Benefits and Safety Impact of Night Work-Zone Activities

FRANK D. SHEPARD AND BENJAMIN H. COTTRELL, JR.

A literature review and discussions with highway and transportation officials in several states provided information on issues relating to the planning, safety, and traffic control aspects of night maintenance and construction activities, and their advantages and disadvantages. The information was used to develop general guidelines for nighttime maintenance and construction work. Although there are many potential disadvantages to working at night, it is believed that experience, proper planning, and attention to workmen and motorist safety make the night alternative feasible for selected work.

The rehabilitation and improvement of freeways, particularly in urban areas, entail considerable problems when closing traffic lanes for these activities creates heavy congestion on roads already loaded to capacity. The consequences are adverse effects on the safety of the traveling public and highway workers, and inconvenience and cost to the delayed motorists, which can lead to adverse public reaction. To minimize such effects, many agencies restrict roadway maintenance activities to hours of off-peak traffic, weekends, and nights. While conducting work during off-peak daylight hours (e.g., 9 a.m. to 3 p.m.) is feasible in some areas, there are many situations where lanes cannot be closed during the day because of high traffic volumes.

To avoid some of the problems encountered in daytime work, nighttime operations have been employed on numerous occasions around the country. In California, it was reported that a concrete paving operation conducted at night was completed in 16 working days, whereas it would have taken at least 35 working days to complete during daylight because of the fewer working hours and more interference from heavy traffic *(1)*. During the nighttime paving operation, traffic flow was at near-normal speeds.

Although night work is being conducted in numerous areas around the country, and is on the increase, important considerations concerning the safety of the motorist and the worker must still be met. Visibility is greatly reduced at night, some drivers are less attentive and travel faster than in daylight, and more impaired drivers are reported to be involved in work-site incidents and accidents. Also, night work creates problems concerning work forces, work scheduling, material acquisition, quality of work, and so on. The research to examine the problems inherent to conducting highway operations at night is described in this paper.

The research was conducted to (a) compile information on current practices in conducting highway maintenance and construction operations at night, and (b) to synthesize the information into guidelines for determining when nighttime work should be done and what traffic control devices should be employed.

The information developed for this paper was obtained from a survey of available literature on nighttime work-zone activities and discussions with personnel in those states and agencies that have developed expertise in night maintenance and construction operations.

Virginia Highway and Transportation Research Council, Box 3817 University Station, Charlottesville, Va. 22903-0817.

CONSIDERATIONS FOR CONDUCTING NIGHT MAINTENANCE AND CONSTRUCTION OPERATIONS

There are two main reasons for conducting night operations: (a) to allow work over a longer period of light traffic than is possible during the off-peak period between the morning and afternoon rushes, and (b) to decrease or eliminate the excessive traffic delays and congestion associated with lane closures during the daytime.

Certain types of road work require more time than is available between the morning and afternoon peaks. For example, a cast-in-place concrete patch in a pavement may require more time for setting than is available between the peak traffic periods.

Although the short length of time available for daytime operations dictates that some types of work be done at night, the interviewees for this research stated that the interference with traffic from daytime lane closures was their primary reason for scheduling night work. The basic factors considered in planning night operations and their interrelationships are discussed.

Agency Policy

Based on experience, and as a response to public and political pressure, some states have issued policy statements that dictate the levels of traffic and other criteria that should be considered when deciding if night operations are warranted.

Traffic Impact

The manner in which traffic volumes are factored into decisions on whether or not to conduct maintenance operations at night varies from state to state and largely depends on how much traffic can be allowed to back up, what the motoring public will tolerate, and the characteristics of the roadway. Some states will allow traffic to back up over long distances to avoid having to work at night, especially if the lane closure can be limited to one or two days, which indicates that night operations are viewed as a last alternative. A series of daily lane closures resulting in continuous congestion are usually followed by adverse public and media reactions leading to adoption of the night-work alternative.

Determination of traffic volumes is necessary to estimate the congestion created by lane or road closures. Also, knowing the daily variations in traffic volumes is helpful to pinpoint the low-volume periods for scheduling work. Although there are some who claim to know, either through experience or judgment, the conditions under which traffic volumes will cause undesirable daytime congestion, there are others who go through a detailed analysis in

estimating congestion and must rely on reliable or recent traffic-volume counts.

Estimates of traffic volumes are usually available from data taken at permanent traffic-count locations; however, care should be taken to ensure that the data are reliable. The data should be current, and should be for time periods similar to those during which it is anticipated the work will be done and for the vicinity of the work zone, because ramps between the count station and work zone can significantly influence recorded volumes.

Analysis of Congestion

The ability of a lane closure strategy to accommodate traffic is the main determinant of whether operations will be conducted during the day or at night. Any strategy that does not adequately accommodate the traffic demand during the anticipated lane closure necessitates consideration of alternatives to daytime work, especially if the strategy imposes excessive congestion.

A procedure frequently used to investigate congestion is simply to plot the hourly volumes for the time period during which the work is to take place. For example, Figure 1 shows the volume distribution on a three-lane freeway during the probable construction period along with estimated capacities for the work area. It is apparent that two lanes will handle the demand during the midday period; however, this time period is too limited for the work to be accomplished. Also, the analysis indicates that there is a lengthy period of time each night when two lanes can be closed and only one lane will be needed to handle the traffic. The times at which the lanes can be closed and reopened to traffic can also be obtained by noting when the traffic demand and capacity are in the same range.

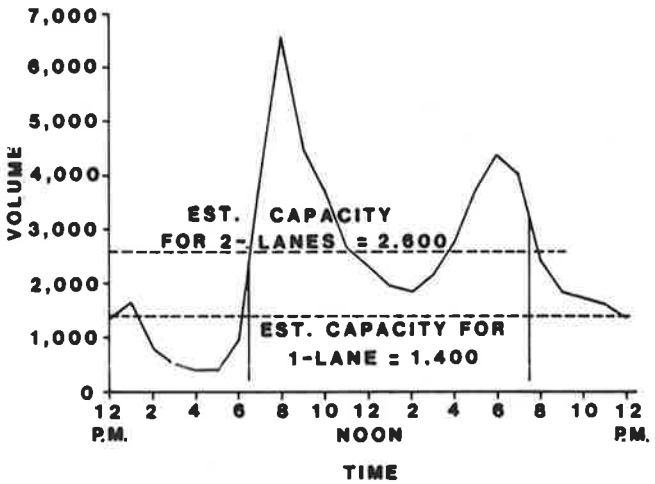

FIGURE 1 Volume distribution for three-lane freeway and estimated work-area capacities.

Clearly, an estimate of traffic capacity that can be accommodated through a work zone is an important consideration in the planning process.

Capacity

Some states and agencies have developed general guidelines for lane capacities based on their policies and experience, the work area, the type of work to be done, and so on. Table 1 summarizes these lane capacities in vehicles per hour per lane (vphpl). These capacities and comments provide a general guide to the capacity level at which the agencies would start considering night operations. Lane capacities for typical operations in California and Texas are given in Table 2, which notes that the type of work affects the capacity. Table 3 gives the average capacities for different lane-closure situations taken from 37 studies in Texas.

TABLE 1 GENERAL GUIDELINES FOR LANE CAPACITY

Area	Capacity (vphp)	Comments
Los Angeles	1,500–1,800	Usually no congestion unless more than one lane is closed for 1,500 vph Sometimes use 1,800 vph with some back ups to give contractor more time
Atlanta	1,200–1,500	No daytime closures. Depending on the area, no daytime closures if two or more lanes are closed
Chicago	1,300–1,500	Depends on location, number of ramps, and so on
Detroit	1,200–1,500	Volume before back ups start for 1,200 vph Expect serious back ups for 1,500 vph
Raleigh	1,300–1,600	Depends on area and experience
Long Island	1,500	If closure is two or more lanes, will detour traffic and work at night
Philadelphia	–[a]	Closures based on experience
Dallas	1,300–1,500	In many cases will accept daytime back ups rather than work at night
Houston	1,200–1,500	Start worrying for >1,200 vph Detailed analysis of the situation required for 1,500 vph <1,500 vph only with special traffic management
Norfolk	1,500	1,500 vph maximum at 35 mi/hr (56 km/hr) without back ups

Note: Capacity is given in vehicles per hour per lane (vphpl).
[a]Not applicable.

Delay

Work-zone closures often cause delays to motorists, with the magnitude of the delay depending on many factors such as the number of lanes closed, approach volume, time of closure, and length of any detours. An estimate of the impacts of vehicle delay is an important part of the analysis of the effects of work zone lane closures. Vehicle delay is divided into two categories:

1. Speed and distance change: delays due to speed changes, increased travel distance (detours), or both.
2. Capacity restriction: delays due to insufficient capacity causing vehicle queueing.

Other Considerations

Other factors that should be considered when contemplating night operations are listed. It is emphasized that each construction or maintenance job differs in some respect from others and each should be considered individually.

TABLE 2 SUMMARY OF CAPACITIES FOR TYPICAL OPERATIONS IN CALIFORNIA AND TEXAS

Type of Operation	Two Lanes in One Direction with One Open		Three Lanes in One Direction with One Open		Three or Four Lanes in One Direction with Two Open		Four Lanes in One Direction with Three Open	
	California	Texas	California	Texas	California	Texas	California	Texas
Median barrier or guardrail repair or installation	1,500	–[a]	–[a]	–[a]	3,200	2,940	4,800	4,570
Pavement repair	1,400	–[a]	–[a]	1,050	3,000	2,900	4,500	–[a]
Resurfacing, asphalt removal	1,200	1,300	–[a]	1,050	2,600	2,900	4,000	–[a]
Bridge repair	–[a]	1,350	–[a]	1,350	2,200	–[a]	3,600	–[a]

Note: Capacity is given in vphpl.
[a]No data available.

TABLE 3 AVERAGE CAPACITY FOR DIFFERENT WORK-ZONE CLOSURES

No. Lanes in One Direction	No. Lanes Open in One Direction	No. Studies	Average Capacity	
			Vph	Vphpl
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

- Supervision and communication,
- Work force morale,
- Material acquisition,
- Labor unions,
- Parts and utility service,
- Noise,
- Lighting,
- Quality of work,
- Efficiency of operations,
- Law enforcement, and
- Liability.

SCHEDULING LANE AND ROAD CLOSURES

Night operations should be scheduled to avoid peak travel periods that may lead to congestion. Also, the schedule should consider peak shopping periods, holidays, and special events.

The scheduling of night operations to avoid or minimize delay requires knowledge of the hourly traffic volumes. For example, in Figure 1, which shows the hourly volume distribution for the work area, it is observed that around 7:30 p.m. traffic volumes diminish to the point that little or no delay would result from a lane closure. Traffic volumes remain low enough throughout the night to allow closures without congestion until approximately 6:30 a.m., at which time the morning peak starts.

Adequate time should be given for opening the lanes to traffic in the morning because the traffic volumes increase rapidly during the morning peak, and a delay in reopening the lanes could result in sizeable back ups.

COST OF WORK-ZONE OPERATIONS

Because of policy decisions or unacceptable daytime traffic delays associated with lane closures, there are many situations where night work must be done regardless of cost; however, cost can be taken into consideration for whether work will be done during the day or at night. The delays, queuing, and so on, associated with day and night operations can be assigned costs, and can be combined with the operation and agency costs to obtain an estimate of the total cost of the project.

The costs associated with day or night maintenance and construction work-zone operations can be subdivided into the following general categories:

- Speed and distance change,
- Queuing,
- Vehicle operating cost,
- Accident cost, and
- Agency costs.

SAFETY

The concern for safety in nighttime maintenance and construction work zones is of utmost importance. The motorist is presented with unique and often unexpected situations where a lane, lanes, or an entire roadway is closed at night when visibility is limited and relatively more drivers are impaired from sleep, under the influence of drugs or alcohol, and so on. These conditions, coupled with the higher speeds generally prevailing at night, add a new dimension to safety considerations. Although night operations are potentially more hazardous, there are several factors that could offset the increased potential for accidents. For example, the reduced volume of traffic at night may be safer and easier to control than daytime traffic with its higher volumes and congestion. It is difficult to compare the safety aspects of night work as opposed to those for day work because of the lack of comparable data.

PUBLIC RELATIONS

Public relations are an important element in nighttime construction and maintenance activities and can facilitate the success of an operation in terms of reduced congestion, increased safety, and

goodwill. With regard to a pavement resurfacing project, one official interviewed for this research noted that "on paper it was thought that traffic would be backed up for miles; however, after a media blitz, no back ups occurred." Various means of informing the public about night operations are discussed. It is difficult to state how extensive the coverage would be because the size of the project, location, traffic volume, experience of the agency, and availability of techniques, can all have an influence. It is believed that the payoff exceeds the cost in time and money for disseminating information, and that all available means of informing the public should be considered. One state official commented: "We go to extremes to get the word to the public that there will be pavement reconstruction upcoming."

It is interesting to note that although releases to newspapers, and radio and television stations constituted the most frequently used technique, the respondents to a survey *(2)* thought that special signs, door-to-door personal contact, and personalized letters were more effective.

Some states have used elaborate procedures to provide the public with information on upcoming maintenance and construction operations. The basic comprehensive plans prepared for major freeways in the Chicago area are a good example. The plans included descriptions of traffic routing, detailed maps, schedules for work, and an explanation of work to be undertaken. Agency officials met with the local radio, newspaper, and television companies for a special press conference. This special effort led to surprisingly little congestion and generally good public understanding and acceptance of the associated inconvenience.

Another example of a comprehensive plan for informing the public is that used for night closing of major freeway sections in the Detroit area. A color map detailing the detour route was distributed along with information on the closure area and time, and other pertinent information.

TRAFFIC CONTROL FOR NIGHT WORK-ZONE ACTIVITIES

The objectives of traffic control are (a) to ensure the smooth and safe movement of vehicles through the work zone, and (b) to provide safety for the workmen and the equipment in the work zone *(3)*. Drivers must be alerted to the hazards presented by the work zone and guided safely past them.

A hazardous condition is created by a lane closure on a roadway carrying a high volume of traffic. The importance and cost of controlling the traffic are emphasized by the following statement. "The development of traffic handling plans must be given as much comprehensive professional attention as is required for the physical repairs themselves. Agencies must be prepared in some instances to spend as many, or more, dollars on the traffic handling requirements of the project as on its basic construction features." *(4)*

Part 6 of the national Manual on Uniform Traffic Control Devices (MUTCD) states that night maintenance and construction activities increase the problems associated with delineating the work area and placing warning devices, mainly because of the reduced visibility at night *(3)*. Consequently, night activities necessitate increased use of warning lights and illumination or reflectivity for work areas and advance warning systems. The specific elements of traffic control are addressed in the section on general guidelines for night operations.

ADVANTAGES AND DISADVANTAGES OF NIGHT OPERATIONS

Note that because of the many variables associated with night work-zone operations, and because no two jobs are exactly alike, some of the advantages and disadvantages cited may not apply to every project, although they do reflect the overall attitude toward night operations.

Advantages

Major advantages of working at night as compared to working during daytime are listed for partial and complete roadway closures:

1. Avoidance of traffic congestion and motorist delay, which is the primary benefit,
2. Opportunity to enlarge work areas and to concurrently conduct multiple work functions,
3. Longer and more productive working hours,
4. Improved working conditions with less traffic interference and less heat,
5. Use of the full capacity of the production plant,
6. Better public relations and fewer motorist complaints, and
7. More efficient hauling because of less congestion.

Complete roadway closure allows for

1. Increased worker safety,
2. Higher efficiency in work performance,
3. Safer movement of vehicles, and
4. Shorter set-up time.

Disadvantages

The possible disadvantages of night work-zone activities as compared to daytime operations are listed for partial and complete roadway closures:

1. More prevalent driver drowsiness, inattentiveness, and intoxication (alcohol and drugs);
2. Greater potential for more severe accidents because of the higher accident rate at night coupled with higher speeds;
3. Unexpected conditions with restricted driver visibility;
4. Lessened visibility for the workmen, even with supplemental lighting, especially for tasks requiring accurate depth perception;
5. Adverse public reaction to noise in residential areas and restrictive noise ordinances;
6. Impaired communications between work-site personnel and main offices, media, police, and so on;
7. Low worker morale and difficulty in recruiting personnel in spite of pay incentives;
8. More employees working two jobs;
9. Difficulty with crew becoming accustomed to night work;
10. Problems in obtaining materials because some plants do not remain open;
11. Problems with quality control;
12. Difficulty in repairing equipment breakdowns;

13. Lower quality workmanship;
14. Difficulty in obtaining service from utilities;
15. Pressure to ensure completion of job or to have road open prior to morning rush period;
16. Higher cost for some operations because of pay differentials, increased traffic control, material acquisition, and so on; and
17. Less advance notice of impending poor weather.

Complete roadway closure results in

1. Problems with communication and coordination with local officials, for detours;
2. Additional traffic control, noise, environmental considerations;
3. Concern for capacity on detour routes;
4. Public resentment of detours and associated consequences;
5. Increased project costs if there is a need to improve the detour route; and
6. Degradation in safety.

GENERAL GUIDELINES FOR NIGHT OPERATIONS

The following general guidelines are offered as an aid in decisions concerning night construction and maintenance operations on high-traffic freeways. Included are factors and general criteria that should be used in deciding if night operations are feasible.

1. Evaluate proposed project.
2. Examine relevant traffic data.
3. Estimate roadway capacity for proposed project.
4. Determine potential daytime vehicle delay using aforementioned input.
5. Analyze feasibility of night work:
   a. Determine if delays associated with potential daytime closures (Step 4) will be excessive.
   b. Determine if cost is a factor including possible extra costs of day work, and possible cost savings.
   c. Determine if adequate time is available during night for work.
   d. Decide if possible secondary considerations are significant:
      (1) Safety including hazard potential, poor visibility, high speeds, impaired drivers;
      (2) Noise including noise ordinances and proximity to residential areas, hospitals; and
      (3) Quality of work, which may be lower quality.
6. Analyze feasibility of closing entire roadway:
   a. Determine if alternate detour routes are available;
   b. Determine if alternate routes have capacity for extra volume;
   c. Determine if traffic control (e.g., signs, signals, etc.) is adequate for traffic mix (e.g., cars, trucks, etc.); and
   d. Identify potential problems in coordinating and communicating with local officials.
7. Decide on night operations.
8. After deciding to conduct night operations:
   a. Perform advance planning,
   b. Ensure adequate advance public information,
   c. Emphasize safety through-traffic control,
   d. Schedule times for closing and opening roadway keeping in mind that work has to be completed and road has to be open to traffic in time to carry the morning peak traffic, and
   e. Continue to monitor project for possible improvements.

Guidelines for traffic control follow.

1. Develop a traffic control plan (TCP) using the standard procedure for the agency with emphasis on increased illumination and reflectivity to increase the visibility of traffic control devices.
2. Use the following elements of work-zone traffic control in the TCP (recommended):
   a. 48-in. x 48-in. or larger reflective warning signs with flashing yellow warning lights and orange flags;
   b. Drums, Type I or Type II barricades, with steady-burn yellow warning lights spaced in conformance with the MUTCD or agency standard (in most cases, this will be approximately 55 ft in the taper);
   c. Desirable and absolute minimum sight distances of 1,500 and 1,000 ft, respectively, to the lane closure;
   d. A flashing arrowboard located within the taper for each lane that is closed; and
   e. A physical deterrent, such as a truck or impact attenuator, immediately in advance of the work area.
3. Consider using the following elements in the TCP (optional):
   a. Advance warning by changeable message signs;
   b. Additional advance warning signs in advance of the end of the queue when lengthy delays causing back up of more than 1 mi from the closure is expected; and
   c. Emergency or enforcement controls, special controls, and flagging operations as needed and at the discretion of the person responsible for the TCP.
4. Use the typical traffic control layouts that conform with the state policy or the MUTCD as the basis for the TCP.
5. Monitor the effectiveness of the TCP to identify and then correct any problems. This requires that a person responsible for traffic control be on site for the duration of the work activities.

CONCLUSIONS

The question of whether to conduct construction or maintenance operations at night is difficult to answer because of the numerous considerations involved. The key consideration is the degree of congestion or vehicle delay caused by daytime lane closures. Although some agencies accept long delays as being a part of daytime road work, others do not and opt for night work, even though working at night is usually considered the least attractive alternative. Because of the increased emphasis on maintenance and reconstruction of existing facilities, coupled with the high traffic volumes in urban areas, there is reason to believe that more night operations will have to be scheduled.

Because night operations are conducted under reduced visibility, and there are more impaired drivers traveling at higher speeds than during the day, every effort has to be made to ensure the safety of workmen and motorists. In addition to increased attention to safety, consideration must be given to informing the public in advance of the work scheduled, and it must be recognized that

cost, coordination of the work force, noise, quality of work, and the acquisition of materials are of more than usual concern.

Although there are many potential disadvantages of working at night, it is believed that through the experience that has been gained and proper planning, the night alternative is feasible for selected work.

ACKNOWLEDGMENTS

This research was financed by funds administered through FHWA. The opinions, findings, and conclusions are those of the authors and not necessarily those of the sponsoring agencies.

REFERENCES

1. C. D. Lee. Nighttime Construction Work on Urban Freeways. *Traffic Engineering*, March 1965.
2. J. A. Chipps et al. *Traffic Controls for Construction and Maintenance Work Sites*. Vol. I. Report FHWA-RD-75, FHWA, U.S. Department of Transportation, Dec. 1975.
3. *Manual on Uniform Traffic Control Devices*. FHWA, U.S. Department of Transportation, 1978.
4. A. H. Meyer, W. B. Ledbetter, A. H. Layman, and D. Saylak. *NCHRP Report 196: Reconditioning Heavy-Duty Freeways in Urban Areas*. TRB, National Research Council, Washington, D.C., 1978, 60 pp.

Publication of this paper sponsored by Committee on Maintenance and Operations Management.

Implementation of Work-Zone Speed Control Measures

STEPHEN H. RICHARDS AND CONRAD L. DUDEK

Recommendations for implementing speed control at construction and maintenance work zones are presented. The following implementation steps are identified and discussed: (a) determining the need for speed reduction, (b) selecting a reasonable speed, (c) selecting a speed control treatment based on effectiveness, practicality and cost, and (d) selecting a location for the speed control treatment implementation. Four speed control approaches are studied: flagging, law enforcement, changeable message signs, and effective lane width reduction. The advantages and disadvantages of each of these approaches are discussed. Limited cost data for each of the approaches are also presented. The conclusions and recommendations are based on the results of field studies and observations at numerous street and highway work zones in Texas.

The issue of speed control through highway work zones has been a topic of concern for several years *(1,2)*. Excessive work-zone speeds can adversely affect the safety of the work crew and motorists. In an attempt to control work-zone speeds, highway agencies have followed standard signing practices, but drivers often do not slow down in response to posted speed limits.

Results of field studies conducted in Texas to evaluate selected methods of slowing traffic in work zones to acceptable speeds are presented elsewhere *(3)*. The methods included flagging, law enforcement, changeable message signs (CMSs), and effective lane width reduction. A detailed description of these methods and their effectiveness is presented elsewhere *(3,4)*. A procedure and several considerations for implementing work-zone speed control measures are presented in this paper.

S. H. Richards, Transportation Center, University of Tennessee, Knoxville, Tenn. 37996. C. L. Dudek, Texas Transportation Institute, The Texas A&M University System, College Station, Tex. 77843-3135.

The implementation of work-zone speed control involves several steps: (a) determining the need for speed reduction; (b) selecting a reasonable speed; (c) selecting a treatment based on effectiveness, practicality and cost; and (d) selecting a location for treatment implementation. Also presented is a summary of treatment implementation considerations and limitations.

DETERMINATION OF THE NEED FOR SPEED REDUCTION

Although previous research did not specifically address the issue of when an agency should encourage reduced speeds at a particular work zone, after numerous visits to work zones, several important considerations became apparent.

Credibility

Speed control abuse and misuse at a work zone can render a speed reduction attempt ineffective and can damage the credibility of work-zone speed reduction efforts in general. Abusive practices include using unreasonably low speed limits, and leaving reduced speed limits in place after the work activity is removed.

Specific Goal

As with all traffic control efforts, any attempt to reduce work-zone speeds should be founded on an identifiable need. This need should be established based on engineering study, and not on