FDM 11-5-1 Scope of Construction Projects

September 18, 1992

1.1 Discussion

Construction projects can frequently be organized into a series of separate contracts by major items of work, or combined into "package" contracts. Some types of contract composition have proven to be more economical than others. It is generally beneficial to the State, and usually preferred by the contractors, to let separate contracts for each major type of work, i.e., grading, structures, base course, surfacing, or specialty work. When contracts include only items the contractors consider to be within their prime area of expertise, the savings are usually significant enough to warrant structuring projects around those abilities, whenever feasible.

The Region should develop an understanding and concurrence with the appropriate Central Office Design Coordinator on whether or not to package the project, early in the project's development.

Combinations of major work items into package contracts may be advantageous to the State when the project requires unusual considerations, such as complex traffic handling.

Combining box culverts or other small structures with grading work is desirable because of the closely interrelated scheduling of construction operations required.

Large structures should be let as separate contracts. Steel structures should be let to contract six months or more in advance of construction, to allow time for fabrication. When several small structures are to be built in the same general area, including those in adjacent Regions, they may be combined into one contract. Future construction project schedules should be examined to determine whether it would be advantageous to reschedule a project to the same fiscal year or otherwise make an adjustment to allow packaging the project.

The use of separate contracts also allows the opportunity to schedule contracts for letting at appropriate times, as may be required for stage construction.

Contracts for signing and signalization should be let at least six to nine months in advance of the anticipated installation date, to allow adequate time for fabrication. Normally, signing work should be let before the paving contract.

Urban highway and street projects should be let early enough in the year to assure that by the end of the construction season, the condition of the project is suitable to carry traffic during the winter months.

Asphaltic concrete paving contracts should not be scheduled for letting during the months of June through October. This is the period when paving contractors are busy with construction, there is a limited construction season remaining, bids are speculative and must reflect anticipated costs for the following year, and experience has shown that bids during this period are least favorable to the state. Off-season lettings for paving contracts allow the contractors ample time to prepare bids which normally results in more competitive bidding. Asphalt paving contracts should generally require completion of construction during the same calendar year as the fiscal year used for funding the project, i.e. during one construction season.

An economic advantage may be realized through utilization of the alternate proposal bidding procedures, as presented in Chapter 19 under Consideration of Proposals. By using the provisions contained in that procedure, the Department may solicit bids for project A, project B, and project A and B combined.

It should be emphasized that there is no substitute for engineering judgment and common sense. When there is any uncertainty, questions relating to contract format should be directed to the appropriate Central Office Design Coordinator.

FDM 11-5-3 Highway Capacity

June 24, 2016

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 6 (Roundabouts Only)

Always use the most current build number for the software listed above (e.g., HCS 6.80, Synchro 9.1, SIDRA 6.1). 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 8 vs. Synchro 9, SIDRA 6 vs. SIDRA 7), 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 6.1). However, please contact BTO-TASU for consideration of the use of different versions of the software (e.g., HCS 6 vs. HCS 7, Synchro 8 vs. Synchro 9, SIDRA 6 vs. SIDRA 7), 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 Guidelines Manual (TGM) 16-25.

The supported programs that perform microscopic simulation are:

- SimTraffic Version 9
- Quadstone Paramics Version 6
- PTV Vissim - Version 8

Always use the most current build number for the software listed above (e.g., SimTraffic 9.1, Paramics 6.9.3, Vissim 8.0). However, please contact BTO-TASU for consideration of the use of different versions of the software (e.g., SimTraffic 8 vs. SimTraffic 9, Paramics 5 vs. Paramics 6, Vissim 7 vs. Vissim 8). 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	Optimization1	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 (version 8 or newer)

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 TGM 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 development in a manner that preserves the safety and efficiency of the transportation system.”

Both the AASHTO GDHS and the TRB Access Management Manual describe Access Management Principles:

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

Table 5.1 Access Management Principles

AASHTO[2]	TRB[3]
Classify the road system by the primary function of each roadway Limit direct access to roads with higher functional classifications Locate traffic signals to emphasize through traffic movements Locate driveways and major entrances to minimize interference with traffic operations Use curbed medians and locate median openings to manage access movements and minimize conflicts	Provide a specialized roadway system Limit direct access to major roadways Promote intersection hierarchy Locate signals to favor through movements Preserve the functional area of intersections and interchanges Limit the number of conflict points Separate conflict areas Remove turning vehicles from through-traffic lanes Use nontraversable medians to manage left-turn movements Provide a supporting street and circulation system

See FDM Chapter 7 for additional guidance on Access management and control.

5.2 State Access Management Plan (SAMP)

Chapter 9 of WisDOT's Connections 2030 Statewide Long-Range Transportation Plan revised the State Access Management Plan (SAMP) and increased the number of tiers from two to five. All STH routes are assigned to one of the tiers.

- Tier 1 maximizes Interstate/Statewide traffic movement
- Tier 2A maximizes Interregional traffic movement
- Tier 2B maximizes Interregional traffic movement
- Tier 3 maximizes Regional/Intra-urban traffic movement
- Tier 4 balances traffic movement and property access

See FDM 7-5-1 for additional guidance.

5.3 Spacing

These guidelines are intended as a tool in relating access to facility type, functional type, and traffic volume of both the route under study and intersecting routes. Attachment 5.1 shows rural arterial access spacing. The access spacing determined from Attachment 5.1 is the minimum distance between that intersecting facility and adjacent similar type or higher type access points (private, public, at-grade, or interchange) without regard to functional classification of the adjacent access points.

Refer to FDM 11-30-1 regarding ramp terminal spacing

Urban charts are not part of this guide. Since urban areas are unique, other controls such as existing development and street spacing usually require varying degrees of access. See FDM 11-25-2 for guidance on corner clearance to driveways. See FDM 11-25-2, FDM 11-25-5 and FDM 11-25-20 for guidance on median openings.

Also, no recommendation is given for "Routes Under Study" functionally classified lower than arterial. Lower classified routes vary considerably.

Consider the possibility of changes in the degree of access control of a highway whenever reconstruction (or new construction) is contemplated. The investigation should consider both the immediate effects of changes and the impact of future development. Changes in land use patterns and intensity that occur during the ultimate life of the right-of-way will have a great effect upon the traffic patterns and highway obsolescence. It is desirable to control access according to conditions expected to exist during the latter part of the road's life expectancy.

By 2010 Wisconsin communities, including counties, will adopt comprehensive plans which are required in order

[2] See p.90 in (*2) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.
[3] See pp.7-10 in (*1)* Introduction and Concepts. In *Access Management Manual* Transportation Research Board, 2003, ch. 1, pp.3-11.

to make valid local zoning and land division decisions. Many multi-jurisdictional and regional plans are also under way. Public utilities base their plans for future expansion of services on predicted population growth and movement. All of these are good sources of information about the future land uses that could affect state highways.

The proximity of adjacent intersections to locations that are or may be signalized should be maintained at a minimum of 1200-ft , unless a greater distance is shown in Attachment 5.2. See Traffic Signal Design Manual (TSDM) at:

http://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/tsdm/tsdm.aspx

5.4 Intersecting Roadways

Determine the extent of access control to apply around intersecting roads. The degree and length of this control depends, for the most part, on the design of the intersection (stop or free-flow design), traffic volumes using the intersecting highway, and traffic generated by the adjacent property. Factors generally considered are the number and speed of vehicles approaching an intersection and the conditions of entrance to the major highway (i.e., stop, yield, unmarked). Other considerations may include intersection sight distance and vision corners addressed in FDM 11-10-5; or functional area and corner clearance addressed in FDM 11-25-2. Further extension or expansion of access control along intersecting roadways has to be evaluated on a project-by-project basis.

5.5 Interchange Areas

Interchanges are expensive to build and to upgrade. Therefore, it is essential that they be designed and operated as efficiently as practical. To preserve their intended function, adequate geometry at ramp termini and appropriate access control along the crossroads are essential.

Many older interchanges have been designed with only limited access control on the intersecting crossroad. As a result, considerable development may occur near the intersection of the ramp terminus and the crossroad. Over time, such ramp termini, as well as several nearby access connections, may require signalization or roundabouts, thereby causing increased delay on the crossroad.

In urbanized areas, high turning volumes and close spacing between adjacent ramp termini and access connections can create operational problems on the crossroad that can cause; extensive queuing, delay, heavy weaving volumes, and poor traffic progression. Ultimately, these types of problems at the ramp termini can affect traffic on the ramp and may cause spill back onto the mainline freeway. These problems consist of queue spillback, stop-and-go travel, heavy weaving volumes, and poor traffic progression.

To ensure efficient operations along the crossroad at an interchange, adequate lengths of access control need to be a part of the overall design of an interchange. This minimizes potential for queue spill back on the ramp and cross road approaches to the ramp terminus. Increased spacing between access points will also provide adequate distances for weaving on the crossroad, provides space for merging maneuvers, and provides space for storage of turning vehicles at access connections on the crossroad.

Access control at interchanges should be coordinated with local zoning authorities.

For additional guidance, see pp. 749-752 of the AASHTO GDHS[4], “Access Separations and Controls on the Crossroad at Interchanges.”

5.5.1 Access Control on Interchange Crossroad

Access control at an interchange along the crossroad shall comply with Table 1 of Attachment 5.2, but not be less than intersection corner clearance as defined in FDM 11-25-2.

- Do not allow new access between the interchange ramp and the public road.
- If private access already exists on the crossroad between the ramp and the public road, evaluate the potential cost of either removing that access or restricting it to right-in, right-out only. It may be justifiable to allow interim access until the access use changes or until the traffic volume from the access point justifies a higher level of intersection control than a stop condition. The access is then re-evaluated for removal. Consider what costs and impacts there may be if it is necessary to go back at some time in the future and acquire or close access due to serious operational problems. Do not allow a median opening between the interchange ramp and the Public Road.
- Do not allow access on the cross road in the transition area (merge or diverge condition) from 4-lanes down to 2-lanes.

Refer to the Transportation Research Board, Access Management Manual 2003, pages 158-162, for additional

[4] (*2) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

guidance on interchange area management.

5.5.2 Access Control Along an Expressway at an Interchange

Access control at an interchange along an expressway shall extend from the merge/diverge point of entrance/exit ramps as shown in Attachment 5.2 and shall comply with the distances shown in Table 2 of Attachment 5.2.

5.6 Traffic Impact Analysis

On both expressways and their cross roads, an approved traffic impact analysis is required to justify a less-than-desirable distance of access control. This analysis shall be included in the project file. Consider the following factors when evaluating access control distance:

1. Mainline, ramp and side road projected design year AADTs, including turning movements to and from the side road.
2. Intersection geometry, including turn lane lengths
3. Weaving and deceleration distances.
4. Posted speeds
5. Sight distance (horizontal and vertical)
6. Intersection sight distance
7. Zoning
8. Estimated cost of real estate acquisition to achieve access control,
9. Estimated cost of roadway improvements to achieve access control

5.7 References

1. TRB Committee on Access Management (ed.). Introduction and Concepts. In *Access Management Manual*. Transportation Research Board, Washington, DC, 2003, ch. 1, pp. 3-11.

2. *A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, Washington, DC, 2004.

LIST OF ATTACHMENTS

Attachment 5.1 Access Spacing Guidelines

Attachment 5.2 Access Control for Typical Interchange

FDM 11-5-10 Earthwork

June 24, 2016

Careful consideration of the design elements affecting earthwork quantities and distribution is necessary for both economic and environmental reasons. (See FDM 19-7-1 for guidance on rock excavation.)

10.1 Preliminary Design

During the preliminary design phase several alternative grade lines and alignments should be evaluated. Earthwork quantities, including the required distribution of earthwork, should be developed for each alternative. It is desirable that the final alternative chosen result in balanced earthwork quantities, but this is not always feasible because of other controlling factors.

For urban projects the primary consideration is to minimize property damage by designing the street or highway to match, as nearly as possible, the elevations of the adjacent development. Because of this requirement earthwork may have to be wasted or borrowed.

For rural projects an alignment and grade line can often be developed that will satisfy the principal controlling features (e.g., clearance under structures, meeting crossroad elevations, adequate fill height over marsh, adequate drainage ditches, etc.) and yet provide balanced earthwork quantities. Design of the grade line should include a detailed analysis of earthwork distribution considering haul lengths, haul direction, and the capabilities of typical earthmoving equipment. Distances to potential borrow or waste sites should also be considered.

10.2 General Considerations

In general, long cuts and fills should be avoided, as larger and more expensive grading equipment becomes necessary for efficient earthmoving operations. Track or wheel type bulldozers are most efficient when material

is moved less than 200 feet or steeply downhill. For longer hauls scrapers become necessary. Very long hauls or hauls on public highways require the use of dump trucks loaded by front-end loaders, power shovels, or belt conveyors.

Analysis of earthwork distribution, including the locating of earthwork divisions and the plotting of a mass diagram, can be accomplished by computer methods. The mass diagram can be a valuable tool in the planning or understanding of a grading operation, as it provides a convenient graphic display of cumulative volume over an entire project. It is not necessary to include the mass diagram in the plans, but the earthwork divisions and mass ordinates should be shown.

Design of grading projects must include provisions for the removal of undesirable or loosely compacted materials. Undercutting the mouths of cuts should be specified to remove the topsoil and humus material, which if left could result in settlement or frost heave in the transition from cut to fill.

Similarly, other sections of the grade may contain material that should be removed to assure adequate compaction can be achieved. Excessively wet or supersaturated soil should be removed and placed where it can be drained. The material itself may be adequate once it is dry.

The shaping and rounding of cut slopes should always be specified, especially in the transition to fill, as this significantly improves the highway's appearance and is less susceptible to erosion.

10.3 Project Scheduling

Earthwork issues must be analyzed carefully whenever a grading project is built in stages. There are times when the earthwork quantities for an overall project will either be in balance or be a waste project. In either case the overall project does not require borrow material. If, however, the project is built in stages, there may not be enough cut material available to meet the fill needs of a particular stage. Designers must evaluate the cut-versus-fill situation for each stage of the overall project.

10.4 Total Volume Concept for Project Earthwork.

The Department employs the “Total Volume Concept” for project earthwork. For earthwork purposes, the project is considered a single entity unless physical barriers (such as river crossings, railroads, highways and etc) or staging needs require separation into two or more divisions. Within each division, the total excavation volume is compared to the total embankment volume to determine borrow volume or waste volume for that division. Payment for all excavation and for all borrow within a division is at the established unit cost with no adjustments for haul distances. This concept involves:

1. A running total of earthwork volume showing excess or deficiencies is included in the plan. This is done on the earthwork data sheets immediately preceding the cross sections on a plan. (an EXCEL spreadsheet: FDM 11-5-10, xls1)
2. No balance points or references to these are shown in the plan. If a project has two or more divisions, each division is identified in the earthwork data sheets and the earthwork summary sheet.
3. Borrow or waste volumes are determined by a summary of all earthwork demands within each specific division. Each determined division of the project is considered a separate entity. If a contractor elects to use the “waste” identified in one division as “borrow excavation” in another division, the contractor will be paid, both, “common excavation” in one division and “borrow” in the other division. Note to the designer: the designer must specify in the special provisions if the contractor is prohibited from using the waste from one division as borrow in another division.
4. The item of overhaul has been eliminated. If there are significant changes in conditions or character of work, the contractor may be justified in seeking payment for additional hauling cost under standard spec 104.2.2 (Issuing Contract Change Orders).
5. Grading operations are conducted in the manner that best fits the operational needs of the contractor while fulfilling contract requirements. This may include wasting common excavation in one portion of the project division and replacing it with borrow in another portion of that division. However, this does not change the contract borrow volume and the Department only pays for borrow needed in excess of suitable available excavation.
6. The engineer may authorize the contractor to obtain material for embankment construction from areas within the right of way, but outside of the grading limits. The Department will pay for borrow material obtained from within the project right-of-way limits but outside project excavation limits at a price determined under standard spec 109.4 (Price Adjustments for Contract Revisions).
7. Common excavation materials determined by the engineer to be unsuitable for the embankment construction will be wasted and replaced by borrow paid at the established unit price. If no item for

borrow is included in the contract, payment will be as extra work.

10.5 Borrow

The designer should strive to eliminate or at least minimize the use of borrow because of its cost and potential to delay project completion. Contractors are required to pay increasingly higher prices for borrow material, especially in areas of the state where acceptable sites are difficult to find. Environmental, archaeological, and historical considerations can prevent the use of otherwise acceptable sites. Even with apparently acceptable borrow sites, there is the potential for delay of the excavation if significant archaeological or historical materials are uncovered. WisDOT has a cooperative agreement with the Wisconsin State Historical Society to advise them of any such finds. (See Chapter 20 for details of this agreement.)

Earthwork designs that result in small borrow quantities, say, less than several thousand cubic yards, should be avoided. Small borrow quantities often result in high unit bid prices; then if actual borrow quantities greatly exceed the estimates, the cost of the item becomes excessive.

10.6 Earthwork Quantities

Earthwork quantities should be included on each cross section sheet unless a separate “Earthwork data” sheet, identified in FDM 15-1-40, is included in the plan.

10.7 Earthwork Computations

The end areas and volumes used in earthwork computations should be the end areas and volumes with all adjustment applied. The expansion and reduction factor for all earth materials should be obtained from the soils report for the project or from the regional soils engineer.

During the process of grading, rock excavation is normally the only excavation item that expands and occupies a greater volume in the fill than it did in its original location. Cut and borrow excavation shrinks and occupies less volume in the fill that it did in its original location.

The marsh expansion factor indicates the percent that the marsh excavation quantity should be increased to determine the amount of marsh backfill required. This factor accounts for; the shrinkage of the backfill material placed in the marsh, the displacement of the marsh during the excavation and backfilling process and one (1) foot of granular backfill or select borrow material placed above the marsh (if granular backfill or select borrow is specified).

If the marsh or EBS will be used as part of the embankment, the earthwork summary sheet should indicate the volume of marsh and/or EBS and the estimated reduction factor for the embankment. When marsh or EBS is used as part of the embankment, outside of the 1:1 slopes, the designer must include a construction detail identifying the area where the material is designated to be used. The soils engineer should be consulted to confirm that the marsh and/or EBS is suitable for use in the embankment and to provide the estimated reduction factor.

The following are some of the volume correction factors that are used in earthwork computations:

1. Fill Expansion (>1): applied to the true fill volume to account for only the shrinkage of the cut and/or borrow material placed in the embankment.
2. Rock Expansion (>1): applied to the rock excavation volume to account for the volume of rock material after it is excavated and placed in the embankment. Rock excavation expands as it is excavated to be used in the embankment. This may also be referred to as “rock swell”.
3. Marsh Backfill Expansion (Typically >1): applied to the volume of marsh that is excavated to account for; the shrinkage of the backfill material, the displacement of the marsh during the excavation and backfilling process, and one (1) foot of granular backfill or select borrow placed above the marsh (if granular backfill or select borrow is specified). This factor is used to determine the volume of marsh backfill that is required. This volume is used in the mass ordinate computations only if cut or borrow is used as backfill material. If select borrow or granular backfill is specified, then this volume is not used in the mass ordinate.
4. Marsh Reduction (<1): applied to the volume of marsh excavation to account for the true volume of marsh material after it is excavated and placed in the embankment. Marsh excavation shrinks considerably as it goes from its natural state to its compacted state in the embankment. If marsh excavation is utilized in the construction of the embankment, it is typically used outside of the 1:1 slope and may be restricted in height of fill. The designer may elect to waste the marsh excavation, in which case this factor is not used in the earthwork computations.
5. EBS Backfill Expansion (>1): applied to the true volume of EBS to account for the shrinkage of the

backfill material used to backfill the EBS. This factor is usually close to, or the same as, the fill expansion factor on a given project, depending on the backfill material specified. Frequently, this is assumed to be the same as the fill expansion factor and the EBS backfill volume may be computed separately or as part of the fill in the mass haul computations. If select borrow or granular backfill is specified for EBS backfill, then this volume is not part of the mass ordinate.

6. EBS Reduction (<1): applied to the true volume of EBS excavation to account for the reduced volume of EBS as it is placed in the embankment. EBS typically shrinks as it goes from its natural state to its compacted state in the embankment. The appropriate factor can vary widely depending on what type of EBS material is encountered on a project. If the material is utilized in the construction of the embankments, it is typically placed outside the 1:1 slopes and may be restricted in height of fill. The designer may wish to waste the EBS material, in which case this factor is not used in the earthwork computations.

There are two methods that are used to determine the volume of earthwork quantities. These two methods are referred to as the “shrink the cut” and the “expand the fill” method.

The “expand the fill” method of earthwork computations requires the user to visualize the fill as expanding in order to account for the actual shrinkage of the cut or borrow material placed in the fill. The fill does not actually expand. The expansion factor applied to the fill is an estimated value that accounts for the percent increase in the volume of cut and/or borrow excavation, as measured in its original location that is needed in the fill.

The earthwork calculations shall use the “expand the fill” method. The “expand the fill” method involves the following process:

Step 1

Determine the usable volumes of all excavation and fill materials as well as the expansion/reduction factors for each material.

Step 2

If rock excavation is present, expand the rock volume and deduct this from the unexpanded fill.

Step 3

If marsh excavation is present, and the excavated marsh will be used in constructing the embankment slopes, reduce the marsh excavation volume and deduct this from the remaining unexpanded fill.

Step 4

If EBS is present, and the EBS material will be used in constructing the embankment slopes, reduce the EBS excavation volume and deduct this from the remaining unexpanded fill.

Step 5

Expand the fill volume that remains after completing steps 2 -4.

Step 6

If marsh is present, expand the marsh excavation volume to determine the required volume of marsh backfill. If common or borrow is used to backfill the marsh, it is part of the mass ordinate. (Note: if select borrow or granular backfill is specified for marsh backfill, this volume is expanded to determine the volume of select borrow or granular backfill, but is not used as part of the mass ordinate.)

Step 7

If EBS is identified, expand the EBS excavation volume to determine the volume of EBS backfill. If common or borrow is used to backfill the EBS, it is part of the mass ordinate. (Note: If select borrow or granular backfill is specified for EBS backfill, this volume is expanded to determine the volume of select borrow or granular backfill, but is not used as part of the mass ordinate).

Step 8

Determine the remaining volume of cut, after the marsh and/or EBS is backfilled, by deducting the marsh and/or EBS backfill determined in steps 6 and 7 from the cut. (Note: if select borrow or granular backfill is specified for marsh or EBS backfill, the marsh or EBS backfill does not affect the cut volume and would have a value of zero (0) in this equation).

Step 9

Determine the required borrow (minus value) or waste (plus value) by subtracting the expanded fill, determined

in step 5 from the remaining volume of cut, determined in step 8.

Earthwork will normally be designed and computed using the CAiCE or Civil 3D earthwork process. However, it is recommended that, as a minimum, the designer perform manual computation checks at each segment and each earthwork division identified in the earthwork summary table in the miscellaneous quantities section of the plan.

Two examples of earthwork calculations are included in Attachment 10.1.

10.8 Excess Incidental Excavation

Excess excavation material from the construction of storm sewer, bridges, retaining walls, etc. should be placed in embankments if the material is suitable for that purpose. On projects where the quantity of unclassified excavation or borrow is small and excess incidental excavation is large, the designer should investigate the adequacy of the incidentally excavated soil for use as fill. If it is acceptable, show such quantities in the plan in the earthwork balance tables or earthwork summaries. If this material is not suitable for embankment construction, it shall be incorporated into the project or disposed of in accordance with standard spec 205.3.11.

10.9 Soil Compaction

Attachment 10.2 is a set of guidelines concerning soil compaction. It explains some of the factors which should be considered when choosing between standard compaction, special compaction, and QMP Earthwork for individual projects.

The Region Soils Section is responsible for analyzing soils and recommending the proper soil compaction inspection method for region designed projects. Region designers should confer with their soils unit to determine which method should be applied to individual projects. Consultants are responsible for analyzing the soils for the projects they are designing and for recommending the proper soil compaction inspection method to use.

10.10 Bridge Approach Embankments

Bridge approaches represent a special earthwork situation. They should be constructed using one of the techniques shown in Attachment 10.3. The recommended procedure is shown in Attachment 10.3, Detail A. The 10:1 slope will permit concrete trucks to approach the bridge site while the 20 foot section provides contractors with adequate room to use standard compaction equipment.

Attachment 10.3, Detail B is an alternative embankment construction procedure. It is best suited for sites having non-cohesive, uniform particle size granular materials. It calls for overfilling the abutment back slope, then cutting it back only that distance necessary to construct the abutment. If possible, this surcharge embankment material should be left in place for at least six months prior to bridge construction if the foundation material is compressible. Sheet piling may be needed to retain granular embankment material.

Designers should seek the advice of their region soils section concerning which method of approach embankment construction to use. Designers should provide their soils staff with tentative grades and foundation site information. Site soils reports should also be reviewed before making a decision.

10.11 Geosynthetics

10.11.1 General

Different types of geosynthetics, geotextiles and geogrids, are used in transportation projects for the following applications:

Table 10.1 Applications for Geosynthetics

GEOTEXTILES (type)		GEOGRID (type)
Subgrade Aggregate Separation (SAS)	Modified SAS(C)	Subgrade Reinforcement (SR)
Subgrade Reinforcement (SR)	Embankment Stabilization (ES)	Marsh Reinforcement (MR)
Riprap (R)	Heavy Riprap (HR)	Slope Stability Reinforcement (SSR)
Drainage Filtration (DF)	Marsh Stabilization (MS)	

Standard spec 645 includes bid items for various applications. Most of these bid items have complete specifications for typical applications, but several require project specific customization and are specifically designed to require associated special provisions.

10.11.2 Items Requiring Project Specific Customization

Designers need to consult the Regional Soils Engineer and/or Bureau of Technical Services Geotechnical Engineering Unit for assistance with the design of type MS, SR, and ES geotextiles; and for type MR and SSR geogrids. Modify the standard bid items for individual projects; do not develop SPV bid items.

Geotextile types MS, SR, and ES require a project specific special provision modifying the standard spec bid items to specify required material properties. In addition, other materials and construction provisions may be required to fit the individual project requirements.

Geogrid types MR and SSR require an STSP modifying the standard spec bid items to specify both materials and construction requirements. These STSPs contain the framework for additional contract requirements, but the designer must come up with the actual requirements.

- For Geogrid Type MR use STSP 645-024 "Geogrid Type MR"
- For Geogrid Type SSR use STSP 645-026 "Geogrid Type SSR"

LIST OF ATTACHMENTS

Attachment 10.1	Earthwork Calculation Examples
Attachment 10.2	Compaction of Soils
Attachment 10.3	Bridge Approach Construction Techniques

FDM 11-5-15 Select Materials in Subgrades

June 24, 2016

The following policy will be in effect for rural state trunk highway projects and urban freeway projects constructed after 2006. In the interim, designers are encouraged to use this policy on a selective basis on applicable projects. However, funding for such applications of select materials must come from established project allocations or from other region program allocations. This policy will not affect the common practice of ordering the use of select materials during construction to correct site-specific problems.

15.1 Policy

WisDOT policy will require using select materials in the upper portions of subgrades developed from soils that are difficult for subgrade construction. These include:

- All silty soils,
- Most silty clay soils,
- Soft clay soils,
- Mineral soils with a high organic content, and
- Any other soil with a history of problems relating to subgrade construction.

The shaded portion of Attachment 15.1 is designated the Standard Inclusion Area. It shows those areas in the state where these soils predominate.

Select materials will be used in subgrades for projects located in the Standard Inclusion Area shown in Attachment 15.1 unless the project soils report recommends against such application and provides suitable justification for this recommendation.

The non-shaded portion of Attachment 15.1 is the Standard Non-Inclusion Area. Here better soils predominate and select materials are normally not needed for subgrade construction. Select materials may, however, be used on specific projects in the Non-Inclusion Areas if the soils report identifies significant areas of difficult soils and recommends such treatment.

15.2 Application

This requirement will apply to all projects with significant earthwork volumes. Select materials may be used in subgrades on safety improvement projects or other projects with minor volumes of earthwork if such use is warranted by project requirements, time constraints, or other considerations. The soils report should provide a recommendation for use on projects of this type. **The requirement for select materials will not apply to resurfacing projects, pavement replacement projects, or projects with incidental amounts of earthwork.**

Select materials may be applied to discreet segments of a project based on changes in soil conditions. Such selective use must be based on recommendations for specific areas contained in the soils report.

Select materials will be required in both cuts and fills unless otherwise recommended in the soils report. Cut areas may be excluded if the material at and below subgrade elevation is identified as stable material such as

rock, gravel, sand, or dense till. Fill areas in which the top four feet of the subgrade is constructed from rock excavation may also be considered for exclusion.

15.3 Design

Attachment 15.2 shows specific materials and depths for eight different systems of select materials. These eight systems are considered to have equivalent performance and shall be used to provide the select materials for subgrades. The soils report should recommend which system or systems may be suitable for the specific project. This recommendation should be based on the materials available in the project area, the estimated cost of those materials, and past experience or performance. The designer shall review these recommendations and select the system best suited to the project.

For preliminary planning purposes, Table 15.1 provides estimated costs per mile for each of the eight select materials systems. The final cost to any project will depend on a number of factors that could result in significant variation from these estimated cost figures. These factors include local material costs, transportation costs, earthwork adjustments, project staging, and project quantities.

Table 15.1 Estimated Cost of Select Material Systems

Select Material System	Estimated Cost per Mile
No.1 – Breaker Run Stone	$110,000
No. 2 – Breaker Run Stone with Geogrid	$150,000
No. 3 – Grade 1 Granular Backfill	$ 95,000
No. 4 – Grade 2 Granular Backfill or Select Borrow	$ 95,000
No. 5 – Pit Run Sand and Gravel	$105,000
No 6 – Pit Run Sand and Gravel with Geogrid	$145,000
No. 7 – Flyash, Lime, Cement Stabilization	$ 90,000
No. 8 – Salvaged Materials or Industrial By-Products	$100,000

When included in project plans, show the chosen select materials system on the appropriate typical section(s). Determine quantities of each of the required materials and include them as separate contract bid items. Adjust other earthwork quantities as necessary to compensate for the inclusion of a select materials system.

When select materials are used as stated in this procedure, they will be considered as part of the subgrade and will be included in the contract for subgrade construction. Soil parameters for pavement design will continue to be those of the project soils as determined in the soils report.

To preserve the integrity of the select materials systems and to facilitate movement of local traffic, it is strongly recommended that the Base Aggregate Dense should be included as part of the same contract.

Breaker Run is quarried rock or concrete material processed through a primary crusher, is not further screened or crushed, and will meet the gradation requirements shown in Table 15.2.

Table 15.2 Recommended Breaker Run Gradation

Sieve	Percent Passing
6-inch **	100
** In at least one dimension.	

Pit Run is an unprocessed aggregate material obtained from a gravel pit and will meet the gradation requirements shown in Table 15.3.

Table 15.3 Recommended Pit Run Gradation

Sieve	Percent Passing
1 1/2 inch	0 - 50

Attachment 15.3 through Attachment 15.7 are schematic drawings showing how the select material is to be placed in various situations. The select materials form the uppermost portion of the subgrade. Drainage of the select material is accomplished with relief trenches at all sag points and at 250 ft intervals between sag points. The flow lines of ditches should be at or below the bottom of the select materials. This may require a special ditch. If this is not possible then Attachment 15.6 shows how a special trench and pipe underdrain system can be built to help drain the select material.

15.4 Other Design Considerations

The use of select materials could have a significant impact on excavation, waste, or borrow quantities. Consider carefully the distribution of any excess material and the impacts to the mass diagram resulting from the use of select materials.

LIST OF ATTACHMENTS

Attachment 15.1 Areas for Inclusion of Select Materials

Attachment 15.2 Standard Select Materials Systems

Attachment 15.3 Typical Half Section with Select Materials

Attachment 15.4 Typical Half Section with Select Materials, 4-Lane Divided Highway, 50 ft Median

Attachment 15.5 Typical Half Section with Select Materials, 4-Lane Divided Highway, 60 ft Median

Attachment 15.6 Median Drain Detail for Select Materials Layer Greater Than cmax

Attachment 15.7 Typical Section for 1-Lane Ramp with Select Materials