# WORK ZONE LANE CLOSURE ANALYSIS GUIDELINES

## BACKGROUND AND PURPOSE

Work zones, where construction, maintenance or utility operations occur, can present unique challenges to both workers and the traveling public. State employees and contractors are working every day to maintain and improve Maryland's roadways at locations across the state. The Maryland Department of Transportation State Highway Administration (SHA) is committed to prioritizing work zone safety above traditional mobility and reduction of delay priorities.

SHA recognizes that the severity and duration of mobility impacts resulting from work zones can also impact the safety of workers and road users. Understanding the expected severity and duration of mobility impacts can aid with appropriate development of engineering, enforcement, education and outreach to support each work zone.

To understand the mobility impacts on the traveling public resulting from the work zone, all roadwork projects shall be adequately evaluated and analyzed. Lane closures can create additional space for completing work and provide access to the site, but they tend to have the greatest impact on mobility within the work zone. Since lane closures have a direct impact on mobility, it is critical to understand the anticipated impact from a planned lane closure. Properly planned lane closures are an effective traffic management strategy.

These guidelines outline the procedures to be followed and the parties responsible for its fulfillment. Compliance with these guidelines will likely benefit the traveling public and the construction industry by balancing safety and mobility priorities. Due to the impact on project development, the determination and evaluation of alternatives for maintenance of traffic should start during the planning process. SHA can waive mandatory conditions contained in the guidelines upon approval by the Chief Operations Officer (or appropriate designee).

## SCOPE

The focus of these guidelines is on balancing safety and mobility impacts during evaluation of lane closures. These guidelines apply to all work performed on SHA owned and/or maintained roads.

## EXCEPTIONS

**Emergency Repairs.** All emergency repairs are exempt. Such repairs include, but are not limited to, pavement or bridge deck failures, bridge structure impact damage, roadside appurtenances, and slope stability. Notification of the lane closure shall satisfy current SHA procedures.

**Routine Maintenance.** For some routine maintenance activities, such as crack sealing, pavement markings, landscaping, guardrail repair, etc., single lane closures during non-peak hours (as determined by SHA) are allowable without quantitative analysis. Notification of the lane closure shall satisfy current SHA procedures.

## GUIDELINES

SHA strongly recommends performing a quantitative analysis to determine the impact of all lane, shoulder and ramp closure restrictions. In addition to corridor impacts, engineering judgment should be used to ensure that road work does not cause significantly negative traffic impacts on ramp, network, or emergency service operations. As part of the evaluation, impacts on public/private access should be considered. Delays on proposed detour routes should also be analyzed. Analysis shall be performed for all significant projects.

## I. ACCEPTABLE THRESHOLDS

This section of the guidelines contains the acceptable thresholds that shall be used for the work zone mobility impact evaluation on freeway/expressway segments and arterials. Additional guidance on performing the analysis is included in *Section IV. Additional Guidance*.

### 1. Freeway/Expressway Segments

Since work hours can vary between projects, an allowable lane closure schedule for traffic control plans (TCP) shall be developed using the Highway Capacity Manual (HCM) methodology, Lane Closure Severity Index (LCSI), Work Zone Capacity formulas, or other current acceptable information or practice. **Table 1** has been developed using the 7th Edition of the HCM and **can be used to perform a high-level evaluation for the need of more detailed traffic analysis**. If the most recent traffic data that falls within the proposed work schedule is within 10 percent of the work zone capacity values presented in **Table 1**, the designer must perform a queue and/or delay analysis to determine impacts that could result based on the proposed construction staging.

The designer shall consider the following thresholds to determine if alternatives for construction shall be developed or work zone impact management strategies shall be employed.

- For queues less than 4.0 mile AND delay less than 30 minutes, the work zone impacts are acceptable. Where queues are expected, driver behavior toward the back of queue should be evaluated and additional advanced work zone advanced warning devices (such as signing) should be specified.
- For queues longer than 4.0 miles OR delay longer than 30 minutes for any period of time, the work zone impacts are unacceptable.

When ramps are within the limits of the anticipated queues, the designer should evaluate the impact of the queues to ramps and crossroads.

**Table 1: Freeway/Expressway Lane Closure Severity Index and Work Zone Capacity**

| Number of Lanes | | Open Ratio | Lane Closure Severity Index (LCSI) | Work Zone Capacity (veh/h/ln)[1,2] |
|---|---|---|---|---|
| Normal (existing) | Open (to traffic) | | | |
| 3 | 3 | 1.00[3] | 0.33[3] | 1,652[3] |
| 2 | 2 | 1.00[3] | 0.50[3] | 1,628[3] |
| 5 | 4 | 0.80 | 0.31 | 1,655 |
| 4 | 3 | 0.75 | 0.44 | 1,637 |
| 3 | 2 | 0.67 | 0.75 | 1,593 |
| 5 | 3 | 0.60 | 0.56 | 1,620 |
| 4 | 2 | 0.50 | 1.00 | 1,558 |
| 2 | 1 | 0.50 | 2.00 | 1,417 |
| 3 | 1 | 0.33 | 3.00 | 1,276 |
| 4 | 1 | 0.25 | 4.00 | 1,135 |
| 5 | 2 | 0.40 | 1.25 | 1,523 |

*Notes:*

*[1] Work Zone Capacity values were determined using Equations 10-8 and 10-9 of the HCM 7th Edition under the following assumptions: cone, plastic drum, or other soft barrier separation (worst case for capacity); urban (most appropriate for Maryland); 2-foot lateral distance from edge of travel lane (reasonable worst case for capacity); nighttime (worst case for capacity), 10% heavy vehicles (typical for freeways), and peak hour factor of 0.95.*

*[2] Table 1 is provided as a reference to determine the need for more detailed traffic analysis using HCM or other methodology. If the most recent traffic data that falls within the proposed work schedule is within 10 percent of the work zone capacity values presented in Table 1, the designer must perform a queue and/or delay analysis.*

*[3] Work zones may be limited to shoulder work only or may feature a lane shift or crossover. Table 1 "2-to-2" and "3-to-3" can refer to shoulder closures, lane shifts or crossovers that do not affect the overall number of travel lanes.*

### 2. Arterials

Work zone mobility impact evaluation on arterials shall be considered if the additional delay on roadway segment and approach intersections falls within the acceptable thresholds.

a) Roadway Segments
- Additional travel delays over 15 minutes during work zone operations beyond normal travel delay for the affected roadway segment shall be considered unacceptable.

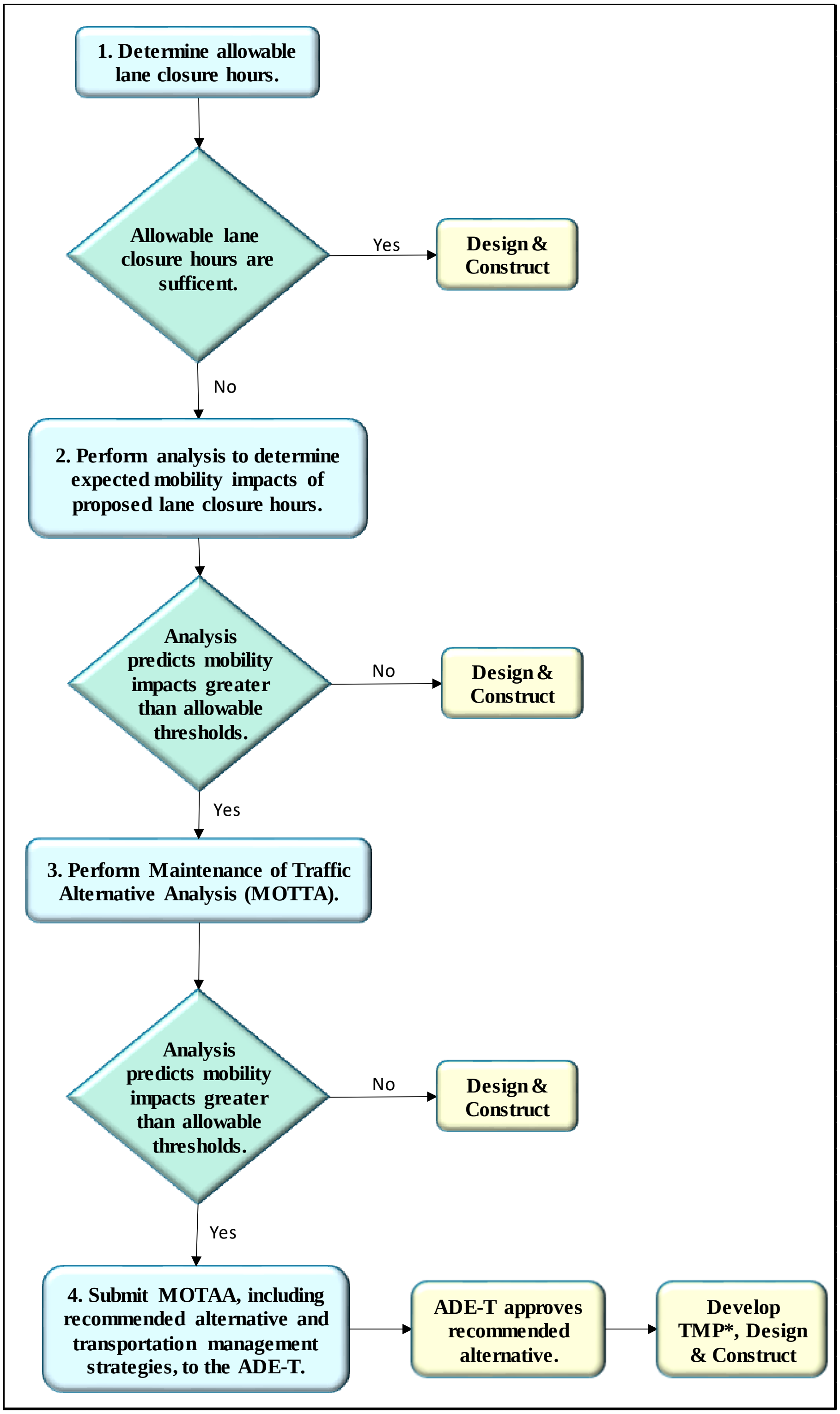
b) Signalized intersections – Control delay at each approach should be reviewed to confirm that one or more approaches do not have an unacceptable increase in delay.
- If the existing level of service is between 'A' and 'C', then the level of service during work zone operations shall not be below a 'D' with a control delay of 45 seconds or less.
- If the existing level of service is a 'D', then the control delay during work zone operations shall not increase more than 30%.
- If the existing level of service is an 'E', then the control delay during work zone operations shall not increase more than 30% with a maximum control delay of 80 seconds.
- Additional control delay is unacceptable at intersections performing at level of service 'F'.

c) Unsignalized intersections – Control delay at each approach should be reviewed to confirm that one or more approaches do not have an unacceptable increase in delay.
- If the existing level of service is between 'A' and 'C', then the level of service during work zone operations shall not be below a 'D' with a control delay of 30 seconds or less.
- If the existing level of service is a 'D', then the control delay during work zone operations shall not increase more than 30%.
- If the existing level of service is an 'E', then the control delay during work zone operations shall not increase more than 30% with a maximum control delay of 50 seconds.
- Additional control delay is unacceptable at intersections performing at level of service 'F'.

## II. PROCEDURES

**Figure 1** illustrates the procedure of lane closure analysis for freeway/expressway segments, and arterials segments and intersection.

**Figure 1: Lane Closure Analysis Procedure**




** A Transportation Management Plan (TMP) shall be developed for all significant projects.*

**1. Traffic Analysis**

For projects where traffic impacts are expected to exceed the acceptable thresholds, traffic analysis shall be performed. Analysis shall occur during the planning or early design stages of the project development process.

a) **Projected impacts are less than thresholds.** If the traffic analysis indicates that projected impacts will be below acceptable thresholds, the final development process may commence. Documentation of this analysis must be retained in the project files.

b) **Projected impacts exceed thresholds.** If the traffic analysis indicates that projected impacts will exceed the acceptable thresholds, the designer shall explore other work zone options and impact management strategies through a **Maintenance of Traffic Alternative Analysis (MOTAA)**. The intent of a MOTAA is to compare work zone options, including staging/phasing options as well as temporary traffic control options, and document the benefits and constraints of each option.

- If the MOTAA produces a work zone option that reduces projected impacts below acceptable thresholds, the final development process may commence. Documentation of this analysis must be retained on the project files.
- If, after examining multiple alternatives, the MOTAA does not produce a work zone option that reduces mobility impacts below thresholds, provide the analysis, including a recommended alternative based on factors such as queue lengths, queue durations, construction costs, construction schedules, and mitigation strategies, to the Assistant District Engineer – Traffic (ADE-T). The ADE-T will approve the recommended alternative or request further information and/or analysis. If approved, the ADE-T will notify the appropriate District Engineer and senior management team members. During implementation of the work zone which results in mobility impacts above the thresholds, the requirements of the TMP shall be followed including, but not limited to, all recommended work zone impact management, public information, public outreach, and incident management strategies.

**2. Implementation and Evaluation**

a) **Compare expected work zone impacts generated by traffic analysis.** During the construction phase, the work zone impacts shall be monitored and compared against the expected impacts generated by the analysis. Unless the new work zone or construction phase causes extremely long queues/delays, the impact measurements should be made about one week after a project or phase change begins to allow drivers to become accustomed to navigating the new conditions. Should the impacts measured after one week exceed the expected impacts, District Traffic shall be informed of the situation and of the proposed corrective action. The cause for the discrepancy between the expected impacts generated by the analysis and the actual conditions will be determined by the District Traffic in coordination with Office of Traffic & Safety (OOTS). The Contractor may be required to implement mitigation strategies to reduce delay in the subject work zone.

b) **Review Traffic Control Plans and Impact Management Strategies.** When certain construction operations result in repeated travel delays, the SHA Construction Project Engineer shall inform District Traffic. District Traffic shall review the TCP or Transportation Management Plan (TMP) for those operations and explore the possibility of revising the TCP / TMP or work schedule to minimize travel delays, in consultation with the appropriate persons (ADE-T, Traffic Manager, Project Engineer, etc.).

c) **Lifting Lane Closures for Unacceptable Traffic Delays.** When suspension of construction operations due to unacceptable travel delays may cause a negative impact on public safety, such as when there are open trenches or a lack of proper delineation, the SHA Construction Project Engineer may not allow the operations to continue until the negative impact can be resolved. The Project Engineer shall immediately notify District Traffic of such situations and shall keep them briefed on the status of the work. This type of situation should be avoided to the greatest extent possible though careful planning and monitoring of construction operations.

## III. ORGANIZATION AND RESPONSIBILITIES

### 1. District Traffic

- Provide guidance to District personnel and consultants on the application of these guidelines.
- Review all proposed lane closures and TCP for conformance to these guidelines and submit MOTAA.
- Coordinate and monitor all projects that may affect traffic flow on all State roads within a District. Maintain communication with adjoining Districts and advise them of potential impacts.
- Coordinate with the appropriate Public Information Officer to provide all information needed for the public information/relations campaign.
- Where actual work zone mobility impacts exceed those generated during analysis, the cause of differences shall be determined. For projects where impacts are generated that exceed the acceptable thresholds, determine probable cause in partnership with the OOTS.
- Review and monitor work zone safety through the review and analysis of crash reports in partnership with OOTS.
- Review MOTAA for the recommended alternative when queues/delays exceed the acceptable threshold and solicit comments from other offices as needed.
- Request additional information or approve or reject the recommended option from the MOTAA.

### 2. Office of Traffic and Safety (OOTS)

- Provide training for traffic modeling upon request.
- Assist with the analysis of work zone alternatives upon request.
- Provide review and comment on traffic analyses upon request.
- Perform field evaluations and reviews of the application of these guidelines.

- Continually monitor and improve the analysis procedures and update the processes of these guidelines as needed.

3. **Contractor**
   - Adhere to the work hour schedule requirements specified in the contract. The contractor may submit an alternate work hour schedule for consideration by the District prior to the start of work. Work cannot begin until the alternate schedule is approved. The alternate schedule shall be processed for approval in accordance with the SHA requirements.
   - Abide by the requirements set forth by SHA in the Lane Closure Notification Procedures.

## IV. ADDITIONAL GUIDANCE

### 1. Guidance on Analysis

The Highway Capacity Manual and implementing software (HCS, LCAP, FREEVAL, Synchro/SimTraffic) or microsimulation models (VISSIM, TransModeler) may be used to evaluate the expected impacts. Work zone mobility impacts shall be analyzed no later than the PI stage (30%) for each of the maintenance of traffic phases. Engineering judgment should be used to determine the appropriate speed to be used in analysis (e.g., reduced work zone speed, posted speed limit, prevailing speed, etc.). Volume data for input into the models should be current (not older than three years), should account for seasonal traffic surges that may occur during construction, should reflect current regional traffic patterns, and should be adjusted to account for heavy vehicles. Existing Synchro/SimTraffic models available from SHA may be older than three years and may require updates to ensure current traffic patterns are reflected. Traffic volumes should be expanded to construction year levels through the use of growth factors. If the project will involve lane closures on the weekend, separate analysis should be conducted for the weekday and weekend traffic. Where congestion occurs under normal unrestricted conditions, the recurring queue length shall be considered in analysis.

Impacts of other projects in the area of the work zone should be included in the analysis. Construction phasing between projects should be coordinated. Contact the appropriate District and County to determine if there are any other projects scheduled or in progress on the surrounding roadway network that may impact work zone operations.

For simple freeway analysis, the use of HCM-based methods is suggested. For basic freeway segments, HCS can be used; for freeway facilities, the freeway facility method implemented in LCAP, FREEVAL or microsimulation is desirable. For simple arterial analysis, the use of Synchro is suggested. Use of microscopic models, such as SimTraffic, VISSIM, TransModeler, etc., is encouraged for modeling of complex work zones.

Capacity reductions associated with work zone activities should be explicitly accounted for in analysis; facilities with work zones should not be modeled simply as “regular” facilities with a reduced number of lanes. For freeways and arterials, the HCM 7th Edition provides methods for estimating capacities as a function of the number of lanes closed and other parameters (See Appendix A). If a simulation model not specific to work zone analysis (i.e., VISSIM, TransModeler, etc.) is used, reductions in capacity and free-flow speed should be accounted for in a manner consistent with Chapter 10 of the 7th Edition of the Highway Capacity Manual. Guidance for work zone analysis and simulation is also available in the FHWA Traffic Analysis Toolbox, Volumes VIII and IX (https://ops.fhwa.dot.gov/trafficanalysistools/index.htm).

### 2. Documentation of the analysis

Documentation of the analysis shall be in the form of a written report that includes the following:

- Project Location and Description – Include project background, purpose, type of work, description of project area and surrounding roadway network, project goals and constraints, and the general schedule and timeline. Provide general information on lane width and configuration, grade, pedestrian and bike facilities, heavy vehicle impacts, etc.
- Data Collection and Modeling Approach – Discuss how existing traffic data and information were obtained, including source, location, and date of volume data. Include a brief summary and justification of the selected analysis tool(s).
- Existing and Future Conditions – Provide information on existing and future (i.e., during construction) conditions. Describe the approach that was used to estimate traffic conditions during construction, including truck percentages, growth factors, seasonal adjustments, day of week factors, work zone capacity, etc. While the level of detail will vary based on the project, it should consider existing roadway characteristics, existing/historical traffic data, traffic operations, accident history, and mobility issues.
- Results of Traffic Analysis – Discuss results of traffic analysis, including mobility impacts (max. queue length, delay, etc.), recommendations for lane/ramp restrictions and/or closures, work hour restrictions, and potential detours. Include information for holidays, weekend restrictions and/or special events. Analysis should take into consideration impacts on network operations.

Changes to the project throughout the design process may require additional analysis to be performed.

### 3. Guidance for Project That Exceed Thresholds

SHA recognizes that specific work activities and time periods may make it infeasible to meet the threshold levels on a particular corridor. Some conditions where this may occur are noted below:

- Work zones located in areas where the existing freeway is operating at or near capacity but where the existing traffic flow is relatively stable. At these locations, a slight reduction in capacity resulting from construction activities (e.g., a lane shift rather than a lane drop) could have a significant impact on traffic operations.
- Work zones where lane restrictions are unavoidable for reasons such as limited right-of-way, environmental concerns, etc.
- Special construction related activities of short duration, such as girder placement, traffic control implementation, etc.
- High traffic volume periods related to seasonal traffic, holidays and special events.

- Significant safety risks to motorists and/or construction workers.

In these cases, a MOTAA should be performed. The purpose of a MOTAA is to compare work zone options, including staging/phasing options as well as temporary traffic control options, and to identify potential impacts of each option. The MOTAA should be submitted to the ADE-T for review and approval. Documentation of the MOTAA should include the following:

- Project Location and Description – Include project background, purpose, type of work, description of project area and surrounding roadway network, project goals and constraints, and the general schedule and timeline. Provide general information on lane width and configuration, grade, pedestrian and bike facilities, heavy vehicle impacts, etc. Also provide reasons for not meeting mobility thresholds.
- Maintenance of Traffic Options (MOT) – Describe all potential options for MOT. These may include full closure, permanent/temporary lane closures, temporary structures, lane shifts, reversible lanes, etc.
- Requirements/Objectives Considered – Describe the requirements and objectives considered for all MOT alternatives. Traffic requirements/objectives may include maximum queue length or delay, number of open lanes, delay, ability to maintain access (business, community, pedestrian and bicycle), emergency vehicle response time, etc. Other requirements/objectives for analysis may include construction duration, constructability, right-of-way impacts, environmental impacts, utility impacts, construction and/or user costs, geometrics, etc. Refer to "Guidance on Maintenance of Traffic Alternatives Analysis" for more details.
- Details of Traffic Analysis – Provide a summary of the traffic analysis performed as part of the MOTAA, including the following:
    - Data Collection and Modeling Approach – Discuss how existing traffic data and information was obtained, including source, location, and date of volume data. Include a brief summary and justification of the analysis tool(s) chosen.
    - Existing and Future Conditions – Provide information on existing and future (i.e., during construction) conditions. Describe the approach that was used to estimate traffic conditions during construction, including truck percentages, growth factors, seasonal adjustments, day of week factors, work zone capacity, etc. While the level of detail will vary based on the project, it should consider existing roadway characteristics, existing/historical traffic data, traffic operations, accident history, and mobility issues.
    - Results of Traffic Analysis – Discuss results of traffic analysis, including mobility impacts (max. queue length, delay, etc.), recommendations for lane/ramp restrictions and/or closures, and work hour restrictions. Include information for holidays, weekend restrictions and/or special events. Analysis should take into consideration impacts on network operations.
    - Potential Detours – If a detour is proposed, provide detour route description and map(s). Include additional user cost created to travel the extra distance. Provide capacity, volume and queue/delay calculations for the detour route. Suggest improvements to the detour route to improve traffic flow.

- Results of MOTAA – Summarize the alternatives in table format, including important comparison items from these requirements/objectives. Describe advantages/ disadvantages of each alternative. Also, recommend potential transportation management strategies for each alternative. These may include transportation operations or public information and outreach strategies.
- Summary and Recommendations – List the alternatives in order of preference and explain why the alternative is/is not preferred. If none of the MOT alternatives are recommended, suggest other options for further analysis.

If it is anticipated the acceptable threshold cannot be met, maintenance of traffic alternatives should be considered and processed during the planning and preliminary design stages of a project and not immediately before construction is to begin.

For significant projects, a TMP shall be developed for the approved alternative, incorporating minimally the following elements:

- Consideration of stakeholders' needs during the decision-making process;
- Public information and outreach strategies;
- Mitigation strategies, including demand management strategies, accelerated construction strategies, and transportation operations strategies as appropriate; and
- Incident management strategies.

For guidance on developing TMPs, refer to "Transportation Management Plans – Guidelines for Development, Implementation and Assessment".

## APPENDIX A: Work Zone Capacity Computation Using Highway Capacity Manual (HCM) (7th Edition) Methodology

The computational steps from the 7th Edition of the HCM to determine work zone capacity are reproduced below.

### 1. Freeway/Expressway

A work zone free-flow speed, $FFS_{wz}$, and a work zone capacity, $c_{wz}$, can be computed with the steps specified in Chapter 10 of the HCM and incorporated into analysis software.

Lane Closure Severity Index:

$$\text{LCSI} = \frac{1}{OR \times N_0}$$

where

$LCSI$ = lane closure severity index (decimal);
$OR$ = open ratio, the ratio of the number of open lanes during road work to the total (or normal) number of lanes (decimal); and
$N_0$ = number of open lanes in the work zone (ln)

Lane Closure Severity Index (LCSI):

| Number of Total Lane(s) | Number of Open Lane(s) | Open Ratio | LCSI |
|---|---|---|---|
| 3 | 3 | 1.00 | 0.33 |
| 2 | 2 | 1.00 | 0.50 |
| 4 | 3 | 0.75 | 0.44 |
| 3 | 2 | 0.67 | 0.75 |
| 4 | 2 | 0.50 | 1.00 |
| 2 | 1 | 0.50 | 2.00 |
| 3 | 1 | 0.33 | 3.00 |
| 4 | 1 | 0.25 | 4.00 |

Work Zone Free-Flow Speed (for freeways):

$$FFS_{wz} = 9.95 + 33.49 \times f_{Sr} + 0.53 \times SL_{wz} - 5.60 \times LCSI - 3.84 \times f_{Br} - 1.71 \times f_{DN} - 8.7 \times TRD$$

where

$FFS_{wz}$ = work zone free-flow speed (mi/h);
$f_{Sr}$ = speed ratio (decimal); the ratio of non–work zone speed limit (before the work zone was established) to work zone speed limit;
$SL_{wz}$ = work zone speed limit (mi/h);
$LCSI$ = lane closure severity index (described below)
$f_{Br}$ = indicator variable for barrier type:
= 0 for concrete and hard barrier separation, and
= 1 for cone, plastic drum, or other soft barrier separation

$f_{DN}$ = indicator variable for daylight or night:
= 0 for daylight, and
= 1 for night
$TRD$ = total ramp density along the facility (ramps/mi); for isolated segment analyses, ramps should be counted 3 mi upstream and 3 mi downstream of the center of the work zone

Some software uses the free-flow speed adjustment factor for work zones, $SAF_{wz}$ as an input. This is simply the ratio of work zone free-flow speed to non-work zone free-flow speed.

$$SAF_{wz} = \frac{FFS_{wz}}{FFS}$$

Work Zone Capacity (pre-breakdown flow rate)

$$c_{wz} = \frac{QDR_{wz}}{100 - \alpha_{wz}} \times 100$$

with

$$QDR_{wz} = 2{,}093 - 154 \times LCSI - 194 \times f_{Br} - 179 \times f_{AT} + 9 \times f_{LAT} - 59 \times f_{DN}$$

Where

$SAF_{wz}$ = Free-flow speed adjustment factor for work zones
$FFS$ = Free-flow speed in non-work zone conditions (mi/h)
$c_{wz}$ = work zone capacity
$QDR_{wz}$ = average 15-min queue discharge rate (pc/h/ln) at the work zone bottleneck
$\alpha_{wz}$ = percentage drop in pre-breakdown capacity at the work zone due to queuing conditions (%). The average value of this in work zones is 13.4%
$f_{AT}$ = indicator factor for area type:
= 0 for urban areas (i.e., typified by high development densities or concentrations of population), and
= 1 for rural areas (i.e., areas with widely scattered development and low housing and employment densities);
$f_{LAT}$ = lateral distance from the edge of travel lane adjacent to the work zone to the barrier, barricades, or cones (0–12 ft);

Some software uses the capacity adjustment factor for work zones, $c_{wz}$ as an input. This is simply the ratio of work zone capacity to non-work zone capacity.

$$CAF_{wz} = \frac{c_{wz}}{c}$$

Finally, the work zone capacity $c_{wz}$ may be converted from passenger cars per hour to vehicles per hour, V, using the typical relationship from Chapter 12 of the 7th Edition of the Highway Capacity Manual (HCM) with the equation.

$$V = (c_{wz})(PHF)(f_{HV})$$

Where

$PHF$ = peak hour factor
$f_{HV}$ = heavy vehicle factor

with

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)}$$

Where

$P_T$ = proportion of SUTs and TTs in traffic stream (decimal), and
$E_T$ = passenger car equivalent of one heavy vehicle in the traffic stream (PCEs). Use *2.0 for level terrain, and 3.0 for rolling terrain*

## 2. Arterials

A work zone saturation flow rate adjustment factor should be computed with the steps specified in Chapter 31 of the 7th Edition of the HCM and saturation flows in analysis software (i.e. Synchro) should be manually lowered. These computational steps are reproduced below.

Computing work zone saturation flow rate adjustment factor for Arterials (see Chapter 31 of the 7th Edition of the HCM)

Saturation flow rate adjustment factor (for signalized intersections) – See HCM Chapter 19, Signalized Intersections.

$$f_{wz} = 0.858 \times f_{wid} \times f_{\text{reduce}} \leq 1.0$$

with

$$f_{wid} = \frac{1}{1 - 0.0057\,(a_w - 12)}$$

$$f_{wid} = \frac{1}{1 - 0.0057\,(a_w - 12)}$$

where

$f_{wz}$ = saturation flow adjustment factor for work zone presence at the intersection,
$f_{wid}$ = adjustment factor for approach width,
$f_{\text{reduce}}$ = adjustment factor for reducing lanes during work zone presence,
$a_w$ = approach lane width during work zone (= total width of all open left-turn, through, and right-turn lanes (ft)),
$n_o$ = number of left-turn and through lanes open during normal operation (ln), and
$n_{wz}$ = number of left-turn and through lanes open during work zone presence (ln).

A vehicle shall be considered part of a queue if its average operating speed is approximately 10 mph or less. Discretion is required during both the analysis portion and field evaluation of the implemented work zone in determining what constitutes a queue. In general, a condition that may cause driver frustration due to stop and go operations should be considered a queue. Delay is defined as the additional travel time experienced by the driver on the corridor.

| **Revision Date** | **Revision Description**: |
|---|---|
| 11/06/2024 | Revised for latest edition HCM 7th and acceptable impact threshold updates |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

| | | |
|---|---|---|
| Approved | Cedric Ward | 11/6/2024 |
| | Director,<br>Office of Traffic and Safety | Date |