LIST OF ATTACHMENTS

FDM 11-5-3 Highway Capacity

January 13, 2017

3.1 General

The analysis of existing and future operating characteristics of a facility can be measured using Level of Service (LOS) to provide an indication of the ability of the facility to satisfy both existing and future travel demand. Level of Service is a quantitative measure of the quality of service of a transportation facility. The LOS measure is stratified into six letter grades, “A” through “F” with “A” being the best and “F” being the worst. Each facility type has a defined method for assessing capacity and level of service, which is based on a set of performance measures. Travel speed and density on freeways, delay at signalized intersections, and speed and ability to pass on a rural two-lane highway are examples of performance measures that characterize the conditions of a facility.

A LOS analysis must be an integral part of a highway improvement project. Capacity and LOS of the mainline facility, including major intersections, must be determined on each project. Capacity and LOS determination is used as one tool to identify potential improvement needs.

When evaluating the LOS and capacity of a highway, follow the procedures in the 2000 Highway Capacity Manual (HCM), published by the Transportation Research Board. For further information on how to obtain this document, write or call:

Transportation Research Board
National Research Council
2101 Constitution Avenue, NW
Washington, D.C. 20418
(202) 334-3214
www.trb.org/bookstore

Other references on capacity and LOS include: (1) "A Policy on Geometric Design of Highways and Streets," AASHTO 2001. (2) “A Policy on Design Standards Interstate System”, AASHTO 2005.

3.2 Congestion and LOS

The LOS thresholds shown in Table 3.1 are considered acceptable degrees of design year congestion on Wisconsin facilities. The designer should strive for a better LOS than those provided in Table 3.1 when practical. When the current LOS on a facility is worse than that shown in Table 3.1 the Department may consider improving the LOS preferably through incremental improvements but in some situations may consider capacity expansion.

Table 3.1 is not intended for use to determine appropriate LOS at controlled intersections. Intersection LOS will be determined on a case-by-case basis dependant on the local land use, economic, social and environmental impacts.

***Table 3.1* Acceptable Levels of Service**

STH Sub-System	Rural & Small Urban Areas	Urbanized Areas with Population > 50,000
C2020 Backbone Routes	LOS C (< = 4.0)	LOS C (< = 4.0)
C2020 Connector Routes and NHS Routes (not including NHS Backbone Routes)	LOS C (< = 4.0)	Mid LOS D (< = 4.5)
Other Principal Arterials	LOS D (< = 5.0)	Mid LOS E (< = 5.5)
Minor Arterials	LOS D (< = 5.0)	Mid LOS E (<= 5.5)
Collectors & Local Function Roads	LOS D (< = 5.0)	Mid LOS E (<= 5.5)

The interstate system within Wisconsin is a C2020 Backbone route. The highest LOS thresholds are applied to the Corridors 2020 system in recognition of its importance from a mobility and economic development perspective. On Corridors 2020 routes, “minimal to moderate” congestion is allowed. Some “severe” congestion is allowed on non-Corridors 2020 routes in highly urbanized areas. It should be noted that, in certain situations, expansion of facilities might be needed for reasons other than relieving congestion (e.g. safety, economic development or system continuity).

Table 3.2 shows the relationship between the traditional alpha value for LOS and the numeric value for level of service at WisDOT. The LOS is converted from the alpha-character scale to a numeric scale in order to facilitate a more detailed comparison between segments and to compare segment values with threshold values. For example, a numeric LOS range of 4.01 to 5.00 represents LOS D; if the computation falls midway within the LOS D range the numeric value for that LOS is 4.5.

See region traffic staff for more guidance on calculating a numeric value for level of service.

***Table 3.2* LOS Alpha/Numeric Value Comparison**

LEVEL OF SERVICE (Alpha Value)	LEVEL OF SERVICE (Numeric Value)
A - (Not congested)	1.01 to 2.00
B - (Not congested)	2.01 to 3.00
C - (Minimal congestion)	3.01 to 4.00
D - (Moderate congestion)	4.01 to 5.00
E - (Severe congestion)	5.01 to 6.00
F - (Extreme congestion)	6.01 to ~

3.3 Incremental Improvements for Non-Interstates and Non-Freeways

One of the most cost effective and safe ways to make highway improvements is through advanced planning and providing incremental improvements to the system. Additional through lanes are considered as a last resort. The most efficient intersection, in terms of minimal delay for the mainline, is a two-way stop control, the next most efficient is usually a modern roundabout. In certain situations the four-way stop control or actuated signal may be determined appropriate after an intersection alternative evaluation.

In rural areas consider the following incremental improvements:

- Passing lanes - providing a passing lane on a two-lane rural corridor could improve the LOS. Passing lanes are advantageous where passing opportunities are limited because of traffic volumes, roadway alignment or a high proportion of slower vehicles. FDM 11-15-10 contains design criteria and guidance on potential locations for passing lanes.
- Truck climbing lanes.
- Turn lanes at intersections.

- Intersection sight distance impacts and geometric improvements.
- Vertical and horizontal alignment improvements,
- Widen lanes and shoulder improvements.
- Access Control.

In urbanized areas consider:

- Access control and review traffic operations at intersections.
- Adding left or right turn bays or extending the length of existing turn bays.
- Review island locations.
- Upgrade the signal timing and phasing.
- Upgrade signal equipment.
- Signal coordination and actuated signal control.
- Conversion to a one-way street, from two-way street.
- Selective removal of on-street parking.

3.4 Incremental Improvements for Interstates and Freeways

Additional lanes should be considered as a last resort to improve congestion and capacity. Below is a partial list of potential improvements:

- Add auxiliary lanes between ramps.
- Lengthen exit or entrance ramps.
- Provide additional ramp lanes for turning movements at the ramp terminal intersection.
- Provide collector-distributor roads.
- Extend the length of weaving sections where possible.
- Where heavy volumes of bus or truck traffic exist, evaluate dedicated bus or truck lanes.
- Consider incident management sites to reduce congestion and delay.
- Implement appropriate ITS strategies.

Facilities which experience occasional severe congestion (such as routes with high flows a few days a year resulting from seasonal tourism or special events) may be candidates for temporary operational strategies such as enhanced motorist assistance patrols, deployment of portable variable message signs, or extra bus service. These mitigation strategies may forestall the need for high-cost capacity improvements for a number of years. Implementation of these measures may require coordination between the DOT, local officials, and the businesses or organizations that generate the extra-ordinary demand. Permanent operational strategies should be considered where recurrent congestion occurs.

3.5 Level of Service Analysis

Conduct a level of service analysis to evaluate the need for incremental improvements, or to determine if additional lanes are needed. The design criteria tables in FDM 11-15-1 and FDM 11-20-1 contain planning level AADT thresholds that could be used for first glance planning applications. The AADT thresholds in the Arterial Design Criteria Tables in FDM 11-15-1 are based on Highway Capacity Manual analyses using conservative data for typical 2-lane and multi-lane roadway configurations. The AADT and DHV thresholds in the Urban Streets Criteria in FDM 11-20-1 provide a general indication of when capacity improvements may be needed. These tables are based on the HCM arterial analysis using the assumptions provided. The dynamics of all the factors used in the urban LOS analysis makes the LOS of individual urban roadways complex and highly variable depending upon the geometric and traffic control conditions.

The WisDOT Meta-Manager model output provides LOS information using site-specific forecasts and roadway information that can be used for more specific planning level evaluation of the need for incremental and capacity improvements. The Meta-Manager mobility model output provides LOS information for existing and proposed traffic conditions under current roadway and geometric conditions. This LOS information is provided for through movements on mainline freeways, rural multilane highways, rural two-lane facilities and urban arterials The Meta-Manager LOS information should not be used to analyze individual signalized intersections, connections with side roads and freeway ramps. The urban arterial analysis uses system averages for traffic signal timing characteristics and should only be used for a planning and preliminary design level analysis of the corridor. The LOS data, traffic forecasts and roadway conditions are stored in an excel table, within the mobility sheet, located in the “Meta Manager” folder on each Highway Region’s local area network. The Meta-Manager document (\\mad00fpH\N8public\BSHP\Meta-manager_data\Metadata.doc) provides more specific information about the location of the data and the LOS calculations. For questions about the Meta-Manager LOS information, contact the Bureau of State Highway Programs (See the contact information for mobility data on page 2 of the Meta-Manager document).

WisDOT approved LOS software should be used for more specific traffic analysis or design applications. Table 3.3 recommends various software programs for various applications. Traffic analyses can be conducted by WisDOT, consultant, or local unit of government trained in the use of the Highway Capacity Analysis methodology. In general, begin a traffic analyses by evaluating the existing operation of the project using existing data collected in the field such as traffic volumes, roadway geometrics, traffic control operations (i.e., signal timing plans) and other features (i.e. parking stalls and maneuvers, driveway operations, etc.). Once the existing traffic analyses are calibrated and the results are validated, the existing traffic analyses can be modified to model future traffic volumes, operations and geometric improvements to meet an agreed to level of service.

The level of service analysis of a facility should consider the following traffic characteristics, roadway conditions and control conditions of the facility.

3.5.1 Design Hour Volume

WisDOT policy is to use the 30th highest hour volume (K30) as the Design Hour Volume for mainline freeways, mainline multilane highways, rural two-lane facilities and for urban arterial analysis of through movements. There may be unique circumstances where K30 is not realistic to use because of exceptionally high hourly volume peaking characteristics. These conditions may occur on highly recreational routes, or routes that are in close proximity to a stadium or seasonal shopping mall. Additionally, higher design hour volumes may be justified when the LOS using K30 cannot be achieved because of social, environmental, or financial constraints. When higher design volumes are justified, the LOS evaluation should also consider the 100th highest design hour for rural or small to medium urban areas and 250th highest hour for highly urbanized areas (>200,000 population) with heavy daily traffic. The Federal Highway Administration must approve deviations from the K30 design hour on interstate projects.

The directional design hour traffic volume for mainline freeways and multilane highways should be computed using the following equation:

DDHV = AADT * K * D, where:

DDHV= directional design hourly volume (veh/hr)

AADT= annual average daily traffic in both directions (veh/day)

K= proportion of AADT occurring in the design hour

D= proportion of traffic in the highest direction during the design hour

The design hour volume used for a detailed analysis of intersections, ramps and ramp terminals should be based on the AM or PM peak hourly volume for individual turning and through movements. In some cases where significant traffic is occurring on the weekend or mid-day, it may also be appropriate to consider mid-day peaking. In urban corridors, directional traffic patterns and intersection turn volumes are seldom the same in the AM and PM peak hours, so it is usually necessary to analyze the traffic operations for at least two different time periods.

The Traffic forecasting section will provide design year forecasts, which include AADT, K, D and directional turning movement projections for intersections. Refer to FDM 3-10-10 for guidance on how to obtain project level traffic forecasts and example forms to use for requesting traffic forecasts. The project schedule should allow sufficient time for the preparation of traffic forecasts, especially for urban and suburban areas where the forecaster may need to integrate and reconcile several manual turn counts, Traffic Impact Analysis studies for proposed developments in the corridor, and regional travel demand forecasting models. In highly congested areas with constrained capacity, the forecaster may also need to make adjustments for changes in time-of-day travel patterns (peak spreading or peak contraction).

3.5.2 Peak Hour Factor (PHF)

This factor is used to convert the rate of flow during the highest 15-minute period to the total hourly volume. A peak hour factor of 1.0 should be used for the mainline design year LOS analysis. For LOS analysis of existing conditions or for specific design of intersections, the peak hour factor should be based on data collected in the field.

3.5.3 Percent Heavy Vehicles in the Design Hour

In general the percentage of trucks in the design hour is lower than the percentage of trucks over an average day. This lower percentage is due to the fact that there is a higher percent of total vehicles in the design hour, and in some cases trucks try to avoid traveling in peak conditions.

3.5.4 Driver Population Factor

In general the LOS calculations should use a driver population factor of 1.0, which assumes the traffic stream is comprised of regular drivers. A lower number may be justified if sufficient empirical data is used to support that a significant amount of the drivers are unfamiliar with the corridor.

3.5.5 Rural Roadway Conditions

Capacity and LOS on rural highways are at a minimum affected by the following:

- Number and widths of travel lanes
- Shoulder widths
- Percent no-passing zones
- Number of access points or interchange density per mile
- Terrain type

Wisconsin highways use only the level and rolling terrain classifications. Level terrain generally includes corridors that contain grades of no more than 3 percent. These corridors include any combination of horizontal and vertical alignment permitting heavy vehicles to maintain approximately the same speed as passenger cars. Within level terrain corridors there may be isolated sections on two-lane highways that require climbing lanes to mitigate the speed variance between passenger cars and trucks. Rolling terrain generally includes grades of significant length greater than 3 percent grade. Typically, rolling terrain corridors are similar to those found near the Wisconsin River Valley, in the southwestern part of the State.

3.5.6 Urban Roadway Conditions

Capacity and LOS on urban streets are at a minimum affected by the following:

- Presence of exclusive turn lanes.
- Number and lengths of exclusive turn lanes.
- Presence of medians.
- Level of access control.
- Presence of parking and bus stalls and frequency of maneuvers within those stalls.
- Number and widths of travel lanes.

3.5.7 Intersection Control Conditions

Capacity and LOS at an intersection will be affected by as the following control conditions:

- Type of intersection control (stop condition, traffic signals, or roundabouts).
- Traffic signal timing characteristics and level of coordination between adjacent traffic signals or within a system of traffic signals.

Refer to Chapter 11, Section 26 for guidance on roundabouts. Refer to FDM 11-50-50 for guidance on traffic signals or the "Traffic Signal Design Manual" (TSDM). The Region traffic personnel typically use the TSDM.

3.6 Level of Service Evaluation for Environmental Documentation

As part of the environmental evaluation process, the design year LOS and supporting information shall be completed for highway improvement projects that involve an Environmental Document (See FDM 21-15 Attachment 5.1, Basic Screening Worksheet, Traffic Summary). This LOS information is not required for projects that require a Programmatic Environmental Report (PER) or lower level environmental analysis.

If the design year LOS for the preferred alternative is worse than the acceptable LOS provided in Table 3.1, include a statement in the environmental document indicating why the LOS is the best achievable. Include a list of probable effects associated with obtaining an acceptable LOS, or indicate if and when a study to determine how to achieve the acceptable LOS is planned.

The Meta-Manager model output can be used to determine the LOS under existing conditions and proposed conditions for environmental reports, when no significant geometric or operational changes are proposed. For example, the Meta-Manager output should not be used to determine the project's LOS when adding or reducing the number of thru lanes, adding or eliminating medians or two-way left turn lanes (TWLTLs), adding or eliminating left or right turn lanes, adding or removing parking lanes, installing or retiming traffic signals, improving signal coordination, and significantly adding or eliminating the number of access points. (See the previous Level of Service Analysis section of this FDM chapter for the location of the Meta-Manager LOS data).

Projects that include significant geometric or operational changes should have a project specific traffic analysis completed to determine the LOS. The following section on Traffic Analysis Software provides guidance on the appropriate analysis software that could be used for those evaluations.

3.7 Traffic Analysis Tool Selection

Several traffic analysis tools are available to assist transportation professionals in evaluating traffic operations on WisDOT facilities. Most studies, including traffic impact analysis, intersection control evaluations, traffic signal timing, design reports, turn lane warrant assessment, work zone delay analysis, corridor studies and system level analyses include an evaluation of operational conditions.

There is no “one size fits all” traffic analysis tool. The tools used for each analysis vary in their data requirements, capabilities, methodology and output. Tools that are more powerful require greater time and effort, so it is important to match the analysis methods with the scale, complexity and technical requirements of the project.

3.7.1 Overview of Available Analysis Tools

The Federal Highway Administration (FHWA) Office of Operations - Traffic Analysis Tools Program provides substantial background and guidance on the available types of tools and careful selection of the right tool for the task. Volume II of the FHWA Traffic Analysis Toolbox was prepared to assist traffic engineers and planners in selecting the most appropriate traffic analysis tool. For more information on the FHWA guidance, visit the Traffic Analysis Tools homepage (http://ops.fhwa.dot.gov/trafficanalysistools/index.htm) and refer to the set of documents in the Traffic Analysis Toolbox series. What follows in this section is guidance on selecting the appropriate tool category before selecting from the WisDOT approved software packages.

3.7.1.1 HCM-Based Deterministic Tools

The Highway Capacity Manual (HCM) provides a number of analytical or deterministic tools that can be used to 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 considered the standard for traffic analysis in the US; its methods are generally reliable and have been well tested through significant validation efforts.

The HCM procedures are good for analyzing the performance of isolated facilities, but do have limitations. For example, the HCM models do not have the ability to account for interactions between network elements (e.g., a queue backup at a ramp terminal cannot be reflected in the adjacent freeway operations). The strengths and limitations of the HCM methods should be considered when selecting a tool for use in a particular analysis or study.

The supported programs that implement the HCM methodology for capacity analysis are:

- Highway Capacity Software (HCS) 2010 - Version 6
- Synchro Version 9
- SIDRA Intersection - Version 7 (Roundabouts Only)

Always use the most current build number for the software listed above (e.g., HCS 6.80, Synchro 9.1, SIDRA 7.0). However, contact the Bureau of Traffic Operations (BTO), Traffic Analysis and Safety Unit (TASU) for consideration of the use of different versions of the software (e.g., HCS 6 vs. HCS 7, Synchro 9 vs. Synchro 10, SIDRA 7 vs. SIDRA 8), specifically as it pertains to the use of Synchro.

3.7.1.2 Optimization Tools

Signal optimization tools help traffic engineers identify the optimal signal cycle lengths, phase times, splits and offsets for signal systems ranging from isolated signals to coordinated signal systems. Generally, the process begins with the analyst setting up a network representing the geometric layout and traffic demand in the intersection or corridor of interest. The software then tries thousands of different combinations of cycle length, split, and offset to determine the “optimal” signal timing.

In this context, the word “optimal” has a strict mathematical definition called the objective function. It is usually based on minimizing total delay per vehicle. The objective can be modified to some degree by the analyst, who may also impose policy- or experience-based constraints on the signal phasing, such as the minimum green time provided to minor movements. The results from signal optimization efforts should be backed by engineering judgment when deciding on new or updated traffic signal timing and phasing; this is particularly important when a corridor includes unsignalized intersections or major driveways that affect operations. Typically, a traffic signal analysis would use an HCM-based tool or microscopic simulation tool to derive performance measures, while using optimization tools to establish the traffic signal timing and phasing. For example, in the Synchro/SimTraffic suite, the signal timings come from Synchro and several network-wide performance measures can be generated using SimTraffic. WisDOT accepts the use of a combination of appropriate tools for the analysis, signal optimization, and/or simulation of a given traffic analysis for an existing or proposed signalized intersection.

The supported programs that perform optimization:

- HCS 2010 - Version 6
- Synchro Version 9

Always use the most current build number for the software listed above (e.g., HCS 6.80, Synchro 9.1, SIDRA 7.0). However, please contact BTO-TASU for consideration of the use of different versions of the software (e.g., HCS 6 vs. HCS 7, Synchro 9 vs. Synchro 10, SIDRA 7 vs. SIDRA 8), specifically as it pertains to the use of Synchro.

3.7.1.3 Work Zone Analysis Tools

Specialty tools are available for analyzing traffic in highway construction zones. For example, Quadro 4 prepares hour-by-hour estimates of queuing and delay on freeways and rural highways. By comparing the work zone travel time with the travel time on a second-best route, Quadro estimates the amount of diverted traffic that can be expected on the alternate route and computes the resulting work zone queue length, speed reduction, delay and road user cost.

For work zones on urban signalized corridors, traffic throughput is usually controlled by the signalized intersections (especially if turn lanes are taken out of service during construction). In these corridors, a signal optimization tool such as Synchro can provide insights about the amount of traffic that can reasonably be accommodated, and can help identify signal timing adjustments that will make the best use of the remaining capacity.

Travel demand forecasting models can be used to analyze changes in regional traffic patterns caused by work zones, but adjustments must be made to account for differences between the capacity of ordinary lanes and the reduced capacity of lanes in the work zone. Similarly, microsimulation tools can be used to analyze traffic flows in work zones if special adjustments are made to account for lane closures and reduced capacity in the remaining lanes. If a need for diversion analysis is anticipated, it should be taken into consideration during the model scoping process. With proper planning, travel demand and microsimulation models can be set up in such a way that capacity changes can be applied categorically to minimize manual re-coding effort.

3.7.1.4 Microscopic Simulation Models

Microscopic simulation refers to tools that analyze the movement of individual vehicles as they travel through a network. During the simulation, factors such as each vehicle’s position and its need to increase/decrease speed or change lanes are updated several times a second. As a result, these tools are suitable for evaluating the interaction of different components of the transportation network, such as queues from an intersection that cause lane blockage upstream. Microsimulation models are useful for public outreach and stakeholder presentations because they provide animations of the simulated traffic flow.

Microscopic modeling work typically requires significantly more time, data and effort than other tools. In addition, improperly calibrated microsimulation models can provide misleading outputs, such as showing congestion where none exists, or free-flowing traffic where there is actually congestion. Whenever the model outputs are being used for critical decisions, the project manager should insist on crosschecking with simpler tools to assure that microsimulation outputs are reasonable. WisDOT supports the use of microscopic simulation models, but the decision to use them should be measured against the sufficiency of the appropriate deterministic HCM-based tool. To ensure the integrity of the results, the region shall conduct a peer review of all traffic models (microsimulation and deterministic models) as outlined in the Traffic Engineering Operations and Safety Manual (TEOpS) TEOpS 16-25.

The supported programs that perform microscopic simulation are:

- SimTraffic Version 9
- Quadstone Paramics Version 6
- PTV Vissim - Version 9

Always use the most current build number for the software listed above (e.g., SimTraffic 9.1, Paramics 6.9.3, Vissim 9.0). However, please contact BTO-TASU for consideration of the use of different versions of the software (e.g., SimTraffic 9 vs. SimTraffic 10, Paramics 6 vs. Paramics 7, Vissim 8 vs. Vissim 9). Do not switch from one software platform to another without first consulting with BTO-TASU.

3.7.2 Tool Selection Matrix

Typically, most traffic analysis projects that are being used to aid in the decision making process for detailed design features or to assess specific operational conditions and scenarios have a design or operational context.

Table 3.3 provides a list of frequently encountered operational analysis situations and associated tool categories. Typically, tools that successfully implement the HCM methods are used to quantify project-specific performance measures. When a limitation from the HCM is encountered, or supplemental information is required, a microscopic simulation tool may also be used. Table 3.3 should be used to identify the likely tool category types for projects with an operational context.

Table 3.3 Traffic Analysis Tool Category Selection

Analysis/Study Type	Tool Category			Notes
	HCM Based	Optimization[1]	Microscopic Simulation	
Traffic Impact Study Traffic Impact Assessment	✓	✓	✓	HCM-based tools and microscopic simulation tools, when applicable, may be used to determine performance measures such as LOS and delay. Optimization tools may be used to establish modifications to signal operations
Signal Timing/Phasing Traffic Control Warrant Study	✓	✓[2]	✓	Detailed signal design and performance assessment may be performed using a combination of all three tool categories, with simulation tools being used when HCM limitations occur or supplemental information is required
Turn Lane Warrant/Restriction Right Turn on Red Restrictions Pedestrian Crossing Study	✓	✓[2]	✓	These studies typically involve the evaluation of established warrants, supplemented with operational parameters. Typically the use of optimization tools is not necessary
Roundabout Study	✓	NA	✓	Base lane configuration design elements and operational conditions at existing and proposed roundabouts can be assessed with HCM-based tools and microscopic simulation when HCM limitations occur or supplemental information is required
Freeway System	✓	✓[2]	✓	HCM-based tools and microscopic simulation tools, when applicable, may be used to determine performance measures such as LOS, density, speed and delay. Optimization tools may be used to establish modifications to signal

				operations at interchange ramps
Multi-Lane Highways	✓	NA	✓	HCM-based tools and microscopic simulation tools, when applicable, may be used to determine performance measures such as LOS, density, speed and delay.
Two-Lane Highways	✓	NA	✓	HCM-based tools, may be used to determine performance measures such as LOS, percent time spent following, average travel speed and delay.
Work Zone Assessment**	✓	NA	✓	Quadro is suitable for analyzing most work zones on freeways and rural highways. Synchro or other signal optimization tools are useful for analyzing construction on urban arterials. For major/mega projects with complicated construction staging microscopic simulation tools can be used to assess work zone operations.

Legend:

NA - Not Applicable

✓ *The particular analysis or study type would be appropriately supported by the tool category.*

** *May also have a planning focus, where scenarios with less available data can be evaluated.*

[1] *Optimization tools would be used to accompany operational analyses performed by deterministic or microscopic simulation tools*

[2] *Some studies may require operational analysis with optimized signal timings*

3.7.3 Highway Capacity Manual (HCM) Analysis

WisDOT accepts the use of HCM 2010 methods in order to meet the planning, operational, and design analysis needs of most traffic studies. The methodologies of the HCM should be the primary way of determining the performance measures required for a variety of traffic study projects reviewed and/or commissioned by WisDOT. This section is intended to provide additional guidance on the specific methodological components for the core facility types addressed by the HCM.

3.7.3.1 Signalized Intersections

WisDOT accepts the use of the HCM 2010 Chapter 18 methods for estimating the performance of a signalized intersection from the perspective of the motor vehicle, pedestrian, and bicycle modes. These procedures should be used for 3-leg and 4-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 should be analyzed with a combination of both the signalized intersection methods of Chapter 18 and the urban street procedures outlined in Chapter 17.

Traffic signal analysis projects 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 5 or more approaches, those with more than 2 exclusive turn lanes on any approach, or those with complex geometry or controller operations. When these or similar limitations are encountered the project manager should specify the use of an alternative microscopic simulation tool.

The supported traffic engineering software programs for signalized intersection analysis are:

- HCS
- Synchro/SimTraffic
- Quadstone Paramics
- PTV Vissim

3.7.3.2 Two-Way Stop-Controlled (TWSC) Intersections

WisDOT accepts the use of HCM 2010 Chapter 19 methods for analyzing the performance of a two-way stop-controlled intersection from the perspective of the motor vehicle mode and the pedestrian mode. These methods are intended for three-leg and four-leg intersections with stop-control only on the side street(s).

TWSC analysis projects should recognize and account for the methodological limitations of Chapter 19 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 pedestrian impedance to major street vehicular traffic. When these or similar limitations are encountered the project manager should specify the use of an alternative microscopic simulation tool.

The supported traffic engineering software programs for TWSC intersection analysis are:

- HCS
- Synchro/SimTraffic
- Quadstone Paramics
- PTV Vissim

3.7.3.3 All-Way Stop-Controlled (AWSC) Intersections

WisDOT accepts the use of HCM 2010 Chapter 20 methods for analyzing the performance of unsignalized intersections with stop control at all approaches. The procedure is intended for typical configurations of independent three-leg and four-leg intersections that require every vehicle to stop before entering the intersection, such that there are no more than three lanes on any given approach.

AWSC analysis projects should recognize and account for the methodological limitations of Chapter 20 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 are encountered the project manager should specify the use of an alternative microscopic simulation tool.

The supported traffic engineering software programs for AWSC intersection analysis are:

- HCS
- Synchro/SimTraffic
- Quadstone Paramics
- PTV Vissim

3.7.3.4 Mid-Block Pedestrian Crossings

WisDOT accepts the use of the methods outlined by the HCM 2010. Chapter 19 (pages 19-30 through 19-36) discusses 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.

Motorists are expected to yield at these locations. Various enhanced treatments have been found to encourage different motorist response rates. In the absence of local data, and subject to engineering judgment, use the default motorist-yield-rates as recommended in the HCM 2010 Chapter 19 (Exhibit 19-17) for traffic analysis projects.

Traffic analysis projects 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.

The supported traffic engineering software for mid-block pedestrian crossing analysis are:

- HCS

- Synchro/SimTraffic
- Quadstone Paramics
- PTV Vissim

3.7.3.5 Roundabouts

WisDOT accepts the use of the HCM 2010 Chapter 21 methods, which are based on the results from NCHRP Report 572 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. 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 SIDRA Intersection for analyzing roundabouts with the HCM capacity and delay model. The limitations of the HCM methodology on lane configuration has been expanded by SIDRA and the resulting capacity analysis for three entry lanes, dual partial right turn bypass lanes, and/or five or more approaches has been determined to follow the capacity equations of the HCM. SIDRA HCM analysis can be used for all roundabout analysis and is ideal for evaluating roundabouts with lane configurations beyond the limitations of the HCM. SIDRA applies the basic HCM procedures and essentially yields the same results as the HCS software. However, SIDRA has implemented model extensions to the HCM methodology that can be utilized as optional tools to account for some of the major methodological limitations of the HCM. Users are encouraged to become familiar with the model extensions and parameters and consider these factors when dealing with any HCM limitations.

In addition to the HCM mode, SIDRA has its own roundabout capacity model based on Australian and international research. This mode may be used as a design checking tool, but is not acceptable as a demonstration that the roundabout provides sufficient capacity.

Roundabout analysis projects 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; the influence of upstream/downstream signals or roundabouts, high level of pedestrian activity and unbalanced circulating flows. Accordingly, the analyst should be aware that results might not reflect an accurate prediction of operations/performance. When reporting of results, the analyst must indicate if there are significant unbalanced conflicting flows, upstream or downstream signals or significant pedestrian activity for any approach and discuss how this may influence the performance of the roundabout/approach. Further analysis with a microsimulation tool can also supplement the study if the effort is justifiable based on the site conditions. The most common reason for using microsimulation is to evaluate queue interaction at a series of closely-spaced roundabouts (such as a tight-diamond freeway ramp terminal) or a roundabout that is near a signalized intersection.

The supported traffic engineering software programs for roundabout analysis are:

- HCS
- SIDRA Intersection (HCM mode only)
- Quadstone Paramics
- PTV Vissim

3.7.3.6 Urban Streets

WisDOT accepts the use of the HCM 2010 Chapters 16 and 17 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 methods for TWSC, AWSC, roundabouts and signalized intersections should also be considered part of the urban street methods to the extent that those facilities exist along the subject roadway. The integration allows for a ‘Complete Streets’ approach in terms of performance measures and capacity analysis.

Corridors of coordinated signalized intersections and other urban street facilities should be analyzed using the urban street methods such that the Chapter 17 average-phase-duration procedure and other analytical components related to progression and vehicular platooning are addressed in the analysis.

Typically, at project scoping stakeholders should determine the need for an overall facility analysis. In those cases, the segment and facility-level performance measures should be analyzed.

Traffic analysis projects should recognize and account for the methodological limitations of the HCM urban streets methods. Accordingly, limitations of the individual intersection methods should also be considered 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 interactions between adjacent intersections, 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 microscopic simulation tool.

The supported traffic engineering software programs for urban streets analysis are:

- HCS
- Synchro/SimTraffic
- Quadstone Paramics
- PTV Vissim

3.7.3.7 Freeway Facilities

WisDOT accepts the use of the HCM 2010 analysis methods in Chapter 10 methods for a combined freeway facility, Chapter 11 for Basic Freeway Segments, Chapter 12 for Freeway Weaving Segments and Chapter 13 for Freeway Merge and Diverge Segments. These methods should be used to assess uninterrupted flow facilities that are generally restricted access, higher-speed roadways through rural, suburban and urban areas.

Freeway analysis projects 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 impacting the performance of the freeway. In those cases, an alternative analysis microscopic simulation tool should be used.

The supported traffic engineering software for freeway analysis are:

- HCS
- Synchro/SimTraffic (freeway ramp terminals only)
- Quadstone Paramics
- PTV Vissim

3.7.3.8 Multilane Highways

WisDOT accepts the use of the HCM 2010 Chapter 14 methods for the analysis of an expressway or multilane highway. These methods should be used to assess uninterrupted flow on multilane highway facilities with speeds between 40 and 65 mph, and 2 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 2 miles apart. The multilane highway will be analyzed using this method and the isolated intersection could be analyzed using the signalized intersection analysis tools outlined in FDM 11-5-3.7.3.1.

Traffic analysis projects 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; lane drops and lane additions, queuing impacts at transition areas (i.e., transitions from a multilane to two-lane highway), on-street parking or significant pedestrian activity the analyst should use an alternative tool.

The supported traffic engineering software programs for multilane highways are:

- HCS
- Synchro/SimTraffic
- Quadstone Paramics
- PTV Vissim

3.7.3.9 Two-Lane Highways

WisDOT accepts the use of the HCM 2010 Chapter 15 methods for the analysis of a two-lane highway. Use these methods to assess uninterrupted flow 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.

Two-lane highways usually have major signalized or unsignalized intersections, which should be analyzed separately using the appropriate tools. In general, this analysis includes any segments that have signalized intersections spaced more than 2 to 3 miles apart. Those segments that have signalized intersections less than 2 miles apart should be classified as an urban street.

This analysis also includes a methodology for predicting the effect of passing and truck climbing lanes on two-lane highways. Traffic analysis projects should recognize and account for the methodological limitations of the two-lane highway methods. Synchro/SimTraffic and Paramics do not model counter-directional passing, so these tools should only be used for two-lane highway analysis if passing maneuvers are infrequent in the study area.

The supported traffic engineering software programs for two-lane highways are:

- HCS
- PTV Vissim

3.7.3.10 Rural Work Zones

The following issues frequently arise for construction on rural highways and rural freeways:

- Selecting appropriate hours for lane closures or the use of two-way, one-lane operation.
- Quantifying the amount of traffic that can reasonably be diverted to alternate routes.
- Determining the expected work zone delay and queue length.
- Selection of appropriate mitigation measures, such as evaluating the costs and benefits of providing a temporary bridge to maintain traffic during construction.

The Department supports the use of Quadro 4 for evaluating these issues. Contact BTO Traffic Design Unit for spreadsheets that facilitate Quadro data entry and presentation of Quadro results. Typically, the analysis is done on an hour-by-hour basis using the following four periods (Monday-Thursday, Friday, Saturday and Sunday). If the construction spans a holiday weekend it may also be appropriate to analyze that period separately.

Quadro's "equilibrium" mode is used for rural work zone analysis. In this mode, traffic is given the option of remaining on the "main" route (where construction is occurring) or switching to a "diversion" route (the second-best route in the area). If traffic is low, all vehicles are assumed to remain on the main route, but as volume (and work zone delay) increases the software adjusts the proportion of vehicles on each route to equalize the travel time on the two routes. This allows Quadro to quantify diverted traffic and compute the average delay per vehicle, the number of vehicles queued on the main route, and the changes in speed on each route. Quadro also computes the associated Road User Costs (RUC). The RUC information can be used to evaluate the cost-effectiveness of intensive mitigation strategies such as temporary bridges.

The supported traffic engineering software program for rural work zone analysis is:

- Quadro

3.7.3.11 Urban Arterial Work Zones

The analysis of work zones on urban arterials is often similar to other types of urban arterial analysis. In general, the traffic throughput in the work zone will be controlled by the available capacity at signalized intersections or roundabouts. Urban arterial reconstruction often requires closing or consolidating turn lanes (e.g., an intersection that normally has a separate left turn bay may have to operate for a time with a shared thru-left lane). In most cases, these conditions can be evaluated using a signal optimization tool such as Synchro by modifying the network to reflect the temporary lane closures. Network-wide performance measures from the SimTraffic module can be used to evaluate the cost-effectiveness of mitigation strategies.

In some cases, it may be necessary to estimate the amount of traffic that can be diverted from the arterial to alternate routes. This analysis can be performed using Quadro's "maximum queue delay" mode. In this mode the analyst selects a threshold representing the maximum delay that drivers in the area can be expected to tolerate (typically 10 to 20 minutes more than the usual travel time). If traffic is low, all vehicles are assumed to remain on the main route, but as volume (and work zone delay) increases the software assumes that delays on the main route will reach the threshold and vehicles will begin diverting to unspecified alternative routes. For each hour (and period) Quadro outputs the amount of traffic that must be diverted in order to stay at or below the delay threshold. It also computes the associated road user costs (RUC), which can be used to evaluate the cost-effectiveness of mitigation efforts that would reduce the delay threshold.

The supported traffic engineering software programs for urban arterial work zone analysis are:

- Quadro
- SIDRA Intersection
- Synchro/SimTraffic

3.7.3.12 Urban Freeway Work Zones

The following issues frequently arise for urban freeway construction:

- Quantifying the amount of traffic that can reasonably be diverted to alternate routes.
- Selecting appropriate hours for lane closures.
- Determining the expected work zone delay and queue length.
- Selection of appropriate mitigation measures.

Urban freeway projects often involve several construction stages with different traffic impacts and each stage usually needs to be evaluated separately. If the freeway in question has one readily-identifiable and relatively uncongested alternate route, Quadro's "equilibrium" mode can be used for the analysis as described in the rural freeway section. If there are several routes that collectively have a fair amount of available capacity for diverted traffic, Quadro can be used in the "maximum queue delay" mode as described in the urban arterials section.

For major/mega projects in cities that have significant congestion on both freeways and alternate routes, a network-based analysis using a microsimulation is often required. Diversion to alternate routes can be evaluated using a travel demand forecasting model as discussed in section FDM 11-5-3.7.1.3. After the diverted volume has been determined, the resulting impacts on nearby arterials can be evaluated using a signal optimization tool such as Synchro and the freeway impacts can be evaluated using a microsimulation tool such as Paramics or Vissim.

The supported traffic engineering software programs potentially applicable to urban freeway work zone analysis are:

- Quadro
- HCS
- SIDRA Intersection
- Syncho/SimTraffic
- Quadstone Paramics
- PTV Vissim

3.7.4 Model Calibration

All traffic analysis tools require some degree of calibration to assure that their outputs match actual field conditions. Calibration is particularly important in microsimulation models, where there are many assumptions and parameters that can affect the simulation. In essence, calibration means making sure that the analysis correctly reproduces the existing conditions. The same parameters are then applied to predict the future traffic conditions. Consequently, calibration is essential for the validity of the analysis process and the project manager should assure that sufficient time and resources are devoted to this crucial step.

Provide clear documentation of the model development and calibration process to identify the model input parameters and any adjustments made to default values to reflect field measured or otherwise expected conditions. The process of developing a model starts with a "Base-Year Model" (representing the existing traffic conditions) and then evolves into various scenarios representing future-year alternatives. Although the existing conditions model may be unimportant to decision-makers, it is vital to the model calibration process. The only way to determine that a model is working properly is to compare the base year model with the real-world traffic. If the base year model cannot reproduce the existing traffic conditions with a reasonable degree of accuracy, then it will be of no value in predicting the future. For both deterministic and simulation tools, WisDOT supports changes to default and input parameters in order to best replicate observed conditions.

To ensure the integrity of the calibration process and model results, the region shall conduct a peer review of all traffic models (microsimulation and deterministic models) as outlined in the TEOpS 16-25.

FDM 11-5-5 Access Control

March 4, 2013

5.1 Introduction

According to the TRB Access Management Manual[1], "Access management is the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway. It also involves roadway design applications, such as median treatments and auxiliary lanes, and the appropriate spacing of traffic signals. The purpose of access management is to provide vehicular access to land

[1] See p.3 in (*1*) Introduction and Concepts. In *Access Management Manual* Transportation Research Board, 2003, ch. 1, pp.3-11.