

Design Components of an Effective Traffic Control Plan

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ABSTRACT

The paper highlights many of the essential design components of an effective temporary traffic control plan. These components were identified during the preparation of a new chapter, "Maintenance of Traffic Design and Construction Staging" for the March 2009 revision to the *ITE Traffic Engineering Handbook*(1). The paper includes a discussion on horizontal geometrics including curves, superelevation, and lane shifts. Vertical geometrics including the use of temporary walls are included. Cross sectional elements such as number of lanes, lane widths, cross slopes, and roadside safety are presented. Temporary traffic control plans are described and include discussion on temporary pavement markings and signs. Several temporary traffic control emerging trends are introduced.

INTRODUCTION

In January 2005, ITE released a call for expression of interest for chapter authors for the ITE *Traffic Engineering Handbook* as ITE planned to revise the book. This appeared to be an excellent opportunity to capture information on an often developed element of construction plans that may have limited published resources. Capturing available information on the essential components of an effective traffic control plan and bringing this information together in a useful format will benefit those that develop such documents. In the past few years, the Federal Highway Administration (FHWA) has encouraged the implementation of the Work Zone Safety and Mobility Rule which compliments the use of temporary traffic control plans. State highway authorities also promote the use of temporary traffic control plans as they have been developing acceptable plans for their jurisdictions.

This paper touches on how the traffic control designer can demonstrate that a project can be built while maintaining required traffic movements. More complete details are included in *Traffic Engineering Handbook 6th Edition* (1). The handbook also presents more complete design information and many photos of in place traffic control applications.

It is important to note that the designer should not dictate the contractor's means and methods of construction; rather the design plans should provide an option for construction that meets the agency requirements. Many contract plans and documents provide for modifications to the maintenance-of-traffic and/or construction staging by the contractor. The designer should identify any agency specific design guidelines as they may have requirements that vary from those noted in this paper. Even when an agency does have its own criteria, this information may supplement the agency's guidelines where information may be lacking.

The temporary traffic control zone is an area of highway where road user conditions are changed because of a work zone or an incident. Temporary traffic control (TTC) devices, uniformed law enforcement officers, or other authorized personnel are used to control the traffic movements (2). The *Manual On Uniform Traffic Control Design* (MUTCD) defines a work zone as "an area of a highway with construction maintenance or utility work activities."(2). In this paper, "work zone" terminology is often used interchangeably with the term "temporary traffic control zone". Another term identified by the authors is "maintenance-of-traffic", which is used to describe temporary traffic control.

EFFECTIVE TRAFFIC CONTROL PLANS

An effective set of traffic control plans and specifications will consider the appropriate design constraints, organize the proposed improvement in a logical manner that facilitates a continued flow of traffic, and provides the contractor the opportunity to construct the project. The designer will utilize important design elements to create plans and specifications that convey to the contractor a method to construct the improvement and will communicate to the public how to navigate the work zone.

Critical Design Elements

When beginning the design process, the proper design vehicle should be identified as this can impact other design considerations and design factors. The designer is reminded that often the predominant user may be a motor vehicle, but the needs of all road users should be considered. Along with the design vehicle, a design speed or speeds for the work zone will need to be established. The speeds should be the same or close to the normal posted speeds, but temporary conditions often require speed reductions. The speed is usually set in a 5 mile per hour

increment and is often dependent on the authority of the agency having jurisdiction on the roadway, permanent posted speed, temporary traffic control zone conditions, and engineering judgment (2). Conditions requiring speed reductions greater than 10 mph should be limited. Further traffic modifications can be determined through traffic analyses to evaluate construction conditions, to determine ideal time of day for lane closures, and to estimate construction queues.

Horizontal Geometrics

Temporary alignments or traffic shifts may be required to maintain traffic flows during construction. Temporary pavement can also be provided (see Figure 1). In some instances a counter flow lane may be utilized. A counter flow lane is a lane that has been shifted away from and has become separated from the remaining lanes heading in the same direction. Often this shifted lane is in close proximity to the opposing traffic lanes and even could be utilizing pavement normally used by the opposing traffic. To the opposing traffic this lane is seen as running counter to their flow (see Figure 2). A lane shift is the temporary transfer of a traffic lane or lanes either left or right of its original location in order to perform a construction activity. Traffic may be shifted to the shoulder, adjacent lanes, or temporary pavement (see Figure 3).



FIGURE 1 TEMPORARY PAVEMENT
Photo By David McDonald



FIGURE 2 COUNTER FLOW LANE
Photo By Amber Huckfeldt



FIGURE 3 LANE SHIFT
Photo By Amber Huckfeldt

The *MUTCD* (2) provides formulas to determine the taper length based on the width of the transition while taking into account the posted speed of the work zone. Table 1 provides taper information for work zones and many agencies utilize this information.

Table 1. Taper Length Guidelines for Work Zones

Taper Type	Taper Length (feet)
Merging Taper	L or greater
Shifting Taper	0.5 x L or greater
Shoulder Taper	0.33 x L or greater
One-Lane, Two-Way Traffic Taper	100 feet minimum
Downstream Taper	100 feet per lane

Notes: When space is available, longer taper lengths can be beneficial to shift traffic

Source: Federal Highway Administration - U.S. Department of Transportation. Manual On Uniform Traffic Control Devices 2003 Edition. <http://mutcd.fhwa.dot.gov/kno-2003ra.htm>, Including Revision No. 1 dated November 2004.

Two equations are used in conjunction with Table 1.

40 mph or less:

$$L_{\min} = \frac{WS^2}{60} \quad (1)$$

45 mph or more:

$$L_{\min} = WS \quad (2)$$

where: L_{\min} = Minimum length of taper in feet,
S = Speed in mph, and
W = Offset distance in feet.

The *MUTCD* Part 6 (2) may be consulted for additional information on tapers.

The design speed, horizontal curvature, existing cross slope (for existing pavements to maintain traffic), and superelevation rate in the curves are all related. A goal is to utilize existing (already in place) facilities as they are normally more cost effective. Most agencies utilize Method 5 superelevation transitioning (see the AASHTO “Green Book”) for permanent pavement design (3). In temporary traffic conditions some agencies utilize Method 2 superelevation transitioning. Method 5 utilizes a combination of applying side friction and superelevation in a curvilinear relationship, while Method 2 applies side friction first, then counters any remaining centripetal force with superelevation. Utilizing Method 2 superelevation transitioning allows the use of smaller curve radii when compared to curve radii required for Method 5, although Method 2 may lead to more driver discomfort due to the lateral acceleration

applied to the vehicle occupants. As construction is temporary in nature this additional discomfort is tolerable. Table 2 was developed to reflect minimum radii for work zone horizontal curves that would not require superelevation. This table is very similar to one in use by the Illinois Department of Transportation.

Table 2

Minimum Radii for Work Zone Horizontal Curves Retaining Normal Crown Cross Slope

Work Zone Design Speed (V) in mph	f_{max} (Open Roadway Conditions)	Normal Crown Section Minimum Radii, R_{min} (e = -1.5%)	Normal Crown Section Minimum Radii, R_{min} (e = -2%)
20	0.27	105	107
25	0.23	194	199
30	0.2	325	334
35	0.18	495	511
40	0.16	736	762
45	0.15	1000	1039
50	0.14	1334	1389
55	0.13	1754	1834
60	0.12	2286	2400
65	0.11	2965	3130

Note: The data in the above chart is provided based on the adverse slope (e) being maintained through the horizontal curve.

Source: Based Upon Federal Highway Administration. NCHRP Report 439 Superelevation Distribution Methods and Transition Designs. 2000.

If superelevation is required, Method 2 transitioning can be used during construction. To determine an appropriate design superelevation based on the minimum allowable radius, consult Table 3. Select a radius for a proposed temporary alignment curve that exceeds the minimum radius found in the table. Transitioning the superelevation in and out of the curve (how much transition to put on the curve and how much transition to put on the tangent) may be applied in the same manner as described in the AASHTO "Green Book's" section on Transition Design Controls (3). If horizontal curves are not required, tapers can be used. Appropriate taper rates are found in the *MUTCD* (2) and were discussed previously.

Table 3 Minimum Radii for Design Superelevation Rate

Superelevation (e) (%)	Design Speed (mph)									
	20	25	30	35	40	45	50	55	60	65
	fmax (Open Roadway Conditions)									
	0.27	0.23	0.2	0.18	0.16	0.15	0.14	0.13	0.12	0.11
	Minimum Radius (feet)									
-2.0 (adverse crown)	107	199	334	511	762	1039	1389	1834	2400	3130
-1.5 (adverse crown)	105	194	325	495	736	1000	1334	1754	2286	2965
0.0	99	182	300	454	667	900	1191	1552	2000	2561
1.5	94	171	280	419	610	819	1076	1391	1778	2254
2.0	92	167	273	409	593	795	1042	1345	1715	2167
3.0	89	161	261	389	562	750	981	1261	1600	2012
4.0	87	155	250	372	534	711	926	1187	1500	1878
5.0	84	149	240	356	508	675	878	1121	1412	1761
6.0	81	144	231	341	485	643	834	1062	1334	1657
7.0	79	139	223	327	464	614	794	1009	1264	1565
8.0	77	135	215	315	445	587	758	961	1200	1483
9.0	75	131	207	303	427	563	725	917	1143	1409
10.0	73	127	200	292	411	540	695	877	1091	1342
11.0	71	123	194	282	396	520	667	841	1044	1281
12.0	69	120	188	273	381	500	642	807	1000	1225

Notes.

1. Based on Method 2 superelevation transition.
2. This table provides the minimum radius. It does NOT preclude the use of larger radii.

Vertical Geometrics

Vertical curves in work zones should be designed using the same criteria as permanent conditions. The designer should continue to consider the combined effect of vertical profile and cross slope in order to minimize the introduction of temporary pavement (especially poor draining temporary pavement). Vertical clearances should be evaluated and if appropriate clearances are not available, detours should be considered.

If complete reconstruction occurs while traffic is present, often with lane additions, it has become more common to find the existing pavement at a significantly higher or lower elevation than either the final or temporary pavement. To minimize the need for temporary easements or the acquisition of additional permanent right of way, temporary walls are becoming more common during construction. These walls may be mechanically stabilized earth (MSE) type walls in a fill situation and often sheet piling or possibly soldier pile walls in cut sections.

Cross Sectional Elements

The number of lanes, which needs to be provided within the construction area, is often determined by roadway capacity and agency requirements. A specific level of service (see *Highway Capacity Manual* (4)) may be required, which will regulate the number of lanes to be provided given the expected traffic volume during construction. Ideally, the level of service should be the same as for existing conditions. There are several methods that can be used to obtain the required number of lanes, such as utilizing shoulders as traveled lanes, constructing temporary pavement, reducing lane widths, or utilizing lanes on the opposite side of the road to facilitate traffic for both directions (counter flow lanes). Whenever possible, existing pavements should be utilized to maintain traffic during construction. The sections on horizontal curvature and superelevation should be referred to for appropriate cross slopes. If temporary alignments

are being added, the typical cross slope would be on the order of 1.5 to 2.0 percent in tangent alignments.

The width of the lanes will depend on the available space. Roadway lane widths may vary in width from 10 feet to greater than 12 feet depending on the roadway classification, design vehicle, and design speed. Existing lane widths should be maintained through construction, if practical. Otherwise, lane widths within a work zone may vary from the standard lane width required for a permanent roadway in order to accommodate the work zone, temporary travel lanes, and traffic control devices.

The roadside is important to provide a recovery area for motorists to correct and take control of an errant vehicle, while also performing such functions as accommodating drainage and lighting. Roadside design for temporary conditions must also be considered for each stage of construction in order to minimize incidents. The various traffic patterns during construction commonly expose motorists to a greater amount of hazards. Potential hazards may include: bridge piers and abutments, concrete barrier ends, moveable construction elements adjacent to the roadway, pavement drop offs, embankments, temporary walls, and opposing traffic, and others.

The clear zone is a suggested value for the lateral clearance that should be provided from the edge of travel lane free of hazardous objects. AASHTO's *Roadside Design Guide* (5) offers suggested clear zone values applicable to permanent conditions based on the roadway's design speed, embankment slope, and average daily traffic. Ideally, this clear zone or a recovery area should be provided for all conditions, in order to accommodate errant motorists, crash vehicles, disabled vehicles, or emergency situations. However, for temporary construction conditions, where motorists may be exposed to a hazard for a brief time, it is often impractical to provide the full clear zone as described in the *Roadside Design Guide* (5). One agency has developed modified clear zone requirements. This is provided in Table 4. These values may be used in conjunction with engineering judgment in order to determine the appropriate design.

Table 4. WORK ZONE CLEAR ZONE DISTANCES

Approach Posted Speed Limit ⁴	ADT	Front Slopes			Back Slopes		
		1:6 or Flatter	1:5 to 1:4	1:3	1:6 or Flatter	1:5 to 1:4	1:3
		Work Zone Clear Zone Distances (ft)					
35 mph or less	Under 750	4 - 6	4 - 6	**	4 - 6	4 - 6	4 - 6
	750-1500	6 - 8	8 - 10		6 - 8	6 - 8	6 - 8
	1500-6000	6 - 8	10		8 - 10	8 - 10	8 - 10
	Over 6000	10	10 - 12		10	10	10
35 - 50 mph	Under 750	6 - 8	6 - 10		4 - 6	4 - 6	6 - 8
	750-1500	10	10-14		6 - 8	8 - 10	10
	1500-6000	10 - 12	12 - 16		8 - 10	10	10 - 12
	Over 6000	12 - 14	16 - 18		10	12	12 - 14
55 mph	Under 750	6 - 8	10 - 12		6	6 - 8	6 - 8
	750-1500	10-12	12 - 16		6 - 8	10	10 - 12
	1500-6000	12 - 14	16 - 18		10	10 - 12	12 - 14
	Over 6000	14 - 16	16 - 20*		10 - 12	12 - 14	14 - 16
60 mph	Under 750	10 - 12	12 - 16	6 - 8	8 - 10	10	
	750-1500	12 - 16	16 - 20*	8 - 10	10 - 12	12 - 14	
	1500-6000	16 - 18	20 - 24*	10 - 12	12 - 14	16	
	Over 6000	18 - 20*	22 - 28*	12 - 14	16	16 - 18	
65 mph	Under 750	12	12 - 16	6 - 8	10	10	
	750-1500	16	18 - 22*	8 - 10	12	12 - 14	
	1500-6000	18 - 20*	22 - 26*	10 - 12	14 - 16	16 - 18	
	Over 6000	18 - 22*	24 - 28*	14 - 16	16 - 18	18	

* Clear zones may be limited to 18 ft for practicality.

** For parallel front slopes steeper than 1V:4H but 1V:3H or flatter, the recommended clear zone includes a distance beyond the toe of the slope. To determine the distance:

1. Determine the clear zone for a 1V:6H or flatter slope for the applicable design speed and traffic volume.
2. To determine the recommended distance beyond the toe, subtract the shoulder width (or the distance from the edge of traveled way to the slope break) from the distance in Step #1.
3. If the distance in Step #2 is less than 10 ft, the minimum clear distance will be 10 ft beyond the toe. If the distance in Step #2 is greater than 10 ft, the clear zone distance beyond the toe will be that distance or 15 ft, whichever is less.

Notes:

1. All distances are measured from the edge of traveled way.
2. For clear zones, the "ADT" will be the total ADT on two-way roadways and the directional ADT on one-way roadways (e.g., interchange ramps and one roadway of a divided highway). Traffic volumes will be the expected traffic volume through the work zone.
3. The values for "back slopes" only apply to a section where the toe of the back slope is adjacent to the shoulder.
4. Approach posted speed limit prior to the work zone.

Source: Based Upon IDOT BDE 2002 Figure 55-4B (6)

When a hazard has been identified for construction traffic, there are several options to consider. The hazard may be temporarily removed, relocated, modified, or shielded. In order to determine the appropriate action, the duration of motorist's exposure to the hazard and the

severity of the hazard should also be considered. If a hazard can easily be removed, relocated, or modified in such a way as to no longer be considered a hazard, this would be the preferred action. If none of these options are available, shielding the hazard may be considered. The designer must keep in mind that placing a traffic control device or barrier adjacent to the traveled lane is also considered a hazard to motorists. Therefore, an evaluation between placing a safety device and not placing one is essential to determine the safest alternative for both motorists and construction workers.

If it has been determined that a hazard is present and it must be shielded, there are several options for providing protection. In order to select the appropriate roadside treatment, roadway conditions should be considered, which include design speed, location of the hazard relative to the roadway and opposing traffic, available installation space, surface grade, desired life of the treatment (i.e. temporary or permanent use), installation and repair costs, anticipated crashes, and desired vehicle reaction (redirective or nonredirective). Concrete barrier with an end mounted attenuator is one type of temporary traffic control zone devices (see Figure 4).



FIGURE 4 MOVEABLE CONCRETE BARRIER WITH ATTENUATOR

Photo By Amber Huckfeldt

Plan Components and Layout

A maintenance of traffic plan or traffic control plan (TCP) has several purposes. It must represent a reasonable and constructible alternative for building the permanent conditions, which will allow a contractor to provide an accurate estimate of construction costs. It must also provide a potential solution to safely maintain roadway operation with as little delay as practical. The TCP should include accommodations for not only motorists, but also bicyclists and pedestrians, if current demand exists. In order to adequately illustrate to the contractor the suggested process

for construction, it is essential to provide an accurate and concise TCP. The level of detail required to create an adequate traffic control plan is variable and dependent on the scope of services. Minor road improvements, such as pavement patching or widening, may only require the insertion of agency standard drawings into contract plans, which provide typical design and placement of traffic control devices. Other projects, such as an interchange reconstruction, may require a more in depth maintenance of traffic plan that is project specific and provides detailed staging layouts, which are not thoroughly represented with typical drawings.

The TCP may include project information such as the project length, stationing, roadway names, and location maps. Existing topography is often used as a background for the drawings. Geometric features provide guidance for implementing the TCP. This may include pavements, horizontal and vertical alignments, and roadside elements. Often traffic flow is identified on the drawings. For unique geometric features, such as crossovers and lane closures, design elements such as sight distance, vehicle maneuvering ability, cross slopes, delineators, temporary pavement markings and signs are included on the plans.

The intended work zone should be noted on the plans. Worker access to the work zones should be considered. A list of construction activities is often noted for each stage for clarification. Including the layout of guide signs, channelizing devices, and special signing devices is a fundamental element of the TCP. Pavement markings and their identifiers are recommended for traffic control plans. Attenuators and other safety devices should be identified on the plans. In some cases, roadside safety analyses are performed to determine the most effective and cost efficient safety protection for the hazards. Drainage items needed for temporary conditions can be provided for clarification. On some projects, temporary lighting is needed during construction. If temporary lighting will be pole mounted, the poles, controllers, power source and other electrical items should be identified.

At each end of the project, the TCP should identify how the contractor should tie in to adjacent contract work zones or existing conditions. When adjacent work zones are present at the construction limits, coordination between work zones and contractors is required. This should be noted on the plans or in the contract documents. Duplicate and overlapping signs would be eliminated.

Typical sections can be used to enhance TCPs. A typical section of each construction stage clarifies the work zone activities, available lanes, the lane widths, direction of travel, work zone areas, barrier and channelization placement, and offset dimensions. Temporary pavements can be further detailed through the use of pavement profiles. Vertical curve information should be provided when profiles are included as this will be useful during construction.

For some traffic control plans, extensive use of cross sections are included to further illustrate the temporary construction conditions. They will typically include the relative location of permanent and temporary alignments, pavement, cross slopes and ditch design. The designs of temporary ditches are difficult to portray on the plans. The use of cross sections can aid in understanding the ditch flows and grading. The sections will allow a visual comparison of construction conditions relative to existing ground or future permanent conditions.

The maintenance-of-traffic plans are often divided into stages. These stages may be identified by constructing major components of the project (i.e., Stage 1: construct eastbound lanes and Stage 2: construct westbound lanes). Another example of stages could be assigning a stage to all items in a particular year of construction. A two-year construction staging plan may have Stage 1 for the first year's activities and Stage 2 for the second year's activities. For large projects, there can be sub stages and combination of stages by year and sub stages by

components. The design needs to coordinate the signing and construction staging with adjacent or overlapping projects.

To help the contractor better understand the stages of construction, a narrative often as a special provision is included, which describes the permanent elements (pavement, bridges, lighting, drainage structures, etc.) and temporary elements (temporary pavement, crossovers, temporary drainage, erosion control elements, temporary walls, etc.) constructed in each stage (or sub stage). In addition to describing what is constructed (or removed) in each stage, it is beneficial to include in the narrative what roadways are open to traffic. Another specification that is often used is a requirement for the contractor to inspect their traffic control for proper placement visibility, and if it is in a usable condition.

Project Communication

When designing the maintenance-of-traffic, the designer should not only consider the contractor but also the average motorist. Motorists may not see the paper plans but they are the ones using the facility. Therefore, the design and layout must be understandable to them in the field to successfully execute the design's intent. If bicycle and pedestrian facilities are provided, the interest of these road users should be considered in the design. The maintenance of traffic plan should propose a concept that allows the motorist, pedestrian, and bicyclist to safely share the roadway during construction activities. Operation effectiveness and safety are key issues. When the project is in an urban location, there are likely going to be a greater variety of road users (i.e., such as bicycles, pedestrians, and transit vehicles in addition to the automobiles, motorcycles, and trucks).

Before a roadway can be opened to traffic, either temporary or permanent pavement markings must be in place to provide the motorist with a clearly delineated path of travel. During roadway construction, temporary pavement markings are utilized for each intermediate stage of the maintenance of traffic. Their function and design are similar to permanent pavement markings. Temporary pavement markings may consist of removable or non-removable preformed retroreflective tape, temporary traffic paint, thermoplastic, epoxy, or raised pavement markers. Temporary striping should be applied on dry and cleaned pavement surfaces in accordance with *MUTCD* (2) or governing agency's policy. Temporary pavement markings are commonly used in conjunction with construction signs and channelizing devices to clarify the intended vehicle path.

Drivers have a minimal amount of time to comprehend the modifications to the roadway and roadside at a construction site. Providing motorists advance warning of construction will aid in reducing collisions and driver uncertainty. Traffic control devices regulate, warn, and guide roadway users on the maneuvers required to safely travel within the work zone. Design considerations for the placement of these items include typical applications and characteristics of the motorist. Signs and channelizing devices need to be placed in a manner that is clear and concise to the traveling public. Placing too many signs or signs close together may confuse the driver whereas not placing enough or placing them too far apart will leave the driver uninformed and susceptible to abrupt maneuvers. Specific agency guidelines and the *MUTCD* (2) should be referenced for appropriate distances and locations depending on the roadway classification and construction work activity.

In order to further increase motorist awareness, preconstruction warnings are being utilized by some agencies. With an increase in the use of technology among the traveling public, local and federal agencies are providing construction websites that communicate construction

work zones, delay information, dates and times of lane closures and detour information. The media are also becoming more actively involved in providing similar information through television, radio, and newspaper reports. The advance notification to motorists allows for a better utilization of detour routes or the ability to find alternative forms of transportation minimizing construction congestion.

MAINTENANCE OF TRAFFIC PRACTICES AND EMERGING TRENDS

The traffic through the construction zone should be analyzed to determine if mobility will be provided. The analysis will identify potential impacts so the designer has an opportunity to mitigate the impacts or at least manage them. Work zones tend to restrict traffic by reducing the number of lanes, lowering the posted speeds, narrowing lanes, reducing shoulder widths, and providing distracting construction activities adjacent to the traffic. If the impacts are not managed, the traffic operations during construction can lead to long delays and long queues. The more complex the project, the more extensive traffic analysis is needed.

One method used to facilitate reconstruction on an existing roadway is called construction by halves. This method entails transferring all traffic traveling in one direction of a divided highway to the opposite side of the roadway, typically with the use of a crossover, where the roadway is shared with opposing traffic. In order to accommodate all traffic, shoulders can be utilized as travel lanes, temporary pavement may be utilized, and/or existing lane widths may be narrowed. An advantage to the construction by halves method is that it allows the complete construction of one side of the road at a time and construction personnel interaction with motorists is minimized.

In some locations, constructing temporary pavement or bridges is cost prohibitive. If the road can not be closed, then construction can be performed by closing some of the lanes to traffic. When this occurs, the designer should evaluate the traffic impacts. The impacts of being able to maintain traffic during construction can affect the final design. This can often be found with the staged construction of two-lane, two-way bridges.

Night Work

The *MUTCD* (2) now states, "Roadway occupancy should be scheduled during off-peak hours and, if necessary, night work should be considered." In order for the workers to perform the nighttime construction tasks, they need to be able to see. Unfortunately, many of the currently used methods of lighting can create glare for motorists. A group of researchers in Illinois has been examining construction lighting glare and has developed a model (7) to measure and quantify the glare produced in and around nighttime roadway construction projects. The report indicated that balloon lights are a low-glare light source, but their use does not guarantee that glare conditions would remain within acceptable limits.

The design engineer should contact and coordinate with the local agencies that are located in the vicinity of the proposed construction project. This coordination should occur during the planning and design process. As a part of this coordination, any noise ordinances or restrictions should be obtained and reviewed. The noise ordinances may limit the type of equipment that can be used on the project or restrict the contractor's available time to work. Many ordinances will place noise restrictions during evening hours.

Contractor Design

A trend that is occurring on some fast track projects is the use of performance specifications. A performance specification is similar to contractor design-build, but the performance specification is often limited to one or only a few project elements. The contractor is provided design plans that are about 30% complete. The contractor completes the design, it is reviewed, and the element is constructed. The performance specification (included as a special provision) then often includes a maintenance of traffic requirement.

Soft Costs

Often “soft costs” such as user costs and delay costs in the past have not been considered in the cost of construction projects. In 1998, the FHWA released a report titled “Meeting the Customer’s Needs for Mobility and Safety During Construction and Maintenance Operations”. Since that time some agencies (8) have been considering the “soft costs” in their decision process. These are example costs:

1. Speed Change Vehicle Operating Cost (due to extra vehicle decelerating and accelerating)
2. Speed Change Delay (time cost associated with decelerating and accelerating)
3. Work Zone Delay (time cost to traverse the work zone)
4. Stopping Vehicle Operating Cost (additional vehicle operating cost associated with stopping and accelerating)
5. Stopping Delay (time cost to stop in work zone and then accelerating)
6. Queue Delay (time to proceed through queue)
7. Queue Idling Vehicle Operating Cost (vehicle cost due to “stop and go” driving – fuel, oil, maintenance, and depreciation)
8. Circuity Vehicle Operating Cost (extra operating cost for extra distance vehicle travels)
9. Circuity Delay (extra time to travel the extra distance)
10. Crash Costs (number of crashes per vehicle miles of travel)

Lane rental costs may also be factored in as a soft cost. NJDOT uses lane rental costs to determine liquidated damage costs. The Utah Local Technical Assistance Program (ULTAP) (9) indicates lane rental has been used on projects where one or more of the following conditions exist:

1. “Traffic restrictions or lane closures result in high road user costs
2. The use of alternate routes or off-site detours is impractical
3. The traffic control plan allows the contractor flexibility in scheduling work to minimize the impact of lane closures.
4. The agency seeks contractor expertise to minimize the time that lanes are out of service
5. The project is relatively free of third party conflicts, design uncertainties, or right-of-way issues which may impact the project schedule
6. The benefit in terms of the reduced impact to the highway user is greater than the additional cost to minimize lane closures.”

Lane Closures

Several agencies have developed lane closure guidelines. This may include a chart that identifies on which days and what times of the day one lane, two lanes, or no lanes can be closed on particular sections of highway. Such charts are based on historical traffic data and the methods and procedures found in the *Highway Capacity Manual* (4). Other factors such as weather, season of the year, proximity to holidays, or special events could modify such a chart.

In addition to short term planned lane closures, longer term lane closures (in some cases described as permanent) occur during construction stages. In order to keep the traffic informed of these potential impacts, it is imperative that the agency is aware of all the various construction activities, lane shifts, stage changes, and any other activities that could impact their roadways. A method to do this is to implement a process that requires the engineers and contractors to submit lane closure requests to the agency. Due dates and times should be established for these requests such that the agency personnel have sufficient time to process the requests and make them available to the public in a format that is easily understood (10).

Speed Control

A growing issue for work zones today is motorist negligence of the work zone speed limit. Since speed reductions are often difficult to enforce, determining a technique that successfully influences motorists to adhere to the work zone speed limits has proven to be a challenge for roadway designers. Techniques believed to be more effective include the use of Variable Speed Limit (VSL), Radar Speed Display Units (RSDU), and speed and law enforcement officers. Highway agencies are enlisting the help of local law enforcement to patrol the work zone and enforce speed limits and traffic control. Law enforcement assistance may be of particular importance for projects with night-time work and high speed roadways where speeding within the work zone is more frequent. Heavy fines are being applied to offenders with the intent of discouraging the activity and even more significant consequences are enforced for repeat offenders including, inflated fines and driver's license suspension.

CONCLUSIONS

This paper presents information on many of the essential design components of an effective traffic control plan that were identified during preparation of the 2009 ITE *Traffic Engineering Handbook*(1). This paper touches on elements used by the traffic control designer to demonstrate that a project can be built while maintaining required traffic movements. As mentioned earlier, it is important to note that the designer should not dictate the contractor's means and methods of construction; rather the design plans should provide an option for construction that meets the agency requirements. The designer should identify any agency specific design guidelines pertaining to temporary traffic control as they may have requirements that vary from those noted in this paper. Even when an agency does have its own criteria, information included in this paper and expounded upon in the *Traffic Engineering Handbook*(1) may supplement the agency's guidelines where information may be lacking.

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