REPORT FHWA/NY/SR-94/116

PB99-100240

Night-Time Construction Operations

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SPECIAL REPORT 116

ENGINEERING RESEARCH AND DEVELOPMENT BUREAU
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
Mario M. Cuomo, Governor/John C. Egan, Commissioner

NIGHT-TIME CONSTRUCTION OPERATIONS

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Special Report 116
December 1994

ENGINEERING RESEARCH AND DEVELOPMENT BUREAU
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ABSTRACT

Night-time construction and maintenance operations often generate widespread debate. Advocates defend them as effective tools in minimizing traffic congestion and maximizing operational efficiency of work-zone operations. Opponents voice concern over greater safety hazards and costs of night work, as compared to daytime work. This report assesses the parameters involved, provides guidance in establishing standard procedures, and offers planning recommendations to be applied before and during night work to ensure safe, efficient operations. The report is intended to complement the evaluation system provided by the NYSDOT night construction policy and operational guidelines issued in August 1994 by the Construction Division to maintain and protect traffic (MP&T) during these operations.

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I. INTRODUCTION

Over the past decade, emphasis has shifted from building new facilities to maintaining and improving those already existing. Steadily increasing traffic demand on the aging, sometimes congested infrastructure has prompted this shift, which is likely to continue for the foreseeable future. Reconstruction operations, however, entail great social, economic, and environmental impacts. They not only increase congestion -- often the very problem they seek to rectify -- but also pose serious hazards for motorists and workers, leading to resentment, frustration, and reduction of public support for road-construction funding.

Transportation officials increasingly are resorting to night operations as an alternative to daytime work, so as to minimize traffic congestion and maximize operational efficiency. Although night operations have become common for many transportation agencies, decisions to conduct them are complex. The primary concern is that potentially adverse safety, economic, and productivity impacts may negate the positive enhancement of mobility.

This report was prepared at the request of NYSDOT Chief Engineer Michael J. Cuddy with three objectives: 1) to assess parameters involved in night operations, 2) to provide guidance in establishing standard procedures to assist decision-makers in reaching informed choices concerning appropriate construction schedules, and 3) to outline an advance-planning process for night operations.

A. Background

Rehabilitation projects are undertaken with the intent of enhancing mobility and alleviating congestion caused by heavy traffic on aging facilities. However, improving safety and minimizing negative economic, environmental, and social impacts of work zones present increasingly formidable goals, with traffic volumes continually increasing on urban and suburban roadways. Some agencies thus are turning to night construction to realize these objectives.

The decision to conduct rehabilitation operations at night involves numerous factors, including level of anticipated congestion, safety of workers and drivers, project costs to their owners, cost impacts on highway users, length of uninterrupted work time available, agency and contractor experience
in performing night work, job productivity, quality of work, noise levels, light glare, paving temperatures, and availability of materials.

The magnitude of these influencing factors and the inherent differences among construction operations dictate that night work be considered with extreme caution, to minimize adverse impacts on the public and for the agency performing the work. In 1991, NYSDOT published a night construction policy (1), establishing minimum requirements to be considered before night construction is approved by a Regional Director. It recommends a two-stage analysis, where all primary and secondary factors are considered. The evaluation process begins with qualitative review to assess feasibility, and continues with quantitative assessment of costs and benefits that may be compared to other construction schedules. The policy sets forth general broad outlines for NYSDOT approval of night-construction operations.

B. Objectives of This Report

This report is intended to complement the evaluation system provided by the NYSDOT night-construction policy. It expands on that policy by providing a detailed approach for comparative analysis between a night shift and other alternative work schedules. This framework offers a necessary practical analytical tool to assist regional offices in making informed decisions regarding night operations. It provides a step-by-step decision methodology applicable in early planning and design stages of a project.

The report also includes a comprehensive review of pertinent literature, and examines factors involved in night-construction decisions. It complements the operational guidelines issued in August 1994 by the Construction Division (2) for maintaining and protecting traffic (MP&T) during night operations. Finally, it offers planning recommendations to be followed before and during night work so as to ensure safe, efficient night operations.

C. The Literature on Night vs Day Operations

The literature has been reviewed on night construction and rehabilitation operations, including various operating parameters influencing day and night operations, and impacts of those parameters on the work zone. Results of past studies are used to develop a systematic analytical process to compare cost-effectiveness of night and daytime work shifts.

Use of night construction as a capacity-improving technique dates back at least to the 1960s. In 1969, Lee (3) reported on "successful completion" of three projects by the California Division of Highways. Night construction work began on a freeway when it was considered to be impractical to close its lanes during daylight hours, since lane closures might result in severe traffic congestion and delays. Work was completed in fewer working days than if it had been undertaken in daylight hours. This was attributed 1) to less interference from lighter traffic at night, 2) to traffic moving at near normal speed, 3) to cooler temperatures contributing to good paving results, and 4) to fewer accidents at night than during the equivalent daytime calendar period. Lee concluded that given the necessary planning, night construction activities contributed to minimizing disruption of traffic, eliminating traffic delays, and improving traffic safety. "This new avenue of handling construction activities on existing freeways can make a major contribution to the over-all field of traffic operations."

In Colorado, Price (4) examined overall night paving operations with respect to lighting, personnel, and communications. He concluded that quality was as good as on a daytime job, and found that advantages of night operations in urban areas where traffic is a problem seem to outweigh the disadvantages.

In 1984, Shepard and Cottrell (5) studied the benefits and safety of night operations. They compiled information on current practices in night construction and maintenance operations, and developed general guidelines for when and how such work should be done at night. Areas covered in their feasibility study included scheduling lane and road closures, work-zone costs, safety, public relations and user costs, and traffic control. They concluded that although night work presented many potential disadvantages, through experience, proper planning, and special concern for worker and driver safety the night alternative was feasible for selected work.

In 1990, Hinze and Carlisle (6) examined factors involved in deciding to use night construction schedules. They surveyed the various parameters to be considered when night construction schedules are required. State personnel and contractors were asked to describe aspects of projects that were different as a result of a night schedule. Qualitative and quantitative factors related to night operations were detailed as well as advantages and disadvantages.

In 1992, Ellis et al. (7) assessed night operations in Florida to evaluate parameters involved in night operations. Their objective was to provide assistance to the Florida DOT in developing a more structured decision-making system as to when a project should be conducted at night. They quantified the effects of various parameters on cost and productivity, and concluded that construction at night is a valuable option, and that night operations may be as good as day operations.

In 1993, the Minnesota DOT (8) conducted a three-stage study surveying motorists, residents, and businesses impacted by a mill-and-overlay project conducted at night. Their goals were to evaluate effectiveness of 1) communication strategies used to generate awareness of construction activities and encourage use of alternative routes, and 2) various traffic safety and management measures. Nearly half (46 percent) of respondents said they were already using alternative routes to avoid the construction, and another 40 percent said they might change routes to avoid construction if it seemed adverse. Overall, a majority of respondents did not seem bothered by construction activities. Several innovative traffic-control components were used to help reduce congestion and accidents.

Generally, the number of references dealing directly with night construction is limited. Only a few provide a comprehensive approach and valuable information on night operations, but reach similar conclusions: night work is a feasible and valuable alternative to daytime operations, but requires careful planning. It is an effective mechanism in mitigating traffic congestion associated with daytime operations.

II. ISSUES TO BE CONSIDERED BEFORE NIGHT OPERATIONS

This section discusses six technical, social, economic, and environmental parameters affecting work-zone construction operations or affected by them. All must be considered critical when they have adverse impacts on the work zone. Note that some have qualitative and others have quantitative attributes. Figure 1 shows factors involved in night operations, and Table 1 lists advantages and disadvantages of lane closure.

A. Traffic-Related Parameters

1. Congestion

This is the overriding factor in selecting night shifts over day work. Mobility is positively affected when selecting night construction, because of less disruption of traffic. Delays and stops are minimized because of less traffic at night. During daytime operations, however, most traffic delays and disruptions result from construction activities and their related traffic-control

Figure 1. Flowchart for factors involved in night operations.

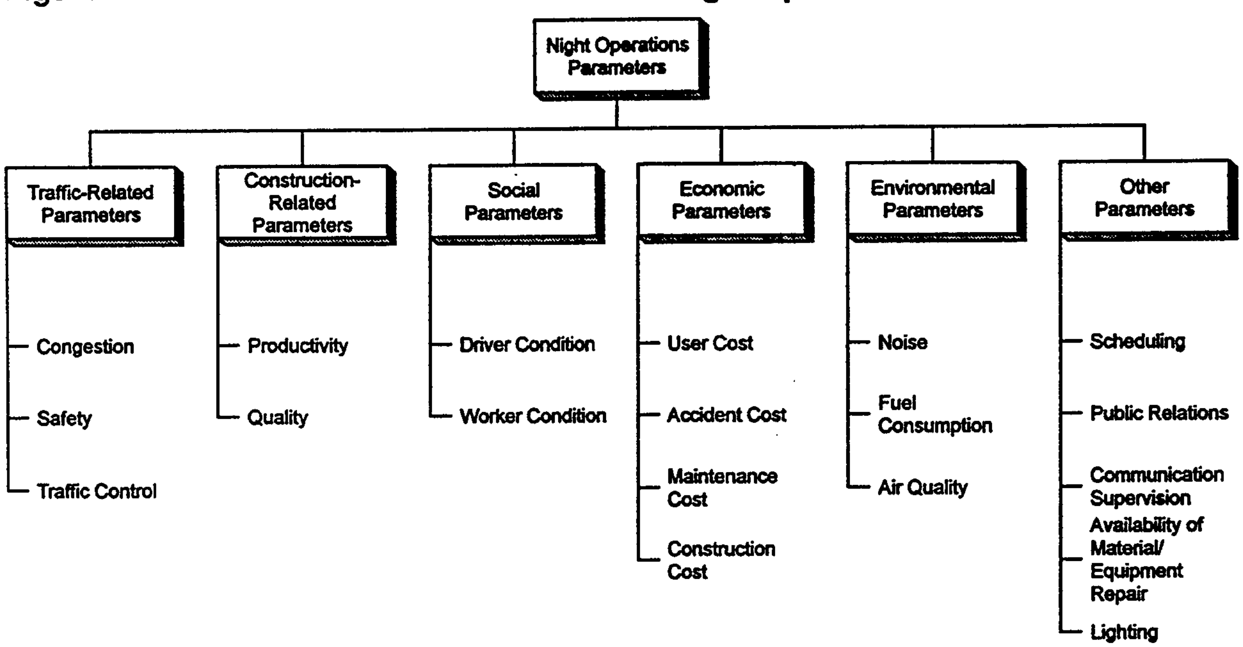


Table 1. Advantages and disadvantages of lane closure for night operations.

Variable	Advantages: Partial & Complete Closure	Advantages: Complete Closure	Disadvantages: Partial & Complete Closure	Disadvantages: Complete Closure
Safety Impacts		* Increased worker safety. * Safer movement of vehicles.	* More driver drowsiness, inattentiveness, and intoxication (alcohol & drugs). * Greater potential for more severe accidents because of poor visibility at night coupled with higher speeds. * Unexpected conditions with restricted visibility. * Reduced visibility despite supplemental lighting, especially for tasks requiring depth perception.	* Danger resulting from drivers penetrating the work zone and possibly confronting unexpected workers.
Productivity Impacts	* Opportunity to enlarge work areas and conduct multiple work functions. * Longer productive work hours due to reduced traffic interference. * Improved working conditions because of less traffic. * More efficient hauling because of less congestion. * Use of the full capacity of the production plant.	* High efficiency in work performance. * Shorter set-up time.	* Lack of communication between work-site personnel and main offices, media, police, etc. * Low worker morale and difficulty in recruiting personnel, even with pay incentives. * Problems with obtaining materials because some plants close at night. * Less advance warning of poor weather. * Difficulty in repairing equipment and obtaining service for equipment.	* For detours, problems with communication and coordination with local officials.
Quality Impacts		* Higher efficiency in work performance.	* More employees working two jobs, leading to fatigue and ultimately lower-quality workmanship. * Problems with quality control due to lack of inspection and supervision. * Pressure to ensure completion of job or to have road open before morning rush period can adversely affect quality.	
Traffic Impacts	* Avoidance of traffic congestion and motorist delay.			* Concern for capacity on detour routes.
Community Impacts	* Fewer motorist complaints, less public resentment.		* Adverse public reactions to noise in residential areas and restrictive noise ordinances.	* Public resentment of noise on detour routes and other adverse consequences.
Economic Impacts	* Reduced user costs (delay costs and vehicle operating costs) as a result of travel time savings. * Lower business losses.		* Higher costs for some operations because of pay differentials, more traffic control, additional lighting, material acquisition problems, etc.	* Additional traffic control needed may drive up costs. Increased project costs may result from the need to improve detour route.
Environmental Impacts	* Reduced emissions. * Reduced fuel consumption as a result of decreased travel time.			* Detours may increase distance and travel time.

strategies. Closing a lane can cause extreme bottlenecking, resulting in queuing, congestion, and consequent delays. A survey of state personnel and contractors (6) revealed that daytime high traffic congestion is the decisive factor in choosing a night schedule.

2. Safety

This is a major factor guiding decisions for night construction. At night, poor visibility, inadequate lighting, worker fatigue, driver condition, and substance abuse can cause hazardous situations for both drivers and workers. Further, with less traffic at night, motorists tend to speed through work zones, while more congestion during daytime results in less speed and thus safer conditions. Hinze and Carlisle (6) concluded that safety and traffic control are of particular concern when selecting night operations. They found that reducing speed improves safety, but the problem is getting drivers to slow down. Options of total road closure available in some night situations provide a more favorable environment, since heavy daytime traffic flow and driver annoyance and frustration can sometimes cause hazardous situations. Safety is also a function of public information programs -- road users may expect delays or identify alternative routes and reschedule their travel accordingly.

3. Traffic Control

Elements of a traffic-control plan include posting lower speeds, complete or partial lane closures, and detours, as well as furnishing, installing, maintaining, relocating, and removing traffic-control devices. These include flashing arrow boards, warning devices, layouts, and police patrols. Traffic control is crucial for night work due to hazardous conditions caused by lane closures and reduced visibility.

B. Construction-Related Parameters

1. Productivity

Night productivity may be reduced by inadequate lighting; poor visibility; poor worker morale and fatigue; lack of effective communication among agency personnel, contract managers, and field staff; problems with availability and supply of materials and spare parts; and longer set-up and take-down time for traffic-control devices and lighting equipment.

On the positive side, less interference from traffic at night improves productivity. Other advantages of night shifts include longer working hours and extended work shifts due to elimination of peak-hour traffic loads. Reporting on a night asphalt-removal operation in Maryland, Kuennen (9) pointed out that absence of congestion allowed a double shift for dump trucks traveling between milling and dump sites, an advantage not offered by a daytime schedule. He cited lack of machine service and truck availability as drawbacks of a night schedule.

Daytime construction operations, on the other hand, are often hampered by heavy traffic interference slowing down the rate of work and resulting in longer project duration. However, better lighting conditions and readier availability of materials and supervision, and communication with headquarters that are open during the day provide favorable conditions for productivity in daytime work shifts.

2. Quality

Factors reducing quality are basically similar to those affecting productivity, and include poor visibility, lighting deficiencies, lack of supervision and inspection, and poor worker morale. Factors having positive impacts on quality include less disruption due to lower traffic volumes, and cooler temperatures contributing to better paving results, especially when days are hotter than nights. Information in the literature is insufficient to conclude that night operations result in poorer-quality work, although that is possible. Hinze and Carlisle (6) concluded that although quality may meet the standards set, defects were apparent in the finished surfaces of both flexible and rigid pavements. The tradeoff was traffic congestion, which had worse effects than the added imperfections.

C. Social Parameters

1. Conditions for Workers

These may impact productivity and quality of the final product. Night work usually raises concerns about worker sleep deprivation, fatigue, the effect of circadian rhythms (e.g., an altered biological clock), and social and domestic adjustment difficulties, all of which may contribute to low energy levels and poor morale.

2. Conditions for Drivers

At night, fatigue and substance abuse are more common. Research indicates that some agencies actually avoid scheduling night work on Fridays and Saturdays because of the higher potential for substance abuse. During daytime, however, anger, frustration, and fatigue caused by delays also pose hazards for drivers and workers.

D. Economic Parameters

1. Construction Costs

The general opinion is that costs are significantly higher at night than in daytime. Night shifts are theoretically more expensive due to overtime and night-premium pay, lighting expense, use of additional traffic-control devices, increased material costs, and higher bids. Hinze and Carlisle (6) said that overall contract costs increase by about 10 percent. The associated cost increase for traffic control is about 25 percent. They found that project construction costs must not be critical in selecting a night schedule, since they are offset by decreased highway-user costs.

Similarly, Heine (10) reported that night operations on a North Carolina freeway involved higher costs due to higher wages and decreased productivity. The workers were paid a 10-percent night differential. North Carolina DOT, however, chose the night alternative for this widening project despite higher costs -- it was more convenient for the public because of significantly lower traffic volumes. Lanes could be closed without affecting commuters. Night work caused least disruption to user lives and had least effect on business.

On the other hand, Shepard and Cottrell (5) reported that an agency performing maintenance activities saved nearly half their costs (44 percent) when they closed a freeway and worked at night, as opposed to partially closing some lanes to do the same work during the day. Savings resulted from reduced traffic control and greater operational efficiency.

2. User Costs

Night operations reduce user costs because of less disruption of traffic. Fewer delays for users translate into lower user/vehicle operating costs and substantial time savings. User costs are higher during daytime work shifts, due to longer delays which increase vehicle operating costs, and added travel time for drivers, as well as their anger, frustration, and fatigue. Business losses are an ultimate adverse impact of delays.

3. Accident Costs

Factors affecting night accident rates include poor visibility, inadequate lighting, inadequate public announcements of night operations, lane closure duration decreasing or increasing exposure to hazardous conditions, proportion of lanes closed, type of work being done, length of the closure, and type of traffic-control devices. Shepard and Cottrell (5) concluded that night operations using lane closures were less safe for workers than daytime operations. On the other hand, heavy daytime traffic in work zones may also cause more accidents, and less traffic at night may result in safer work zones for drivers and workers.

Night accidents are less frequent but more severe than daytime accidents. Data are limited comparing night and daytime accident characteristics of work zones. Graham et al. (11) reported three studies documenting increased accident rates as a result of construction work, but did not conclude that accidents increase due to night construction operations.

Lum (12) studied occurrence of accidents in night work zones in seven states, and reported that although the ratio of total night accidents to total accidents remained constant (30 percent) before and during construction for all states combined, night accidents increased 9.4 percent as a result of construction.

Nemeth and Rathi (13) concluded that 61.9 percent of night accidents occurred in crossover zones, where traffic is forced to shift to other lanes. He also found that trucks have difficulty passing through such zones.

4. Maintenance Costs

Post-construction cost is a function of the quality of construction work. Maintenance costs can be indirectly affected by worker morale, which may adversely affect quality and increase post-construction costs. Cooler temperatures during night shifts may contribute to better paving results if construction work occurs during summer.

E. Environmental Parameters

1. Air Quality

There is little doubt that reduced congestion, shorter delays, fewer stops, and enhanced mobility translate into air-quality benefits -- i.e., reduced vehicle emissions. Operating under these assumptions, night operations would be the environmentally friendly alternative, particularly valuable in areas having poor air quality.

2. Noise

More noise near operating businesses or residences can cause major problems. Many jurisdictions have established noise ordinances. Construction noise that might be acceptable during daytime is unacceptable at night, particularly when the work is near residential communities. Noise is often a problem for which few means of mitigation are available. Noise attributed to construction operations could adversely affect public opinion about night work.

3. Fuel Consumption

This increases with delays and stops by vehicles passing through a construction zone.

F. Other Parameters

1. Scheduling

According to Hinze and Carlisle (6), difficulties in scheduling are problems associated with night operations. The time needed to set up traffic-control devices and remove them before the morning rush hour, delaying too long before lane closure, and scheduling work hours for agency inspectors and project engineers to coincide with night activities make scheduling a night shift problematic. Although night worker scheduling is difficult, task scheduling and materials deliveries are easier at night.

2. Public Relations

An adequate information campaign minimizes congestion and enhances mobility. Dissemination of information about project location, duration, and type of work results in motorists adjusting their routes and schedules, and better public attitudes toward delays and noise.

3. Lighting

This has considerable effect on quality, productivity, and safety. Highway agencies generally lack standard procedures to ensure proper lighting in work zones. Adequate lighting makes construction operations at night as good as by day. Lighting glare must not be hazardous for passing motorists, and must be sufficient for efficient operations. Insufficient lighting may cause poor visibility, but excessive glare can be hazardous to motorists and annoying to nearby residents.

4. Availability of Materials, Equipment Repair, Supervision, and Communication

Business hours of material suppliers do not commonly extend into the night, but if they do material prices may be higher. Equipment breakdown may disrupt work, leading to loss of productivity. Equipment repair may be a problem at night -- machines or parts may not be available until the next day. Lack of communication and supervision are also factors that may adversely affect night operations. Remote offices closed at night make on-site decisions difficult.

III. EVALUATING NIGHT VS DAY ALTERNATIVES

This section outlines basic guidelines for evaluating night construction against other alternative work schedules. To determine if night construction is more viable than daytime, it is recommended that the process outlined here be applied to all projects, since no two construction jobs are alike and each must be examined individually, weighing work-zone characteristics and magnitude of the construction involved.

This simplified analytical approach is meant to assist an evaluating team in deciding on the most viable work schedule and should be applied early in project development, when a future work zone undergoes intensive evaluation to determine the most appropriate traffic-control strategy to deal with reduced traffic capacity.

Using this process, night scheduling of construction work may be evaluated, considering all potential impacts against all feasible alternatives. The outcome will be determination of the most cost-effective scheduling alternative. The method is considered suitable for choosing between possible night and daytime construction schedules, because of 1) the number of qualitative variables involved in night operations to which monetary values cannot be assigned, and 2) the flexibility offered in allowing evaluators to conduct an objective analysis tailored to local circumstances and to public policies and attitudes. This eight-step process is adapted from procedures for work-zone evaluation developed by Abrams and Wang (14) and from FHWA's National Highway Institute Course 13355 ("Transportation Alternatives During Highway Reconstruction") (15), a course now being taught nationally.

A. Step 1: Evaluate the Proposed Project

This includes describing the work to be done and assembling the required project-specific database of relevant traffic and roadway data. The degree of project impact expected will determine how detailed the data must be to analyze various work-zone traffic-control strategies. Typical project data include:

1. Type of work,

2. Anticipated duration,

3. Roadway encroachment required,

4. Limits of the work,

5. Tentative schedule,

6. Tentative phasing, and

7. Estimated costs.

Required traffic data include:

1. 24-hour traffic counts,

2. Prevailing operating speeds,

3. Roadway geometrics,

4. Description of potential detour routes,

5. Daily and seasonal volume variations,

6. Intersection/interchange turning movements, and

7. Accident histories of roadway segments.

Under special circumstances, as in the case of critical urban road segments, other data may be needed such as emergency access routes, special access conditions, detour routing for transit, and clearances.

B. Step 2: Assess Roadway Occupancy

This is the initial assessment of roadway capacity -- i.e., spatial requirements and time duration of roadway occupancy. This step examines the relationship between traffic demand and roadway capacity. To determine extent of roadway occupancy (i.e., the degree to which it is "occupied" by construction activities), the following factors should be defined to determine spatial requirements for the occupied roadway and how long it will be occupied:

1. Total project length and its beginning/ending points,

2. Length of the occupied roadway at any one time and during a particular 24-hour period,

3. Portion of the roadway where normal traffic will be prohibited,

4. Expected number of working days to complete the project, and

5. Number of hours each day when the roadway will be occupied.

C. Step 3: Identify Traffic-Control Alternatives

By this stage, information has been compiled to identify:

1. Work activity in terms of road space needs,

2. Duration of the work,

3. Traffic conditions normally prevailing in the work area while work is underway, and

4. Physical characteristics of the facility in the work area: lane width, shoulder type, and width, right-of-way width, and median type and width.

Based on this information, the evaluating team identifies feasible traffic-control alternatives, determining which strategies may be appropriate for the type of work activity (e.g., lane constrictions, lane closures, shared rights-of-way, median crossovers, detours, temporary bypasses, intermittent closures, use of shoulders or medians, etc.).

D. Step 4: Analyze Volume/Capacity Relationships

Ability of traffic-control strategies to accommodate traffic volumes is analyzed. In other words, the objective is to determine work-zone capacities of the various work-zone strategies and compare them to traffic volumes that will use the facility. The Highway Capacity Manual (16) offers various procedures to estimate work-zone capacity. It may be estimated using the following equation:

Vehicles Per Hour Per Lane (VPHPL) = Z Fw Fhv Fp

where Z = capacity under ideal conditions at the design speed with a maximum volume/capacity ratio for the desired level of service. (Based on LOS E (at or near capacity) and design speed of 60 mph, Z = 2000.),

Fw = a lane width and or lateral clearance adjustment factor,

Fhv = a heavy-vehicle (non-passenger car) adjustment factor, and

Fp = a driver population adjustment factor.

Appropriate tables for the adjustment factors are also found in the Highway Capacity Manual. If volume exceeds capacity, queue length and duration should be calculated. The analysis may be based on internal agency policies, need at the work site, duration of construction, effect on motorists and public reaction, and it may include mathematical models. Many state agencies use the Highway Capacity Manual, which provides prescribed formulas through which an agency may estimate the queue formed and resulting delays. Following computation of queue formation and resulting delays, an agency must decide whether these delays are "acceptable."

E. Step 5: Identify Capacity-Improving Techniques

If work-zone capacity generated by traffic-control strategies produces unacceptable queue length and congestion, additional techniques should be considered to reduce delays and congestion. Techniques to improve capacity may include trip diversion to other corridors, diversion within the corridor, diversion to other travel modes, and/or trip reduction through use of high-occupancy vehicles.

F. Step 6: Quantify Impacts

For comparison of traffic-control strategies, quantitative and qualitative assessments of various parameters are warranted.

1. Quantitative Analysis

a. User Costs

(1) Traffic Delay Costs

Vehicles can be delayed by changes of speed or distance within a zone. Delay costs are incurred as a result of increased travel time. The difference in average vehicular delay between normal and work-zone conditions can be computed from one of the following three equations from Hinze and Carlisle (6), depending on the data available:

$$AD = Dw/Sw - Dn/Sn$$

$$AD = TTw - TTn$$

$$AD = Dw/Sw - TTn$$

where AD = average delay - difference between normal and work-zone routes

TTn = travel time on the normal route

TTw = travel time on the work-zone route

Dw = work zone route distance in miles

Sw = average work-zone route speed in mph

Dn = normal route distance in miles

Sn = average normal route speed in mph

Each component of delay as estimated by these procedures can be converted into monetary values, using the relationships given in Table 2.

(2) Vehicle Operating Costs

Many methods for calculating user costs are available: AASHTO's Manual on User Benefit Analysis of Highway and Bus-Transit Improvements (17), Lytton at al. (18), Dudek et al.(19), and Wang and Abrams (14) are sources offering methods to estimate user costs. It is important, however, once a method has been selected to estimate user costs, that it be used consistently in evaluating all alternatives.

The QUEWZ computer model for estimating user costs, developed by Dudek et al. was specifically designed for freeway applications, but may be used in other situations with proper adjustments in input data. This model has flexibility and precision and is less time-consuming than other manual methods, thus greatly simplifying comparison of alternatives.

Input data for QUEWZ are either required (lane closure strategy, total number of lanes, number of open lanes through the work zone, length of closure, time of lane closure and work-zone activity, actual traffic volumes by hour) or optional (factors to update cost calculation, percentage trucks, speeds and volumes for speed-volume curves, capacity-estimate risk-reduction factor of work-zone capacity, problem description). Output data from QUEWZ include vehicle capacity, average speed through the work zone by hour, hourly user costs, daily user costs, and average length of queue during each hour.

b. Construction Costs

Construction costs incurred by the agency performing the work include traffic control and enforcement, maintenance of traffic-control devices, construction, and labor premiums. Direct monetary values are available for comparison of construction costs.

Table 2. Costs of traffic delays.

Minutes Lost or Saved	Cost ($) Per Vehicle	Minutes Lost or Saved	Cost ($) Per Vehicle
1	0.00	31	3.15
2	0.00	32	3.24
3	0.01	33	3.34
4	0.01	34	3.44
5	0.01	35	3.55
6	0.04	36	3.64
7	0.06	37	3.74
8	0.10	38	3.85
9	0.15	39	3.94
10	0.23	40	4.04
11	0.34	41	4.15
12	0.47	42	4.25
13	0.63	43	4.34
14	0.79	44	4.45
15	0.94	45	4.55
16	1.10	46	4.65
17	1.26	47	4.76
18	1.40	48	4.85
19	1.55	49	4.95
20	1.69	50	5.06
21	1.84	51	5.15
22	1.98	52	5.25
23	2.12	53	5.36
24	2.25	54	5.45
25	2.38	55	5.55
26	2.39	56	5.66
27	2.65	57	5.76
28	2.78	58	5.86
29	2.92	59	5.97
30	3.04	60	6.06

Based on typical trip-purpose distribution, composite household income, average car occupancy, and typical mix of passenger cars and commercial vehicles.

Source: Highway Statistics (1975), from Abrams and Wang (14).

2. <u>Qualitative Assessment</u>

From a traffic-flow perspective, assess community reaction to delays resulting from construction activities, and air-quality and fuel-consumption impacts. Evaluate alternative impacts on safety, and estimate adverse impacts on business loss(es).

Assess duration of the project. If anticipated congestion from a daytime schedule is severe as a result of lane closure(s) and the project is expected to require several days for completion, repeated lane closures may generate adverse public and media reaction, thus giving a night schedule an advantage over a daytime schedule.

At this point, the evaluator should decide whether alternative strategies considered so far would result in intolerable impacts. If so, the evaluator should proceed to Step 7 to assess feasibility of night operations. If daytime alternatives would result in acceptable traffic flow and insignificant environmental and social impacts, the evaluator then would proceed to Step 8 to select the preferable alternative. A process flowchart is shown in Figure 2, including a feedback loop to illustrate the various analytical steps.

G. Step 7: Assess Feasibility of a Night Schedule

Failure of daytime strategies for alternative traffic control to accommodate traffic demand usually leads to considering night options. Feasibility of night operations is analyzed using the same steps as other schedules/procedures:

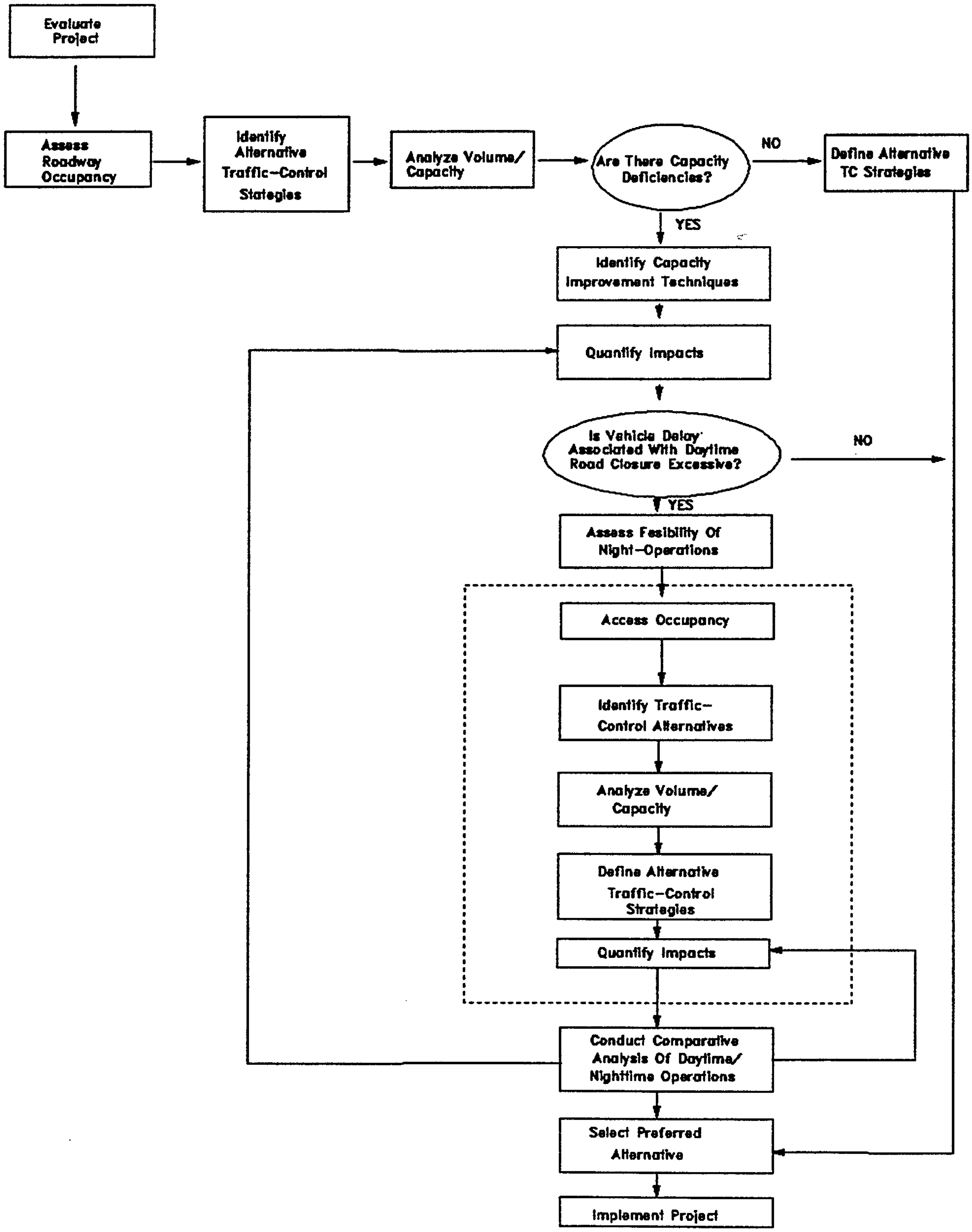
1. Determine extent of roadway occupancy -- assess roadway capacity under night conditions. Extent of occupancy defines the constraints within which the traffic-control strategy must be developed.

2. Identify feasible traffic-control alternatives -- note that a night schedule <u>may</u> offer a a wider range of traffic-control options than a day schedule. For example, an extra lane closure that might not be possible during daytime might be possible at night. A night alternative also requires more traffic-control devices to increase visibility. Documentation of traffic-control plans at various stages of construction work is the objective of this procedure.

3. Analyze the volume/capacity relationship -- a detailed analysis of capacity, queue length, and delays. Estimating equations are available in the <u>Highway Capacity Manual</u>. Note that if road closure is considered, capacity on detour routes should be estimated.

4. Define alternative night traffic-control strategies that are most easily implemented.

Figure 2. Guidelines for night operations.



5. Quantify impacts (classified as qualitative or quantitative) of a night work schedule on the work zone and on detour routes. All these factors must be considered in systematic evaluation of the alternatives.

1. Quantitative Analysis

a. User Costs

These decrease because of less traffic at night. The reduction may more than offset increased costs of night construction, but this is felt only by users while the increase in construction costs is incurred by the agency performing the maintenance activities. Estimation of user costs is covered in Step 6.

b. Construction Costs

Increased traffic control at night may drive up costs. Also, need for law enforcement increases at night. Other cost differences occur for lighting, labor premiums, and supply of materials. Direct monetary values are available for those rates. Other indirect costs incurred as a result of lack of familiarity with night work and inexperience of workers, leading to loss of productivity, may also be estimated based on personal judgment.

2. Qualitative Assessment

a. Environmental Impacts

At lower speeds, vehicles consume more fuel and generate more emissions. Clearly, less traffic is an advantage of night scheduling. Theoretically, the night alternative results in lower emissions and less energy consumption. Although appropriate models are available to estimate emissions and energy consumption, assigning monetary value to air-quality impacts is difficult so this measure needs to be considered in analyzing overall cost-effectiveness. Night schedules for large reconstruction projects in urban areas may offer valuable alternatives to daytime schedules, especially in areas of poor air quality.

b. Safety

Evaluate hazard potential: effectiveness of lighting plan, ability of traffic-control strategy to minimize hazards, level of risk of operations, visibility levels for workers and motorists.

c. Quality

Evaluate lighting plan, suitability of temperatures for operations, duration of night work, experience of potential contractor in night work, potential lower worker efficiency affecting quality of finished product.

d. Noise

Determine if project violates noise ordinances and its proximity to residential areas and hospitals.

e. Community Impacts

Assess potential community reaction to noise and glare from high-intensity lighting.

H. Step 8: Select Preferred Alternative

When both quantitative and qualitative assessments are completed, results for each analysis are compared to determine cost-effectiveness, to assist the evaluating team in selecting the preferred alternative. It is suggested that the comparative analysis methodology be based on cost-effectiveness -- the concept combining the qualitative and nonqualitative variables for each alternative into a single "figure of merit." This facilitates comparison of the proposed alternatives. This method is considered the most suitable because of the magnitude of qualitative variables involved in night operations (e.g., community impacts, noise, quality, condition of workers and drivers, environmental impacts, etc.). Impacts of those variables are adequately estimated in the following cost-effectiveness study.

Principal steps in evaluating cost-effectiveness are as follows:

1. Identify goals and objectives for the project.

2. Determine relative importance of each goal and objective within a goal.

3. Develop measures for each objective. These are specific statements allowing evaluators to determine how well a given alternative meets a given objective. Assign a weight to each measure of effectiveness or to each objective.

4. Rate each alternative of each measure of effectiveness (on a scale of 0 to 10).

5. Find an effectiveness or utility score for each alternative by multiplying the objective weight by its rating, and then summing to obtain a single rating for each alternative.

6. Compare the utility or effectiveness rating for each alternative with the quantitative costs computed (i.e., user and construction costs) in a utility-cost ratio. The alternative having the highest ratio, either total or incremental, is considered the best.

Table 3 gives an example of this technique in determining the "merit" of night and daytime scheduling alternatives. The table indicates the objectives [or measures of effectiveness (MOE)] with weights assigned for each, and the determined rank for each alternative for each MOE or objective. The effectiveness rating is then measured against the alternative's total estimated cost (user cost + construction cost) in a utility-cost ratio to determine relative cost-effectiveness of each alternative in meeting the established goals. The most cost-effective alternative is that having a high rating and moderate cost. Select the alternative with the highest ratio, and develop the necessary traffic-control plans for implementation (i.e., develop an implementation plan).

As stated in the Department's Policy, "night-time construction should be considered with great caution due to the significant trade-offs that may occur among competing objectives." Using the step-by-step procedures outlined here will ensure selection of the most appropriate scheme. The process allows evaluators to conduct an objective analysis tailored to local circumstances and public attitudes.

Table 3. Evaluation of cost-effectiveness.

1. Assign a Utility Score to Each Alternative

OBJECTIVE	WEIGHT	ALT A (NIGHT)		ALT B (DAY)		ALT C (DAY)	
		Rank	Score	Rank	Score	Rank	Score
Minimize Travel Time	3	10	30	5	15	0	0
Maintain Access	4	7	28	5	20	10	40
Minimize Accidents	1	10	10	5	5	0	0
Minimize Pollution	1	3	3	5	5	10	10
Increase Work Efficiency	1	1	1	10	10	10	10
Effectiveness Rating			72		55		60

2. Calculate A Utility-Cost Ratio

OBJECTIVE	ALTERNATIVES		
	NIGHT A	DAYTIME B	DAYTIME C
Effectivness Rating	72	55	60
Cost of Traffic Control	$500,000	$50,000	$250,000

Source: From Transportation Alternatives During Highway Reconstruction (15).

IV. PLANNING A NIGHT OPERATION

This section addresses planning of work before and during night construction. After deciding to build or reconstruct at night, advance planning is essential. A 12-point checklist is given here of key items for cost-effective, safe operations, including practical solutions in mitigating common night construction problems, and suggesting specifications for night operations.

1. Evaluate the Traffic-Control Plan

The Manual on Uniform Traffic Control Devices (MUTCD) (20) is based on national standards for all highways. Part IV of MUTCD covers traffic control for work zones. Night traffic-control plans follows the same standard as daytime plans, but involve additional devices and supplemental lighting to address reduced visibility at night. A traffic-control scheme has ten elements:

1. Changeable-message signs.
2. Warning signs.
3. Channelizing devices.
4. Sight distance.
5. Arrow boards.
6. Emergency enforcement controls.
7. Deterrent controls.
8. Special controls.
9. Flagging operations and worker visibility.
10. Police patrols.

In August 1994, the Construction Division issued comprehensive interim guidelines (2) for M&PT during night paving. Their typical traffic-control layout conforms to state policy and should be used with MUTCD as the basis for all traffic-control plans. To ensure good control practices, a set of standards and specifications for safety and traffic control should be added to contract plans as special provisions.

2. Evaluate Lighting Plan

Lighting is crucial to success of night operations. Because so many parameters depend on it, lighting should be evaluated from the perspectives of contractors, the public, Department personnel, and all other parties involved. It is recommended that the contractor be asked to submit a lighting plan for NYSDOT approval. To assist the contractor in designing this plan, NYSDOT should provide detailed guideline specifications for various conditions.

Ellis et al. (21) reported a recent study for the Florida DOT to develop lighting standards for night operations, identifying factors influencing illumination requirements for work- zone lighting. Three minimum illuminance level categories were suggested -- 5, 10, and 20 foot-candles (54, 108, and 215 lx) -- based on IES and OSHA recommendations, various state provisions, opinions of experts, and responses during field reviews. The categories were intended as recommendations rather than regulatory minimum requirements.

For comparison with typical highway tasks, non-highway tasks having similar visual requirements were listed and assigned appropriate factor levels (which were then compared with typical highway tasks). Based on this comparison, illumination levels were recommended for highway tasks. Assigned levels and categories were prepared to develop guidelines for various highway tasks. Table 4 is adapted from their report and summarizes the recommended illumination levels and glare control criteria.

For equipment lighting standards, it was determined that most highway construction equipment can be broadly categorized into two speed categories -- slow-moving and fast-moving. Distances were determined for illumination at the front and back -- 16 ft (4.9 m) for slow-moving equipment and 58 ft (17.7 m) for fast-moving. To control glare from equipment-mounted lights, AGI software was used. AGI simulation revealed that a beam tilt of 60 deg or less can eliminate considerable glare from the equipment, and from tower lighting if maximum height is limited to 30 ft (9 m).

3. Ensure Adequate Advance Public Information

Public-awareness techniques include meetings with the community, advertisements in local newspapers, radio and television announcements, flyers, etc. This will help drivers find alternative routes or to drive more carefully in the work zone.

Table 4. Lighting guidelines for night operations.

Recommended Illumination Levels for Typical Highway Tasks		
Task No.	Construction and Maintenance Tasks	Suggested Minimum Level Illumination, Ft-c
1	Excavation (regular, lateral ditch, channel)	5
2	Embankment, Filling, and Compaction	5
3	Barrier Walls, Traffic Separators	10
4	Milling and Removal	10
5	Resurfacing	10
6	Concrete Pavement Construction	10
7	Subgrade Stabilization and Construction	5
8	Base Courses (clay, cement, asphalt)	10
9	Surface Treatment	10
10	Waterproofing/Sealing	10
11	Sidewalks	10
12	Riprap	10
13	Guardrail, Fencing	10
14	Painting Stripes/Markers/Metal Buttons	10
15	Landscaping, Grassing, Soddling	5
16	Highway Signing	10
17	Traffic Signals	20
18	Highway Lighting System	20
19	Bridge Decks	10
20	Drainage Structures, Culverts, Storm Sewers	10
21	Other Concrete Structures	10
22	Maintenance of Earthwork/Embankment	5
23	Reworking Shoulders	5
24	Repair of Concrete Pavement	10
25	Crack Filling	20
26	Pothole Filling	10
27	Resetting Guardrail/Fencing	10

Recommended Illuminated Areas For Typical Construction Equipment	
Type of Equipment	Illuminated Areas in Front and Back
Fast-Moving Equipment	
Paver	16 ft (4.9 m)
Milling Machine	16 ft (4.9 m)
Slow-Moving Equipment	
Backhoe Ladder	58 ft (17.7 m)
Wheel Loader	58 ft (17.7 m)
Wheel Tractor	
Scraper	58 ft (17.7 m)
Compactor/Roller	58 ft (17.7 m)
Motor Grader	58 ft (17.7 m)
Recommended Orientation and Height of Tower-Mounted Lights for Glare Control	
Orientation of Tower Lights:	Angle of centerline of the beam should not be greater than 50 degrees with vertical
Height of Tower Lights:	Maximum tower height for the above beam angle should not exceed 30 ft (9 m)

Source: Adapted from Ellis, Herbsman, and Kumar (21)

4. Consider Possible Mitigation Measures for Worker Morale

Key mitigation measures include a consistent work schedule, short-duration projects, extra time off or extra compensation, a volunteer work force, good human relations, and good planning.

5. Evaluate Administrative and Manpower Coordination

If lack of communication is likely to be a problem, hiring temporary personnel by both state highway agencies and contractors may be effective in improving supervision and inspection. Designated person(s) on-site must have authority to make decisions.

6. Assess Provision of Manpower

Some persons are better suited than others for night work. The contractor should identify and avoid workers having problems coping with night work shifts or holding day jobs, both of which will intensify with fatigue.

7. Evaluate Procurement of Materials

Flow of materials must not be interrupted. Review work-zone terrain to assess potential for stockpiling on-site to ensure continuous flow.

8. Evaluate Consequences of Noise

Review possible use/need for noise abatement measures (e.g., noise barriers).

9. Assess Equipment-Repair Requirements

Estimate potential repair requirements, based on equipment age and condition. Have spare parts available on-site if possible.

10. Schedule Involvement of Law-Enforcement Officials

Studies have proved that motorists tend to reduce speed upon entering a work zone if a uniformed traffic officer is present with a car and flashing emergency lights. Presence of police will increase safety.

11. Evaluate Scheduling Plans

Schedule times for closing and opening the roadway, keeping in mind that work must be completed and the road opened to traffic in time to carry morning peak traffic.

12. Closely Monitor the Project for Possible Improvement

Corrective changes should be implemented whenever a deficiency is obvious. Effectiveness of the traffic-control plan should be continuously monitored, requiring that a person responsible for traffic control be on-site throughout work activities.

V. CONCLUSIONS

In the ISTEA decade, as transportation officials are working to enhance mobility and reduce environmental impacts of the surface transportation system, night construction operations will probably become increasingly common. In a survey of state DOTs, 85 percent reported that they are performing night work. This can be a valuable transportation management measure, but since no two construction jobs are alike, and since work-zone characteristics, public attitudes, and local policies vary significantly, each project should be evaluated individually, weighing all the considerations involved.

The two parameters that are most influential when considering a night work schedule are 1) impact on the roadway traffic pattern, and 2) cost of alternative schedules, but equal attention must be given to safety. Since it is more likely that impaired drivers will be traveling at night, greater efforts should be taken to ensure safety of drivers and workers.

Safety should be emphasized through a comprehensive traffic-control plan. Guidelines issued by the Construction Division will be useful to contractors in developing effective M&PT for night projects. Further, since safety as well as productivity and quality are functions of lighting, an effective lighting plan must be developed. The state must issue lighting specifications to assist the contractor in developing an effective plan.

Coordination of the work force, quality, productivity, and acquisition of materials are problems potentially associated with night work, for which there are practical solutions. Advance planning is the key to success of these operations.

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