Traffic Control Safety: Meeting the FHWA Minimums Is Not Enough

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Introduction

What is a temporary traffic control zone? Section 1A.13 of the Federal Highway Administration's Manual of Uniform Traffic Control Devices (MUTCD) states that a "traffic control zone is an area of highway where the road user conditions are changed because of a work zone or incident by the use of temporary traffic control devices, flaggers, uniform law enforcement offices or other authorized personnel.(1) The work zone may be as short as several feet or as long as several miles. Work zones are a dynamic process based on the type of project to be completed. The work zone varies in terms of required protection again depending on the type of project, the duration, the location (in terms of relationship to the traveled way –off the shoulder, on the shoulder or in the traveled way) the time of day or night the work is to be completed. The detail of how to design the minimum level protective systems for construction, incident or maintenance is contained in part 6 of the MUTCD.

What are the Work Zone Hazard results? There are several organizations that acknowledge this national tragedy on our roadways. The FHWA, National Safety Council, The AGC of America, American Transportation Safety Services Association (ATSSA), the American Road Transportation Builders Association (ARTBA) etc. have all joined in promoting a National Work Zone Safety Week . The losses are staggering and are not diminishing; in fact losses are on the rise from more vehicles occupying the same space that is being worked on to maintain original design conditions. "Between 1982 -2002 vehicle miles traveled increased by 79% while highway lane miles only increased by 3% … An average of 23,745 miles of roadway had federal aid roadway improvement projects underway per year from 1997 -2001… An estimated 3,110 work zones were present on the National Highway System (NHS) during the peak summer roadwork season of 2001…In 2005, 1,074 fatalities resulted from motor vehicle crashes in work zones. This has grown from 1028 in 2003 (a 4% increase) and 693 in 1997 (a 55% increase)… More than 41,000 people were injured in 2003 as a result of motor vehicle crashes in work zones."(2) The 2003 statistic illustrates the breakout of who is killed, of the 1024 fatalities 85% were motorists. The majority of fatal work zone crashes for all vehicles (59%) and large trucks (71%) occurred on roads with speed limits of 55 mph or greater. Highway and street construction activities (SIC 1611) are among the most hazardous. Fatality rates for construction highway workers are double the rate for other construction. Data shows that 38% of LIUNA (Laborers International Union of North America) members are employed in road construction activities yet over 73% of on-the-job fatalities occurred in road and highway construction. In the U.S. 120-130 workers die each year in road construction activities.

The complexion of work continues to change; we are seeing many more projects being pushed to night-time or off peak hours to minimize the impact to traffic. However, 53% of work zones are designated as day work, 22% as night work and 18% are active all day or nearly all day (18 or more hours).(2) Having more work occur during off peak hour may have an impact on the data in the future, but for now the work zone facts (2003) show approximately half of all the crashes occur during the day, and about three quarters of the fatal large truck work zone crashes were during the day. More than two times as many work zone crashes occurred on weekdays compared to weekends. Fatal work zone crashes occurred most often in the summer and fall.(3) That may have more to do with weather in many parts of the country and that summer is historically a high traffic season than other factors.

Going forward we need to get better in terms of how we approach work zones. Much of the Dwight D. Eisenhower National System of Interstate and Defense Highways are more than 30 years old. Obligations of federal funds for roadway projects increased by $2.86 billion on average per year between the years 1997 – 2001. Between 1980 – 2000 capital spending on highways increased 112% and maintenance spending increased 14% after adjusting for inflation. In the year 2000 more than 81% of highway capital expenditures were allocated to system preservation (52%) expansion (21.2%) and enhancement (7.9%), all improvements that involve active work zones on existing roads with traffic present. Work zones on freeways are estimated to account for nearly 24% of non-recurring delay. (4) WE CANNOT SHUT THESE ROADS DOWN! Additionally, the MUTCD clearly states the goal is to minimize the impact to traffic. Greater than 60 million vehicles per hour per day of capacity were estimated to be lost due to work zones over a two week period during the peak summer road work season in 2001. Motorists encountered an active work zone one out of every 100 miles driven on NHS in 2001. Highway workers spent 246.4 million hours working on the NHS in 2001.

The MUTCD is the recognized national standard for road work zone design, it includes 10 parts that detail most aspects of roadway construction both on a permanent and temporary basis. Part 6 details the aspects that are required, are recommended and that are optional techniques for temporary traffic control zones during construction, incident and maintenance activities. This document details the effective minimums for all States. Many States will adopt the manual while others will adopt with supplements to fit local laws or circumstance. OSHA has adopted the manual in it's entirety under the construction standard 29CFR 1926.200(g)(2), but because of the date of the final rule publication identified the 1993 supplement and the millennium edition, with no provision for updating to the current edition. In Colorado OSHA is enforcing the 2003 edition standard (mandatory) provisions. Also in Colorado we have been working under a local emphasis program that has become a regional emphasis program.

The following concepts are key to using the MUTCD and to be able to analyze the compliance of work zone design or Temporary Traffic Control Zones (TTCZ). Use the typical applications or TAs, including the related text to provide the basis for good judgment. There are 46 TAs in the 2003 edition; however, your project will probably not be among them. You may have to combine the concepts from one TA to another TA to design a safe TTCZ. The fundamental data charts and formulas for determining lengths and distances of TTCZ elements are based on roadway speed. These charts, formulas and TAs are found in part 6 of the MUTCD. Other resources and data may be used to determine the compliance with design criteria. These other resources may be found in State required documents and standards or contract specials and plans.

The components of a TTCZ are found in Part 6 of the MUTCD page 6C-3, the basic elements starting upstream traveling downstream trough the TTCZ the first element we encounter is the advance warning area typically defined by a three sign warning system. In the illustration there is a closed right lane of two northbound lanes. The signs would be Road Work Ahead, we then travel the C distance, the second sign in the series of three would be Right Lane Closed, we then travel the B distance, the third sign in the series of three would be a transition symbol (known around the country by different names: merge symbol, lane closed symbol, turkey tracks, turkey leg, dog leg, etc.) At the termination of the A distance the transition (taper) begins. The length of the taper depends on the speed of the roadway (measured, calculated or posted) and the width of the lane or offset to be closed. As we proceed downstream, the next element we encounter is the start of the activity area. This area is defined by the longitudinal buffer (defined by speed) and the work area (defined as the project). The length of the activity area is calculated by adding the buffer, the work and downstream buffer distances to create the tangent line or line that is parallel to the direction of motorist travel. In this illustration there is a downstream buffer determined by engineering judgment. The length of the activity area is calculated by adding the buffer, the work and downstream buffer distances to create the tangent line or line that is parallel to the direction of motorist travel. The activity area is followed by the downstream or termination taper that is one hundred feet per lane closed. The optional end work sign is shown in this illustration and is placed 500 feet downstream from the end of the activity area.

Traffic control devices (TCD) include all the items you would see in the TTCZ such as signs, markers tubes cones, glow posts or grabber cones, vertical panel's drums, barricades, barriers. The TCD is used to guide motorist in a positive manner through the work zone. The devices create the channel or safe path of travel for motorists. All of the devices must be crashworthy complying with the NCHRP 350 crashworthy criteria. With appropriate set up and maintenance the motorist will follow this safe path with out creating queues that cause undue delays. This is the part of the design and implementation that may be somewhat counterintuitive. The more bottle necks that are created the more dangerous the work zones become for the motorist and worker. The less impact to traffic, the more efficient the traffic flows, the safer the work zone becomes. However, the installation and removal of the devices become the most hazardous time in the life of the work zone. At this time the protection for workers is incomplete and may expose workers to live traffic or motorists that are inattentive, confused, distracted or otherwise not in complete control of there vehicles.

Some the devices you see on the road are the traffic cones. They are usually orange in color with or without retroreflective stripes on high speed roads and for night time use they are 28" tall (An example of how States may exceed the federal standard is in Colorado the DOT requires a 36" retroreflective cone for high speed roads and for night time operations). Vertical panels are used to obtain more attention from motorists and the panels are from 8 to 12 inches wide with a minimum height of 24". Some of the designs will accept beacons or lights. The diagonal stripe is from 4-6 inches wide and points at the lane in which you expect the motorist to travel. (How many motorist have a clue what this means? - Probably none to a few. How many plaintiff attorneys know how these devices should be located? - Probably all of the attorneys know this!)

Drums or barrels are 36” tall and approximately 18” in diameter, the color scheme is two orange strips with two white bands (usually retroreflective). This device may also accept beacons or lights and ballast is required. Steel or open topped drums are prohibited from use.

Barricades come in three distinct styles or types. Type I is a single 4”-6” horizontal rail often on a sawhorse type of design and is used on conventional roads or sidewalk closures. The diagonal stripe must point to the lane in which you expect the motorist to travel. These devices must also be crash worthy even when ballast is applied. The ballast must not be applied in a manner that would cover the retroreflective rail. The type II barricade has a two 4”- 6” horizontal rails designed on a sawhorse arrangement and is used for high speed applications including being used as a canalization device in tapers and on tangents for freeway operations in some states. Type III barricades are used for road closures, or in some circumstances, on lanes or exit ramps where high visibility is required to control the volume and traffic speed. The diagonal stripes also are important on the type III barricade to get the motorists’ attention to the direction that they need to travel or not travel.

Temporary Traffic Barriers have been known by several names: Jersey or Georgia Barriers, K-rail, portable concrete barriers, type IV and now type VII temporary traffic barriers. Barriers are positive protection for workers and motorists when used as a separation technique. They should not be use in high speed tapers unless recommended by an engineering study and receive special treatment such as crash attenuation. They may be used to provide positive protection in work zones when designed in a flare that would redirect errant vehicles and the upstream side of the flare has a crash attenuation treatment or is placed in the clear zone (defined by the project).

In the power point presentation I’ve illustrated a few potential hazards on road work projects with photographs. The first photo shows workers moving drums within a few feet of live traffic. This illustrates the proximity of live traffic without any lateral buffer space between the workers and live traffic. This happens often in congested traffic situations. The workers become focused on the work to be completed and may become somewhat cavalier about the hazard posed by nearby traffic. The second illustration shows private vehicles in the limited space work area. An internal traffic control plan is recommended to identify the appropriate method to transport workers to the site, identify where the superintendent will park their vehicle and how haul trucks will enter and exit the work space. The third photo on this slide illustrates an arrow panel malfunction. The arrow board is not flashing either the directional arrow or the caution mode. Again, in this photo there is congestion in the workspace with private vehicles, work trucks and construction equipment.

There are many traffic control photos available from various web sites. The photo used for the slide showing attack helicopter hovering behind a highway sign stating “Speed Enforced by Aircraft” is from a collection of traffic control signs and misinformation that may confuse motorists from the US Naval safety center. (6) Folks that do traffic control or work in road construction would love to have this type of enforcement on their jobs. Motorists may get the point. However the protection workers have is in part provided by the advance warning area defined by the warning sign. These warning signs are typically diamond shaped with orange background and black legends with three words being a desirable maximum. The stereotypical set up is a three sign system in sequence of:

1. Advising the motorist of the “Road Work Ahead”

2. Warning the motorist that the “Right Lane closed”
3. Instructing the motorist to move with the “transition symbol”

The matrix provided in appendix 1 titled TCS Job Aid shows the distances between the signs for various types of roadways. The first column of the matrix is the roadway types, low speed urban <40mph, High speed urban >45mph, Rural (highways other than Freeways) and Expressway/ Freeway. The rows are the distances for each of the roadway types in columns A, B, and C. Please note when reviewing the design or implementation of appropriate advance warning (see the TTCZ diagram on the bottom of the TCS Job Aid) is that distances between the signs are applied in reverse order. Traveling downstream we encounter the first sign, “Road Work Ahead” in the series of three; travel the C distance then encounter the second sign “Right lane Closed”; travel the B distance and see the “transition symbol”; travel the A distance to the transition or taper or Flagger station location. To determine the total advance warning distance, the A, B, and C distance must be added. I.E. advance warning in a high speed urban scenario would be 1050 feet minimum. While on a freeway the minimum would be 5140 feet. In the MUTCD the primary numbers for these distances are in metric notation for distance (meters), while the secondary numbers in parentheses are in American notation for distance measurement (feet).

As the motorist travels downstream through our work zone, they first are warned by our advance warning system. We now must guide them positively through our system with the use of tapers of various types. The first type of taper is the merging taper that takes an entire lane closure and moves traffic from one lane to another driving lane. The length of the taper is expressed as “L”. (The formulas for calculating L are included in the Appendix and will be covered in the next paragraph.) The second taper type is a shifting taper used when two or more lanes of traffic are shifted from the original lane configuration by the use of 0.5 L shifting tapers. The shoulder taper is used when a shoulder is closed and the paved shoulder exceeds 8 feet in width. The length of this taper is determined by calculating 0.33 L. There are two tapers that calculations are not necessary, they are the one-lane-two-way taper and the termination taper. Each of these tapers is generally 100 feet in length. The one-lane-two-way taper in meant to be short to minimize the impact to traffic while the termination taper is a minimum of 100 feet in length for each lane closed in the work zone.

Appendix 1 and the slide “Solve for L” illustrate the two basic formulas that are based on the speed for the roadway. When speeds are less than 40mph the formula for L is the width of the lane or offset multiplied by the speed squared divided by 60. When speeds of the roadway are 45 mph or greater, the formula to find the length of the taper or L is: the width of the lane multiplied by the speed. Examples are: an urban high speed road with a lane width of 11 feet and a speed of 45mph will produce a taper length or L of 495 feet; a highway with a lane width of 12 feet and a speed of 60mph will produce a taper length of 720 feet.

The buffer and work areas of the work zone comprise the next element that is encountered by the motorist on their travels through our system. The buffer space is determined from the chart on Appendix 1 and pages in the MUTCD. The title of the chart in the MUTCD is “Sight Stopping Distance As a Function of Speed”. Again, the MUTCD has metric and American notations for speed and distance. Appendix 1 is in American notation for speed and distance.

The next concept can become a bit confusing for those new to traffic safety. That is the spacing of devices in the TTCZ; there are three basic spacing approaches outlined in the MUTCD. Contractors and DOT personnel may use another system we'll cover in a moment. The first spacing technique is that of taper spacing where we determine the number of spaces in a taper by dividing the total length or L of the taper by the speed of the roadway expressed in feet. Expressed as an algebraic formula it is (L/S) + 1. The reason for adding one is that dividing the length of the taper by the speed results in determining the number of spaces in that length and one device must be added to create the number of spaces required in that element. The first device is placed on the edge line and at 60 mph the next device would be placed 60 feet from the first device placed. Each subsequent device is placed 60 feet from the last. Once the device has been added in the taper the devices and spaces between the devices are equal for the remainder of the device spacing calculations. The next spacing approach is for the one-lane-two-way taper and the termination taper; no calculation is required twenty feet apart or 5 devices in each of these tapers because they are each 100 feet in length. Tangent spacing is the next approach that must be calculated. The tangent is parallel to the path of motorist travel and is defined by the length of the longitudinal buffer(s) upstream/downstream and the work area. To determine the total tangent length, add the buffer and work. The product of the addition is divided by two times (2X) the speed to determine the distance between the devices and to identify the number of devices that are required (as a minimum) on the tangent line. Traffic control folks normally exceed this minimum device spacing to place more devices in a given length. Typically, the dashed lines or skips are used as a measuring tool: the dashed lines are 10 feet long, and the spaces between the lines are 30 feet long for a 40 foot skip. For example, on a 60mph roadway instead of 60 feet apart in the taper the devices would be placed 40 feet apart. On the tangent line, instead of placing the devices 120 feet apart (2X the speed), the devices are placed 80 feet apart or every other skip. This arrangement exceeds the minimum defined in the MUTCD and provides a clearly defined safe path of travel for the motorist.

Worker safety considerations are detailed in the MUTCD Part 6 in section 6D.03 There is reference to the OSHA Law and standards in this section with competent person and the general duty clause 5(a)(1) called out specifically. The guidance (should action word) recommends planning, job hazard analysis, safety apparel and other considerations for worker safety. Some of the techniques include specific training, law enforcement personnel, Truck mounted attenuators (TMA), buffer zones etc.

The TMA is a recommended addition to work zones to protect workers from motorists. In Colorado many of the new projects that have high speed lane closures are requiring TMA as part of the plan to protect workers. During our highly visible TREX project (redesign and rebuild of a major traffic corridor I-25 going through the South end of the Metro Area called the Denver Tech area) TMAs were used extensively. At one point approximately midway through the project, a striping company experienced three shadow vehicles equipped with TMAs hit within 6 weeks while part of the work truck caravan for striping operations. There were no serious employee injuries from these incidents.

Nighttime traffic control requires different techniques than the standard daytime operation. The MUTCD part 6 is for daytime operations. There are a few mentions of different approaches for night time operations as compared to day time operations in part 6. One such item is in the section defining the duration of operations to be used by the traffic control professional. In Section 6G.02 under standard for work duration: **"B. Intermediate –term stationary work is**

work that occupies a location for more than one daylight period up to 3 days or nighttime work lasting more than one hour." Another document that is used more extensively by State DOTs and other professionals in the field is the NCHRP 476 report. This document recommends techniques for designing night work for construction and maintenance operations. The basic approach is to upgrade the warning signs, add more signage, extend tapers, decrease the distance between devices, add buffers and use TMAs in the system. Other techniques for nighttime work injury prevention are to add illumination for critical operations such as Flagger stations and haul road crossings. High visibility clothing is required with class/type III as a minimum for Flaggers.

Work zone traffic control is only successful when the minimum requirements identified in the MUTCD are followed and exceeded when the need is identified. Some situations require exceeding the minimums such as the number of devices in the taper and tangent area, signage upgrades or additional use of Portable Changeable Message Signs PCMS or "message boards", arrow boards, pilot cars, TMAs and other techniques that will provide the motorist with a clear safe path to follow. With that clear safe path the motorist will not endanger the road construction worker or pedestrians.

Flagger performance is one of the FHWA's recurring deficiencies that is observed in work zones. There are several flagging training programs available around the country by NSC, ATSSA, and others. In Colorado the staff from CDOT is working on upgrading our certification process. Generally, for Flagger safety appropriate and properly placed signage for advance warning is required. The proper location for controlling traffic must be defined for the project. Routes of escape must be part of the plan and adjustments may have to be made for phases of the project such as bridge or overpass locations. Appropriate clothing must be worn and in serviceable condition (meeting the manufactures specifications). The Flagger must be alert at all times and especially at night when in the illuminated area. Drunks do drive to the light like a moth. Routes of escape are extremely important during night operations.

- Work zone observations for system improvement by the FHWA while developing the Safety and Mobility program include:
- There is universal agreement that the most effective way of controlling speed in the work zone is to have staffed police car with flashing lights at the beginning of the work zone.
- There is a need for accurate work zone crash data and the evaluation of traffic handling techniques in order to make sound decisions
- Traditional traffic control practices do not encourage the contractors to minimize motorist delay and/or enhance the safety of the work zone
- There is a need for a comprehensive effort to educate the general public, road users, and elected officials on the need for work zones, how to navigate safely through a work zone and the dangers associated with them.

The FHWA has promulgated a Safety and Mobility program that State DOTs are working on for plan completions by October of 2007.
The goals of the new rule are:
- "Expand thinking to address corridor, network and regional issues while planning and designing road projects"
- "Expand work zone impact mitigation beyond traffic safety and control by developing Transportation Management Plans (TMPs) for road projects. A TMP always consists of

temporary traffic control strategies, and where necessary, it also consists of transportation operations and public information strategies."

- "Advocate innovative thinking in work zone planning, design and management, so as to consider alternative/innovative design, construction, contracting and transportation management strategies. "

The rule can be defined by three primary components:

- "Policy-level provisions that help states implement an overall work zone safety and mobility policy for the systematic consideration and management of work zone impacts"
- "State-level processes and procedures that help states implement and sustain their respective work zone policies."
- "Project-level procedures that help states assess and manage the work zone impacts of individual projects." (7)

Some overall improvements in the current system could follow the three D's of Durability, Duration and Density. They are:

- Facility Durability - Reduce the number of work zones: Reduce the need for work zones through the use of improved materials and methods that increase the life cycle.
- Project Duration - Reduce the time a work zone is in place: Reduce construction time in the roadway through better methods, policies, technologies, and operations.
- Traffic Density - Improve traffic flow in and around those work zones that must occur: Decrease traveler delay and safety impacts due to work zones through better traveler information, traffic control, incident response, and work zone geometry.

All the above lead to making work zones better by utilizing best practices and continuously improving. We could accomplish this by:

- Work zone operations managers and operators realize distinct benefits from being aware of the current best practices available nationally.
- "Solutions" come from partners working together successfully to solve problems within the resources, authority, and relationships available to them.
- We can learn from the successes of federal, state, and local agencies and private sector partners working to "improve safety and mobility on both sides of the barrel." (8)

There is a FHWA Best Practices Guidebook available through the internet. This website and other helpful websites are listed below. There are various states developing there own best practices guidelines. In Colorado we are on our second edition and an update will be available on the CDOT website by mid June 2007. The FHWA publication was a collaborative effort with AASHTO Best Practices taskforce and contains points of contact for information. This document will be updated as the best practices evolve.

Web sites for Information and tools to improve your traffic control plans.

- FHWA Office of Operations Work Zone Mobility and Safety Web Site
- http://www.ops.fhwa.dot.gov/wz/workzone.htm
- FHWA Office of Safety Web Site Work Zone Information:
- http://safety.fhwa.dot.gov/programs/wsz.htm

- FHWA National Work Zone Awareness Week Web Site:
- http://safety.fhwa.dot.gov/fourthlevel/nwzaw01.htm
- National Work Zone Safety Information Clearinghouse:
- http://wzsafety.tamu.edu
- INTERNET:
- http://mutcd.fhwa.dot.gov//
- Colorado Contractors Association
- AGC MUTCD 2003 edition - parts 1,5,6
- 303.290.6611: www.coloradocontractors.org
- Professional Traffic Graphics for a MUTCD on CD and Traffic Control Plan software 1.877.827.3279; www.trafficgraphics.com
- ATSSA www.atssa.com, 1.800.272.8772

Footnotes / Bibliography:

1. FHWA MUTCD 2003 edition 1A.13
2. Facts and Statistics – FHWA Work Zone web site 2005 facts
3. FHWA training May 2001 Work Zone Best Practices
"how to" workshop for making work zones better
4. Facts and Statistics – FHWA Work Zone web site 2005 facts
5. FHWA MUTCD 2003 edition part 6
6. Webmaster US Naval Safety Center "Signs of the times"
7. FHWA publication Final rule on WORK ZONE safety and mobility
September 9, 2004
8. FHWA training May 2001 Work Zone Best Practices
"how to" workshop for making work zones better
9. Wayne State University, Department of Civil and Environmental Engineering.
"Highway Construction Work Zones and Traffic Control Hazards."

Appendix

TCS Job Aid

Advanced Warning Area Sign Spacing (pg. 6C-4):

Road Type	A	B	C
Urban (low speed)	100 ft	100 ft	100 ft
Urban (high speed)	350 ft	350 ft	350 ft
Rural	500 ft	500 ft	500 ft
Expressway/Freeway	1000 ft	1500 ft	2640 ft

Formulas for Determining Taper Length: (pg. 6C-8)

High Speed (45 mph or more): L=WxS
Low Speed (40 mph or less): L=WxSxS/60
Shoulder taper 1/3 L
One lane, two way taper
(traffic alternates each direction): L=100' (max)
Termination Taper: 100 ft per lane closed

Legend: L – Taper Length (in feet), W – Lane Width, S – Speed (mph), Tan – Tangent

Flagger Station & Buffer Length (pg 6C -7)

Speed (mph)	Distance (ft)
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
70	730
75	820

Determining Tangent Length (Activity Area):
Work Space + Buffer Space

Device Spacing:
Taper: S (in feet) i.e.: 60 mph = 60 ft.
Tangent: 2S i.e.: 60 mph = 120 ft.
End Work Sign 500 ft. past work space

Number of Devices
Taper: (L/S) + 1
Tangent: Tan/2S, total tangent length/2S
Termination taper 5 devices