The Highway Capacity Manual (HCM) provides several analytical or deterministic tools that can estimate roadway or intersection capacity, delay, density, and other performance measures for various elements of the street and highway system. The HCM also includes procedures for evaluating bicycle, pedestrian, and transit facilities. In most cases, the HCM is the standard for traffic analysis in the US; its methods are generally reliable and have been well-tested through significant validation efforts. The Highway Capacity Manual, 6th Edition: A Guide for Multimodal Mobility Analysis (HCM6) (1) is the most current version of the HCM.

The HCM6 consists of the following four volumes:

- Volume 1: Concepts
- Volume 2: Uninterrupted Flow
- Volume 3: Interrupted Flow
- Volume 4: Applications Guide (a web-based document, requires a user account)

Each chapter within Volume 2 and Volume 3 of HCM6 has six or more sections covering the following topics: introduction, concepts, methodology, extensions to the methodology, applications, and references. The methodology section (typically Section 3) highlights the scope, strengths, and limitations of the applicable HCM methodology, and as such, serves as a good reference when determining whether use of the HCM methodology is appropriate. HCM6, Volume 1, Chapter 7 provides additional guidance as to when an alternative (non-HCM based) analysis methodology may be appropriate.

The HCM procedures are good for analyzing the performance of isolated and non-congested facilities but do have limitations. For example, the HCM models cannot account for interactions between network elements (e.g., they cannot reflect the effect of a queue backup at a ramp terminal on the adjacent freeway operations) and they may under-predict the extent of congestion in oversaturated conditions. Consider the strengths and limitations of the HCM methods when selecting the methodology to apply. Document the rationale for choosing the selected traffic analysis methodology (HCM-based, microsimulation, etc.) in the Traffic Analysis Tool Selection memoranda and submit to the WisDOT regional traffic staff for approval.

TEOpS 16-10 provides a brief description of when and how to apply the HCM methodologies and identifies the WisDOT-supported programs that implement the HCM methodology.

5.1 Introduction

WisDOT accepts the use of the HCM6, Chapter 19 methods for estimating the performance of a signalized intersection from the perspective of the motor vehicle, pedestrian, and bicycle modes. These procedures are applicable for three-leg and four-leg intersections that operate in isolation from nearby signals with a pre-timed, semi-actuated or fully-actuated controller. Signalized intersections that are not isolated, that operate in an actuated-coordinated manner, or are part of a system or corridor require the use of a combination of both the signalized intersection methods of Chapter 19 and the urban street segment procedures outlined in Chapter 18. For closely spaced signals, such as those found at freeway ramp terminals, the analyst should follow the methodology presented in Chapter 23 for interchange ramp terminals. If the project spans multiple contiguous urban street segments, consider applying the Chapter 16 urban street facilities methodologies.

The analyst should recognize and account for the methodological limitations of the signalized intersection methods. There are cases that may not fit within the analytical framework of the HCM, including but not limited to intersections with five or more approaches, those with more than two exclusive turn lanes on any approach or those with complex geometry or controller operations. When these, or similar limitations exists, the project manager should specify the use of an alternative tool such as microsimulation. See TEOpS 16-20 for additional details on performing microsimulation analysis.
The WisDOT-supported tools that implement the HCM methodology for signalized intersection analysis are:

- Highway Capacity Software (HCS), McTrans
- Synchro, Trafficware
- Vistro, PTV Group (requires prior approval from WisDOT regional traffic engineer)

Refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version and build of the above software that WisDOT currently supports. See TEOps 16-10-5 for additional guidance on how to select the most appropriate traffic analysis tool for a specific project.

When conducting capacity analysis for signalized intersections, apply the basic signal parameters as outlined in the following section in conjunction with the HCM-based analysis methodologies.

5.2 Basic Parameters for Capacity Analysis

The Traffic Signal Design Manual, Section 3, Chapter 2-2 (TSDM 3-2-2) provides recommended parameters to use for the general analysis of state-owned signals; including minimum and maximum green times, pedestrian phase times and cycle lengths. The following provides updated direction for the use of right-turn on red (RTOR) and saturation flow rate. Unless noted otherwise, the policy within this section supersedes the guidance provided in TSDM 3-2-2. If it is unclear which guidance to follow, contact BTO-TASU (DOTTrafficAnalysisModeling@dot.wi.gov) for clarification.

5.2.1 Right-Turn on Red (RTOR)

5.2.1.1 Background

Right-turns made while facing a red traffic signal indication, permitted under Wisconsin statute 346.37(1)(c)3, can have a beneficial effect on traffic flow and intersection capacity as they reduce the number of vehicles serviced during the green phase. The following section describes how to apply RTOR when conducting capacity analysis for signalized intersections.

5.2.1.2 Dedicated Right-Turn Lanes

Since vehicles making other movements (through or left-turns) may block right-turn access at shared left-through-right (LTR) or shared through-right lanes, WisDOT has only investigated RTOR volumes at locations with dedicated right-turn lanes. For the purposes of RTOR inclusion in capacity analyses, a dedicated right-turn lane is any lane that satisfies at least one of the following criteria:

- Pavement markings or signage clearly dedicate the lane for a right-turn only movement
- Field observations indicate that the lane functions as a de-facto right-turn only lane (requires approval from WisDOT regional traffic staff)
- Subject approach flares out at the intersection such that a right-turning vehicle can safely fit beside a through vehicle within the same lane and field observations show vehicles using the approach flare to make right turns (requires approval from WisDOT regional traffic staff)

Additionally, for RTOR inclusion to be applicable for capacity analysis, the following must exist:

- Right-turns on red are permissible (i.e., field signage does not prohibit this maneuver during the analysis period)
- Vehicle queuing from the adjacent lane does not prevent vehicles wishing to make a right-turn from accessing the dedicated (or de-facto) right-turn lane

For additional clarification, as to what constitutes a right-turn lane for purposes of capacity analysis at signalized intersections, contact the WisDOT regional traffic engineer or BTO-TASU.
5.2.1.3 RTOR Estimation

An estimate of the proportion of vehicles making RTOR from a dedicated right-turn lane is most accurate when derived from field counts taken at the intersection in question. As it is not always practical to gather this information, WisDOT developed the following recommendations regarding RTOR volumes ($V_{RTOR}$) in relation to total right-turn demand ($V_{RT}$):

- Single Right-Turn Lanes at Intersections: $V_{RTOR} = 0.38V_{RT}$  \[\text{Equation 5.1}\]
- Single Right-Turn Lanes at Interchange Off Ramps: $V_{RTOR} = 0.66V_{RT}$  \[\text{Equation 5.2}\]
- Dual Right-Turn Lanes (Intersections and Interchanges): $V_{RTOR} = 0.30V_{RT}$  \[\text{Equation 5.3}\]

Field studies conducted throughout Wisconsin in 2009 (2) and 2015 (3) guided the development of these recommendations. WisDOT has not studied RTOR at any other intersection configuration, such as shared lanes or triple right-turn lanes, thus unless intersection-specific field data is available to indicate otherwise, the analyst should assume that vehicles do not make RTOR movements at these locations. Obtain approval from WisDOT regional traffic staff prior to including RTOR volumes for triple right-turn lanes or shared lanes within the capacity analysis.

Equation 5.2, is only applicable for single right-turn lanes exiting the off ramp at an interchange. For single right-turn lanes turning onto an on-ramp at an interchange, utilize Equation 5.1.

The analyst shall not use RTOR volumes in the analysis when field signage prohibits this maneuver during the analysis period.

5.2.1.4 RTOR Application

WisDOT supports the use of HCS for traffic signal analysis and supports the use of Vistro and Synchro for both traffic signal analysis and signal optimization (see TEOps 16-10). Use and acceptance of Vistro for signal analysis and optimization, however, is up to the discretion of the WisDOT regional office. Due to limitations of the HCS optimization methodologies, WisDOT does not support the use of HCS for signal optimization.

Vistro uses the same module for both HCM-compliant analysis and for signal optimization. Synchro, however, uses two distinct modules – one which provides HCM-compliant analysis and another which provides signal optimization as well as non-HCM-compliant analysis. The later module uses a proprietary methodology to calculate intersection delay and other values. Changes made in one module do not necessarily transfer to the other module. Therefore, there are nuances in how to conduct HCM-compliant analysis and signal optimization in Synchro which are not present in Vistro.

Figure 5.1 provides an overview of the various methodologies available for affecting RTOR in the two modules of Synchro. A subset of the methodologies, those which adjust demand, affect both Synchro modules. As noted in the figure, the “growth factor” method is the preferred methodology when the analyst is using Synchro to conduct HCM-compliant analysis and signal optimization. This methodology involves applying a growth factor of less than one to the right turn movements. Apply the following growth factors, derived from Equations 5.1 and 5.3, unless field data is available and supports otherwise:

- 0.62 for Single Right-Turn Lanes at Intersections
- 0.70 for Dual Right-Turn Lanes (Intersections and Interchanges)

Note that the above rates do not include a growth rate for Single Right-Turn Lanes at Interchange Off Ramps. Applying Equation 5.2 would yield a growth factor of 0.34 for this scenario; however, Synchro currently sets a floor of 0.5 for growth rates preventing the use of the 0.34. When dealing with Single Right-Turn Lanes at Interchanges, use the manual reduction method detailed below.

The other methodology to affect both modules in Synchro is to manually reduce the right-turn volumes by the $V_{RTOR}$. This is less transparent when conducting a peer review and is more prone to typographical error. Therefore, WisDOT prefers the use of the growth factor method where possible.
5.2.1.4.1 HCM-Compliant Analysis

WisDOT provides the following guidance on incorporating RTOR volumes when conducting HCM-compliant analysis. The RTOR volumes used may be based on field-collected values or the equations above (see Equations 5.1 – 5.3).

- **HCS**: Enter the \( V_{RTOR} \), rounded to the nearest whole vehicle per hour (veh/h), into the “RTOR, veh/h” field for the relevant approaches. This field is at the bottom of the “Primary Input Data” within the HCS “Streets” module, which includes traffic signal analysis.

- **Vistro**: Check the “Right Turn on Red” boxes for the relevant approaches in the “Intersection Setup” tab. Enter the \( V_{RTOR} \), rounded to the nearest whole vehicle per hour (veh/h), into the “Right-Turn on Red Volume (veh/h)” field in the “Volumes” tab.

- **Synchro**: Use the growth factor method outlined above. Checking the “Right Turn on Red” box in the “Lane Settings” area does not affect the HCM-compliant analysis. Entering the \( V_{RTOR} \) value associated with the approach into the “Right Turn on Red Volume” field in the Synchro HCM module is also acceptable, though WisDOT does not prefer this method as it only affects the HCM module. The analyst shall not enter a volume other than the default of 0 into the “Right Turn on Red Volume” field in combination with the growth factor method, as it will lead to incorrect results.

5.2.1.4.2 Signal Optimization

In Synchro, changes to the “Right Turn on Red Volume” field in the HCM module do not affect the signal timings or optimization calculations. If the analyst checks a box to allow RTOR within the “Lane Settings” module (automatically checked by default), Synchro uses an algorithm to determine a “Saturated Flow Rate (RTOR)”. Synchro uses the “Saturated Flow Rate (RTOR)” value within the signal optimization function. The RTOR checkbox does not affect the HCM results. Synchro’s proprietary RTOR methodology, enabled via the RTOR checkbox, is not straightforward and is thus not a preferred methodology for developing signal timing plans. When optimizing signals, the analyst should uncheck the RTOR checkbox for all approaches.

WisDOT prefers the use of the growth factor method for conducting signal optimization in Synchro.

5.2.1.4.3 Microsimulation Analysis

WisDOT also currently supports two microsimulation software programs for traffic signal analysis: SimTraffic (associated with Synchro, affected by demand reductions but not by changes within the HCM module), and Vissim. The analyst should not dictate RTOR volumes within microsimulation programs, as the models should determine when these turns happen based on how the right-turning vehicles interact with other vehicles in the system. Where right-turns at signals are critical movements, a good check for reasonableness could be...
comparing modeled RTOR volumes to field-collected ones. The analyst should direct any questions regarding how to model RTOR within a specific microsimulation software program to BTO-TASU (DOTTrafficAnalysisModeling@dot.wi.gov).

5.2.2 Saturation Flow Rate

5.2.2.1 Background

One of the many variables that influence the performance of traffic signals is saturation flow (sat. flow) rate. The base saturation flow rate for a lane is the theoretical number of vehicles that could travel through the intersection during one hour of green time under ideal conditions. The saturation headway, or the average time between the front bumper of one vehicle and the front bumper of the vehicle behind it under ideal conditions, determines the saturation flow rate. The HCM6 default values for base saturation flow rate are:

- 1900 passenger cars per hour per lane (pc/h/ln) in metropolitan areas with population >250,000
- 1750 pc/h/ln otherwise

The HCM provides several factors to adjust these base saturation flow rates to account for prevailing conditions at the approach, including heavy vehicle percentages, grade, lane width, etc. More information on flow rate concepts is available in HCM6, Chapters 4 and Chapters 19.

Through movements at signalized intersections typically have high volumes relative to other movements, and therefore have an oversized role in determining the overall timing and phasing, as well as level of service (LOS). Therefore, this policy focuses on the saturation flow rate for through lanes.

5.2.2.2 Saturation Flow Rate Methodology

A field saturation flow study at an intersection will provide the most accurate measure of experienced flow rates on its approaches. Given the expense, it may not be practical to conduct these studies, especially at locations that are operating significantly under capacity.

Since it is impractical to conduct field studies for every intersection and in an effort to gain a better understanding of the range of saturation flow rates, WisDOT funded a study in 2015 to evaluate saturation flow rates at various signalized intersections across the state (3). The study aimed to identify the variables, beyond those already accounted for by the HCM, which influenced the field saturation flow rates. The study followed the methodology laid out in the HCM and only collected data on the saturation flow rate for through lanes.

The 2015 WisDOT sat. flow study (3) found that the following three factors affect the base saturation flow rate of a through lane at a signalized intersection: the urbanized area or cluster population, the total number of approach lanes (left, through and right), and the posted speed limit of the approach. Accordingly, the base saturation flow rate may differ from one approach to the next at a given signalized intersection. The field conditions or traffic signal design dictate the total number of approach lanes and the posted speed limit of the approach. The urbanized area or cluster population information is available from either the table or map provided by the 2010 Census Bureau.

WisDOT used the results of this study to develop a methodology to estimate the base saturation flow rate for through lanes at signalized intersections in Wisconsin. Since the methodology accounts for more variables and reflects Wisconsin-specific data, analyst should use the WisDOT sat. flow methodology as described below to estimate the base saturation flow rate for through lanes at signalized intersections in Wisconsin. If the WisDOT estimation methodology results in a sat. flow rate less than the relevant HCM default value, specifically if it is less than 1750 pc/h/ln, the analyst should consider completing a field study or using the HCM6 default values.

Coordinate with WisDOT regional traffic staff to determine the most appropriate methodology for calculating the base saturation flow rate for through lanes. Unless instructed otherwise, use the HCM default values for the base saturation flow rate for left and right turn lanes.

5.2.2.3 Saturation Flow Rate Estimation

Use the WisDOT sat. flow spreadsheet (a Microsoft Excel based spreadsheet) or the adjustment factors shown in Table 5.1 to implement the WisDOT sat. flow methodology. The WisDOT sat. flow spreadsheet implements equations to apply the various site-specific adjustments in the same general form as HCM6 and calculates the base sat. flow rate by approach.
In lieu of the WisDOT sat. flow spreadsheet, the analyst may use the adjustment factors shown in Table 5.1 in conjunction with a starting saturation flow rate value of 1980 pc/h/ln (derived from the 2015 WisDOT sat. flow study (3)) and the following equation:

\[ s_0 = 1980 \times f_{\text{pop}} \times f_N \times f_{\text{SL}} \quad \text{[Equation 5.4]} \]

Where:

- \( s_0 \) = Base saturation flow rate
- \( f_{\text{pop}} \) = Adjustment factor for population
- \( f_N \) = Adjustment factor for number of approach lanes
- \( f_{\text{SL}} \) = Adjustment factor for speed limit of approach

As with the WisDOT sat. flow spreadsheet, apply the adjustment factors at the approach level. Note that due to rounding, use of the adjustment factors from Table 5.1 will result in a slightly different sat. flow rate than that calculated through use of the WisDOT sat. flow spreadsheet. The WisDOT sat. flow spreadsheet uses formulas to calculate the adjustment factors and does not round until after it computes the sat. flow rate, where the adjustment factor methodology utilizes rounded values from Table 5.1 to compute the sat. flow rate.

An example of how to apply the adjustment factors for saturation flow rate follows:

A signalized intersection is in a city with a population of 29,000 (\( f_{\text{pop}} = 0.95 \)). Looking at an approach with a left-turn lane, two through lanes, and two right-turn lanes (five total approach lanes, so \( f_N = 0.97 \)) and a posted speed limit of 40 MPH (\( f_{\text{SL}} = 1.00 \)), the resulting base saturation flow rate would be:

\[ s_0 = 1980 \times 0.95 \times 0.97 \times 1.00 \quad s_0 = 1825 \text{ pc/h/ln} \]

Use the resulting \( s_0 \), or base saturation flow rate (1825 pc/h/ln), for operational analysis of the two through lanes on this approach. Unless instructed otherwise, use the HCM default values for the left and right turn lanes. Calculate the base saturation flow rate for the other approaches in a similar manner.

<table>
<thead>
<tr>
<th>Population Adjustment Factor</th>
<th>Lane Adjustment Factor</th>
<th>Speed Adjustment Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urbanized Area/Cluster Population</strong></td>
<td><strong>Adjustment Factor</strong></td>
<td><strong>Total # Approach Lanes</strong></td>
</tr>
<tr>
<td>&lt; 2,000</td>
<td>0.91</td>
<td>1</td>
</tr>
<tr>
<td>2,000 - 4,499</td>
<td>0.92</td>
<td>2</td>
</tr>
<tr>
<td>4,500 - 8,999</td>
<td>0.93</td>
<td>3</td>
</tr>
<tr>
<td>9,000 - 18,999</td>
<td>0.94</td>
<td>4</td>
</tr>
<tr>
<td>19,000 - 39,999</td>
<td>0.95</td>
<td>5</td>
</tr>
<tr>
<td>40,000 - 82,999</td>
<td>0.96</td>
<td>6</td>
</tr>
<tr>
<td>83,000 - 170,499</td>
<td>0.97</td>
<td>≥7</td>
</tr>
<tr>
<td>170,500 - 347,499</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>347,500 - 704,499</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>≥ 704,500</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

Since the WisDOT sat. flow methodology calculates a Wisconsin, site-specific base saturation flow rate; the analyst should apply all other HCM adjustment factors, including the Central Business District (CBD) adjustment factor, as appropriate to calculate the final adjusted sat. flow rate. It is important to note that the WisDOT sat. flow estimation methodology applies only to exclusive through lanes and shared through-right lanes, as these two types of through lanes were the only ones included in the 2015 study.

### 5.2.2.4 Saturation Flow Rate Application

#### 5.2.2.4.1 HCM-Compliant Analysis and Signal Timing Plan Development

As detailed in TEOpS 16-10, WisDOT currently supports three HCM-based software programs for traffic signal analysis, HCS, Vistro, and Synchro, although use of Vistro requires prior approval from the WisDOT regional...
traffic engineer. WisDOT provides the following guidance on entering base saturation flow rates generated from the WisDOT sat. flow methodology.

- **HCS**: Enter the base saturation flow rate, rounded to the nearest 5 pc/h/ln, into the “Saturation, pc/h/ln” field for the relevant approaches. This field is in the “Traffic” section within the HCS “Streets” module, which includes traffic signal analysis.

- **Vistro**: Check the “Override Base Saturation Flow Rate per Lane” box for the relevant lane groups in the “Saturation Flow” area of the “Traffic Control” tab. Enter the base saturation flow rate, rounded to the nearest 5 pc/h/ln, into the “User Defined Base Saturation Flow Rate per Lane (veh/h/ln)” field.

- **Synchro**: In the HCM module, used to generate fully HCM-compliant results, enter the base saturation flow rate, rounded to the nearest 5 vehicles per hour per lane (vphpl), into the “Ideal Satd. Flow (vphpl)” field for the relevant approaches. Alternately, edit this field through the “Lane Settings” module – changes made there carry through to the HCM module.

### 5.2.2.4.2 Microsimulation Analysis

Capacity is not typically an explicit input within microsimulation programs, as it will vary based on vehicle interactions and various parameters. Since headway dictates saturation flow rate and because each microsimulation program has one or more adjustable parameters characterizing the concept of headway, adjustments to these settings will increase or decrease potential and realized capacities. The analyst should calibrate each signalized intersection, ensuring that the model meets the applicable validation thresholds and adequately replicates field behavior. Direct any questions regarding how to apply saturation flow rate within a specific microsimulation software program to BTO-TASU (DOTTrafficAnalysisModeling@dot.wi.gov).

### 16-15-10 Two-Way Stop-Controlled (TWSC) Intersections September 2019

WisDOT accepts the use of HCM6, Chapter 20 methods for analyzing the performance of a two-way stop-controlled (TWSC) intersection from the perspective of the motor vehicle mode and the pedestrian modes. Currently, no specific methodology exists to assess the performance of bicycles at TWSC intersections. These methods are applicable to three-leg and four-leg intersections with stop-control only on the side street(s).

Analysts should recognize and account for the methodological limitations of Chapter 20 methods. Some of the limitations of the TWSC methodology include, but are not limited to, the following:

- Only applicable for TWSC intersections with up to three through lanes (either shared or exclusive) on each major-street approach and up to three lanes on each minor-street approach (max of one exclusive lane per movement)

- Limited to no more than four approaches

- Limited to one stop-controlled approach on each side of the major street

Additionally, apart from a TWSC intersection located between two signalized intersections, the HCM methodology typically does not account for the effects from other intersections. For TWSC intersections located on an urban street segment between two coordinated signalized intersections, to account for the interaction of the adjacent signalized intersections, the analyst should follow the methodologies presented in Chapter 18 for urban street segments. When these, or similar limitations exists, the project manager should specify the use of an alternative tool such as microsimulation. See TEOpS 16-20 for additional details on performing microsimulation analysis.

The WisDOT-supported traffic engineering software programs for HCM-based TWSC intersection analysis are:

- **HCS, McTrans**
- **Synchro, Trafficware**
- **Vistro, PTV Group (requires prior approval from WisDOT regional traffic engineer)**

Refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version and build of the above software that WisDOT currently supports. See TEOpS 16-10-5 for additional guidance on how to select the most appropriate traffic analysis tool for a specific project.
WisDOT accepts the use of HCM6, Chapter 21 methods for analyzing the performance of unsignalized intersections with stop control at all approaches (i.e., requires every vehicle to stop before entering the intersection). HCM6, Chapter 21 methodologies focus on the motor vehicle mode but do offer some guidance for how to assess the performance of pedestrian and bicycles. The procedure is applicable for typical AWSC configurations of three-leg and four-leg intersections with no more than four approaches and no more than three lanes on any given approach.

Analysts should recognize and account for the methodological limitations of Chapter 21 methods. There are cases that may not fit within the analytical framework of the HCM, including but not limited to queue interactions from adjacent intersections, or the impact of pedestrians. When these, or similar limitations exists, the project manager should specify the use of an alternative tool such as microsimulation. See TEOps 16-20 for additional details on performing microsimulation analysis.

The WisDOT-supported traffic engineering software programs for HCM-based AWSC intersection analysis are:

- HCS, McTrans
- Synchro, Trafficware
- Vistro, PTV Group (requires prior approval from WisDOT regional traffic engineer)

Refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version and build of the above software that WisDOT currently supports. See TEOps 16-10-5 for additional guidance on how to select the most appropriate traffic analysis tool for a specific project.

WisDOT accepts the use of the HCM6, Chapter 22 methods for the analysis of isolated roundabouts with one-lane and two-lane entries, up to one yielding or non-yielding bypass lane per approach, and up to two circulating lanes. HCM6, Chapter 22 methodologies focus on the motor vehicle mode but do offer some guidance for how to assess the performance of pedestrian and bicycles.

WisDOT requires the use of Wisconsin based headway values for the calibration of the roundabout capacity equation. For guidance on these values and the operational analysis of roundabouts with the HCM procedure, supported software and supplemental design-aid software refer to FDM 11-26-20. For the analysis of existing roundabouts, which are experiencing delay, collect critical and follow-up headway data and adjust them in the HCM procedure accordingly.

WisDOT accepts the use of HCS and SIDRA with the US HCM6 capacity and delay model for analyzing roundabouts. SIDRA expanded upon the limitations of the HCM methodology on lane configuration to allow for the analysis of roundabouts with three entry lanes, dual partial right turn bypass lanes, and five or more approaches. Review of the expanded methodology in SIDRA has been determined to follow the capacity equations of the HCM. The analyst may use SIDRA HCM analysis for all roundabout analysis and SIDRA is ideal for evaluating roundabouts with lane configurations beyond the limitations of the HCM. SIDRA applies the basic HCM procedures and yields almost identical results as HCS. HCS is suitable for roundabouts with one or two circulating lanes and SIDRA intersection is suitable for all roundabouts but is the only WisDOT-supported software available for evaluating roundabouts with five or more approaches, three entry lanes, or dual partial right-turn bypass lanes.

Within SIDRA, there is the option to apply an HCM Roundabout Capacity Model extension to address unbalanced flow conditions. Additionally, SIDRA has an Extra Bunching parameter, that when checked, adjusts the proportion of platooned vehicles in the traffic stream according to the proximity of and level of queuing at an upstream signalized intersection. Prior to utilizing either the unbalanced flow model extension or the extra bunching parameter for operational analysis, the analyst should verify the appropriateness of their use with the WisDOT regional traffic engineer or BTO-TASU.

In addition to the HCM mode, SIDRA has its own roundabout capacity model (i.e., SIDRA Standard) which is based on Australian and international research. The analyst may use the SIDRA Standard model as a design-checking tool, but this mode is not acceptable for demonstrating that the roundabout provides sufficient capacity.

Analysts should recognize and account for the methodological limitations of Chapter 22 methods. For roundabouts that are not isolated, part of a system or corridor of roundabouts, or located within the influence area of an adjacent signal, the analyst should utilize a combination of the roundabout methods of Chapter 22 and the urban street segment procedures outlined in Chapter 18. For closely spaced roundabouts, specifically those found...
at freeway ramp terminals, the analyst should follow the methodology presented in Chapter 23 for interchange ramp terminals.

There are cases that may not fit within the analytical framework of the HCM, including but not limited to; volume-to-capacity exceeding 0.80, high pedestrian or bicycle activity, priority reversal under extremely high flows, and flared entry lanes. The analyst should consider the limitations of the HCM methodology when reporting results. Further analysis with a microsimulation tool can also supplement the study if the effort is justifiable based on the site conditions. See TEOpS 16-20 for additional details on performing microsimulation analysis.

The WisDOT-supported traffic engineering software programs for HCM-based roundabout analysis are:

- HCS, McTrans
- SIDRA (HCM mode only), Akcelik & Associates

Refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version and build of the above software that WisDOT currently supports. See TEOpS 16-10-5 for additional guidance on how to select the most appropriate traffic analysis tool for a specific project.

16-15-25 Alternative Intersections September 2019

Alternative intersections separate out one or more of the turning movement conflicts (typically left-turns) by rerouting them away from the center of the intersection to a secondary junction. Alternative intersections may be signalized or stop-controlled on the minor street movements. Examples of alternative intersections include, but are not limited to, the following:

- Restricted Crossing U-Turn (RCUT), also known as the J-Turn or superstreet,
- Median U-Turn (MUT), also known as the Michigan left turn or modified J-Turn, and
- Displaced Left Turn (DLT), also known as the continuous-flow intersection

Refer to FDM 11-25 Attachment 3.3 for a brief description, summary of the key elements to consider, and some of the potential benefits/concerns associated with these alternative intersections.

By rerouting one or more of the turn movements away from the center of the primary intersection, alternative intersections result in two or more closely spaced intersections that are operationally dependent on one another. Thus, the analyst should treat these intersections as a single unit.

WisDOT accepts the use of HCM6, Chapter 23 to assess the performance of the RCUT, MUT, and DLT from the perspective of the motor vehicle, pedestrian, and bicycle modes. Note that the Chapter 19 signalized methodology for pedestrians and bicycles is typically applicable for the minor street crossings at a signalized RCUT and for all crossings at the signalized MUT. The HCM6, Chapter 23 methodology provides a means to measure experienced travel time and considers the control delay experienced at each intersection plus the additional travel time needed to travel from the primary/center intersection to the secondary junction and back to the primary/center intersection.

Analysts should recognize and account for the methodological limitations of the HCM methodology. Specifically, the analyst should bear in mind that the analysis methodology is relatively new. Additionally, the HCM Chapter 23 methodology is only applicable to the RCUT, MUT, and DLT. Consider using microsimulation analysis tools for those alternative intersections that do not fit within the methodological limitations of the HCM. See TEOpS 16-20 for additional details on performing microsimulation analysis.

The WisDOT-supported traffic engineering software for HCM-based analysis of alternative intersections is:

- HCS, McTrans

Refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version and build of the above software that WisDOT currently supports. See TEOpS 16-10-5 for additional guidance on how to select the most appropriate traffic analysis tool for a specific project.

Trafficware has not yet implemented the HCM methodology for alternative intersections within Synchro; however, the analyst may be able to manipulate the coding within Synchro to analyze these intersections in accordance with the HCM6 methods. Confirm with the WisDOT regional traffic engineer whether it is appropriate to utilize Synchro for the analysis of alternative intersections.
16-15-30 Interchange Ramp Terminals  

The close spacing and interdependency of most ramp terminals requires that the operational analysis consider all ramp terminals within the interchange as a single unit. WisDOT accepts the use of HCM6, Chapter 23 for the analysis of interchange ramp terminals. As no specific methodologies for pedestrian and bicycle operations at interchange ramp terminals currently exist, the HCM6, Chapter 23 methodologies for interchange ramps focus on the motor vehicle mode. Chapter 23, however, does provide some guidance for addressing bicycles and pedestrians at interchanges.

The HCM6, Chapter 23 methodology addresses the following conventional interchange designs:

- Diamond interchanges,
- Partial cloverleaf (parclo) interchanges, and
- Interchanges with roundabouts.

Additionally, the HCM6, Chapter 23 methodology addresses the following alternative interchange designs:

- Diverging diamond interchanges (DDIs) and
- Single-point interchanges (SPI).

Refer to FDM 11-25 Attachment 3.3 for a brief description, summary of the key elements to consider, and some of the potential benefits/concerns associated with each of these interchange designs.

The HCM6, Chapter 23 methodology calculates the control delay experienced at each ramp terminal plus any additional travel time associated with driving between ramp terminals within the interchange. This allows for an equal comparison of the various interchange designs.

The analysts should recognize and account for the methodological limitations of the HCM6, Chapter 23 methods. Specifically, the analyst should bear in mind that the analysis methodology is not applicable for freeway-to-freeway or system interchanges. Additionally, the methodology does not cover interchanges with TWSC intersections or interchanges consisting of both a signalized and roundabout intersection. Consider using microsimulation analysis tools for those interchanges that do not fit within the methodological limitations of the HCM. See TEOpS 16-20 for additional details on performing microsimulation analysis.

The WisDOT-supported traffic engineering software programs for HCM-based analysis of interchange ramp terminals are:

- HCS, McTrans
- Synchro, Trafficware (conventional ramp terminals only)

Refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version and build of the above software that WisDOT currently supports. See TEOpS 16-10-5 for additional guidance on how to select the most appropriate traffic analysis tool for a specific project.

Trafficware has not yet implemented the HCM methodology for the alternative interchange ramp terminals (e.g., DDI, SPI) within Synchro; however, the analyst may be able to modify the coding within Synchro to analyze these types of interchange ramp terminals in accordance with the HCM6 methods. Confirm with the WisDOT regional traffic engineer whether it is appropriate to utilize Synchro for the analysis of the alternative interchange ramp terminals.

16-15-35 Urban Street Facilities  

WisDOT accepts the use of the HCM6, Chapters 16 and 18 for an integrated multimodal analysis of an urban street facility, including the intersections and segments that comprise it. The methodology provides the analytical framework to assess the automobile, pedestrian, bicycle, and transit modes by calculating delay and other performance measures by mode for each direction of travel along each segment of the given urban street facility, in addition to mid-block access points and other study intersections. The analyst should also consider the methods for TWSC, AWSC, roundabouts, and signalized intersections to the extent that those facilities exist along the subject roadway.

For intersections along an urban arterial or collector street that do not operate in isolation (i.e., the operation of one intersection influences the operation of the adjacent intersection), follow the Chapter 18 Urban Street Segment methodology. If the project spans multiple contiguous urban street segments, consider applying the Chapter 16 urban street facilities methodologies. The Chapter 16 Urban Street Facilities methods allow the
analysis of corridors of coordinated signalized intersections to capture average-phase-duration and other analytical components related to progression and vehicular platooning. If travel time reliability performance measures are of interest, consider using the urban street reliability methodologies in HCM6, Chapter 17. For additional information on incorporating travel-time reliability into the analysis, contact BTO-TASU (DOTTrafficAnalysisModeling@dot.wi.gov).

Analysts should recognize and account for the methodological limitations of the HCM urban streets methods. Accordingly, limitations of the individual intersection methods are also limitations of the urban street methods. For urban street facilities that do not fit within the analytical framework of the HCM, including but not limited to cases involving turn-lane spillover, impacts due to mid-block parking maneuvers, or capacity constraints between intersections, the project manager should specify the use of an alternative tool such as microsimulation. See TEOpS 16-20 for additional details on performing microsimulation analysis.

The WisDOT-supported traffic engineering software programs for HCM-based urban streets analysis are:

- HCS, McTrans
- Synchro, Trafficware

Refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version and build of the above software that WisDOT currently supports. See TEOpS 16-10-5 for additional guidance on how to select the most appropriate traffic analysis tool for a specific project.

### 16-15-40 Freeway Facilities  
**September 2019**

WisDOT accepts the use of the HCM6 analysis methods in Chapter 10 for a combined freeway facility, Chapter 11 for freeway reliability analysis, Chapter 12 for basic freeway segments, Chapter 13 for freeway weaving segments and Chapter 14 for freeway merge and diverge segments. Analysts should use these methods to assess uninterrupted flow facilities that typically have restricted access and consist of higher-speed roadways through rural, suburban, and urban areas. Since there is no pedestrian/bicycle traffic on freeways, the HCM methodology focuses on the vehicular travel mode of travel. For additional information on incorporating travel-time reliability into the analysis, contact BTO-TASU (DOTTrafficAnalysisModeling@dot.wi.gov).

Analysts should recognize and account for the methodological limitations of the HCM methods for freeway analysis. The methodology does not account for off-ramp or surface street conditions affecting the performance of the freeway. In those cases, the project manager should specify the use of an alternative tool such as microsimulation. See TEOpS 16-20 for additional details on performing microsimulation analysis.

The WisDOT-supported traffic engineering software for HCM-based freeway analysis is:

- HCS, McTrans

Refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version and build of the above software that WisDOT currently supports. See TEOpS 16-10-5 for additional guidance on how to select the most appropriate traffic analysis tool for a specific project.

### 16-15-45 Multilane Highways  
**September 2019**

WisDOT accepts the use of the HCM6, Chapter 12 methods for the analysis of an expressway or multilane highway. The methodology provides the analytical framework to assess the automobile and bicycle modes of travel. The analyst should use these methods to assess uninterrupted flow on multilane highway facilities with free-flow speeds between 45 and 70 mph, and two miles or more between traffic signals. These facilities may be divided, undivided, or have a two-way left-turn lane (TWLTL).

Many multilane highways will have periodic signalized intersections that are more than two miles apart. In these cases, the analyst should evaluate the highway segment portion using the Chapter 12 method and evaluate the isolated intersection using the signalized intersection analysis tools outlined in TEOpS 16-10-5.

Analysts should recognize and account for the methodological limitations of the multilane highway methods. For multilane highway conditions that do not fit within the analytical framework of the HCM, including but not limited to; effect of lane drops and lane additions at the beginning or end of the multilane highway segment, queuing impacts at transition areas (i.e., transitions from a multilane to two-lane highway), significant presence of on-street parking, or significant pedestrian activity, the analyst should use an alternative tool such as microsimulation. See TEOpS 16-20 for additional details on performing microsimulation analysis.
The WisDOT-supported traffic engineering software for HCM-based multilane highway analysis is:

- HCS, McTrans

Refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version and build of the above software that WisDOT currently supports. See TEOpS 16-10-5 for additional guidance on how to select the most appropriate traffic analysis tool for a specific project.

16-15-50 Two-Lane Highways September 2019

WisDOT accepts the use of the HCM6, Chapter 15 methods for the analysis of a two-lane highway. The methodology provides the analytical framework to assess the automobile and bicycle modes of travel. Use these methods to assess uninterrupted flow (i.e., there are no traffic control devices that interrupt traffic) on two-lane highways that have one lane in each direction. Passing takes place on these facilities in the opposing lane of traffic when sight distance is appropriate and safe gaps exist in the opposing traffic. The two-lane highway methodology also includes a procedure for predicting the effect of passing and truck climbing lanes on two-lane highways.

In general, this analysis includes any segments that have signalized intersections spaced two or more miles apart. Classify two-lane highways with signalized intersections spaced closer than two miles apart as an urban street or arterial and apply the methodologies of HCM, Chapter 16 as appropriate. Further, analyze any major signalized or unsignalized intersections within the two-lane highway corridor using the appropriate tools as outlined in TEOpS 16-10-5.

Analysts should recognize and account for the methodological limitations of the two-lane highway methods. The HCM-methodology does not model counter-directional passing, and thus the analyst should only use the HCM-methodology for two-lane highway analysis if passing maneuvers are infrequent in the study area. If counter-directional passing is critical within the study area, the analyst should consider using an alternative tool such as microsimulation. See TEOpS 16-20 for additional details on performing microsimulation analysis. (Note that currently Vissim is the only WisDOT-supported microsimulation tool that considers counter-directional passing.)

The WisDOT-supported traffic engineering software for HCM-based two-lane highway analysis is:

- HCS, McTrans

Refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version and build of the above software that WisDOT currently supports. See TEOpS 16-10-5 for additional guidance on how to select the most appropriate traffic analysis tool for a specific project.

16-15-60 Pedestrian and Bicycle Facilities September 2019

60.1 Mid-Block Pedestrian Crossings

WisDOT accepts the use of the methods outlined by the HCM6, Chapter 20 (pages 20-37 through 20-44) for one-stage and two-stage unsignalized mid-block pedestrian crossings, with or without a median refuge area, which are not located at an intersection. Assess the operations of mid-block pedestrian crossings by calculating seconds of delay per pedestrian or pedestrian-group.

Wisconsin-state law requires motorists to yield to pedestrians at designated mid-block pedestrian crossings. Motorist compliance, however, can vary. Implementation of pedestrian crossing treatments that are proven safety countermeasures (e.g., high visibility crosswalk markings, median refuges, and rectangle flashing beacons or pedestrian hybrid signals) have shown to increase motorist compliance rates and reduce pedestrian crashes. In the absence of local data, and subject to professional judgment, use the default motorist-yield-rates as recommended in the HCM6, Chapter 20 (Exhibit 20-24) for the analysis of mid-block pedestrian crossings.

Analysts should recognize and account for the methodological limitations of the mid-block pedestrian crossing methods (i.e., TWSC pedestrian mode method). For mid-block pedestrian crossings that do not fit within the analytical framework of the HCM, including but not limited to, signalized mid-block crossings or cases where the impact on the major street vehicular traffic is relevant, the project manager should specify the use of an alternative tool such as microsimulation. See TEOpS 16-20 for additional details on performing microsimulation analysis.
The WisDOT-supported traffic engineering software for HCM based mid-block pedestrian crossing analysis are:

- HCS, McTrans
- Synchro, Trafficware

Refer to the BTO Traffic Analysis, Modeling and Data Management Program area webpage for the version and build of the above software that WisDOT currently supports. See TEOpS 16-10-5 for additional guidance on how to select the most appropriate traffic analysis tool for a specific project.

### 60.2 Off-Street Pedestrian and Bicycle Facilities

WisDOT accepts the use of the HCM6, Chapter 24 methods for the analysis of off-street pedestrian and bicycle facilities (i.e., non-motorized vehicle usage only). The methodology provides the analytical framework to assess the capacity and LOS for the following types of facilities:

- **Walkways**: pedestrian-only paved facilities (paths, ramps, and plazas) typically located more than 35 feet from an urban street
- **Shared-use paths**: paths, separated by a physical barrier from highway traffic, dedicated for the shared-use of all forms of non-motorized (pedestrian, bicyclists, runners, inline skaters, etc.)
- **Exclusive off-street bicycle paths**: separated by a physical barrier from highway traffic, dedicated for bicycle-only traffic

Analysts should recognize and account for the methodological limitations of the HCM. For off-street pedestrian and bicycle facilities that do not fit within the analytical framework of the HCM, the project manager should specify the use of an alternative tool.

WisDOT has not currently identified a specific analysis tool for analyzing off-street pedestrian and bicycle facilities. Direct any specific questions regarding the analysis of off-street pedestrian and bicycle facilities to the WisDOT regional and statewide bicycle and pedestrian coordinators.

### 16-15-70 References January 2018


3. **TranSmart Technologies, Inc.** Signalized Intersection Capacity Data Collection: A Statewide Evaluation of Saturation Flow Rate and Right Turn on Red. 2015.