal operations, was $49,581 for sweeping and catch basin cleaning.

As a result, additional maintenance was scheduled for July and September 1982, as well as for 1983. Examples of closure analyses for July 1982 and April 1983 are shown in Tables 8 and 9. Three scheduled closures in 1983 resulted in savings of $562,797, a 36 percent savings over normal operations for the year. Table 10 shows aggregate savings for the maintenance activities over the two-year period.

TABLE 9
APRIL 1983 CLOSURE ANALYSIS (*16*)

Item	Activity							
	Sweeping	Catch Basin Cleaning	Mud Jacking	Patrol Patching	Pavement Replacement	Bridge Repairsg	Presigning	Totals
Actual Total Accomplishment	565.2 pass-miles	312 units 61 crew-day	13 locations	325 tons 97 crew-days	2 locations	11 locations[a]		
Cost/Unit[b,c]	$474/pass-mile	$3053/crew-day	N.A.[d]	$1692/crew-day	N.A.[d]	$2646/crew-day		
Estimated Total Costs under Normal Open Traffic Conditions[b]	$267,905	$186,233	$35,625[e]	$164,124	$16,264[e]	$37,044		$707,195
Actual Cost During Closure[b]	$257,514	$62,992	$25,496	$100,328	$11,052	$17,320	$34,787	$509,489
Savings	$ 10,391 4%	$123,241 66%	$10,129 28%	$ 63,796 39%	$ 5,212 32%	$19,724 53%		$197,706 28%

[a]Includes expansion joint repair and deck scaling at 10 locations.
[b]Costs include labor additives and overhead.
[c]Based on Manpower Management System.
[d]No previous unit or daily costs have been developed for these activities.
[e]Costs developed using actual costs plus traffic control.

TABLE 10
COMPOSITE 2-YEAR COST ANALYSIS (*16*)

Item	Activity							
	Sweeping	Catch Basin Cleaning	Mud Jacking	Patrol Patching	Pavement Marking	Bridge Repairs	Pavement Repairs	Totals
1982 Savings	$177,825 33%	$ 69,461 69%	$22,757 45%	$ 18,471 46%	$10,460 33%	$101,738 75%	$29,803 50%	$431,515 45%
1983 Savings	$212,559 30%	$260,455 68%	$39,911 42%	$106,493 38%	$25,289 59%	$ 19,815 49%	$ 6,416 32%	$562,797 36%
2-Year Savings	$390,384 32%	$329,916 68%	$62,668 43%	$124,964 39%	$35,749 48%	$121,553 69%	$36,219 46%	$904,312 40%

The overall improvement in worker morale and increased level of maintenance were reported to far outweigh any disadvantages, and night closures are now part of the standardized plan for the Detroit Freeway System. Other maintenance now incorporated in the night operations includes spot surface replacement, cold patching, mudjacking, gore and lane line painting, and miscellaneous bridge repairs. Private contractors, public utilities, and other departmental divisions use the closures to perform their work. There are considerable cost and safety benefits from this common-use work zone, because of the elimination of the need for separate traffic control.

CHAPTER FOUR

ANALYSIS OF TRAFFIC DEMAND AND CAPACITIES

TRAFFIC DATA INPUT

The character of traffic on each urban freeway, as well as the traffic volumes for various hours and days of the week, are elements of data that must be obtained. In the past, the proportion of commercial (truck) traffic used in the design for many freeways ranged from 5 to 15 percent. Today, the actual percentage using these roads may range from 15 percent to as high as 45 percent. In some cases the volume of truck traffic has caused agencies to segregate truck traffic by separate lanes or even separate roadways. Therefore, it is important to know the amount of commercial traffic and how it should be handled when freeway lanes are closed.

The following sections report on the findings of research efforts to develop reliable traffic data from field experience, so that traffic volumes can be accommodated when freeway lane closures are required for maintenance.

TRAFFIC DATA SOURCES

There are a number of sources of traffic data available to the maintenance manager. Some are located in the immediate vicinity of the locations where maintenance must be performed, whereas in other cases it may be necessary to have traffic counts taken before maintenance activities are scheduled.

Automatic Traffic-Counting Stations

Each state transportation or highway agency is required to furnish traffic data to the FHWA on a quarterly and annual basis in accordance with traffic or speed-sampling guidelines furnished to the state (*17*).

In the majority of urban areas these data are collected by the use of permanent automatic counting and/or data-collection equipment that is operated by the appropriate agency in each state. Although this information is not collected system wide on a short-mileage basis for each freeway, there are a great deal of data available from the state transportation/highway agency in the central unit that is assigned the responsibility for data collection and reporting.

Traffic data from the counting stations can provide total traffic volume information, with a breakdown of commercial traffic, and are available on an hourly basis for 24 hr a day. If desired, traffic data can be provided in smaller increments of time.

Computerized Traffic Surveillance and Control Systems

A number of urban highway agencies have implemented computerized traffic surveillance and control systems (CTS&C) as their primary traffic management method to increase the operational efficiency of urban freeways and arterial corridors. These systems are designed to collect traffic data automatically and feed back data to control centers, which activate on-freeway motorist-information or ramp-metering systems.

For those maintenance managers fortunate enough to have these systems on-line, the ability to obtain timely and accurate traffic data is greatly simplified. Normally, the CTS&C systems manager can furnish any data desired for freeways within the urban freeway control system network.

Some CTS&C system managers have developed an additional management tool that produces daily reports of freeway lane closures that can be furnished to the maintenance manager, as well as to the agency public-information officer and the local news media. For example, the Chicago, Illinois, traffic systems center produces a daily lane-closure report that indicates the freeway, location, and hours of each closure.

ANALYSIS OF TRAFFIC CONGESTION CAUSED BY MAINTENANCE WORK

There are a number of research studies that have been performed to determine the impact of potential congestion caused by maintenance activities that require lane or freeway closures. Some have been developed to aid in freeway incident management, but the principles learned apply regardless of the reason for the reduction in the normal flow of traffic on freeways. A number of these strategies are summarized to demonstrate the options available to the maintenance manager.

Traffic Volume/Capacity Profiles

As previously mentioned, the key element in developing a practical schedule for conducting maintenance activities that require lane or freeway closures is a thorough knowledge of the traffic demands and the capacity available on the affected freeway or network of freeways, as well as the alternative routes, service roads, or surface streets onto which traffic may be diverted.

Once 24-hr traffic volume data for the location of the maintenance work have been obtained, the traffic data may be plotted as a profile along with tolerable lane service volumes to deter-

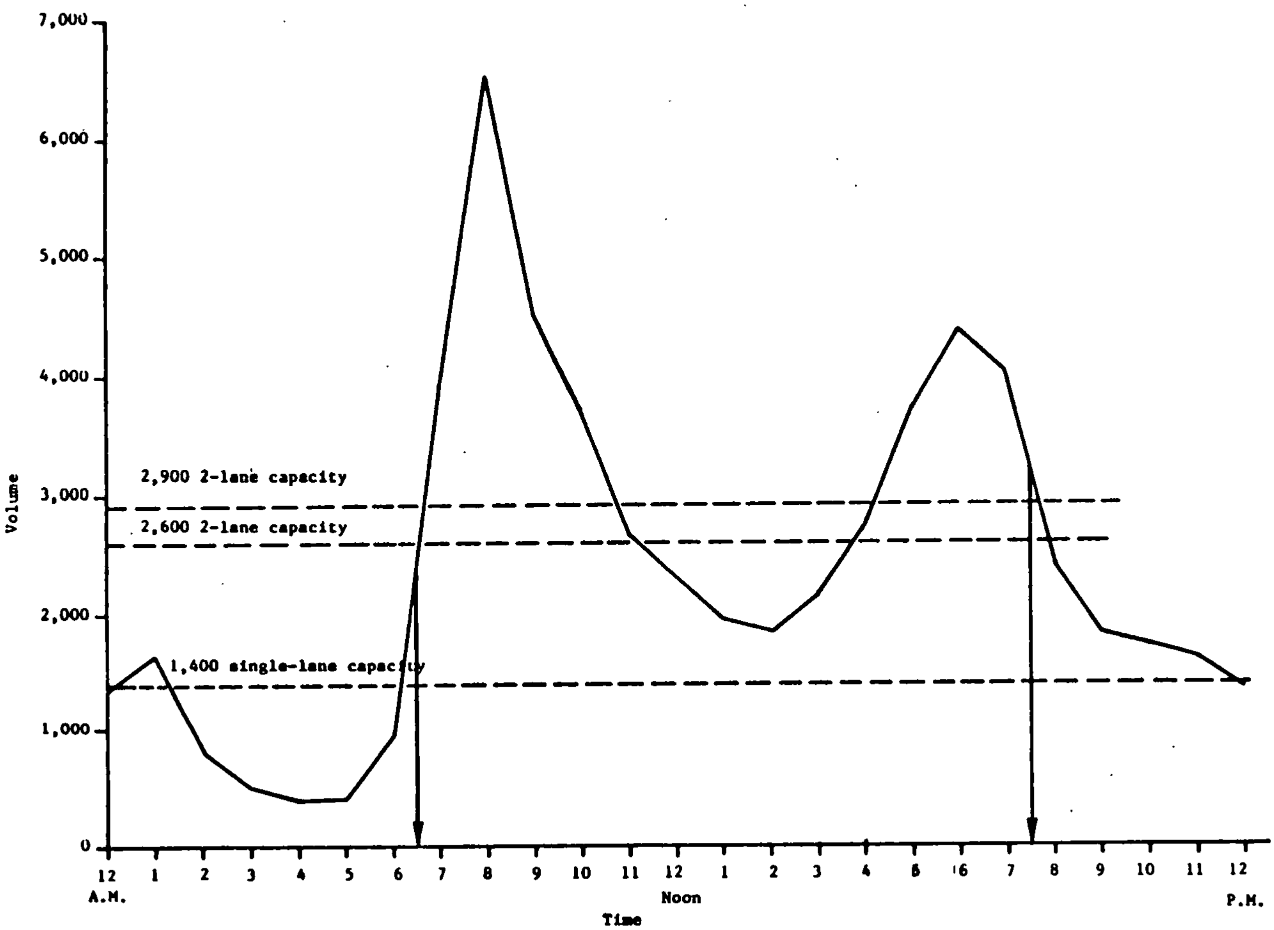


FIGURE 5 Volume distribution for three-lane freeway (*12*).

mine when the maintenance work can be performed. Figure 5 presents a representative volume distribution for a six-lane (three-lane bi-directional) freeway (*12*). Superimposed on this distribution is the maximum volume of two lanes or one lane for an acceptable level of service. This is then used to determine the hours of the day when lanes can be closed, and traffic disruptions minimized.

Some agencies have developed tables for their various freeway sections. An example of a table used by Missouri is shown in Table 11. The table indicates the hours that should be avoided (i.e., when the demand exceeds the freeway capacity with one lane closed). A lane volume threshold is used by some agencies. This threshold varies depending on the allowable capacity figures used by the agency. Lane volume threshold used by selected agencies is shown in Table 12 (*12*). As can be seen in this table, agencies use different allowable lane volumes that range from 1200 to 1800/hr, depending on the degree of backup permitted or delay that can be tolerated for a given section of freeway.

Capacities for Typical Maintenance Operations

Some agencies have also determined capacities for freeway sections by classification of maintenance operation. Some observed capacities for typical applications are shown in Table 13 for various multilane categories of freeway. Dudek and Richards (*18*), based on studies they conducted, developed a set of average capacities for lane closures through work zones (Table 14). It should be noted in using Tables 13 and 14 that capacities are affected by a number of factors such as profile grades, percentage of commercial vehicles (trucks), shoulder clearances, spacing of ramps entering or leaving the freeway, horizontal alignment, lane widths, diversion of motorist attention, etc.

It can be seen from the information presented that the range of lane capacities may vary considerably, depending on the physical characteristics of each freeway. The *Highway Capacity Manual* (*19*) provides procedures for determining lane capacities for freeways. It also has examples of existing highways and actual traffic volumes observed for various periods of time.

Delay Influence on Scheduling Lane Closures

Work zones often delay motorists from reaching their destinations. Factors influencing delay can include the number of closed lanes, approach volume of traffic, and time of closure, as well as length of any detours.

Shepard and Cottrell (*12*) defined two types of delays in their study of work zones. If there is crack sealing or other activity that warrants a closure of significant length, then there may be a delay caused by the *speed and distance change* that is created over the entire length of the work site. Other maintenance activi-

TABLE 11

VOLUME-CAPACITY TABLE FOR A FREEWAY SECTION (MISSOURI)

I- 44 EAST BOUND

CAPACITY WITH ONE LANE CLOSED

HOURLY VOLUME

HOUR ENDING	(1292)	(1602)	(1634)	(1292)	(1602)	(1292)	(1602)
1 AM	165	210	194	148	135	2C5	495
2 AM	144	214	186	106	122	176	465
3 AM	166	199	199	89	136	183	2C7
4 AM	157	181	179	90	125	156	214
5 AM	242	320	287	150	205	252	250
6 AM	648	998	891	545	820	828	572
7 AM	1255	1725●	1550	1151	1569	1839●	1851●
8 AM	1216	1649●	1560	1113	1701●	2215●	2855●
9 AM	618	961	847	625	798	1177	1631●
10 AM	643	1006	896	630	764	1035	1328
11 AM	643	947	830	645	713	927	1274
12 AM	619	835	752	641	679	855	1346
1 PM	568	861	745	647	666	855	1298
2 PM	606	924	810	701	723	900	1497
3 PM	735	1108	971	880	929	1C34	2062●
4 PM	788	1263	1115	964	1015	1134	2644●
5 PM	1C59	1596	1362	999	1224	1415●	2277●
6 PM	720	1102	896	966	876	1129	2024●
7 PM	541	867	692	681	637	820	1541
8 PM	402	590	477	525	441	577	1294
9 PM	363	465	398	413	325	457	816
10 PM	374	530	413	356	330	413	718
11 PM	295	468	388	317	347	412	760
12 PM	237	385	325	227	274	340	619

● VOLUME GREATER THAN CAPACITY WITH ONE LANE CLOSED

ties may have a very short or "spot" work zone location that generally causes delay to motorists approaching the work zone. For a "spot" improvement, such as pavement patching, the primary cause for the delay can be considered a *capacity restriction* caused by the lane closure at the location of the work site.

Speed and Distance Change

Delays caused by reduced speed through the work zones and detours may be estimated. The following formula may be used to determine such delays (*12*):

$$\text{Delay} = \frac{D_w}{S_w} - \frac{D}{S}$$

where:

D_w = work zone route distance, miles
S_w = average work zone route speed, miles per hour
D = normal route distance, miles
S = average normal route speed, miles per hour

The distances D_w and D will differ based on the length of a detour or alignment change. If there is no alignment change or detour, then D_w and D would be equal.

TABLE 12
LANE CAPACITY (*12*)

Area	Veh/hr/lane	Comments
Los Angeles	1,500 - 1,800	a) 1,500 - usually no congestion unless more than one lane is closed. b) Sometimes use 1,800 (with some backups to give contractor more time).
Atlanta	1,200 - 1,500	a) No daytime closures for Atlanta. Depending on the area, no daytime closures if 2 or more lanes are closed.
Chicago	1,300 - 1,500	a) Depends on location, number of ramps, etc.
Detroit	1,200 - 1,500	a) 1,200 - volume before backups start. b) 1,500 - expect serious backups.
Raleigh	1,300 - 1,600	a) Depends on area and experience.
Long Island	1,500	a) If closure is 2 or more lanes, have to detour traffic and work at night.
Philadelphia	-	a) Closures based on experience.
Dallas	1,300 - 1,500	a) In many cases will accept daytime backups rather than work at night.
Houston	1,200 - 1,500	a) >1,200 - start worrying. b) 1,500 - requires a detailed analysis of the situation. c) >1,500 - only with special traffic management.
Norfolk	1,500	a) 1,500 maximum at 35 mph without backups.

TABLE 13
SUMMARY OF OBSERVED CAPACITIES FOR SOME TYPICAL OPERATIONS (VPH) (*6, 17, 18*)

	No. Lanes One Direction (Normal Operation/During Work)				
Type of Work	3/1	2/1	5/2	3 or 4/2	4/3
Median Barrier/Guard Rail Installation/Repair	-	1,500	-	3,200 2,940	4,800 4,570
Pavement Repair	1,050	1,400	-	3,000 2,900	4,500
Resurfacing, Asphalt Removal	1,050	1,200 1,300	2,750	2,600 2,900	4,000
Striping, Slide Removal	-	1,200	-	2,600	4,000
Pavement Markers	-	1,100	-	2,400	3,600
Bridge Repair	1,350	1,350	-	2,200	3,400

Capacity Restrictions

The *Highway Capacity Manual* (*19*) includes capacity restrictions for various construction activities that may be used for determining delays. If there is a length to the work zone activity, both the speed and distance change and the capacity restriction must be taken into account in making a determination as to the total delay that will result from the lane closures for the maintenance activity. More information for determining total delay can be found in the report by Shepard and Cottrell (*12*).

TABLE 14
AVERAGE CAPACITIES FOR DIFFERENT WORK ZONE CLOSURES (*18*)

No. Lanes One Direction	No. Lanes Open One Direction	No. Studies	Average Veh/hr	Capacity Veh/hr/lane
3	1	5	1,130	1.130
2	1	8	1,340	1,340
5	2	8	2,740	1.370
4	2	4	2,960	1,480
3	2	8	3,000	1,500
4	3	4	4,560	1,520

If there is a need for lane closures, another possible source for determining the delay caused by a maintenance activity is a report by Morales (*20*) that uses analytical procedures for estimating traffic congestion. This paper deals primarily with incident management, but has similar principles that can be applied to lane closures.

Lane Closure Computer Model—QUEWZ

The Texas Transportation Institute of Texas A&M University in cooperation with the Texas SDH&PT has developed a computer model for use as a design and management tool for scheduling maintenance work on Houston freeways (*21*). The computer model is known as QUEWZ (Queue and User Cost Evaluation of Work Zones) (*22, 23*). It evolved as a result of the Houston district's need for a quick reference tool to determine what additional daytime hours were available for lane closures for maintenance work. Heavy traffic volumes had forced all maintenance work to be performed during nighttime and weekend hours. Unfortunately, these hours still did not provide sufficient time to complete all maintenance work. The computer model used assumed lane capacities matched against demand to arrive at hours when delays could be tolerated during daylight hours. The model only addresses single-lane closures and is being modified for use on personal computers as a design tool for developing traffic control plans for freeway work zones. This computer program is available and in use by a number of state transportation and highway agencies.

Delay Criteria

Driver operating habits and public tolerance of traffic congestion vary widely in locations around the United States. These variances affect freeway capacities as well as the length of time motorists will tolerate delays on freeways caused by incidents or maintenance operations that reduce the normal freeway capacity. The Los Angeles district of Caltrans has determined that the motoring public in Los Angeles will generally tolerate a 20-minute delay on freeways, unless there are special events or circumstances that warrant lowering this general guideline. The 20-min delay is also used as the criterion in Texas when potential disruptions to traffic flow for maintenance activities are considered.

CHAPTER FIVE

PUBLIC-INFORMATION AND NEWS MEDIA CONTACTS

Good public relations is an essential element of the successful management of urban freeway maintenance activities. Most agencies surveyed have established routines and practices regarding the advance notice of freeway or lane closures that are required for maintenance activities. In addition to maintaining in-house public-relations efforts and communicating with news media, agencies planning urban freeway maintenance must keep other agencies that may be affected by maintenance activities (e.g., those mentioned in Chapter 3) informed.

AGENCY PUBLIC-INFORMATION EFFORTS

A number of state highway and transportation agencies are becoming more conscious of public-relations needs and they employ public-information specialists to assist in the management effort at the local level. A public-information office receives notices of highway maintenance activities and transmits these to the various news media, which in turn notify the motoring public of areas where traffic congestion may be expected as a result of maintenance activities. Developing and fostering a good relationship with the news media can be of great assistance to the maintenance manager by providing for a more informal exchange of information. The result may be a better understanding of the overall maintenance program by the media and the public.

All agencies indicated that they use press releases to the various news media (radio, television, and newspapers) in advance of and during planned lane or freeway closures. Some agencies furnish teletypes, recorded telephone messages, and highway advisory radio communications to provide information about maintenance work. These sources list the freeway locations and dates and times of lane closures in advance of the start of the work. Some agencies meet with the news media in the spring before the major maintenance season commences. This affords an opportunity to provide an overview of the maintenance management program for the entire season.

The Chicago District of the Illinois Department of Transportation furnishes to the news media by 5 a.m. each day a computer printout that shows the day's maintenance schedule and lane closures. These reports are generated daily by the traffic systems center, which operates the computerized freeway traffic surveillance and control system for metropolitan freeways in Chicago.

If maintenance work is required on a given section of freeway, some agencies place information signs on the freeway at least a week in advance of the scheduled work to alert the motoring public of the planned work and the scheduled dates for the actual work.

NEWS MEDIA PUBLIC-INFORMATION EFFORTS

Print, radio, and television communications to the motoring public are generally effective. However, the effectiveness of the message depends on the extent of the data or information provided by the highway agency in the urban or metropolitan area. Most news media recognize the value of providing this type of service, and some have provided staff or created special programs that complement the efforts of the highway agency. It also helps if news media personnel are willing to visit some of the sites and observe some of the conditions.

For example, in Houston two of the local newspapers have special staff persons assigned to handle and release the notices furnished by the Houston district of the Texas SDH&PT. Personally dealing with the same media personnel and getting to know their requirements and deadlines simplifies the task of providing dates and locations of lane closures and other pertinent information.

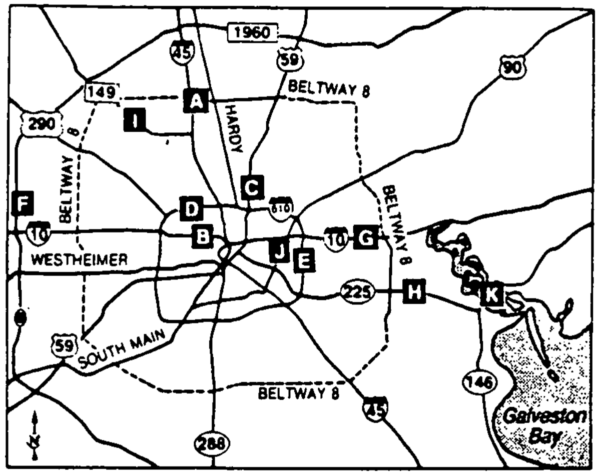
One Houston newspaper has generated a computerized map of the metropolitan freeways as shown in Figure 6. This map is published daily with information from the district highway office listing the freeways and showing the locations where work is to be performed the next day. This gives the motorists a visual aid to assist in planning their trips on the freeway system.

In Chicago several radio stations have traffic news reporters who have computer terminals in their offices that are compatible with the district's traffic systems center. Each traffic reporter reviews the cathode-ray tube (CRT) display directly and reports on the current peak-hour traffic conditions monitored by the traffic systems center. Using their knowledge of the historical patterns, each traffic reporter directly interprets the CRT display and reports the traffic patterns, which are often directly related to maintenance activities that are in progress on the metropolitan Chicago freeway system.

Today very few urban areas are without one or more "eye in the sky" helicopters from which traffic conditions can be reported directly to the motoring public. Using this view from above, the freeway maintenance manager can improve the techniques of maximizing operational efficiency on the urban freeway network.

GETTING AROUND HOUSTON

This column provides information on activities affecting travel by private automobile and public transit in the Houston area. For more information, call the state highway department at 869-4571, extension 704 or 708.



TODAY

A. North Freeway: northbound — FM 525 to North Belt — one inside lane closed 9 a.m. to 3 p.m. for drainage improvements; northbound — entrance ramp between Airline and Tidwell — closed until further notice for construction; northbound — Quitman to Link — one outside lane closed 6 a.m. to 2 p.m. for pavement repair; north- and southbound service roads — Crosstimbers to Gulf Bank — one inside lane closed 7 a.m. to 5 p.m. for retaining wall construction; southbound — U-turn at Crosstimbers — closed 7 a.m. to 5 p.m. for retaining wall construction; southbound — Little York to Airline — alternate blocking of lanes 8 p.m. to 5 a.m. Thursday for striping; southbound — Airline to North Loop — one outside lane closed 9 a.m. to 6 p.m. for pavement repair; southbound — Tidwell to Crosstimbers — two inside lanes closed 8:30 p.m. to 5:30 a.m. Thursday for pavement repair; southbound — Patton to Quitman — alternate blocking of lanes 10 a.m. to 5 a.m. Thursday for pavement repair.

B. Katy Freeway: eastbound — Heights to Studemont — three outside lanes closed 9 a.m. to 9 p.m. for pavement repair.

C. Eastex Freeway: northbound — Greens Road to Will Clayton Parkway — one outside lane closed 8 a.m. to 3 p.m. for pavement repair; north- and southbound — at Bennington — one outside lane closed 7 a.m. to 5 p.m. to place concrete median barrier; north- and southbound — Mount Houston to Aldine Mail Route — one inside lane closed 7 a.m. to 3:30 p.m. to place concrete median barrier.

D. North Loop: eastbound — T.C. Jester to Yale — two outside lanes closed until further notice for construction.

E. East Loop: north- and southbound — at Ship Channel Bridge — one inside lane closed 9 a.m. to 3:30 p.m. for bridge inspection.

F. Texas 6: north- and southbound — Clay Road to Interstate 10 — one outside lane closed 7 a.m. to 6:30 p.m. for pavement repair.

G. East Freeway (I-10 East): westbound — Thompson to Monmouth — two inside lanes, and entrance ramp from Spur 330, closed until further notice.

H. Texas 225 (La Porte Freeway): eastbound — Shell overpass to Texas 146 — alternate blocking of lanes 7 a.m. to 3:30 p.m. for pavement repair.

I. FM 149: east- and westbound — Champion Forest Road to Seton Lake — one outside lane closed 7 a.m. to 6 p.m. for pavement repair.

J. U.S. 90A (South Main): north- and southbound — Market Street to Buffalo Bayou — alternate blocking of lanes 9 a.m. to 5 p.m. for guardrail repair.

K. Texas 146: north- and southbound — at Baytown Tunnel — alternate one-way operations 10 p.m. to 5 a.m. Thursday for lighting repair.

FIGURE 6 Newspaper map showing freeway work (Houston).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

It can be concluded from this synthesis that the area of managing urban freeway maintenance is a dynamic field. It is one that must continue to be addressed openly in seeking innovative ways to effectively match available resources and personnel in an effort to maintain urban freeways efficiently and safely while minimizing inconvenience to the motoring public.

Among those items that remain critical to this task are the following:

- Once the annual maintenance program is defined it is essential for the maintenance manager to determine what activities can be performed most efficiently by contract and what should be performed by agency forces.
- For maintenance to be performed effectively, it is important to develop efficient and well-trained work crews that know their assignment and can execute the work in a safe and efficient manner.
- It is necessary to have knowledge, on a continuing basis, of the traffic demands and available capacity so that maintenance can be scheduled during the hours and days that minimize disruption to traffic and provide safe conditions for the motoring public and the work force.
- Agency policies that can be defined should be in written form to provide consistent communications to the agencies and individuals responsible for performing the work, as well as to provide guidelines for those involved in the approval process.
- Agencies must maintain clear and timely communication and close cooperation with the various news media.
- A flexible approach to problem solving must be maintained by all agencies involved in managing freeway maintenance activities.
- Better methodologies for protecting the motoring public and the work force involved in performing maintenance activities must be developed. This will require innovative thinking to develop better plans while minimizing the trade-offs between productivity and highway safety.
- Communication channels should be kept open between the maintenance division and the various other operating divisions within the overall highway agency. This will ensure the cooperation that is necessary to achieve the desired goals and objectives.

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