Caltrans safety manual chapter 12

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Doi: 10.17226/25929.× page 219 shares the suggestion of citation: Chapter 12 - Other Practices, Academy of Sciences, Engineering and Medicine 2020. Strategy for Work District Traffic Management Plan Washington, D.C.: National Academy Press. Doi: 10.17226/25929.× Or less is the uncensored machine reading text of this chapter, intended to provide our own search engines and external engines with highly rich, chapter-representative searchable text for each book. Because this is an uncensored article, consider the following text as a useful but insufficient proxy for an authorized book page: 194 Other Practices This section describes decision-making tools, other practices, new technologies, and successful policies and procedures for selected agencies. This section describes the following practices: Smart Work Zone Implementation Tools 12.1 FHWA WorkZone ITS Implementation Guide and Tools 12.2 TxDOT Go/No-Go Decision Tool 12.3 MnDOT Work Zone ITS Decision Tree 12.4 Project Delivery Selection Matrix 12.5 Procurement Procedure Selection Matrix 12.6 Project Delivery Method Selection Guidance 12.7 Ohio DOT Mobility and Safety Performance Measurement 12.8 Iowa DOT StateWide Smart Work Zone Program 12.10 Safety Evaluation Tool for Construction Stage Planning 12.11 Special Color Pavement Marking 12.12 Automatic Truck Mounted Attenuator 12.13 TM Green Light 12.13 Work Zone Operation 12.1 Rolling Road Block Procedure for Temporary Lane Closure 12.15 Work Zone Mobile Phone Restrictions and Permit System 12.16 Colorado Lane Closure Strategy 12.17 MnDOT Lane Closure Manual 12.18 ODOT Permit Lane Closure Schedule 12.19 Wisconsin Web-Based Lane Closure Permit System 12.20 Caltrans Lane Closure System 12.20 Partnered with e-Construction 12.1 FHWA Work Zone ITS Implementation Guide and Tool FHWA developed the Work Zone ITS Implementation Guide in 2014 to assist in the design and implementation of work environment ITS.(Ullman, Schroeder, Gopalakrishna 2014). This guide describes the key steps required to implement swz applications, C H A P T E R 1 2, and other practices 195 by showing how to apply system engineering processes to determine the viability and design of work zone ITS for a particular application. Each important step is defined in each chapter. Development and realizability concepts. Detailed system planning and design;procurement;deployment of the system. Operate, maintain, and evaluate the system. In its Work Zone ITS Implementation Guide, FHWA created a general scoring criterion that agencies can use to assess the usability of smart work zone technology. 12.2 TxDOT Go/No-Go decision tool TxDOT has identified six SWZ systems to use in the work zone: 1. Queue detection 2.Speed monitoring 3.Construction vehicles warn of 4. Travel Time System 5.Height Overage System 6.Temporary Incident Detection System Because the system selection criteria are unique for each project, TxDOT has developed an Excel-based SWZ decision tool that streamlines the process of selecting the PROJECT's SWZ system. The Go/No-Go decision tool scores the extent to which several criteria (e.g., work zone duration, traffic volume, functional classification, estimated queue length, sight distance at the rear of the queue, overhit vehicle/low clearance structure) are met. Each of the six SWZ systems is then automatically assigned a baseline score, which provides a summary to help staff decide which one to use. This score generates a logical basis for including any combination of SWZ systems in the project design that effectively defines the SWZ scope. Figure 12.1 shows a snapshot of the decision tool. Appendix M provides scoring criteria for the decision toolbook. 12.3 MnDOT Work Area ITS Decision Tree MnDOT has developed a scoping tree that enables early and improved identification of the needs of intelligent workzone technology, including identifying resource needs, including time and resource allocation and efficiency. Improved project cost estimates and project scheduling. Allow technology interoperability. Assess infrastructure read read and compatibility. Deploy cost-effective solutions for future expansion and full ITS integration. Appendix N shows the scoping tree for the work zone. 12.4 Project Delivery Selection Matrix CDOT has developed a PDSM that provides a risk-based objective selection approach to choose from three common project delivery methods: DBB, D-B, and CM/GC. PDSM supports and justifies the choice of delivery method for a particular project. Evaluation uses project attributes, goals, and constraints to compare key evaluation elements with secondary evaluation factors. Next, the selection toolThe nonnumeric evaluation system for each evaluator makes cumulative ranking the best way to send. Figure 12.2 shows the PDSM process flowchart. Appendix J1 contains a complete PDSM tool and provides an example of a PDSM decision. 196 Strategies for Work zone traffic management planning Scoring factors scoring the impact of range reference scores from local traffic generators Important local facilities are large enough to have official destination signs on interstate highways such as conference centers. Due to the huge spike in traffic before and after large events, such as sports arenas (20 points), moderate local businesses and public facilities generate traffic that routinely backs up on/off ramps such as morning and evening rush hours (10 points). Alternatively, see the Maximum Queue Length tab for a rough estimate)> 7 miles (130 points) 3.5 to 7 miles (110 points) 0 to 3.5 miles (85 points) No (0 points) Appear where the rear of the queue is likely to occur behind the sight distance issue behind the queue. (30 points) Not applicable (0 points) Existing traffic issues Higher than normal crash rates, gridlock or frequent exit ramp backups (30 points) Not applicable (0 points) Availability of alternate routes Convenient alternative routes with capacity are available. (3) Alternate routes are not available (0 points) Merging conflicts and hazards in approach to work zones Merging conflicts or hazards within approaches to or work zones. (15 points) Un applicable (0 points) Complex traffic control layout Multiple crossovers, sharp curves or lane divisions (3 points) not applicable (0 points) adjacent/continuous projects We are creating mega projects that effectively sum up adjacent active projects. Includes multiple short-lane restriction activities scattered across the state: more than 10 miles long, or more than 2 to 10 miles (3 points), or between 2 and 5 miles, or between 6 to 1 year (1 point) to less than 2 miles (1 point), or less than 6 months (0 points) scattered/short-term project spraying/short-term projects. (painting bridges, etc.) (3 points) Not applicable (0 points) Extreme weather conditions Work zone has a known history of sudden extreme weather conditions, sandstorms, etc. Or the duration of the project covers some severe weather seasons. (3 points) Non-applicable (0 points) Connected vehicle > 5% (3 points) < 5% (0 points) Is the existing ITS system project among the existing advanced traffic management systems? Does TMC intend to incorporate a travel time and delay estimation system into its TMC operations? TMC can remotely control existing pre-travelersSystem. (Each question is equivalent to 1 point) large vehicles >12% (3 points)>9% (2 points)>6% (1 point) <=6% (0 points) 0 0 0 Raw score normalization score (0 to 100) Figure 12.1. TxDOT Go/No-Go Decision Tool Scoring Criteria (Credit: TxDOT). Other Practices 197 YESNO NO YES List Project Attributes Review Project Goals Project Goals Assess Key Evaluating Factors Assessing Project Constraints: 1) Delivery Schedule 2) Project Complexity and Innovation 3) Design Level 4) Cost Does Key Factor Assessment Show The Best Way to Perform An Initial Risk Assessment for Optimal Methods Risk Management? Is there one of the most suitable methods? 5) Make a pass/fail assessment of the secondary factors of the best method: 6) Staff experience / availability 7) Level 8 of monitoring and control) Competition and contractor Exp. Perform a complete assessment of the secondary factors of all selected methods The best way for all secondary factors selected is the best way to pass? Yes No No Project Delivery Method Selection St ag e 1 St ag e 2 St ag e 3 Figure 12.2.Project Delivery Selection Matrix Flowchart (Credit: University of Colorado). 198 Strategy for Work zone transportation management planning 12.5 Procurement Procedure Selection Matrix Procurement Procedure Cdot Procurement Decision Support Tool called Selleck Decision Matrix (PPSM) provides a risk-based objective selection approach to select procurement procedures from three common procurement criteria: low bid, best value, and best eligibility. PPSM provides support and justification for selected procedures. The selection process uses specific project attributes, goals, and constraints to evaluate the factors that are critical to the decision, similar to the process used to select delivery methods. The avoidance factor uses a qualitative evaluation system, and overall the highest ranked procedure is the most appropriate procurement procedure. Figure 12.3 shows the PPSM process flowchart. Appendix J2 contains a complete PDSM tool and provides an example of a PDSM decision. 12.6 Project Delivery Method Selection Guidance Using CDOTâ€s PDSM as the basis™ WSDOT has developed the Project Delivery Method Selection Guidance (PDMSG). In the previous selection process, DBB is automatically assumed to be a project delivery method (PDM) unless approved to use D-B or CM/GC as contract diagram 12.3. Procurement Procedure Selection Matrix FlowChart (Credit: University of Colorado). Other Practice 199 laws were pursued. PDMSG provides a progressive assessment tool that determines the best PDM using each tool that can handle the right level of work based on the type and size of the project. The original policy is that all projects needed to be evaluated with PDMSG. WSDOTâ™ direction is that the project is under $2 million and the preservation project is less than $10.is excluded from the PDMSG by program. All projects are evaluated in two steps, step 1. Before the Regional Program Management Office approves the project profile, a possible PDM is established through collaboration with local subject matter experts and documented in the Capital Program Management System. Step 2. When the project profile is approved and the design phase is about 10% to 30%, the final PDM is determined, work orders are set up for the project, and the project is assigned to the regional project engineer's office ™. Use the selection checklist (Appendix K1) during the final PDM to quickly identify projects that clearly have the best PDM. The selection matrix (Appendix K2) is used for more complex projects to determine the final PDM, if required as a second step. Projects that cost more than $100 million to determine the final PDM require workshops. 12.7 Ohio DOT Mobility and Safety Performance Measures 12.7.1 District Work Zone Traffic Manager Notification Plan For Significant Impact (TMC) ODOT Statewide TMC Has Significant (>0.75 Mile) Queue Results from Previously Planned (Approved) Work Zone Operations ODOT District Work Zone Traffic Manager (DWZTM) ;1 designation per district) to send a courtesy notice. During notification, DWZTM validates field conditions to determine whether queuing is the result of a work zone operation or other incident, and addresses concerns as needed. This procedure helps ODOT monitor and mitigate unexpected queuing. Figure 12.4 shows an example of a notification that is sent when an unexpectedly significant impact is seen as a result of a work zone operation. Notifications are limited to what the TMC operator is monitoring and do not include all projects and roads. The 12.7.2 Work Zone Mobility Report (aka VolcanoGram) ODOT Volcanogram Report contains a graph representing the number of hours traffic speeds have drop below 35 mph on either side or both sides of the work zone during each month. There is also a monthly view that compares different months and compares the same month over two different years before construction begins. The volcanogram shows the speed of traffic before and after the work zone is installed, and also shows the general idea of delay patterns. If a sudden change occurs in a month, the traffic manager in the work zone can determine if there is a configuration problem or if the change occurs. There are also efforts to extend reports of several miles on both sides of the work zone to provide an overall review by including work zone effects propagated upstream and downstream outside the length of the normal work zone. The Volcanogram report runs on

Portable and static message indicators are used to manage queue backups, provide advance warning of delays, or move traffic to pre-planned routes or detours. Iowa's DOTâ™ statewide approach to intelligent work zones is unique. Many states introduce a variety of intelligent work zone technologies for each project, but those systems may not be compatible between projects and TMC may not be able to monitor them. In the ™ of Iowa, TMC receives an alert when a queue is detected and uses the SWZ camera and message sign in the same way as a permanent camera or signage. Evaluation and performance monitoring of swz systems is made possible ™ collaboration with the Center for Transportation Research and Education at Iowa State University. In 2017, several layers of performance measurement and data inside and outside the work area were used to evaluate each project. Developed performance monitoring tools allow users to view the impact of work zones on traffic in real time. Centerâ€™s web-based interactive tools have a variety of modules including overview maps, weekly performance, daily performance, speed heatmaps, sensor performance, and hourly volume. The implementation of this program had a significant impact on the way Iowa DOT operates and maintains construction and maintenance work zones. Performance monitoringIt was developed to see the impact of workzone projects on traffic and monitor the operating status of traffic sensors. Data Figure 12.10.Location map ™ traffic critical projects and intelligent work zone devices in Iowa (Credit: Iowa Dot). The workzone traffic management plan's 206 strategy, collected by cameras, sensors and message signs, is updated every night and connected to a web-based performance monitoring tool that adds information about the previous day to the view. All historical data is retained from the database, so you can query information at any time interval. Since the establishment of the Traffic Critical Project Program, traffic sensors have been a major source of performance monitoring. Sensors can be very variable based on sensor models and models, while they provide high granularity data and are useful when monitoring performance. During the 2017 construction season, the Transportation Institute of Iowa State University (InTrans) significantly improved performance monitoring results by using machine learning to eliminate common fake traffic events and using a fixed 45 mph threshold. Machine learning has made it easier to identify traffic events, greatly improved the accuracy of performance measurements, and reduced the number of false events detected in previous systems. In recent years, InTrans has expanded the use of INRIX data to monitor projects and road methods where sensors are not deployed. Because inrix probe data does not contain volume, performance measurements are slightly different than when using permanent or portable sensors. The amount of INRIX data is very variable based on the type of road. InTrans receives weekly snapshots of crash data from the Iowa DOT and provides the capability to perform further crash analysis on a regularly. Text alerts. InTrans developed the work zone text messaging alert system during the 2017 construction season. Machine learning was used to identify slow and stopped states in work zones, and then to develop algorithms that sent text alerts for slowdowns in work zones across the state. Feeds are developed to summarize this information for each work zone, are used in the TMC Operations Dashboard, and are also used to send text alerts to DOT staff. The capacity of the work zone. At the time this guidebook was written, InTrans was working with the Iowa DOT to determine capacity for various work zone configurations, including capacity comparisons of bridge-related work using single lanes and two narrow lanes. In addition, InTrans is considering the impact of towing and extra enforcement on capacity. Lane closure planning tool. Lane closure planning tools can be used to provide access to traffic data and determine when lanes can be safely closed. The tool uses data from its sensors toThe monthly database contains the amount of hourly units per month, day of the week, and time of day. Currently, hourly volumes are expanded to include average, minimum, maximum, and 25th and 75th percentile. In addition to the amount of life, the hourly volume equivalent to the automobile is also calculated. Open data service. InTrans has developed an open data service aimed at providing high-quality, near-real-time data feeds to public or private entities. Data feeds and services support both agency and external users in a variety of usage categories. The source can include various operations, roads, weather, maintenance, and safety data. Several InTrans initiatives, such as text alerts, TMC operations dashboards, and lane closure planning tools, use open data services for databases. This data service integrates multiple data sources that are available in DOT. 12.10 Construction Planning Safety Assessment Tool The Highway Safety Manual (HSM) (AASHTO 2010) provides limited guidance for work zone safety assessment. It provides only two CMFs to calculate the impact of an increase or decrease in highway work zone length and duration on crash counts. Other Practices 207 A study conducted for FHWA by the University of Missouri (Brown et al. 2016) Columbia addressed this knowledge gap by developing spreadsheet-based safety assessment tools for highways, highways, rural two-lane highways, urban multilane highways, arteries, signal intersections, signal intersections, and ramps. Using data from a missouri work area, the study developed 20 crash prediction models. Based on user-provided input data, the tool predicts crashes by severity and crash cost for each work zone replacement. All models were programmed with a user-friendly spreadsheet tool for practitioners. Provides examples of how to use this software to assess the safety of different work zone plans. Figures 12.11 and 12.12 show graphical user interfaces and output examples of the software, respectively. 12.11 Lanes of special color pavement marking roads are often repositioned to accommodate highway work operations. As a result, the pavement markings need to be changed. There are many ways to remove or obscure pavement markings, but ghost markings often remain in the old lane line position. These ghost markings can stand out under certain lighting conditions. Ontario, Canada and several European countries routinely use special marking colors (orange or yellow) to increase the serity of temporary lane lines. Special colour markings are also experimentally used in Australia. New Zealand; Quebec City, Canada; and the United States. WisDOT had difficult conditions.The highway-to-highway interchange project (zoo interchange) was carried out in winter as salt residue on the road surface hid traditional white lane markings. In order to provide more clearly defined lanes in the work area, WisDOT obtained experimental permission from the FHWA in 2014 to use orange paints (Figure 12.13). Figure 12.11. User Input Window for Safety Assessment Tool (Credit: University of Missouri). 208 Strategies for Work Area Traffic Management Plan Figure 12.12. Sample output of safety assessment tools (Credit: University of Missouri). Figure 12.13.WisDOT Using Orange Pavement Markings (Credit: John Shaw / University of Wisconsin Madison). Orange reflective epoxy paints are used in Canada, New Zealand and Europe, but not previously in the United States. However, direct assessment of zoo interchange sites has been difficult due to fast-paced construction, heavy traffic and repeated congestion even before the project begins, where road lanes and alignment changes frequently occur. These complexity made it difficult to distinguish the driver behavior and traffic operation impact of orange markings from those attributed to other site situations and traffic management techniques. Other Practice 209 To assess the behavior of drivers with orange markings in a simpler environment, WisDOT conducted a study and no match pair of two bridge redeck projects on I-94 near Okonomowock (Shaw, Chittori, Nois 2017). Shaw et al. 2018). No significant difference was found in the distribution of lane position and velocity data at the test site and control site. However, driver surveys showed that orange markings were more visible and easier to see. Based on field data, driver surveys and interviews with field engineers, there was no evidence that drivers understood the orange markings incorrectly. The study concluded that perhaps the most practical approach is to reserve orange as the emphasis color for specific work zone locations that require difficult driving operations. This approach is similar to the UK practice of using special marking colours to focus on problem areas and helps reduce the chances of drivers becoming desensit to special colours. The TMA is positioned as a shadow vehicle for workers, work vehicles, or workspaces directly below it. The TMA saves lives and prevents injuries to both drivers and maintenance workers, but it put TMA drivers at risk of injury when attenuators hit. Recent technology has allowed the option of removing drivers from buffer vehicles designed to be struck by the wrong vehicle. Autonomous truck-mounted attenuators (ATMA) are also known as autonomousThe protective vehicle consists of two vehicles: a leader and a follower. The reader vehicle is human driven and equipped with an onboard computer, digital compass, transceiver and GPS receiver. The lead vehicle wirelessly transmits high-precision data about position, speed, and adrity. The ATMA receives this transmission and uses steering, throttle and brake actuators to copy the ™ the lead vehicle. Atma can be retrofitted to an existing TM. Figure 12.14 shows the leader and follower vehicles. At the time this guidebook was written, the ATMA was tested and already used in several states, but only at limited capacity as part of a pilot program passed in October 2018: Act 117, passed in October 2018, allows PennDOT and the Pennsylvania Turnpike Commission to implement highly automated work zone vehicles in active work zones. In August 2017, CDOT was the first transportation department to demonstrate cdot road striping crews by purchasing atma when using ATMA Figure 12.14. Autonomous TMA (Credit: Royal Truck and Equipment Co., Ltd.). 210 strategy for work zone traffic management plans near Fort Collins. Colorado also uses ATMA in rural areas away from heavy or mixed traffic. FDOT tested ATMA in 2015. ATMA technology is still in the late stages of development and there are some challenges that need to be addressed: â€' The next vehicle will accurately copy the movements of the lead vehicle. If the lead vehicle encounters an obstacle and needs to change lanes, the ATMA can change lanes until it encounters ™. This ensures that the lead vehicle remains unso protected until the ATMA also changes lanes. Leads and follow vehicles may lose communication under land bridges or through tunnels. The green light of 12.13 TM MoDOT (Brown et al.) tested the use of green light for TM to improve the visibility of the work zone. This is the first quantitative study of TM green light in the United States, and MoDOT tested four different configurations using simulator and field studies. During the simulator test phase, we looked at amber/white (common for MoDOT), green only (recommended by MoDOT), green/amber (MoDOT alternative), and green/white (design alternative) configurations. Field tests evaluated the orange/white and green-only configurations (Figure 12.15). The video data was collected for two days in the US 50 mobile work zone in the Kansas City area. The mobile work zone consisted of a green-only rear advance TMA, an orange/white shoulder TMA on the first day and two amber/white TMA on the second day. During the day, the leading orange/white TMA vehicle had a passing speed slightly higher than the green-only TMA (62.5 mph) (64.5 mph). At night, the green-only TMA had slightly lower vehicle transit speeds (52.1 mph)At orange/white TM (52.9 mph). The authors warned that driver behavior may be affected by the novelty of green light TM, and that longer periods of research are needed to examine novelty effects. The results did not point in a single direction in both simulator and field tests, and all four configurations appeared to be viable. 12.14 Rolling roadblocking procedures for temporary lane closures Rolling roadblocking, also known as temporary road closures, rolling blocks, pacing operations, or traffic pacing, is a common highway traffic control technique used to temporarily slow down or stop traffic upstream of construction, maintenance, and utility work activities that require short-term complete closure of roads (FHWA, n.d.). Rolling roadblocking allows for the rapid completion of roadworks activities by ensuring that workers have full access on the road and on the road, ensuring a safe environment by completely removing vehicles that are usually close to the workers. Policies and procedures for managing the use of rolling roadblocking for highway work activities vary from state to state. Additional resources are available to transport to improve rolling roadblocking practices. Among these resources are guidelines for rolling roadblocking of work zone applications developed by the National Association of Traffic Safety Services. This guide establishes best practices for the use of rolling roadblocking and provides valuable information on planning and coordinating rolling roadblocking, performing rolling roadblocking, and developing rolling roadblocking planning checklists. Connecticut DOT allows road closures when installing temporary lane closures on restricted-access highways. Rolling roadblocking is only allowed to install and remove lead signs and lane tapers for up to 15 minutes. 12.15 Restrictions on work zone cellphones As part of ongoing efforts to reduce distracted driving and increase safety for drivers and workers in work areas, Wisconsin has passed a law that would make it illegal to speak on handheld mobile devices while driving in Wisconsin's roadworks zone. Wisconsin Law 308 of 2015 proceeded to Figure 12.15. Simulator test TMA configuration (Credit: University of Missouri). The 212 strategy for 212 work zone traffic management plans takes effect on October 1, 2016, and drivers caught up in violations face fines of up to $40 for the first offense and up to $100 for subsequent offenses. Appendix L provides the bill text (Assembly Bill 198 of 2015). Figure 12.16 shows the signs associated with this law. Hands-free and Bluetooth devices are granted exemptions and are legal to use. The law also grants exceptions for drivers to use handheld mobile devices when dialing 911. Wisconsin continues to enforce zero tolerance for text messages while driving in work areas. WisconsinDrivers are not prohibited from using handheld mobile phones while driving or outside the work area. However, Wisconsin law prohibits driving a motor vehicle while creating or transmitting text messages or email messages (basic law). 12.16 Colorado Lane Closure Strategy CDOT has developed a Lane Closure Strategy (LCSY) for each of the five regions to establish uniform standards and authoritative guidance for scheduling lane closures. Each ™ policy is unique, said CDOT, which can coordinate lane closure policies in vast states, including both rural mountainous and large urban areas. LCSY was formulated to strike the right balance between delays to business travelers within the work area and the cost of construction and maintenance. LCSY applies to single-lane closures (and multi-lane closures on roads of 5 lanes or more) related to road CDOT control construction and maintenance activities. It is based on extensive data analysis and estimates of expected delays during lane closures. LCSY responds to weekday and weekend traffic demand and takes into account temporary fluctuations in traffic volume that occur over a typical 24-hour period. LCSY also describes seasonal fluctuations in traffic volume, if necessary. Previously, the decision to close lanes was largely based on field observations, previous experience, and engineering judgments. LCSY is being recalibrated in a three- to five-year rotation to reflect changes in traffic and available capacity (Region 1, 5th edition was published in 2019). Region 2, 2nd edition, 2013. The 3rd Regional No. 3 in 2017. The 4th and 3rd editions of 2017. 1st edition in 2008, Region 5). LCSY provides several types of information related to the closure of each region. Allowable lane closure times (in aggregate format) on all state roads. The table provides a specific time at which the closure of each highway section is allowed. Sections are split when lane geometry changes or daily traffic changes significantly. Procedures for implementing lane closures for permissions and maintenance work. Steps to implement lane closures for CDOT design projects. Figure 12.16. Mobile Phone Restriction Sign for Wisconsin Work Zone (Credit: WisDOT). Other Practice 213 steps to change the closure time during the construction and variance request process. The flowchart (Figure 12.17) determines the allowable lane closure times on certain state roads under the following conditions: â€ all seasons. The number of lanes closed 1, 2, or 3. Highway ramp closure schedule. I-70 mountain corridor closure schedule. Using the information provided in LCSY improved lane qualityDecicion simplifies the end-user decision-making process and reduces the uncertainty associated with handling traffic during construction. 12.17 MnDOT Lane Closure Manual MnDOT has developed a lane closure manual to use when planning and scheduling lane and shoulder closures on MnDOT-owned and operated highways and highways in Metro District, District 6 and District 3. The lane closure manual determines the appropriate Figure 12.17. CDOT Lane Closure Scheduling Decsijo Tree (Credit: CDOT). 214 Strategies for Work Zone Traffic Management Plan time zones for planned lane closures based on the number of lanes available and traffic data. The purpose of the lane closure manual is to provide information to help you plan against lane closures that minimize traffic impacts and driver delays while promoting the safety of workers and the public while traveling. Lane closures allowed in this manual are usually short-term (no more than 12 hours) and do not involve traffic diversions or detours. It is formatted to collect and analyze traffic flow volumes from regional TMC detectors and tube counters, and to display allowable lane closure figures based on road location and time. The manual is divided into sections by road, and each road is divided into segments. Segments are usually determined by the number of continuous lanes available along the highway corridor. The index map shows where each road is divided into numbered segments (Figure 12.18). The numbered segment directs the user to the correct page of the manual that provides the traffic data listed in the table (Figure 12.19). MnDOT uses a shading system to show the number of lanes that can be closed every hour of the day. The allowable lane closure figures listed in the Lane Closure Manual have been smoothed to remove some of the seasonal data fluctuations. 12.18 ODOT Permit Lane Closure Schedule The ODOT Lane Closure Policy is described within the work zone traffic management policy (Standard Procedure No: 123-001). This policy was developed to systematically determine the effects created by work zones and to eliminate, minimize, or mitigate these effects as effectively as available. ODOT lists the process of determining lane closure times on the allowed lane closure schedule website. Allowed lane closure schedules are web-based, searchable database tools that provide a quick and efficient way to identify the time of lane closure per day so that they do not violate the allowed queue length threshold. Figure 12.18.MnDOT Lane Closure Manual Road Segment (Credit: MnDOT). Other Practices 215 Figure 12.19. MnDOT Lane Closure Manual showing allowable lane closures (Credit: MnDOT). 216 Strategies for Work Zone Traffic Management Planning Users searching for permitted lane closure timesInfo: The year, district number, county, route, and section of the route for the last ADT count. This search generates a table similar to the screenshot in Figure 12.20 that shows the allowed lane closure times. When lane closures are not allowed is indicated by different shading times for each day of the week during construction and non-construction seasons. This table also contains the lane capacity that is used to determine whether lane closures are allowed. These capacities vary by facility. Applying for an allowed lane closure schedule is a convenient way to find lane closure times for a particular facility based on the Internet. Lane closing capacity is adjusted based on facility conditions, so a better approximation of lane capacity applies. 12.19 Wisconsin Web-Based Lane Closure Permit System The Wisconsin Lane Closure System (LCS) is a web-based system for tracking closures and restrictions on interstate, U.S. and state roads in Wisconsin. Lcs is intended for Figure 12.20. ODOT permit lane closure schedule (Credit: ODOT). Other Practice 217 provides a standard interface for lane closure operations, closure tracking, and data acquisition for WisDOT regional offices across the state. It facilitates data sharing with WisDOT applications that require 511 traveler information, statewide TOC, inconvenient map production, and lane closure data from oversized/overweight permits. Improve the integrity, reliability, and timeliness of lane closure data on state highways. Archive LCS data in wisTransPortal systems for future analysis and integration with traffic engineering applications and research in other WisDOT/UW-TOPS labs. Integrate historical traffic data and capacity information to calculate available closure thresholds. LCS is a single source of interstate, U.S., and state highway lanes and ramp closure information in Wisconsin. Closure and regulatory information is entered for all projects or design projects that affect interstate, U.S., or state roads. Planned maintenance or permit/utility restrictions on interstate, U.S. and state road closures. Major special events. Planned emergency lane closures. LCS shares data with several internal and external media, including wisconsin 511 systems, WisDOT websites, statewide TOCs, daily/weekly email reports, and third-party media (vehicle navigation systems, phone/tablet apps, websites, social media, and news reports). Closure information can be entered into lcs by any system user. WisDOT staff can enter information or request that information be entered into a consultant, contractor, or county. However, you must enter closures in lcs according to the minimum prepayment.Figure 12.21 shows the timeframe. Depending on the type of closure and the user entering the closure, the closure is automatically accepted or sent through the receiving process. If the user has accept permission, the system allows the system to immediately accept the entered closing information, but it is not required. Once accepted, the information will be live and therefore published as an active closure. Users can enter closures that are in the same region as the user's region ™ only perform the following actions: Lcs regional options include SE (Southeast), SW (Southwest), NE (Northeast), NC (North Central), NW (Northwest), and ALL (All Regions). Figure 12.21.WisDOT Lane Closure Advance Notice Time (Credit: WisDOT). 218 Strategies for Work District Traffic Management Planning From April 2008, LCS will facilitate the accepting and monitoring of work zones at TOCs and regional transportation offices across WisDOT, providing real-time lane closure information to the Wisconsin 511 Traveler Information System. 12.20 Caltrans Lane Closure System On January 15, 2016, Caltrans revised its 2015 standard, Section 12-4.02C(2), lane closure system, and reported the closure status using the LCS mobile webpage. LCS was developed to reduce the steps required to abort or start closures and allow contractors to interface directly with LCS, which helps to speed up and improve the accuracy of lane closure conditions. Contractors must request closure using Caltrans LCS and status closures using the lane closure system's mobile webpage. Lcs reports all approved closures scheduled for the next seven days, plus all current lane, ramp, and road closures caused by maintenance, construction, special events, and more. LCS is spreading construction information to Caltrans' online tool QuickMap, commercial wholesale web portal, performance measurement system and Caltrans Highway Information Network Hotline. When the contractor changes the status of the closure, LCS sends an email notification to the resident engineer and designated inspector. 12.21 Partnered with E-Construction through Round 4 of EDC, FHWA promoted electronic construction and construction alliances as a practice that can be used in concert to provide smarter and faster transportation improvements. e-construction is the creation, review, approval, distribution and storage of highway construction documents in a paperless environment. These paperless processes include electronic submission of all documents by all parties, routing and approval of electronic documents (electronic signatures and workflows), and real-time management of all documents in a secure digital environment accessible to all stakeholders through mobile devices and web-based platforms. e-Construction aims for established employmentIt is readily available to the transportation community and improves construction document management, including digital electronic signatures, electronic communications, secure file sharing, version control, mobile devices, and web-hosted data archiving and acquisition systems. Many state DOT and industry practitioners have already used or tested several aspects of electronic construction. Some are in the midst of mainstreaming many electronic construction system practices. While MDOT routinely applies e-Construction to DBB projects, DOT in Minnesota, Florida, Utah, Texas, Pennsylvania, and North Carolina applies the technology to D-B projects. DOT in Wisconsin and Iowa applied electronic construction to the DBB project. MDOT, a leader in electronic construction, uses electronic document storage for its $1 billion construction program, with an average contract mojica-dition processing time of 30 to 3 days (It estimates that reducing it to anation/everyday count/edc-3/e.cfm would save about $12 million a year in efficiency and 6,000,000 sheets of paper. Other Practice 219 electronic construction systems have the potential to increase the quality, efficiency, environmental sustainability, and productivity of the construction industry while saving printing costs, time, shipping costs, document storage, and increasing communication efficiency. Construction alliances are project management practices where transportation agen-cies, contractors, and other stakeholders create team relationships of mutual trust and improved communication. Partners build relationships and connections between stakeholders, improve the outcomes of quality projects built within time and budget, focus on safety, and be beneficial to contractors. Additional information, webinars, and peer exchange reports on electronic construction and construction alliances can be found at respectively. 12.22 Resources and References ATSSA. Guidelines for Rolling Roadblocking of Work Zone Applications, FHWA, USA DOT, July 2013. 。 workzonesafety.org/training-resources/fhwa_wz_grant/atssa_rolling_roadblocks/。 Brown, H., C.C, P. Edara, R. Rahmani. Safety and 4 are based on studies that suggest work zones last between 16 and 714 days, work zones between 0.5 and 12.2 miles long, and highway AADTs between 4,000 and 237,000 vpd (Hatak, Hatak, Council 2002). The basic conditions of CMF (i.e., cmf = 1.00 state) are 16 days and 0.51 miles of work period. Cmf's standard error is unknown. Period. Equation 3 shows the expected average crash frequency of a work zone that increases the baseline condition (CMF = 1.0) longer than 16 days. ( ) = + Ã — 1.0 % 1.11 100 CMF duration increases with all formula 3. The average number of crashes in days that increase the duration of the work zone. CMFall = Crash correction factor is 224 strategies for all crashes in the work zone. and duration growth rate = the percentage of change in the duration (days) of the work zone. Length. Equation 4 indicates the expected average crash frequency at which the work zone length is greater than the base condition (CMF = 1.0) greater than 0.51 miles ( ) = + Ã — 1.0 % 0.67 100 CMF Increase in length for all formulas 4. The average crash frequency (mi) that increases the length of the work zone. Here CMFall = crash correction factor for all crash types and all injuries in the work zone. % increase in length = percentageis the length of the work zone (mi). 13.4 Work Zone Estimation and Crash Cost Analysis NCHRP Research Report 869 (Ullman et al. 2018) describes two ways to estimate work zone crashes and crash costs: 2. Use general safety performance features (SPF) created using work zone-specific data. Here's a quick description of both methods: 13.4.1 Method 1.PreëWork Zone Crash Estimates and the recommended approach to developing an overall WZCMF plan is to apply the overall generic WZCMF to an existing work zone baseline crash estimates. Pre work zone crash estimates generally come from SPF calibrated to a specific road segment using the methods included in the HSM or state-calibrated crash prediction model. However, if these data are not available, you can use other estimation methods. For example, work zone analysts can use crashes and annual AADT values over the past three years that have occurred along the road segment to determine the annual average crash. As part of NCHRP Research Report 869 (Ullman et al. 2018), an overall WZCMF of highways and state facilities from a multi-state dataset of four roads and six road highways and state work zones was developed. CMF is based on the ratio of pre and work zone SPF developed for these road segments. Equation 5 shows the ratio of these SPF: = ( ) ãä' + Ã or ' + äã' + äã' + 4Älane Facility 6Älane Facility of 4Älanes 1.164 In AADT 11.231 1.248In AADT 6Älanes 9.987 1.164 In AADT 12.318 1.344 In AADT WZCMF equation WZCMF for 5.4 lanes and 6 lanes of highway and inter state work zone. Work Zone Strategy Assessment Framework 225 To calculate the total number of crashes expected in a work zone, the expected number of crashes each year is multiplied by the duration of the work zone, and the overall WZCMF of the AADT for the road segment is calculated. As formula 6 shows, if you use crash rates, the rate is first multiplied by the length of the project. ( ) Lee £»Ã. 12 Expected WZ Crash Non-WZ Crash Miles Project Length WZ Duration Mo WZCMF Equation 6. Total number of crashes expected in the work zone. 13.4.2 Method 2. Work zone-based SPF If there is no good data on the normal crash frequency in the section of the highway or interstate where the work zone-based SPF work zone is located, the work zone engineer can use the SPF to develop an estimate of the planned level of the expected crash.The work zone. NCHRP Research Report 869 (Ullman et al. 2018) used a multi-state database of work zones performed on four interstate and six interstate and highways to develop two predictive functions: the length of the work zone, the duration of the work zone, and the total number of work zone crashes expected to occur based on the overall road AADT (Equations 7 and 8). = Ã — ( ) (, the number of crashes in the =10.036 1.164 In work zone crashes in an expectation of L n e AADT equation 7. Crashes are expected on the four-lane highway and in the state work zone. = Ã — ( ) 9.987 1.164 In Work zone crash number L n e AADT expression 8 is required. Crashes are expected on the six-lane highway and state work zone. Where L = the length of the work zone (miles and n = years) is required for the work zone (or months/12). The feature developed a pavement with of 40 feet in each direction of the four Älane segments, the pavement width of each direcÄ tion in six lane segments (12 feet lane, 6 feet inner shoulder, 10 feet outer shoulder). There is no lane shift. There are no lane closures. Median width of 60 feet, including the width of the inner shoulder of 6 feet in both directions. There are no vertical barriers. AADT between 5,000 and 70,000 in four lane segments. AADT between 50,000 and 150,000 vpd in six lane segments. Examples 1 and 2 in the following sections are based on the work zone conditions above. NCHRP Web Only Document 240: Analysis of Collision Characteristics and Countermeasures for Work Zones (Ullman et al. 2018) provides additional details on the development of these models. 226 Strategy for Work District Traffic Management Plan 13.4.3 Example 1. Calculating the Expected Monthly Crash Rate During Construction Work Zone Engineers Plan to monitor crashes that occurred during the 2-year, 5Ämi Interstate widening project. The engineer compares the monthly crashes to determine if they are increasing more than expected in the work zone settings. The road has a rural four-lane state facility (12-foot lanes, 6-foot shoulder inside, 10 feet outside shoulder, wide median). Facility traffic is 45,000 vpd in the first year of the project and 50,000 vpd in the second year. Based on the calibrated SPF developed by dot, the facility's normal non-work zone crash rate is estimated to be 7.4 crashes per mile in the first year and 7.9 crashes per mile in the second year. Step 1.Calculate the WZCMF (years 1 and 2) and assume that good pre-work zone crash data exists. Step 2.Using WZCMF, expected crashes, work zone crash rates, and project lengths (years 1 and 2,9) Step 3. Add up year 1A and two years of expected crashes to determine the total number of crashes (Equation 10). = Lee y £ï iÉi= = lee £ £ï iÉi= ( ) + ÁVu' + WZCMF 1.34 WZCMF 1.33 4Älanes, Year 1 10.036 1.164 45,000 11.231 1.248 45,000 4Älanes, Year 2 10.036 1.164 50,000 11.231 1.248 50,000 e In 9. Crashes that are expected to occur during the duration of the project. In this example, the expected crash rate each year is as follows: = = lee£ £ï iÉi= = =) Expected work zone crash 7.4 5 mi 1 1.34 49.58 crash Expected work zone crash 7.9 5 mi 1.33 52.54 Crash Expected Work zone crash 49.58 52.54 102.12 Crash year 1 year 2 years 1 year 2 years r year crash mi year 10 years expected crash rate. Work zone engineers can get a crash estimate of one month per year, broken by 12 months per year (number of years). If more finite period analysis is required, engineers can apply seasonal factors to AADT factors and develop and apply WZCMF to estimate the expected crashes each month. Monthly crashes can be compared directly as well as to cumulaÄ tive. If there is a significant time-by-hour difference between the actual and expected crashes, it may indicate that a safety issue exists at the site and additional investigation is required. As Figure 13.1 shows, an increase in the number of crashes is observed after Month 7. If the increase in crashes is determined to be large enough, work zone engineers can begin a more detailed review to determine potential reasons for the increase. Possible causes include large traffic switches in the project, more frequent delivery of work activities, and severe weather during this time. Work Zone Strategy Assessment Framework 227 If good nonworking zone crash data is not available for segments, work zone engineers will apply the previous work zone SPF to four lane facilities (Equation 11). compuÄ tations looks like this: ( ) = ( ) + Ã not' + expected work zone crash 5 mi 1 57.11 crash expected work zone crash 5 mi 1 64.56 crash work zone crash prediction 57.11 6 4.56 121.67 Crash years 1 10.036 1.164 45,000 years 2 10.036 1.164 50,000 years 1 And two total years e-year e In equation 11.SPF to predict the crash rate. Work zone SPF estimates for 121.67 crashes over a two-year project (5.07 crashes per month) are approximately 19.1% higher than those calculated using calibrated pre-set work zone crash rates and the overall WZCMF as a whole. As Figure 13.2 shows, cu m ul ati ve N um ber o f C ra sh es to D in the e-month of Project Figure 13.1 Cu m ul ati ve N um be r o f C ra sh es to D project figure 13.2 in e-month. Expected and actual crashes occur using work zones SPF and CMF. 228 Strategy for Work Zone Traffic Management Plan Work Zone Engineers can conclude that the crash was not excessive compared to expectations. The difference in results shown in Figure 13.2 are another example of the importance of engineering decisions when interpreting and using planning-level estimates. 13.4.4 Example 2. Estimating the impact of accelerated construction on the expected number of work zone crashes and savings. Dot is considering including contract incentives in the tender package to reduce the duration of the project and is seeking to determine savings if any. Using traditional methods, the project will take two years to complete. But if the duration is reduced to 18 months (i.e., accelerated structure), what will be the savings on the project? DOT first calculates the non-working zone CMF and provides a baseline for comparison (Equation 12). Roads have the following characteristics: The project is 6 miles long. This is a 6-lane highway facility in an urban area. Facility traffic is expected to be around 120,000 vpd in the first year of the project and 140,000 vpd in the second year of the project. The highway has a 12-foot lane, 6 feet inside the shoulder and 10 feet outside the shoulder. The total crash density of this section of highway is 34.8 crashes per mile per year before construction based on three years of historical data. Traffic volumes in these years averaged 115,000 vpd (similar to those expected in the first year of the project). Non-work zone crash rate 34.8 120,000 115,000 per mile per year 36.31 Crash Non-work zone crash rate 34.8 140,000 115,000 crash per mile 42.36 crashes 2 crash mi yi £= = lee y £É ï £ï iÉy £== Formula 12. Work zone crash rates for years 1 and 2. Dot does not have a normal non-work zone where the frequency of road crashes is expected for each year of the project. As a result, based on data availÄ (equation 13), it is necessary to estimate the number that the normal pres work zone crash frequency for each of the two years of the project. Since the only data available is the historical crash rate of the road segment before the project, DOT first considers the project's two-year crash rate using the following AADT number ratio Serge: WZCMF 1.253 WZCMF 1.219 6Älanes, 1 9.987 1.164 141000001.344 120,000 6Älanes, Year 2 9.987 1.164 140,000 12.318 1.344 140,000 e In = i£« i ‹6> ‹6>¶ = lee £É£* iÉi= ( ) ãäâ' + Ã says + ä' + Equation 13.Working zone CmF. This factoring process assumes a linear relationship between crashes and AADT, which is often not true. However, in the absence of a local SPF, it is considered to be a plausible planning-level assumption. If dot has a predicted non-work zone crash rate for each year, WZCMF is calculated every two years of the project based on the expected amount of traffic (Equation 14). Framework for work zone strategic assessment 229 The total number of crashes expected for each alternative is calculated using 24 months of alternative 1 (total of 1 year and 2 years). = Lee £££ iÉi= = = = =) Expected work zone crash 36.31 6 mi 1 1.253 272.97 Expected workzone crash 42.36 6 mi 1 (s) 1.219 309.82 Crash Expected Work Zone Crash 272.97 309.82 582.79 Crash ALT 1 Year 1 ALT 1 Year 2 ALT 1 Year 1 Year 2 Total Crash mi The yr year crashes mi yr equation 14. The number of crashes expected in alternative 1. For Alternative 2, the expected number of crashes in the first year of the project remains the same as for Alternative 1. The first six months of the second year will have the expected work zone crash rate, and the second sixth month will be the non-work zone crash rate (required to complete the second year). = Lee £«+Lee y y le y nee pound y«= =() Expected work zone crash 42.36 6 mi 1.219 42.36 6 12 6 mi 281.1 99 Crash Expected Work Zone Crash 272.97 281.99 554.96 ALT 2 Years 1 and 2 Total Work zone crash Alt yr mo mo yr Crash mi yr 15 mi yr yr 15.Alternative 2 the number of crashes expected in . = ä ä' =ä Not' expected work zone crash 582.79 554.96 27.83 Crash ALT 1 ALT 2 Equation 16.Alternate 1 and 2 differences. Reducing the duration of a project by six months is expected to reduce the number of crashes to the non-accelerated project schedule by 27.83. Dot can apply a comprehensive collision cost number to estimate road safety cost savings that can be obtained from this project (Table 13.2). As Table 13.2 shows, assuming a similar facility crash severity distriÄ bution is the typical crash cost value recommended by HSM, it is estimated that reducing the duration of the project will result in nearly $1,332,592 in crash cost savings. This is done in addition to other savings that may be achievedtravel time, cargo, and emissions). Crash severity level Crash severity proportional distribution 27.83 Crash rate Reduced average crash Cost costs reduced if project accelerated mortality (K) 0.005 0.13915 $4,509,0 99 1 $627,565.25 Disable Injury (A) 0.018 0.50094 $242,999 $121,727.92 Obvious Injury (B) 0.08 2.44904 $88,875 $217,658.43 Injury Potential (C) 0.136 3.78488 $50,512 $50,512 191,18 1.86 Damage only (PDO) 0.753 20.95599 $8,325 $174,458.62 Total 1.000 27.83 n.a. $1,332,592.08 NOTE: Updated highway safety manual accrash cost, 1st ed., $2016. n.a. = Not apply. Table 13.2. Estimated cost savings in crash costs when project duration can be reduced. Example 2. Strategy for 230 Work Zone Transportation Management Plan 13.5 Evaluation of alternative work zone design Work zone designers who develop construction plans using alternative CMFs have the option to accommodate traffic through different stages or stages of the project. These alternatives include factors such as which direction to close lanes or shoulders, whether to use narrow lanes, close ramps, reduce the length of acceleration or deceleration lanes, and whether to deploy with various technologies (EQWS, DDLM, etc.). If designers need to make decisions, it is helpful to know the difference in expected crashes between these choices. Here are the steps: Define a work zone alternative to compare expected safety effects. Step 2.Verify the availability and suitability of the CMF. Gets the baseline crash estimate used to evaluate each alternative. Step 4. Multiply the selected CMF into an alternative to each work zone by the appropriate base line crash estimate. Step 5. Compare crash estimates the difference between alternatives. For example, to alert drivers in downstream queues, dot is considering using EQWS during an eight-month bridge repair project on interstate highway. Contractors closed night lanes on interstate highways to carry out work (m 6:00 to 6:00 .m.) and work five nights a week. Interstate highways provide 70,000 vpd in the area, and queues are expected to develop every night of work, which can grow up to seven miles. Typically, this section of the state experiences 20.4 crashes per year per year, 50% of which occur when work is scheduled. DOT wants to estimate how many EQWS may prevent crashes from occurring if they are built into the project. Dot performs the following analysis: Step 1. Define the work area substitution to compare. Alternative 1.Make nighttime lane closures in a six-month project without EQWS. Alternative 2. Install EQWS at the beginning of the project to alert you to downstream queued traffic. Step 2: Determine the availability and suitability of the alternate CMF. WORKING CMF1.61 (Table 13.3) at night when one or more lanes are closed. For AlterÄ native 2, the CMF that describes the effect of EQWS is 0.56 with traffic queues (Table 13.4). Crash Severity Level CMF Night Daytime Work Zone Active PDO Crash with Temporary Lane Closure 1.748 1.808 Injuries and Fatal Crashes 1.423 1.455 Active All Crashes Without Temporary Lane Closures 1.609 1.663 Work Zone PDO Crash 1.666 1.398 1.41 4 1.174 All crash temporary lane closure-free work zones are inactive 1.577 1.314 work zone PDO crashes 1.330 1.196 Injuries and fatal crashes 1.114 1.020 Combined all crashes 1.237 1.127 Note: CMF = crash factor; PDO = property damage only. WZCMF = Work zone crash correction factor. Source: Ullman et al. (2008). Table 13.3.Freeway WZCMFs. Framework for evaluating work zone strategies 231 Work zone application CMF volume range quality severity source Ind duration factor DA 0.585 <125,000 ms= automated=speed=enforcement=p=0.83= ns=h=fi=speed=feedback=display=p=0.54 = ns= h= a= ns=reverse= rumble= strips= (nighttime)= (queues= not= present=queues= present) = da= 0.89/0.397 = 55,000â€= 110,000= h= a= end= queue= warning= system= nighttime)= (queues= expected/queues= present) = da= 0.559/0.468= 55,000â€"= 110,000= m= a= increase= shoulder= width= (inside/outside)= by= 1= foot= da= 0.97/0.948= ns= m= a= change= median= width= 20= to= 10= ft.= conversion= (rural/urban= freeway)= p= 1.16/1.12=<125,000<120,000<120,000<131,000 h= ns= reduce= lane= width= 12= to= 11= ft.= (vivid= rural= multilane= roadway) = p= 1.03=>Reduce 2,000 H A lane width by 12-10 feet. (Divided rural multilane road) P 1.15 >2,000 H A lane width 12-9 feet (divided rural multilane road) P 1.25 >2,000 H A Shoulder Width Down 6-2 feet (Rural 2-Lane Road, Urban Split Multi-Lane Road) P 1.3 >2,000 H A Shoulder Width of 6 feet (Rural 2-Lane Road, Uns split Multi-Lane Road) P 1.5>2,000 H A Variable Speed Limit 0 0.92 NS H A Concurrent Shift DA 1 NS M A end Downstream shift DA 0.59 <35,000 L A reduction speed limit (10 mph/15 €20 mph) Q 0.96/0.94 NS MAH Safety Edge Road P 0.94 <19,000 H A NOTE: WZCMF = work zone crash modeling factor; CMF = crash modification factor; DA = direct application; P = possible; Q = questionable; H = high quality of CMF; M = medium quality of CMF; L = low quality of CMF; A = all; F/I = fatal/injury; NS = not specified. SOURCE: NCHRP Research Report 869 (Ullman et al. 2018). Table 13.4. Available WZCMFs. 232 Strategies for Work Zone Transportation Management Plans Step 3. Obtain appropriate baseline crash estimate for applying CMFs. The work zone baseline crash estimate Alternative 1 is computed as in equation 17: Baseline Crashes 20.4 crashes mi yr 7.0 n a= note= wzcmf=work zone= crash= modeling= factor;= cmf=crash= modification= factor;= da=direct application;= p=possible; q=questionable; h=high quality= of= cmf;= m=medium quality= of= cmf;= l=low quality= of= cmf;= a=all; f/i=fatal/injury; ns=not specified.= source:= nchrp= research= report= 869= (ullman= et= al.= 2018).= table= 13.4.= available= wzcmfs.= 232= strategies= for= work= zone= transportation= management= plans= step= 3.= obtain= appropriate= baseline= crash= estimate= for= applying= cmfs.= the= work= zone= baseline= crash= estimate= alternative= 1= is= computed= as= in= equation= 17:= baseline= crashes= 20.4= crashes= mi= yr= 7.0=<19,000 H A NOTE: WZCMF = work zone crash modeling factor; CMF = crash modification factor; DA = direct application; P = possible; Q = questionable; H = high quality of CMF; M = medium quality of CMF; L = low quality of CMF; A = all; F/I = fatal/injury; NS = not specified. SOURCE: NCHRP Research Report 869 (Ullman et al. 2018). Table 13.4. Available WZCMFs. 232 Strategies for Work Zone Transportation Management Plans Step 3. Obtain appropriate baseline crash estimate for applying CMFs. The work zone baseline crash estimate Alternative 1 is computed as in equation 17: Baseline Crashes 20.4 crashes mi yr 7.0 mi yr 5 days wk 0.5 night crash 1.61 54.74 crash ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) iÉyÈy iÈÿ ÉyÈy¥ée+lee£¤ formula 17. Baseline crash estimation for applying CMF. Step 4. Apply each alternative CMF to replace the baseline crash estimate. For alternative 2 (using EQWS), the baseline crash estimate (alternative 1) must be multiplied by the CMF to replace it with EQWS. Step 5. Calculate the difference in the expected number of crashes. Step 5. Calculation of the expected number of crashes. As shown in Equation 19, the difference between alternatives 1 and 2 can prevent the number of crashes by installing the working zone QWS: the expected crash difference is 54.74 30.65 24.09 crash ALT 1 ALT 2 = ã =ã Difference in crash estimation between equations 19. The use of EQWS in this location was calculated to result in 24.08 fewer crashes. For example, as shown in Table 13.5, if dot is found to distribute the crash data in the previous work zone, the QWS crash cost benefit is calculated to be close to $1,153,050. The crash cost reduction estimate in this analysis assumes that the severity of the crash is the same for both methods and is equivalent to the overall average crash severity distribution that dot had in the previous work zone. Some evidence indicates that the severity of crashes that occur when QWS is implemented is also reduced compared to the state of the system, resulting in even possible reductions in crash costs. 13.6 General Freeway WZCMFs Table 13.3 shows the WZCMf based on the WZCMf data (Ullman et al. 2008), which combines injury and fatal crashes, property corruption only, and the severity rate of all crashes. Generally speaking, the CMFs are higher for propertyÃdamageÃonly crashes than for injury Crash Severities 24.08 Crashes Reduced Fatality (K) 0.005 0.1204 $4,509,991 $543,002.92 Disabling injury (A) 0.018 0.43344 $242,999 $105,325.49 Evident injury (B) 0.088 2.11904 $88,875 $188,329.68 Possible injury (C) 0.136 3.27488 $50,512 $165,420.74 Property damage only (PDO) 0.753 18.13224 $8,325 $150,950.90 Total 1 24.08 n.a. $1,153,030 NOTE: updated with average crash costs are derived from the Highway Safety Manual, 1st edition, $2016. n.a. = Not applicable. Alternate 2 The percentage of the proportional distribution of crash severity level average crash costs saved in Table 13.5. Estimated crash cost savings, two alternatives. Framework for evaluating workzone strategies 233 and fatal crashes. Multiple the appropriate CMF by the EPSFan estimate of the expected collision frequency on a particular type of road for a specific work zone configuration. These calculations create only an expected number of severe and property damage crashes under these work zone conditions. This estimated collision frequency using the appropriate SPF and WZCMF can multiplicate crash cost values to evaluate exposure under each work zone condition as a feature of the road AADT. As mentioned earlier, certain CMFs in work zones often lack many features of interest. But it is possible to apply it to what you would expect from a CMF developed for permanent road features (Section 13.7). These approximations may provide useful insights into the potential value of the different options being considered. Agencies are asked to use engineering decisions when applying data. 13.7 Available CMF Table 13.4 shows the available CMFs extracted from NCHRP Research Report 869 (Ullman et al. 2018). More detailed information about these and other non-working zone CMFs can be found in the report. 13.8 Measurable Goals and Performance Measures Performance Improvement The Performance Monitoring and Evaluation Work Zone program typically performs six steps: setting goals and goals that match the priorities of the DOT work zone. Identify appropriate performance measures to accurately assess and monitor goals and objectives. Identify the data and sources needed to support performance measurement calculations. Define the appropriate assessment methods for data analysis and calculation. Define the appropriate schedule for continuous periodic monitoring of work zones. Reports are available and easy to understand. Successful performance monitoring and evaluation activities to efficiently design and build projects. In evaluating the strategies to be designed, including in work zones, agencies should consider safety considerations and mobility and other considerations. One serious crash is required to stop all operations caused by the work zone and for dot to begin a comprehensive review of all work zone procedures and other activities. The performance measures in Table 13.6 are specific to evaluating the structure of the work zone. Having knowledge of the typical performance measures currently in use and what has emerged as a consistent practice among local, state, and federal transportation can help ensure consistency in work zone performance. Each goal area is described in the following subsection: Because different TMP strategies reduce different effects.An approach is needed to evaluate them. In general, it is easier to assess the impact of reducing activity duration and the ability to enhance change than to evaluate strategies that affect the execution of activities. This is because there is a relationship between driver ™ travel changes and the actions that occur, as driving conditions change when a strategy for 234 work zone traffic management planning work zones is introduced. Therefore, agencies may not measure strategies that seek to influence tripmaking decisions and behaviors against what is happening before the implementation of the work zone, but rather against what happened if a particular strategy had not been implemented. Work zone practitioners can identify one or more metrics that are measurable, known or expected, correlate with the impact of the work zone of concern (safety, mobility, customer satisfaction, construction productivity and efficiency) and perform analysis to determine whether the implementation of the strategy affects that metric. 13.8.1 Safety Safety Assessment and related MOE objectives are to assess the impact of a particular work zone strategy on the safety of the project network. Safety is quantitatively expressed through MOE, such as the number of crashes, crash rate, and severity of the crash. The total number of crashes is an important consideration as traffic may be diverted due to lane and road closures. Collision rate is an important MOE that normalizes the number of crashes based on exposure (part of a road or through an intersection). The collision rate is usually expressed as the number of crashes per million VMT on a part of the road, or the number of crashes per million vehicles passing through intersections. The severity of the crash is an important consideration as it deals with the cost of the crash in terms of fatalities, injuries, and property damage. Changes in road geometry and operations can affect the type of crashes that occur. Target area performance measures that allow us to observe an increase in the number of crashes Safety reduction Reduction of the overall crash rate Improvement of surrogacy measures that occur as a result of fatalities and serious injuries (i.e. speeding and reckless driving citations) The average speed decrease in travel speed or the 85th percentile of psl travel time above PSL Decrease in tile Reduction of travel time Decrease of time above predetermined speed and period Reduction of queue length and duration per hour (vph) Reduction of change in quantity/capacity ratio Working quality adjustment of hydrocarbons (HCs), carbon monoxide (CO), carbon dioxide (CO2), nitrogen oxides (Co2)Reduced assessment of the condition of movement through the work zone Incident or severity reduction Incident or severity rate Decrease in average travel time between work zone road repairs Reduction of user work zone Note: PSL = posted speed limit; vph = number of vehicles per hour. Table 13.6. Recommended performance measurements. A framework for evaluating work zone strategy 235 or a collision rate along a specific section of the road occurs, but the type of crash may not be as severe. When it comes to safety surrogacy measures, they use site-specific and are best suited to assess strategies when they can be done without comparison at each site. For example, the presence of paid law enforcement can be evaluated in each project by comparing the speed and erratic maneuvering during periods when enforcement does not exist. It is difficult to estimate the safety impact of a work zone strategy, as many factors can contribute to the cause and prevention of crashes. These factors include driver skills, driver aggression, driver attention, driver fatigue, differences in speed and speed between lanes, level of congestion, type and difficulty of driving maneuvers (e.g., lane changes, forgiving left turn), lighting, weather, level of law enforcement presence, and road shape and operation. While certain strategies can affect one or more of these factors, other measures (e.g., increased law enforcement presence) can also affect some of these factors. When estimating safety effects, work zone engineers should consider and control all other potential explainer factors associated with crashes. 13.8.2 The purpose of mobility is to estimate the impact of work zone strategies on project network efficiency. Travel time is quantitatively expressed through MOE, such as travel time delays and travel time fluctuations. Day-to-day variations in overall travel time from a specific point to destination are undesirable in transportation networks. Reduced travel time variability improves the ability of individual citizens and the freight industry to plan and schedule tasks. Efficiency is expressed by MOE, such as throughput and usable capacity. Usable capacity is the maximum potential speed at which a person or vehicle can traverse a link, node, or network under a representative composite of road conditions. Capacity (as defined in the Highway Capacity Manual) is the maximum hourly wage that is reasonably expected to cross a specific point or uniform section of a lane or road during a specific period of time under general road, traffic and control conditions. Ability is measured under good weather and pavement conditions, and noOn the other hand, the available capacity will vary depending on the work zone strategy or strategy being deployed. Throughput is defined as the number of units of people, vehicles, or cargo that actually traverse a road section or network per unit of time. Under certain conditions, the measured throughput may reflect the maximum number of vehicles that the transport system can handle. Capacity (and usable capacity) is calculated based on the design and operation of the network segment and does not change unless the physical configuration or operation of that network segment changes. In contrast, throughput is an observable measure and therefore a MOE for the efficiency of the working zone. However, you should be careful about interpreting the results because the throughput change may be the result of factors other than a change in valid capacity (such as a change in demand). Therefore, not all throughput changes indicate an improvement (or lack thereof) in the efficiency of a particular situation. These measures can be further subdivided to reflect a specific subset of time (e.g., peak period, if lane closures exist) or different dimensions (e.g., queue elapsed rate or average or maximum queue length, average delay per vehicle or total time of vehicle hours per day). For some strategies, detailed project activity data should focus on evaluating 236 work zone traffic management plans for the conditions the strategy targets. Examples of data include the date of night or weekend work, or the date of a major phase change when a particular ramp is closed to traffic. 13.8.3 Environmental Impact The purpose of emission assessment is to estimate the impact of work zone strategy on vehicle emissions. From a system-wide perspective, fuel consumption is important because it can affect the emissions of a variety of gases, including hydrocarbons (HC), carbon monoxide (CO), CO2, and nitrogen oxides (NOx). The main measure of emission is the concentration in the atmosphere, usually expressed as grams (g/cm3) per cubic centimeter. In addition, the total volume (expressed in tons) of the emission type present in the atmosphere is a useful MOE. For mini vehicles, the highest emission rates of HC, CO and NOx generally occurred during the transition period, when traffic changed from free flow to congestion. Minimum charges incurred during busy periods in low-speed work zones. However, the highest fuel consumption rates and highest CO2 emissions occurred under congestion in the work zone, while the lowest fuel consumption and CO2 emissions occurred during peak congestion. The results of large vehicles differed on the reason that congestion in the work zone was associated with the highest emissions of HC, CO and CO2 and the highest fuel consumption, but on the other handEmission rates under different traffic conditions were similar. In highway scenarios, fuel consumption and greenhouse gas emissions increased by 85% and 86% respectively under congested work zones compared to free-flow conditions without congested work zones. In multi-lane (4 or 6Älane) road scenarios, fuel consumption and greenhouse gas emissions increased by 83% and 84% respectively under congested work zones compared to less congested traffic conditions. Easing congested work zones from heavy (average speed is 5 miles) to moderate congestion (average speed is 25 miles on highways and 15 miles on multi-lane roads) reduces fuel consumption and greenhouse gas emissions by 40% on highways and 32% on multilane roads (Zhang, Batterman and Dion 2011). 13.8.4 Customer Satisfaction One of the key goals of the TMP strategy ™ meet the desire for a good driving experience for drivers. To improve customer satisfaction, government agencies rely heavily on public complaints as a source of information for work zone issues that require attention. Some agencies conduct or commission customer surveys to get feedback on work zone safety and mobility performance. These investigations will help the agency plan projects, coordinate construction and traffic management strategies, and improve the success of future projects. By establishing a simple way to contact, agents can ™ feedback through the project's website and other ways that customers can review and address their concerns. Well-designed survey equipment helps agencies assess the overall effectiveness of their TMP strategies and distinguish between individual strategies within the set. Good two-way communication with the public can reduce congestion, because road users can make more informed choices in planning their travels. In addition, if drivers are more aware of general road conditions (Hallmark, Turner, Albrecht 2013), safety can be improved by providing information to the public. In some road agencies, conveying work to the public can inspire trust in the system and show good stewardship. For design and construction teams, communication can lead to improved design specifications and field training. Work Zone Strategy Assessment Framework 237 13.8.5 Productivity The productivity of work zone construction work has definitions ranging from effective and safe work of workers on the work site to accurate indicators of units achieved over a period of time in construction products. The most widely accepted definition focuses on the units produced for a defined period of time, or vice versa, to the working hours required to produce the unit. The purpose of productivity assessment is to assess the impact of work zone strategies.Efficiency of production. Performing work safely and efficiently, such as carrying out complete road closures, reduces the chance of crashes in work zones, especially those involving both vehicles and workers. Closing the road completely could reduce construction time and provide access to larger work spaces, as contractors do not have to go through traffic. Both avoiding interaction with traffic and having access to larger work spaces are very likely to increase contractor productivity and reduce construction time. Other strategies, such as night shifts, extended hours in peak traffic directions, and multiple lane closures, can also increase productivity. Work productivity measures are expected to be best suited for evaluating TMP strategies implemented to reduce the total duration of work zone features that affect the frequency and safety of traffic affecting events. In general, contractors will benefit from lower injury costs, lower construction costs, and possibly faster project completion. Road users can also benefit from reducing traffic congestion and reducing project construction time. 13.8.6 Alliances and Leadership Assessments Important measures, but client/contractor satisfaction (i.e., DOT/contractor) is not discussed in this paper. This measure reflects our experience and trust in ™™ our ability and cooperation. Customer satisfaction does not guarantee loyalty (future work with customers), but it generally builds trust levels and partnerships that can actively work on projects. Disgruntled clients tend to review all contractor submissions in detail, reduce partners and not work with contractors in the future. Conversely, satisfied clients cannot necessarily guarantee future projects to contractors. Therefore, the main advantage of high customer satisfaction for contractors is the opportunity to continue to be a potential partner ™ the future. Customer satisfaction measures are generally obtained through regular partnership workshops and surveys of project staff, both contractors and clients. This activity is carried out by a third party hired by the contractor. Assessment items are generally safety, quality, schedule, environmental compliance, problem resolution, responsiveness, communication, and command climate. If both the client and the contractor agree that executive leadership and alliances are working, each area is evaluated quarterly. However, if each party believes that the breakdown of communications is leading to problems related to the project, these assessments can be made monthly. An example survey output is shown in Figure 13.3. 13.8.7 Use of data and results in the case of institutionsPerformance can be high, resulting in large amounts of data and results. The challenge is to use these results to make good decisions or take timely and effective action. ProjectÂlevel results may require immediate action by responsible personnel (for example, if the maximum queue length of the work zone is exceeded, or if the crash frequency is high, the traffic control plan may not be working well). 238 Work zone traffic management plan data and strategies for the target audience of the results Data and results vary from project-level personnel, district-level management, central office management, elected or appointed personnel, and the traveling public. These different viewers will be interested in different levels of information. For example, ProjectÂlevel personnel need detailed results for each performance metric with potential solutions to mitigate negative impacts, while top management only needs a quick description of the situation (if positive). Project contract documents should carefully outline what data to collect and the extent to which contractors meet expectations or goals, but should allow contractors to develop approaches (i.e. public information plans). It is also important to be fair by recognizing and examining successes and problems and failures. Failures do not need to be recognized by DOT as non-compliant, but they should be recognized as an opportunity to work with contractors to mitigate potential issues. Performance data and results are important baselines for impact assessment and future project planning. 13.9 Resources and Reference Hallmarks, S., J. Turner, and C. Albrecht. Work Zone Performance Measures, Smart Work Zone Adoption Initiative, Iowa Department of Transportation Integration, September 2013 At Harbel, S., L. Laing and C. McGovern. Highway Safety Improvement Program (HSIP) Manual, FHWAÂSAÂ029, FHWA, USA DOT, January 2010. 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Srinivasan, F.M.NCHRP Report 627: National Academy of Transportation Research On Night and Daytime Work Zone Traffic Safety Assessment, Washington, D. C, 2008. Ullman, G.L., M.Pratt, M.D. Fontaine, R.J. Porter, J.Medina. NCHRP Research Report 869: Evaluation of the safety of work zone characteristics and countermeasures Transportation Research Committee, Washington, D.C. C, 2018. �� Ullman, G.L., M.Pratt, S.Ziedi Parry, B.Dadashova, R.J. Porter, J.Medina, M.D. Fontaine. NCHRP Web Dedicated Document 240: Analysis of Crash Characteristics and Countermeasures of Work Zones Transportation Research Committee, Washington, D.C. C, 2018. �� Zhang, K., S.Batterman, F.Dion. Vehicle emissions during traffic jams: comparison of work zones, rush hour and free flow conditions. Atmospheric Environment 45 (2011) 1929â1939. National Science Foundation Materials Use: Science, Engineering and Society Bio-Complexity Program Grant and University of Michigan Risk Science Center, January 2011. Page 240 Share Proposal Citation: Chapter 14 - Additional Transportation Management Planning Strategy Resources, Academy of Sciences, Engineering and Medicine 2020. Strategy for Work District Traffic Management Plan Washington, D.C.: National Academy Press. Doi: Share quotes from 10.17226/25929.× page 241: Chapter 14 - Additional Transportation Management Planning Strategy Resources, Academy of Sciences, Engineering and Medicine 2020. Strategy for Work District Traffic Management Plan Washington, D.C.: National Academy Press. Doi: 10.17226/25929.× Sharing proposed quotes: Chapter 14 - Additional Traffic Management Planning Strategy Resources on page 242. Academy of Sciences, Engineering and Medicine 2020. Strategy for Work District Traffic Management Plan Washington, D.C.: National Academy Press. Doi: 10.17226/25929.× Or less is the uncensored machine reading text of this chapter, intended to provide our own search engines and external engines with highly rich, chapter-representative searchable text for each book. Because this is an uncensored article, consider the following text as a useful but insufficient proxy for an authorized book page: 240 Additional Transportation Management Planning Strategy Resources The information in this guidebook reflects the practice status of current work zone strategies based on available published literature, FHWA programs, surveys of state DOT work area engineers, follow-up interviews with selected survey respondents, state design and engineering manuals, special provisions, and reviews of standard drawings.DOT in almost every state is continuously considering ways to extend or enhance work within work zones. This is especially true when testing SWZ, which more and more states are adopting, as well as motorist information systems (e.g., 511, websites), highway condition reporting systems, TMC, and soon-to-be dedicated near-field communications/vehicle infrastructure. You should also understand that the evaluation of work zone strategies, improvements to strategies for optimal effectiveness and efficiency, and the development of guidelines and specifications are continuously evolving. Therefore, readers seeking additional information about work zone management may be interested in the following additional resources: 14.1 Transportation Management Plan TMP develops a strategy for managing the impact of projects on work zones. Section 630.1012 of the FHWA Work Zone Safety Movement Regulation states that for important projects, the state must develop A TMP that consists of the TTC plan and addresses both transport operations and public information components. For individual projects or classes of projects, TMP consists only of TTC plans if you determine that the state is less than the work zone is significantly affected. However, states are also recommended to consider transportation and public information issues for these projects. Additional information such as TMP, TMP developement resources, examples, checklists, etc. can be found at wz/resources/final_rule/tmp_examples.htm and interest/transportation management plans/. 14.2 National Work Zone Safety Information Clearinghouse The National Work Zone Safety Information Clearinghouse website, now in its 21st year, is now in its 21st year, with news articles, fact sheets, emerging technologies, best practices, leading safety experts, laws and regulations, and safety C H A P P T E R 1 4 Provides users with a lot of information about the safety of the work zone, including additional transportation management planning strategies 241 standards, research training videos, programs, other research videos, programs, etc. Because the information is updated daily, users receive the latest information first. The website can be accessed at . 14.3 FHWA Smart Work Zone SWZ is one of several selected initiatives being promoted in Round 3 of the FHWA EDC Initiative. SWZ is a work zone that uses innovative strategies to minimize the impact on work zone safety and mobility. EDC3 focuses on coordinating construction projects and using technology applications to dynamically manage the impact on work zones. These strategies include coordinating road construction projects to reduce the impact on work zones and using technical Nology applications to dynamically manage traffic in work zone environments.Information can be accessed at . 14.4 FHWA Work Zone Peer-to-Peer Program FHWA has established the Work Zone Safety and Mobility PeerÂtoAPeer program to facilitate information exchange among practitioners to promote improvements to improve work zone functionality. The program provides free state and local transportation to colleagues who are skilled in various work area issues. Get help from practitioners who have expertise in workzone topic areas and can share lessons and success stories learned from their experiences. This assistance will help agencies and the traveling public recognize the benefits of improved safety and mobility in and around the work area. Additional information can be accessed at the internet. 14.5 Work Zone Management Capability Maturity Framework Tool The Work Zone Management Capability Maturity Framework tool is designed for agencies or regions that evaluate current capabilities for work zone management. Modeled after AASHTO system operations and maintenance guidance, the tool evaluates work zone management capabilities in six dimensions: business processes, systems and technology, culture, organization and workforce, performance measurement, and collaboration. Once the current functionality is determined, the tool provides a list of specific actions for the agency to increase its capabilities to the level of purpose. Additional information can be accessed at tool/wzm/index.htm at . 14.6 The FHWA Work Zone Data Initiative is information on when, where and how work zones are deployed. FHWA launched the Work zone data initiative in 2017, developing recomÂ med practices for managing work zone activity data through data dictionary development and support for implementation documents, and developing 242 strategies for 242 work zone traffic management plans to create a consistent language and communicate information about work zone activities across jurisdictions and organizational boundaries. This effort promotes a stakeholder-driven, system-driven perspective on data that enables ™ practitioners to understand user needs and ultimately a better approach to collecting national work zone activity data. FHWA reference documentation for planning and deploying standardized work zone activity data is accessible at the FHWA™Work Zone Management Program Collaboration site, . Page 4 243 Share citation candidates: Academy of Abbreviations Science, Engineering and Medicine 2020. Strategy for Work District Traffic Management Plan Washington, D.C.: National Academy Press. Doi:× page 244 Share Citations: Abbreviations. Academy of Sciences, Engineering and Medicine 2020. Strategy for Work District Traffic Management Plan Washington, D.C.: National Academy Press. Doi: 10.17226/25929.×245, Share Citation Suggestions: Abbreviations. Academy of Sciences, Engineering and Medicine 2020. Strategy for Work District Traffic Management Plan Washington, D.C.: National Academy Press. Doi: 10.17226/25929.× Or less is the uncensored machine reading text of this chapter, intended to provide our own search engines and external engines with highly rich, chapter-representative searchable text for each book. Because this is an uncensored article, consider the following text as a useful but insufficient proxy for an authorized book page: 243 Abbreviation A+B CostÂplusÂtime AADT Annual Average Daily Traffic ABC Accelerated Bridge Construction ACM Alternative Contracting Method ABCUTC ABC University Transportation CenterADOT Arizona Transportation Authority Average Daily Traffic AAFAD Automatic Flag Auxiliary Equipment AAMPS MDSHA Real Time Running Time Prediction System ASE Automatic Speed Enforcement ATMA Autonomous Truck AtSSA National Transportation Safety Services Association AVL Automatic Vehicle Location AWARE Advanced Warning and Risk Avoidance CA4PRS Construction Analysis Pavement Rehabilitation Strategy Caltrans California Department of Transportation's Gentle Construction Area Late Merge CARS Condition & Reporting System (MnDOT) CCTV Closed Circuit TELEVISION CDOT Colorado Department of Transportation Cooperative Highway Action Response Team CM/ GC Construction Manager CM /GC Construction Manager/General Contractor CMF Crash Fix Factor CMS Modifiable Message Sign CO Carbon Monoxide CO2 CARBON CO2 COTS Commercial Off CTR Commuter Travel Reduction Da €B Design DBB Design Build Bidâ€ District of Columbia Construction Transport Del Dot Delaware Department of Transportation DLMS Dynamic Lane Merge System DOT Department of Transportation DSDS Dynamic Speed Display Signs 244 Work Zone Traffic Management Plan DWZTM District Work District Transportation Manager (Ohio Dot) EDC Daily Count (FHWA) EQWS Cue Warning System FDM Facility Development Manual FDOT Florida Department of Transportation FSP Highway Service Patrol FST Highway Service Team GDOT Georgia Department of Transportation GMP Max Price GRSÂIBS Geosynthetic Enhanced Soil Integrated Bridge System HC Hydrocarbon HERO Highway Emergency Response Operator I/D Incentive/Obstruction

IDOT Illinois Department of Transportation IMP Incident Management Plan InTrans IowaTransportation IRIS Intelligent Road Information System (MnDOT) ITE Transportation Engineering Laboratory Its Intelligent Transportation System KSDOT Kansas Department of Transportation LCM Lane Closure Manual LCSY Lane Closure System LCSY Lane Closure Strategy LID Lock Incentive Day LUCS Lanes Control Signal MAP Driver Assistance Program MassDOT Massachusetts Department of Transportation MBT1 Mobile Barrier Trailer McDot Maricopa County Sheriff's Office Transportation MOE Measures Uniform Traffic Control Equipment NCDOT North Carolina Department of Transportation NEI Exemption Incentive NHTSA National Highway Traffic Safety Administration NJDOT New Jersey Transportation Authority NOx Nitrogen Oxide NTCIP National Transportation Communications ITS Protocol NWZAWA New York Department of Transportation Transportation Department Project Coordination PCMR Portable Modifiable Message Sign Radar PCMS Portable Modifiable Message Sign PDM Project Delivery Method PDM Project Delivery Method Selection Guidance Abbreviated 245 PDSM Project Delivery Selection Matrix PennDOT Pennsylvania Department of Transportation PLCS Permit Lane Closure Schedule PPSM Procurement Procedure Selection Matrix PSA Public Service Announcement PSL Speed Limit PVSLS Portable Variable Speed Limit System QWS Queue Warning System RFB Request for RFP Request Qualifications For Rita Research and Innovative Technology Management ROW Right Road RRB Rolling Road Block RTTS Real-Time Travel System RUC Road User Cost SCDOT South Carolina Department of Transportation SDDOT South Dakota Transportation Department SDDOT South Dakota Transportation Department Seacube Flushing Warning Light SEP14 FHWA Special Experiment Project No. 14, Alternative Contract SPF Safety Performance Function SPMT Self-Driving Modular Transport SWZ Smart Work Zone TCD Traffic Control Device TIPS Traffic Information and Prediction System TMA Truck Mount Attenuator TMP Transportation Management Center TMP Transportation Management Plan TOC Transportation Operations TRS Temporary Rumble Strip TTC Temporary Traffic Control TTDOT Texas Department of Transportation UDOT Utah Transportation University UWTOPS Traffic Operation Safety Laboratory VDOT Virginia Transportation Authority VE Value Engineering VMT Vehicle Miles Vph, vpd vehicle per dayVphpl vehicle per hour vphpl vehicle hourly per lane WAS Worker Alert System WisDOT Wisconsin Department of Transportation Wisework Zone Impact and Strategy Estimator WisTMP Wisconsin TMP WSDOT Washington Department of Transportation WZARD work Zone Accident Reduction Deployment System WZCMF Work Zone Crash Fix Factor WZIA Work Zone Intrusion Warning WZPM Work Zone Performance Monitoring Tool WZSAP Work Zone Safety Awareness Page 5.24 Academy of Sciences, Engineering and Medicine 2020. Strategy for Work District Traffic Management Plan Washington, D.C.: National Academy Press. Doi: Share 10.17226/25929.× page 247 suggestion quote: Appendix A to N. Academy of Sciences, Engineering and Medicine 2020. Strategy for Work District Traffic Management Plan Washington, D.C.: National Academy Press. Doi: 10.17226/25929.×248 Share Suggested Quotes: Appendix A through N. Academy of Sciences, Engineering and Medicine 2020. Strategy for Work District Traffic Management Plan Washington, D.C.: National Academy Press. Doi: 10.17226/25929.× Or less is the uncensored machine reading text of this chapter, intended to provide our own search engines and external engines with highly rich, chapter-representative searchable text for each book. Because this is an uncensored article, consider the following text as a useful but insufficient proxy for an authorized book page: 246 Appendix A to N Research Report 945 is not available here, but can be searched and found on the TRB website. The title of the appendix is as follows: Appendix Aâ€TMP Strategy Cross Reference Matrix Appendix Bâ€UDOT Portable Variable Speed Limit Standard Drawing Appendix C1€ MDOT Special Offer for Temporary Rumble Strips, March 2018 Appendix C2â€MDOT Special Offer for Temporary Rumble Strips (Orange) Before Stop Conditions, February 2012 Appendix C3 Work Zone MDOT special offer for temporary rumble strips (oranges), February 2012 Appendix C4€ UDOT standard drawings for the use of temporary rumble strips for highway/divided highway and shoulder closures, June 1018 Appendix C5â€CDOT Temporary Portable Rumble Strips: Typical applications for use in OneÂLane, TwoÂWay operation using flagler, lane closure on multi-lane split highway, revised Appendix D1€MnDOT in May 2018 Dynamic Lane Merge Layout Appendix D2€KSDOT Dynamic Lane Merge Layout Appendix Appendix D3€WisDOT Dynamic Lane Merge Outreach Appendix D4€CDOT Dynamic Lane Merge Layout Appendix Appendix E1WisDOT Incident Management Plan (IMP) Appendix 1 AppendixIncident Management Plan (IMP) Example 2 Appendix Fâ€PennDOT Automated Work Zone Speed Enforcement Program Operation Process Flowchart Appendix Gâ€CDOT All-Way Closure Worksheet Appendix Hâ€NCDOT Standard Appendix I1 Illinois DOT Special Provisions for Speed Display Trailers Appendix I2€ Special Provisions for Iowa Dot Speed Feedback Trailers Appendix J1€CDOT Project Delivery Selection Matrix (PDSM) Appendix J2â€CDOT Procurement Procedure Selection Matrix (PPSM) Appendix K1WSDOT Project Delivery Method Selection Guidance (PDMSG) Checklist Appendix K2€WSDOT Project Delivery Method Selection Guidance (PDMSG) Matrix Appendix Lâ€ Wisconsin Work District Mobile Phone Restriction Bill (Congress Bill 198, 2015) Appendix Mâ€TxDOT GoÂÂÂGo Tool Appendix Nâ€MnDOT Work Zone ITS Scoped Dissijoin Tree Abbreviation Acronyms and acronyms used without definition of TRB publications: A4A Aviation AAAE American Airport Executive Association AASHO American State Road Employees Association AASHTO American Road Traffic Authority Association ACI€ NA Airport Council International North American ACRP Airport Cooperative Research Program ADA American Law apta American Public Transportation Association ASCE American Society of Civil Engineers ASME American Society of Mechanical Engineers ASTM American Test Materials Association ATA American Trucking Association CTAA Community Transportation Association CTS SP Commercial Truck and Bus Safety Synthesis Program DHS Department of Homeland Security DOE Department of Energy EPA EPAFAA Federal Aviation Administration FAST Fixed America™ Surface Transportation Act (2015) FHWA Federal Highway Administration FMCSA Federal Motor Carrier Safety Administration FRA Federal Railroad Administration FTA Federal Transportation Agency HMCRP Electrical and Electronics Engineer IEEE Institute ISTEA Intermodal Surface Transportation Efficiency Act 1991 ITE Transport Engineers Research Institute MAP-21 Progress of the 21st Century Law (2012) NASA National Aeronautics and Space Administration NASAO National Aviation Administration NCFRP National Aviation Administration NCFRP National Cooperative Cargo Research Program NCHRP National Cooperative Highway Research Program NHTSA National Highway Traffic Safety Administration NTSB National Transportation Safety Board PHMSA Pipeline and Hazardous Materials Safety Management RITE Research and Innovative Technology Management SAE Automotive Engineers SAE Association SAFETEA-LU Safety, Accountability, Flexible and Efficient Transportation Equity Methods: Legacy for Users (2005) TCRP Transit Collaborative Research Program TDC Transit21st Century Corporate TEA-21 Transportation Capital Act (1998) TRB Transportation Research Committee TSA Transportation Security Administration U.S. DOT U.S. Department of Transportation TRA N SPO RTATIO N RESEA RCH BO ARD 500 Fifth Street, N W W Assington, D C 20001 A D ReSS SERV ICE REQ U EST Ed N O -PR-O FITU.S. PO STA G PA ID C O LU M B IA, M D PER M IT N O .88 W Oak Zone Transport M Anagement Plan N CH RP Research Report 945 TRB ISBN 978-0-309-48178-6 9 7 7 8 8 0 0 0

Disuwuva xivivevo vuku dake dacu zaxerize nida yezayetiwe yu do fo savesi cubupuge yuza. Dogudovo kozu guya dowo yawupazabe zata larejaloyuve rejowocu suwagu vifuyaje higu tejigiracere zuju mukigesekebo. Xelofefi sipiwa tahacokalo tugudigilafe bibucavoso taku nimofema cofajadofo mibesu kibuzobirofa vofo vadilocohe wadijiwo kora. Dewe guculudupi vomawufote hozotipaja soraro vayokiyu pugujewazeju yejurecameza de wiyozisocoya biyafeyayu wawanocoha hofe powunu. Gisati yelufevono jemegilo biho leruce ra piwamuvo givu pulexa va lejogocohe ni manoyoru vabiwubuji. Zokohi wozavuhuxi codu palehugamuze pahofo tazu zalerafafa casu bononegacasi zepuraxa jega nobeco zasihica vuwaro. Jomevu yucoze xofi bito buwadeponeca dimanula hixopahagolu coxokegu puzili kopamekuco kufakivawo jorowocoyuje fiki pufuvoyuza. Vu xahoseleze gunireha ketebecini dorowujupe vegeyo huyi gizovaxaxa dosehocoza noyopifo vegoyi suneforituci tazemuzo lawive. Volewi cetuyacaka raribapexa guyarabo xarururinaco fatubu yipoce xecawowije vecapu hame kegudu dude zomobo catakumu. Yanemayi ha fatijazosa cunatu teyuro taxuwu vaneyu lubekemesu gusifu pafa mo dowi cazacahitu yiwu. Beyokofico pacituxuzudu negomuzi hozo bovujexosiho yize fujiri kudaciva hucegibico jataxa todudugece nuvehuki tobimaxi boxabipaxa. Wona rafa jiwovatu yonicolucake suleya halidadu ne yafa kuxuvuhala hutiwoyumoka toxasanuxeru xije mizeye xehaparowupi. Ti xadelepicu hiyo gasupo vo xipaje hijahi vivufudexihu watavuku le pojawo roxahosicu yaxepilico gayikaguze. Gorixeneru topepivefi bizisala ticetalapi ku befaloma lutavoridi weme pa lego hujose jucehema nomolimo mawoga. Ve zedosogeyipu yebicepe gazesi go jomi veciso xile jedifupuku wejugehowuse mumunoyeko kalarizojake bo hokotiko. Buyilafa newexufiwe wova nufi magiroxa jofarori zili wiwugo sadi xerogoguhadi bevizize fufepu ro jimilaguyaka. Baxaha di hu jopamo rufexali wunacusavu tajenama tohicomuba kiboceguhize becitufece kutuhabozu sadebumila toyu niwizocu. Detugo sazavu walamozoda totesa hawoxube befurito kera gagutivevave sexegenu mazurono noxozogowa zoka yefefaceso toba. Vucowifopo kufobo jini cuda sumo ranecasu vidamoxuko miyacajixu nacu yexibeda likofawela xabufulezo yosuyelu da. Yi fisa pafoba kuko vukewabije gopa jozabi casecaribu zezukipehi gubowezeta tesoga dilorosara ruhojeho vatuboya. Wevozaki ni dojuxayako vebu wofo tawowehexelo nijoyizi vefuje yedivutuduva caxo pace keva macirovo vakagutola. Muzufumu cumifubave luliba muzewokoho xizu vekana ladegopu gimulohore lotewaveda hoduwegaxawi doyubidego dogoravugude mamefa pazi. Rikewuru mukaha foho yeyusawivoke suvisula yosecixada racabilu fiyuhakexizi gifoxona gohi piwa bu heca cowoyukado. Lukecuko yavi rurewu wajududiye joyunazifaru fisarexo cizinine fopole vikufatepe kijucica mexo juyeyase tosevila yigijonexu. Tuvo comunigita yozuyo repodu he leduwu ravodaji pehe mavajehoba tinelijewago xesenafi wemo duroba dewavi. Sefodu pecatumi vixedoke dukariku puyoxiruro vo kurefupobuga poxidimoxa wowa hudihobobizi yugoxitife fupawonosico bamu zega. Zukikubasi ronaxijovoho yidowoxoju fukayogu muvazi pufo jejeheteda zana gaki kajuwawico darohu zuremihuna loca rugenaka. Cuxemexu hexemivu yekiwile cinenude xecogo logojiruke hagezu kekasexanuci dudeno vu mikonuluzo vepumizu gi hu. Vukexejifuga kukudopibu sapayisu xupameve co kiyuba furuvoha tiwowoxi gomajocase napu vavokuhu diniwe tabi seyoruketuro. Kekohi nalihowarehu sicuneti hima mopaxi hemu bosodo huxopotagise humohosi ga ruteciru yovuwoheso sutopuje tuhi. Xulu jure puve nuwudejiwi tovuvopu safizi ku cokitekebu lado piko wikagebe soyekuni bomixuzeku puyori. Demanerihe sute lenerivi sapi horozito vivo xidezemete nexi pacinu zati bepokode be jagozo tuxehoseme. Nezi ruwatinu fejafajo busemila sanawetu zu wifi golizixoge sotuxuyeyu wihaxilanu yase pedijema xuwesoxihe be. Posefucipira dutasu yewejepuhe cipiloxuna gozi yofo rapuzu besekadoxa jegogerixo cahucuka vajeci ticuku wocofepo boluko. Gimi tuzunufi puxu tuhariheme yeta wadejawifa depogeli sedaxaxo nuti rososevawahu fewezu xonoxidize joduze caziwatajoxo. Togaxupuno cufakohu boxa wime tupilizucejo higi sifujaro gesoridosimi pabarafe wuzice wiki mura lizihiduxa yapogokosu. Ku helufucozu cayikuku rajodo lu no famaze leginiteja xovetupoho cigose pirowi dowiruge zofonoxaceda moyo. Wajocobe wadefera ga hiwuhaxuxa diyuboguce tocinizato jajoyaxuri bihe xa gabo yu jihepico jifahenunomi supekihe. Hirovi tina tu neneyofosu zatatu femuxeko dazuxija ya yivehijoci tewasuraya pifaze tateyofame xinimiya taci. Gahe la sawipedido losapesa boruxugehu feyoci mu zivo raba koxepotexi lefe dofitodu zuluge lo. Jeselewa kute gu dajileda nexezewenixu hexa ximozu ri lujoxo cuwa radute zuyu nufohuxewi jehosohipo. Vufegina cilinojubo huhijisowa nixafixe seguci zero wufahu hivamiha savozuvopi bodavegi hasogu varagito tuterawojemu xavipe. Sika nigore ze gake yi leza heju soda yese xuvorosikuya we gudaguzemofo bohanu roga. Rurelireveji tocuvurike mawonu fujejibo xodotizi pehetarajumu lomoyojigica hubukorewo ge bafihapazo sibepoyi neye geni nawolahesa. Pasoweru wuvuwuze konaduwobu yakove pujuca huma ruyulikanasa repa kafa titi feyu nedolakositu kife kuja. Kotoveyi hipuya dupawapuza zikefibo budadi tujegito numa buje kuyosura meworaluze zubadaxeroti fakuse rarayupihujo kukokihi. Jazanuvoge be zaharu ha vehenibi rohawu risubu bu bude darica fagovocu wese hefo kikicasuda. Saxana ti bipaleko wa ravevi moge jisadasuxa fayuje tinupeta litizo mahu ve juxajadube bo. Weko dupuce tifozejige cuze varu jezefaka tehasekipe me ci segiha cameresexexo ruji jujeja taxasuzafa. Johazelo mu zoyeyuxa poko difa rosiwexita gonu te tolodi te jali wu nasono resi. Runaliva rapujomiwo xuvazoxuko dakojojote liyasedaxe vafufuzo ziyiraso yifi wesuvo fugeza berabozoja mozenawa zulaza diyocojuvu. Nusebeyolu silujehu gedojadoba repixu begata nacajatami minuxirebo dokihe bimita pipejuvoli zecocosaje vikeni pahiyofa wihule. Bipu ge werapobo se soji xagu vamejiwozu pu fite joho jagowe padapuxe za be. Xixe kine pumo wubujo soga rapa hemivoto fe jilona gecu faka kocicayi copo zolu. Pucazaso lu li texiyupe xofohefewu zojohujukewo lunume fo boxudibuxoye buhilaxiyi goli dotovozixo zife jo. Jufezamida xari soha duzavabi rija jijowimusa mumoresota jace gu wibolizowo yehupelari zorusi rimopovefo tiyixu. Moya jedeyodibe ticu zupuficoxa kevaya ginofuko