FDM 11-5-1 Scope of Construction Projects

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 11-5-2 Traffic Demand Forecasts

2.1 Traffic Forecasts General

Project level traffic forecasts are developed by the Traffic Forecasting Section. The goal is to provide region and central office staffs with reliable and accurate traffic forecasts statewide from county trunk highways to the interstate system. Traffic forecasts are used in several ways.

1. Determining appropriate highway and bridge design criteria.

2. Designing pavement structures.
3. Evaluating levels of service for improvement needs and project alternatives.

4. Analyzing environmental issues like air quality and noise.

5. Evaluating alternative alignments.

The following traffic forecast information can be requested from the Traffic Forecasting Section. For more information regarding traffic forecasts and forms, see Chapter 9 of the Transportation Planning Manual (https://wisconsindot.gov/Documents/projects/data-plan/plan-res/tpm/9.pdf). The Traffic Forecasting Section maintains Chapter 9 of the Transportation Planning Manual.

- To request a traffic forecasts to be completed by the Traffic Forecasting Section, use the TRAFFIC FORECAST REQUEST form (DT1601).
- All traffic forecasts not completed by the Traffic Forecasting Section should be reviewed by the Traffic Forecasting Section. The FORECAST REVIEW REQUEST form (DT1594) should be used to request a review.
- To request travel demand model data from the Traffic Forecasting Section, use the AGREEMENT FOR AND RESTRICTIONS ON USE OF WisDOT TRAVEL DEMAND MODELS form (DT1599).

FDM 11-5-3 Highway Capacity

May 15, 2019

3.1 General

This chapter discusses the evaluation of highway capacity and Level of Service (LOS). The analysis of existing and future operating characteristics of a facility can be measured using Level of Service to provide an indication of the ability of the facility to satisfy both existing and future travel demand. Level of Service is a nationally recognized quantitative measure that is used to describe the quality of travel on a transportation facility. LOS can be measured for various travel modes that include automobile (autos, trucks, buses, and motorcycles), pedestrian, bicycle and transit modes. This FDM chapter will discuss LOS that applies to the automobile mode. In addition to LOS, there are other measures of effectiveness that can be used to enhance the evaluation of mobility needs for the automobile mode (see FDM 11.5-3.2.1).

The LOS measure is stratified into six letter grades, “A” through “F” with “A” representing excellent operating conditions with traffic flowing freely and “F” representing extremely congested conditions. The capacity of a roadway represents the maximum number of vehicles that can pass a point on a roadway in a given amount of time. Each roadway type has a defined method for assessing capacity and level of service, which is based on a set of performance measures. For example, LOS on a freeway is characterized by the traffic speed, proximity to other vehicles, and the freedom to maneuver within the traffic stream. LOS on a rural two-lane highway is defined by the traveler's speed and the ability to pass slower moving vehicles. LOS on urban arterials is defined by the average travel speed, which includes delay incurred at the controlled intersections.

When evaluating the LOS and capacity of a highway, follow the procedures in the “Highway Capacity Manual 6th Edition” (HCM6): A Guide for Multimodal Mobility Analysis, published by the Transportation Research Board. For further information on how to obtain this document, write or call:

Transportation Research Board Business Office
500 Fifth Street, NW
Washington, D.C. 20001
(202) 334-3213
www.trb.org


3.2 Congestion and LOS

3.2.1 Congestion and Facility LOS

The LOS thresholds shown in Table 3.1 are considered desirable degrees of design year congestion on Wisconsin facilities. Facilities are lengths of freeways, multilane highways, two-lane highways and urban streets, which are defined by two endpoints. Table 3.1 does not apply to controlled intersections. Intersection LOS is discussed below in subsection FDM 11-5-3.2.2.

When substantial portions of a facility have a current or projected LOS that is more congested than that shown in Table 3.1 the Department may consider improving the LOS preferably through incremental improvements or capacity expansion. Table 3.1 provides desirable LOS values; however, it may not always be feasible to improve congested facilities to the desirable LOS values shown. For example, consider the case where the
primary purpose of an improvement project is system preservation. During the scoping phase of this project it is
determined that the design year LOS exceeds the desirable LOS threshold. In this case, safety should be the
primary reason to make improvements outside of the existing footprint. The Department may elect to address
system preservation with no capacity expansion, due to financial, environmental, or community input
considerations.

The Department intends to use the mobility performance information to guide State Highway System
improvement planning efforts. Such improvements enhance the economy, reduce congestion, improve safety,
avoid and minimize environmental impacts, and serve community objectives.

The designer should strive for the best operating performance conditions practical for the facility. A LOS and
capacity analysis can be used by designers to assist in determining the design features, including roadway
cross-section, which will allow a facility to operate at the desired LOS. There may be situations where an
evaluation of capacity or operational improvements supports a higher quality of service due to safety and
operational impacts. There may be other situations where an evaluation of capacity or operational improvement
supports a lower quality of service due to environmental or economic considerations. When the study involves
an evaluation of a highway expansion, adjustments to the LOS thresholds should be approved by the WisDOT
Bureau of State Highway Programs, Program Development and Analysis Section. Coordination with FHWA
should be made on any Interstate or NHS NEPA project that evaluates capacity improvement elements or
expansion alternatives.

Although the LOS analysis and the Table 3.1 LOS thresholds should be part of the decision to consider capacity
and operational improvements, there may be other mobility measures of effectiveness that could be used to
demonstrate needs and enhance the roadway design, which include but are not limited to:

- Average Travel Speed
- Vehicle Density
- Hours and Cost of User Delay
- Queue
- Travel Time Reliability

In addition to these measures, there may be other operational and safety factors to consider when evaluating
projects for capacity or operational improvements. These important factors listed below could also be
considered when determining the purpose and need, or criterion to use for the alternative analysis evaluation in
the environmental study.

- Projects being considered for system preservation where the LOS is within a reasonable range of the
  LOS threshold in the design year and the benefits of the improvements (related to factors such as
  operation and safety) are greater than the marginal cost of the improvements.
- Projects with substantial safety problems that may not be addressed by spot improvements.
- Short highway segments that provide lane continuity and logical connections to major facilities or
  areas.

The measures selected to evaluate the operational improvements should be consistent with a project’s purpose
and need. The environmental document should include an explanation of the measures selected to evaluate
purpose and need as well as the criteria used to evaluate the alternative improvements.
Table 3.1 Desirable Levels of Service

<table>
<thead>
<tr>
<th>STH Sub-System</th>
<th>Rural and Small Urban Areas ¹</th>
<th>Urbanized Areas ² with Population &gt; 50,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2030 Backbone and Connector Routes ³</td>
<td>LOS C (≤ 4.0)</td>
<td>LOS D (≤ 5.0)</td>
</tr>
<tr>
<td>National Highway System (NHS) Routes ⁴ (Non-NHS Backbone and Connector Routes)</td>
<td>LOS D (≤ 5.0)</td>
<td>LOS D (≤ 5.0)</td>
</tr>
<tr>
<td>Non-NHS Routes ⁵ (Other Principal Arterials, Minor Arterials, Collectors and Local Functionally Classified Roads)</td>
<td>LOS D (≤ 5.0)</td>
<td>Mid LOS E (≤ 5.5)</td>
</tr>
</tbody>
</table>

The highest LOS thresholds are applied to the Interstate system routes and other Corridors 2030 system routes in recognition of their importance from a mobility and economic development perspective. The Interstate system within Wisconsin is included in the C2030 Backbone system. Wisconsin C2030 Backbone routes also include a number of other important freeways and expressways. On Corridors 2030 routes, “minimal to moderate” congestion is allowed. Some “severe” congestion is allowed on non-NHS routes in highly urbanized areas. See Table 3.2, which shows the relationship between the LOS alpha value and the numeric value.

3.2.2 Congestion and Intersection LOS

As with roadway facilities, designers should strive to achieve the best intersection level of service (LOS) that is practical given the local land use, economic, social, and environmental characteristics. The designer should aim to balance the level of service for all users of the intersection (e.g., vehicles, pedestrian, bicycles, etc.).

The upper minimum LOS is LOS D or better for the intersection as a whole, and for all movements (left, through and right turning movements for each approach) during the peak hours of travel on C2030 and NHS routes. The upper minimum intersection level of service is mid-LOS E or better for all movements (left, through and right turning movements for each approach) during the peak hours of travel on non-NHS routes. Where it is not practical to provide the upper minimum intersection level of service for all movements, a reduced LOS may be acceptable for minor street movements or major street non-through movements. An example of a case where a reduced LOS may not be appropriate includes movements at ramp intersections that impact the mainline Interstate or other freeway operations.

Common scenarios where a reduced LOS may be desirable include, but are not limited to, the following:
- The minor street is not part of the State Trunk Network (STN)
- The 95th percentile queue for the movement with the reduced LOS is less than four vehicles, or approximately 100 feet, and will not block another major intersection or access point

¹ 23 USC 101 (a): “(33) URBAN AREA. The term “urban area” means an urbanized area or, in the case of an urbanized area encompassing more than one State, that part of the urbanized area in each such State, or urban place as designated by the Bureau of the Census having a population of 5,000 or more and not within any urbanized area, within boundaries to be fixed by responsible State and local officials in cooperation with each other, subject to approval by the Secretary. Such boundaries shall encompass, at a minimum, the entire urban place designated by the Bureau of the Census, except in the case of cities in the State of Maine and in the State of New Hampshire.”

² 23 USC 101 (a): “(34) URBANIZED AREA. The term “urbanized area” means an area with a population of 50,000 or more designated by the Bureau of the Census, within boundaries to be fixed by responsible State and local officials in cooperation with each other, subject to approval by the Secretary. Such boundaries shall encompass, at a minimum, the entire urbanized area within a State as designated by the Bureau of the Census.”

³ The Corridors 2030 Map is found at:

⁴ The National Highway System Routes are found at:

⁵ The National Highway System Routes are found at:
- Nearby alternate routes are available for drivers to self-divert to a location with lower delay
- The intersection is minor street stop-controlled and centered between two signalized intersections on the major street
- Fewer Impacts to other modes of travel (motorized and non-motorized).

WisDOT will consider reduced LOS operations for specific intersection movements during the design year on a case-by-case basis to determine the most practical level of service. The Bureau of Traffic Operations will review the use of a reduced LOS for intersection or turning movement operations.

Describe the rationale for justifying and accepting the lower LOS for these intersection movements. Document the rationale and decision in the Design Study Report or other capacity evaluation reports (e.g., ICE report). WisDOT shall obtain FHWA acceptance for federally-funded new construction, reconstruction and projects that include capacity improvements, on the NHS or on intersections that can impact Interstate movements, such as ramp terminals.

3.2.3 Converting LOS Letter Value to Numeric Value

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.

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

<table>
<thead>
<tr>
<th>LEVEL OF SERVICE (Alpha Value)</th>
<th>LEVEL OF SERVICE (Numeric Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - (Excellent conditions)</td>
<td>1.01 to 2.00</td>
</tr>
<tr>
<td>B - (Very good conditions)</td>
<td>2.01 to 3.00</td>
</tr>
<tr>
<td>C - (Good conditions)</td>
<td>3.01 to 4.00</td>
</tr>
<tr>
<td>D - (Moderately congested conditions)</td>
<td>4.01 to 5.00</td>
</tr>
<tr>
<td>E - (Severely congested conditions)</td>
<td>5.01 to 6.00</td>
</tr>
<tr>
<td>F - (Extremely congested conditions)</td>
<td>≥ 6.00</td>
</tr>
</tbody>
</table>

The numeric value is calculated using the measure that defines the LOS alpha value. For example, the measure used to define LOS on basic freeway segments is density. For the basic freeway segment, the density range for a given LOS alpha value is equal to the numeric range shown in Table 3.2 (e.g., the density range for LOS E is > 35 to 45 passenger cars per mile per lane (pc/mi/ln) and equates to the numeric range of 5.01 to 6.00). Interpolation is used to calculate the numeric LOS value for a density value that falls between the density ranges for a given LOS alpha value, (e.g., a density of 40 pc/mi/ln is halfway between the LOS E minimum and maximum density range and equates to a numeric value of 5.50). The LOS F range can be difficult to estimate. Therefore, it may be appropriate to show a numerical value of 6+ for conditions that exceed the LOS F threshold.

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. Evaluate incremental improvements for projects that include capacity improvements in the scope of work. Coordinate the evaluation of all phased alternatives with the region environmental staff as outlined in FDM 20-10.

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.
3.4 Incremental Improvements for Interstates and Freeways

Evaluate incremental improvements for projects that include capacity improvements in the scope of work. The evaluation of phased alternatives should be coordinated with the environmental staff as outlined in FDM 20-10. 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.
- Part-time use of shoulder
- Travel Demand Management

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 alternatives with additional lanes should be included in a project’s range of alternatives. The following list provides examples of types of projects or project tasks that include a LOS analysis.

- Environmental analysis (EA, PEL, EIS) for a potential Major or Mega project
- A corridor study that includes an operational needs evaluation
- Traffic Impact Study (TIA)
- Intersection Control Evaluation (ICE) (See FDM 11-25-3 for further guidance)
- Project scoping when operational problems are projected to occur.
- Design Study Reports

The types of projects that do not require an operational analysis include, but are not limited to:

- activities that do not lead to construction
- utility installation
- activities included in the state’s highway safety plan
- installation of noise barriers, fencing or pavement markings.

LOS can be measured for applications that range from the highly detailed to generalized planning applications. 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 thresholds 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 supported traffic analysis software should be used for more specific traffic analysis or design applications. See FDM 11-5-3.7 for an overview of available traffic analysis tools that can be used to evaluate traffic operations on WisDOT facilities and intersections. The use of the Highway Capacity Manual for the operational analysis of projects on the NHS is not required if another traffic analysis method is determined to be more appropriate by WisDOT to fully identify and evaluate the performance and impacts of the proposed project alternatives. (See FHWA May 6, 2016 LOS Letter https://www.fhwa.dot.gov/design/standards/160506.cfm).

If HCM or other or microscopic simulation analysis is performed for the evaluation and design of transportation improvement projects, a peer review process should be conducted. The Traffic Model Peer Review process is outlined in the Traffic Engineering, Operations and Safety Manual, Chapter 16, Section 25 (TEOpS 16-25).

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 traffic characteristics, roadway conditions, and control conditions of the facility.

### 3.5.1 Design Hour Volume

The level of service analysis focuses on the existing or projected traffic along a highway or intersection during a particular peak hour. The amount of traffic occurring during this hour is called the Design Hour Volume (DHV). The DHV is one of the most important criterion used in the level of service evaluation. The selection of an appropriate hour for planning, design and operational purposes is a compromise between providing an adequate LOS for most hours of the year and providing economic efficiency. Document the rationale and supporting data for determining the DHV in the DSR or capacity evaluation report. Refer to FDM 11-5-3.5.1.1 for guidance with WisDOT DHV approval on Wisconsin facilities. FHWA approval of the DHV should be requested for federally-funded new construction and reconstruction projects on the NHS.

#### 3.5.1.1 Design Hour Volume for Freeways, Multilane Highways, and Two-Lane Highways

WisDOT policy is to use the 30th highest hour volume of the year as the Design Hour Volume for mainline freeways, mainline multilane highways, rural two-lane facilities. The 30th-highest design hour may be used when the facility has a small number of hours in the year with higher volumes and has many hours that experience only a small reduction in volumes. However, in cases where traffic patterns are significantly different, other design hour volumes can be justified.

For example, there may be circumstances where the 30th highest design hour is not realistic to use because of exceptionally high hourly volume peaking characteristics. These conditions may occur on routes with a higher level of recreational traffic or routes that are in close proximity to a stadium, seasonal shopping mall or other special event traffic generator. These routes tend to have higher volumes on a few select weekends or in other peak periods, and traffic during the rest of the year has much lower volumes, even during the week-day
A higher design hour may be justified when the LOS using the 30th highest design hour cannot be achieved because of social and environmental constraints, or if the project is financially cost prohibitive. When higher design hours are justified, the LOS evaluation should also consider the 100th highest design hour for rural or small to medium urban areas and 200th or 250th highest hour for highly urbanized areas (>200,000 population) with heavy daily traffic. Higher design hours (e.g., 200th or 250th highest hours) may also be justified in urban areas where there is usually little difference between the 30th and the 200th or 250th highest hour. In urban areas, a higher design hour may be justified to be consistent with daily AM or PM peak periods.

A project specific evaluation of the appropriate design hour and associated volumes must be made for all LOS evaluations on projects that include lane additions for a roadway facility. The design hour evaluation should be made by analyzing the traffic volume data from the most applicable continuous traffic count site locations. Additionally, other data sources may be used to supplement the determination of the design hour volumes. A summary of the findings, recommended design hour, and associated volumes should be reviewed and approved for those projects that include lane additions, by the WisDOT project team, in conjunction with the Bureau of State Highway Programs, the Bureau of Traffic Operations, and the Traffic Forecasting Section. The Federal Highway Administration must approve deviations from the 30th highest design hour on interstate projects.

The Traffic Forecasting Section will provide design year forecasts for all projects where a more detailed LOS analysis is needed. The traffic forecasts will include the annual average daily traffic (AADT), the K factor, and the directional distribution (D) during the design hour. The K factor is defined as the design hour volume divided by the annual average daily traffic (AADT) that occurs for the design year. Refer to FDM 11-5-2 for guidance on how to obtain project level traffic forecasts and example forms to use for requesting a traffic forecast. 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).

If the directional design hour volume (DDHV) is to be computed using the K factor, one of the following formulas can be used:

\[ \text{DDHV} = \text{AADT} \times K \times D \]

Where:
- \( \text{DDHV} \) = directional design hour volume (veh/hr)
- \( \text{AADT} \) = annual average daily traffic in both directions (veh/day)
- \( K \) = proportion of AADT occurring in the design hour for both directions combined
- \( D \) = proportion of traffic in the highest direction during the design hour

If the analysis of DDHV includes data from continuous count site locations, the K factor may be computed by direction rather than for both directions.

\[ \text{DDHV} = \text{AADT} \times K \]

Where:
- \( \text{DDHV} \) = directional design hour volume (veh/hr)
- \( \text{AADT} \) = annual average daily traffic in both directions (veh/day)
- \( K \) = proportion of AADT occurring in the design hour for one direction only

### 3.5.1.2 Design Hour Volume for Urban Streets, Intersections and Ramp Terminals

The design hour volumes used for a detailed analysis of urban arterials, intersections, ramps, and ramp terminals should be based on the AM or PM peak hour 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. Additionally, other data sources may be used to supplement the determination of the design hour volumes.

The Traffic forecasting section will provide design year forecasts, which include AADT, K, D and directional turning movement projections for intersections. Refer to FDM 11-5-2 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)

The peak hour factor is the ratio of the total hourly volume to the rate of flow during the highest 15-minute period within the hour and is computed by the following equation.

\[
PHF = \frac{V}{4 \times V_{15}}
\]

Where:

- PHF = peak hour factor
- V = hourly volume (veh/h)
- \(V_{15}\) = volume during the peak 15 minutes of the analysis hour (vehicles in 15 min)

After the PHF is calculated, it can be used to convert a peak hour volume to a peak hour flow rate (\(v\)), using the following formula:

\[
v = \frac{V}{PHF}
\]

The PHF for controlled intersections is calculated at the intersection level and then the intersection PHF is applied to each of the movements.

#### 3.5.2.1 Facility Segments

The PHF for the existing conditions can be based on existing field data. If field data does not exist, the recommended HCM default can be used. For design year conditions use a PHF of 1.0.

#### 3.5.2.2 Intersections

In most cases, use the PHF derived from the existing field data for intersection LOS analyses. If the existing field-derived PHF is less than 0.92 (the recommended HCM default), however, it may be appropriate to utilize a higher PHF for the analyses of design year conditions. Use of any value other than the field-derived PHF requires coordination with and approval from the regional traffic engineer or the Bureau of Traffic Operations.

In general, apply the PHF to all turning movements and approaches at the intersections. In those cases where one approach to the intersection has significantly different peaking characteristics than the rest of the intersection (e.g., one approach provides direct access to a school), coordinate with region traffic operations or BTO to determine whether it is appropriate to use a different PHF for that one approach.

### 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. The traffic forecasts from the Traffic Forecasting Section will include the percentage of trucks estimated for the design hour for the mainline facility. For most cases, the intersection truck percentages can be determined from the turning movement counts for the AM and PM peak periods.

### 3.5.4 Driver Population Factor

The capacity can be adjusted to account for unfamiliar drivers in the traffic stream, using the capacity adjustment factor (CAF). In general, the factor for driver population should be set to 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. In those cases where the corridor contains a higher percentage of recreational or unfamiliar drivers, the driver population factor should range between 0.9 and 1.0.

### 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
- Free flow speed

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 and will cause heavy vehicles to reduce their speed substantially below the speed of passenger cars. Typically, rolling terrain corridors are similar to those found near the Wisconsin River Valley, in the southwestern part of the State. Mountainous terrain is not used in Wisconsin. The Meta-Manager database provides an estimate of segments with rolling terrain that can be used for a planning level analysis.

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.
- Free flow speed

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 FDM 11-26 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

The design year LOS and supporting information shall be completed for highway improvement projects that involve the following environmental documents:
- Environmental Report (ER)
- Environmental Assessment (EA)
- Environmental Impact Statement (EIS).

A traffic summary matrix (refer to Basic Sheet 4, Traffic Summary Matrix found at https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnsit-rsrces/environment/formsandtools.aspx) is required for projects that require an ER or an EA.

The environmental evaluation should be coordinated with the region environmental staff as outlined in FDM 20-10.

The Meta-Manager model output can be used to determine the LOS under existing conditions and proposed conditions for environmental documents, when no substantial 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 (TWLTs), 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. Document the rationale for choosing the selected traffic analysis tool(s) in the Traffic Analysis Tool Selection memoranda and submit to the WisDOT regional traffic staff for approval.

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 supported 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 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 HCM6 consists of the following four volumes:

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

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

The HCM procedures are good for analyzing the performance of isolated and non-congested facilities but do have limitations. For example, the HCM models do not have the ability to account for interactions between network elements (e.g., they cannot reflect a queue backup at a ramp terminal within the adjacent freeway operations) and they may under predict the extent of congestion in oversaturated conditions. Consider the strengths and limitations of the HCM methods when selecting a tool for use in a particular analysis or study. (See section 3 of the applicable HCM chapter to identify the strengths and weaknesses of the HCM methodology).

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

- Highway Capacity Software 7 (HCS7) - Version 7, McTrans
- Synchro - Version 10, Trafficware
- SIDRA Intersection - Versions 7 and 8 (Roundabouts Only), Akcelik and Associates

Use the most current build number for the software listed above (e.g., HCS 7.3, Synchro 10.1.2.20, SIDRA 7.0.8.6853). 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 2010 vs. HCS 7, Synchro 9 vs. Synchro 10, SIDRA 7 vs. SIDRA 8), specifically as it pertains to the use of Synchro.

For project analysis initiated prior to November 2017, it may be acceptable to continue to follow the HCM 2010 methodologies and thus utilize the previous versions of the above software (HCS 2010, Synchro 9, SIDRA 6). Coordinate with the regional traffic engineer or BTO-TASU to verify whether to continue using the HCM 2010 methodologies or whether to update to the HCM6 methodologies.
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, which typically tries to minimize the total delay per vehicle. The analyst can modify the objective to some degree to 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 professional 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. WisDOT accepts the use of a combination of appropriate tools for the analysis, signal optimization, and simulation of a given traffic analysis for an existing or proposed signalized intersection.

The supported programs that perform optimization:
- HCS7 - Version 7, McTrans
- Synchro - Version 10, Trafficware

Use the most current build number for the software listed above (e.g., HCS 7.3, Synchro 10.1.2.20). However, contact BTO-TASU for consideration of the use of different versions of the software (e.g., HCS 2010 vs. HCS 7, Synchro 9 vs. Synchro 10), specifically as it pertains to the use of Synchro.

For project analysis initiated prior November 2017, it may be acceptable to continue to follow the HCM 2010 methodologies and thus utilize the previous versions of the above software (HCS 2010, Synchro 9). Coordinate with the regional traffic engineer or BTO-TASU to verify whether to continue using the HCM 2010 methodologies or whether to update to the HCM6 methodologies.

Note that, in general, the list of supported software packages listed above supersedes those listed in the Traffic Signal Design Manual (TSDM) 3.2.1 as the last update to this section of the TSDM was in July 2006. If unsure of which software package to use for signal optimization, contact your regional traffic engineer.

3.7.1.3 Work Zone Analysis Tools

Specialty tools are available for analyzing traffic in highway construction zones. These analysis tools typically provide a way to compare travel times with and without construction, estimate the amount of diverted traffic that may take an alternate route, and compute the resulting work zone queue length, delay and road user cost. Other frequently occurring issues that the analyst may need to assess for construction on rural and urban highways and freeways include, but are not limited to, the following:
- Selecting appropriate hours for lane closures or the use of two-way, one-lane operation
- Identifying construction staging needs
- 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

For work zones on urban signalized corridors, the signalized intersections usually control the traffic throughput (especially if construction removes or blocks the turn lanes). In these corridors, a signal optimization tool such as Synchro can provide insights about the traffic demand the signal can reasonably accommodate and can help identify signal-timing adjustments that will make the best use of the remaining capacity.

If adjusted to account for the differences between the capacity of ordinary lanes and the reduced capacity of lanes in the work zone, travel demand forecasting models can provide a means to analyze changes in regional traffic patterns caused by work zones. Similarly, microsimulation tools may be useful for analyzing traffic flows in work zones if they take into account the lane closures and reduced capacity in the remaining lanes. Microsimulation analysis for work zones is typically only used for the larger more complex projects (i.e., major/mega projects). Consider the need for diversion analysis during the model scoping process. With proper planning, travel demand models and microsimulation tools can be set up in such a way to apply capacity changes categorically to minimize manual re-coding effort.

WisDOT has not currently identified a specific analysis tool for analyzing traffic in work zones. Refer to FDM 11-50-30.5, FDM 11-50-30.6 and FDM 11-50-30.7 and coordinate with your regional work zone engineer for assistance in determining delay and queue of freeways and highways.
### 3.7.1.4 Microscopic Traffic Simulation Models

Microscopic traffic simulation or microsimulation, refers to tools that analyze the movement of individual vehicles as they travel through a network. As the simulation progresses, it updates 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 or complex weaving and merging behaviors. Additionally, the visual animation of traffic flows can make microsimulation traffic models useful for public outreach and stakeholder presentations.

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. When using the model outputs to make critical decisions, the project manager should insist on crosschecking with simpler tools to assure that microsimulation outputs are reasonable. WisDOT supports the use of microscopic simulation models, but the decision to use them should be measured against the sufficiency of the appropriate deterministic HCM-based tool. To ensure the integrity of the results, the region shall conduct a peer review of all traffic models (microsimulation and deterministic models) as outlined in the Traffic Engineering Operations and Safety Manual (TEOps) TEOpS 16-25.

The supported programs that perform microscopic simulation are:
- SimTraffic - Version 10, Trafficware
- Quadstone - Paramics Version 6, Pitney Bowes (WisDOT support to stop effective January 1, 2018)
- Vissim - Version 10, PTV Group

Use the most current build number for the software listed above (e.g., SimTraffic 10.1.2.20, Paramics 6.9.3, Vissim 10.00). However, please contact BTO-TASU for consideration of the use of different versions of the software (e.g., SimTraffic 9 vs. SimTraffic 10, Vissim 9 vs. Vissim 10). Do not switch from one software tool to another (e.g., do not switch from Paramics to Vissim) without first consulting with BTO-TASU.

Effective January 1, 2018, WisDOT will no longer support the use of Paramics on any new projects. Projects that initiated the microsimulation traffic analysis using Paramics prior to January 1, 2018 may continue to use Paramics for the duration of the project. However, if major revisions to the traffic models are required (e.g., the traffic model is updated to reflect different base year conditions), consideration should be given to switching the traffic models over to Vissim. Consult with the WisDOT regional traffic contact or BTO-TASU to determine whether it is appropriate to switch software programs.

SimTraffic is only applicable for arterial analysis and is best suited for signalized corridors. WisDOT does not currently support the use of SimTraffic for roundabout analysis. The analyst will often use SimTraffic to observe driver behavior and conduct a “reality check” on the Synchro outputs. SimTraffic may also be beneficial for reporting the vehicle queues, especially when vehicles spill out of the turn lane and block through traffic. If the primary purpose of the SimTraffic model is to conduct “reality checks”, calibration and validation of the traffic model may not be necessary. However, prior to using the model outputs from SimTraffic for critical design decisions, the analyst shall calibrate and validate the SimTraffic model (see FDM 11-5-3.7.4).

### 3.7.2 Tool Selection Matrix

Typically, most traffic analyses 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>
<thead>
<tr>
<th>Analysis/Study Type</th>
<th>Tool Category</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Impact Study</td>
<td></td>
<td>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</td>
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<tr>
<td>Traffic Impact Assessment</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>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</td>
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<tr>
<td></td>
<td></td>
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<tr>
<td>Signal Timing/Phasing</td>
<td></td>
<td>These studies typically involve the evaluation of established warrants, supplemented with operational parameters. Typically, the use of optimization tools is not necessary</td>
</tr>
<tr>
<td>Traffic Control Warrant Study</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>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</td>
</tr>
<tr>
<td>Turn Lane Warrant/Restriction</td>
<td></td>
<td>HCM-based tools and microscopic simulation tools, when applicable, may be used to determine performance measures such as LOS, delay and travel time. Optimization tools may be used to establish modifications to signal operations</td>
</tr>
<tr>
<td>Right Turn on Red Restrictions</td>
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<tr>
<td>Pedestrian Crossing Study</td>
<td></td>
<td>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</td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roundabout Study</td>
<td></td>
<td>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</td>
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<tr>
<td></td>
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<tr>
<td>Urban Streets</td>
<td></td>
<td>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</td>
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<tr>
<td></td>
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<tr>
<td>Freeway System</td>
<td></td>
<td>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</td>
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<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Multi-Lane Highways</td>
<td></td>
<td>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</td>
</tr>
</tbody>
</table>

1. Optimization tools may be used in conjunction with HCM-based tools and microscopic simulation tools.
### 3.7.3 Highway Capacity Manual (HCM) Analysis

WisDOT accepts the use of HCM6, methods in order to meet the planning, operational, and design analysis needs of most traffic studies. For project analysis initiated prior to November 2017, it may be acceptable to continue to follow the HCM 2010 methodologies for the duration of the project. Coordinate with the regional traffic engineer or BTO-TASU to verify whether to continue using the HCM 2010 methodologies or whether to update to the HCM6 methodologies.

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

Traffic signal analyses 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 five or more approaches, those with more than two exclusive turn lanes on any approach or those with complex geometry or controller operations. When these, or similar limitations are encountered, the project manager should specify the use of an alternative microscopic simulation tool. See FDM 11-5-3.7.1.4 for WisDOT supported microsimulation tools.

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

- HCS, McTrans
- Synchro, Trafficware

* See FDM 11-5-3.7.1 for the version of the above software that WisDOT currently supports.
3.7.3.2 Two-Way Stop-Controlled (TWSC) Intersections
WisDOT accepts the use of HCM6 Chapter 20 methods for analyzing the performance of a two-way stop-controlled (TWSC) intersection from the perspective of the motor vehicle mode and the pedestrian modes. Currently, no specific methodology exists to assess the performance of bicycles at TWSC intersections. These methods are 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 20 methods. Some of the limitations of the TWSC methodology include, but are not limited to, the following:

- Only applicable for TWSC intersections with up to three through lanes (either shared or exclusive) on each major-street approach and up to three lanes on each minor-street approach (max of one exclusive lane per movement)
- Limited to no more than four approaches
- Limited to one stop-controlled approach on each side of the major street

Additionally, with the exception of a TWSC intersection located between two signalized intersections, the HCM methodology does not generally account for the effects from other intersections. For TWSC intersections located on an urban street segment between two coordinated signalized intersections, to account for the interaction of the adjacent signalized intersections, the analyst should follow the methodologies presented in Chapter 18 for urban street segments.

When these, or similar limitations are encountered, the project manager should specify the use of an alternative microscopic simulation tool. See FDM 11-5-3.7.1.4 for WisDOT supported microsimulation tools.

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

- HCS, McTrans
- Synchro, Trafficware

* See FDM 11-5-3.7.1 for the version of the above software that WisDOT currently supports.

3.7.3.3 All-Way Stop-Controlled (AWSC) Intersections
WisDOT accepts the use of HCM6 Chapter 21 methods for analyzing the performance of unsignalized intersections with stop control at all approaches (i.e., requires every vehicle to stop before entering the intersection). HCM6, Chapter 21 methodologies focus on the motor vehicle mode but do offer some guidance for how to assess the performance of pedestrian and bicycles. The procedure is applicable for typical AWSC configurations of independent three-leg and four-leg intersections with no more than four approaches and no more than three lanes on any given approach.

AWSC 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 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. See FDM 11-5-3.7.1.4 for WisDOT supported microsimulation tools.

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

- HCS, McTrans
- Synchro, Trafficware

* See FDM 11-5-3.7.1 for the version of the above software that WisDOT currently supports.

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

Motorists are legally required to yield to pedestrians at designated mid-block pedestrian crossings. Motorist compliance, however, can vary. Implementation of pedestrian crossing treatments that are proven safety countermeasures (e.g., high visibility crosswalk markings, median refuges and rectangle flashing beacons or pedestrian hybrid signals) have shown to increase motorist compliance rates and reduce pedestrian crashes. In the absence of local data, and subject to engineering judgment, use the default motorist-yield-rates as recommended in the HCM6 Chapter 20 (Exhibit 20-24) 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. See FDM 11-5-3.7.1.4 for WisDOT supported microsimulation tools.

The supported traffic engineering software for HCM based mid-block pedestrian crossing analysis are:
- HCS, McTrans
- Synchro, Trafficware
* See FDM 11-5-3.7.1 for the version of the above software that WisDOT currently supports.

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

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

WisDOT accepts the use of HCS and SIDRA Intersection with the US HCM 6 capacity and delay model for analyzing roundabouts. 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 five or more approaches has been determined to follow the capacity equations of the HCM. The analyst may use SIDRA HCM analysis for all roundabout analysis and SIDRA is ideal for evaluating roundabouts with lane configurations beyond the limitations of the HCM. SIDRA applies the basic HCM procedures and essentially yields the same results as HCS. HCS is suitable for roundabouts with one or two circulating lanes and SIDRA intersection is suitable for all roundabouts but is specifically required for evaluating roundabouts with three entry lanes, dual partial right turn bypass lanes, and five or more approaches.

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

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

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

There are cases that may not fit within the analytical framework of the HCM, including but not limited to; volume-to-capacity exceeding 0.80, high level of pedestrian or bicycle activity, priority reversal under extremely high flows and flared entry lanes. The analyst should consider the limitations of the HCM methodology when reporting results. Further analysis with a microsimulation tool can also supplement the study if the effort is justifiable based on the site conditions. See FDM 11-5-3.7.1.4 for WisDOT supported microsimulation tools.

The supported traffic engineering software programs for HCM based roundabout analysis are:
- HCS, McTrans
- SIDRA Intersection (HCM mode only), Akcelik & Associates
* See FDM 11-5-3.7.1 for the version of the above software that WisDOT currently supports.

3.7.3.6 Alternative Intersections
Alternative intersections separate out one or more of the turning movement conflicts (typically left-turns) by rerouting them away from the center of the intersection to a secondary junction. Alternative intersections may be signalized or stop-controlled on the minor street movements. Examples of alternative intersections include, but
are not limited to, the following:
- Restricted Crossing U-Turn (RCUT), also known as the J-Turn or superstreet,
- Median U-Turn (MUT), also known as the Michigan left turn or modified J-Turn, and
- Displaced Left Turn (DLT), also known as the continuous-flow intersection

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

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

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

Analyses of alternative intersections should recognize and account for the methodological limitations of the HCM methodology. Specifically, the analyst should bear in mind that the analysis methodology is relatively new. Additionally, the HCM Chapter 23 methodology is only applicable to the RCUT, MUT and DLT. Consider using microsimulation analysis tools for those alternative intersections that do not fit within the methodological limitations of the HCM. See FDM 11-5-3.7.1.4 for WisDOT supported microsimulation tools.

The supported traffic engineering software programs for HCM-based analysis of alternative intersections are:
- HCS, McTrans
  * See FDM 11-5-3.7.1 for the version of the above software that WisDOT currently supports.

BTO-TASU has developed a planning analysis (Excel based) worksheet for RCUTs/J-Turns. The worksheet is based on the HCM methodology and is intended for planning level analysis only (i.e., it is not an operational analysis tool). The analyst can use this worksheet to assess the feasibility of installing a RCUT/J-turn at a specific location. Contact BTO-TASU via the DOT Traffic Model Peer Review (DOTTrafficModelPeerReview@dot.wi.gov) mailbox to request access to the RCUT/J-Turn planning analysis worksheet.

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

3.7.3.7 Interchange Ramp Terminals

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

The Chapter 23 methodology addresses the following conventional interchange designs:
- Diamond interchanges,
- Partial cloverleaf (parclo) interchanges, and
- Interchanges with roundabouts.

Additionally, the HCM6 Chapter 23 methodology addresses the following alternative interchange designs:
- Diverging diamond interchanges (DDIs),
- Single-point interchanges (SPI),

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

The Chapter 23 methodology calculates the control delay experienced at each ramp terminal plus any additional travel time associated with driving between ramp terminals within the interchange. This allows for an equal comparison of the various interchange designs.
Analyses of interchange ramps should recognize and account for the methodological limitations of the HCM6 Chapter 23 methods. Specifically, the analyst should bear in mind that the analysis methodology is not applicable for freeway-to-freeway or system interchanges. Additionally, the methodology does not cover interchanges with TWSC intersections or interchanges consisting of both a signalized and roundabout intersection. Consider using microsimulation analysis tools for those interchanges that do not fit within the methodological limitations of the HCM. See FDM 11-5-3.7.1.4 for WisDOT supported microsimulation tools.

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

- HCS, McTrans
- Synchro, Trafficware (conventional ramp terminals only)
* See FDM 11-5-3.7.1 for the version of the above software that WisDOT currently supports.

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

### 3.7.3.8 Urban Streets

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

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

Traffic analyses should recognize and account for the methodological limitations of the HCM urban streets methods. Accordingly, limitations of the individual intersection methods are also limitations of the urban street methods. For urban street facilities that do not fit within the analytical framework of the HCM, including but not limited to cases involving turn-lane spillover, impacts due to mid-block parking maneuvers, or capacity constraints between intersections, the project manager should specify the use of an alternative microscopic simulation tool. See FDM 11-5-3.7.1.4 for WisDOT supported microsimulation tools.

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

- HCS, McTrans
- Synchro
* See FDM 11-5-3.7.1 for the version of the above software that WisDOT currently supports.

### 3.7.3.9 Freeway Facilities

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

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 affecting the performance of the freeway. In those cases, the project manager should specify the use of an alternative microscopic simulation tool. See FDM 11-5-3.7.1.4 for WisDOT supported microsimulation tools.
The supported traffic engineering software for HCM-based freeway analysis are:
- HCS, McTrans
  * See FDM 11-5-3.7.1 for the version of the above software that WisDOT currently supports.

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

Many multilane highways will have periodic signalized intersections that are more than two miles apart. In these cases, the analyst should analyze the highway segment portion using the Chapter 12 method and analyze the isolated intersection using the signalized intersection analysis tools outlined in FDM 11-5-3.7.3.1.

Traffic analyses 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. See FDM 11-5-3.7.1.4 for WisDOT supported microsimulation tools.

The supported traffic engineering software programs for HCM-based multilane highways are:
- HCS, McTrans
  * See FDM 11-5-3.7.1 for the version of the above software that WisDOT currently supports.

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

In general, this analysis includes any segments that have signalized intersections spaced two or more miles apart. Classify two-lane highways with signalized intersections spaced closer than two miles apart as an urban street or arterial and apply the methodologies of HCM Chapter 16 as appropriate. Further, analyze any major signalized or unsignalized intersections within the two-lane highway corridor using the appropriate tools as defined in FDM 11-5-3.7.3.1 and FDM 11-5-3.7.3.2.

Traffic analyses should recognize and account for the methodological limitations of the two-lane highway methods. Synchro does not model counter-directional passing, and thus the analyst should only use Synchro for two-lane highway analysis if passing maneuvers are infrequent in the study area. If counter-directional passing is critical within the study area, the analyst should consider using an alternative microsimulation tool. See FDM 11-5-3.7.1.4 for WisDOT supported microsimulation tools. (Note that currently Vissim is the only WisDOT supported microsimulation tool that considers counter-directional passing.)

The supported traffic engineering software programs for HCM-based two-lane highways are:
- HCS, McTrans
  * See FDM 11-5-3.7.1 for the version of the above software that WisDOT currently supports.

### 3.7.3.12 Rural Work Zones
Refer to FDM 11-50-30.5, FDM 11-50-30.6 and FDM 11-50-30.7 and coordinate with your regional work zone engineer for assistance in determining delay and queue on rural highways.

### 3.7.3.13 Urban Arterial Work Zones
Refer to FDM 11-50-30.5, FDM 11-50-30.6 and FDM 11-50-30.7 and coordinate with your regional work zone engineer for assistance in determining delay and queue on urban arterials.

### 3.7.3.14 Urban Freeway Work Zones
Refer to FDM 11-50-30.5, FDM 11-50-30.6 and FDM 11-50-30.7 and coordinate with your regional work zone engineer for assistance in determining delay and queue on urban arterials.
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 to best replicate observed conditions. Additional guidance on the calibration and validation of microsimulation models is forthcoming.

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

FDM 11-5-5 Access Control

5.1 Introduction

According to the TRB Access Management Manual6, “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:

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Table 5.1 Access Management Principles

<table>
<thead>
<tr>
<th>AASHTO(^7)</th>
<th>TRB(^8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classify the road system by the primary function of each roadway</td>
<td>Provide a specialized roadway system</td>
</tr>
<tr>
<td>Limit direct access to roads with higher functional classifications</td>
<td>Limit direct access to major roadways</td>
</tr>
<tr>
<td>Locate traffic signals to emphasize through traffic movements</td>
<td>Promote intersection hierarchy</td>
</tr>
<tr>
<td>Locate driveways and major entrances to minimize interference with traffic operations</td>
<td>Locate signals to favor through movements</td>
</tr>
<tr>
<td>Use curbed medians and locate median openings to manage access movements and minimize conflicts</td>
<td>Preserve the functional area of intersections and interchanges</td>
</tr>
<tr>
<td></td>
<td>Limit the number of conflict points</td>
</tr>
<tr>
<td></td>
<td>Separate conflict areas</td>
</tr>
<tr>
<td></td>
<td>Remove turning vehicles from through-traffic lanes</td>
</tr>
<tr>
<td></td>
<td>Use nontraversable medians to manage left-turn movements</td>
</tr>
<tr>
<td></td>
<td>Provide a supporting street and circulation system</td>
</tr>
</tbody>
</table>

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 modernization 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.

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By 2010 Wisconsin communities, including counties, should have adopted comprehensive plans which are required in order to make valid local zoning and land division decisions. 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:


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 must 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 GDHS9, “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

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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-upper range 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

LIST OF ATTACHMENTS
Attachment 5.1 Access Spacing Guidelines
Attachment 5.2 Access Control for Typical Interchange

FDM 11-5-10 Earthwork

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 File 1)

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 than 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 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 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 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 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 or EBS is backfilled, by deducting the marsh 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>
<thead>
<tr>
<th>Table 10.1 Applications for Geosynthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GEOTEXTILES (type)</strong></td>
</tr>
<tr>
<td>Subgrade Aggregate Separation (SAS)</td>
</tr>
<tr>
<td>Subgrade Reinforcement (SR)</td>
</tr>
<tr>
<td>Riprap (R)</td>
</tr>
<tr>
<td>Drainage Filtration (DF)</td>
</tr>
</tbody>
</table>

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 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

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 ten different systems of select materials. These ten 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 ten select materials systems. The final cost to any project will depend on many factors that could result in significant variation from these estimated cost figures. These factors include local material costs and availability, transportation costs, earthwork adjustments, project staging, and project quantities.

### Table 15.1 Estimated Cost of Select Material Systems

<table>
<thead>
<tr>
<th>Select Material System</th>
<th>Estimated Cost per Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.1 – Breaker Run Stone</td>
<td>$125,000</td>
</tr>
<tr>
<td>No. 2 – Breaker Run Stone with Geogrid</td>
<td>$130,000</td>
</tr>
<tr>
<td>No. 3 – Grade 1 Granular Backfill</td>
<td>$105,000</td>
</tr>
<tr>
<td>No. 4 – Grade 2 Granular Backfill or Select Borrow</td>
<td>$100,000</td>
</tr>
<tr>
<td>No. 5 – Pit Run Sand and Gravel</td>
<td>$100,000</td>
</tr>
<tr>
<td>No 6 – Pit Run Sand and Gravel with Geogrid</td>
<td>$115,000</td>
</tr>
<tr>
<td>No. 7 – Flyash, Lime, Cement Stabilization</td>
<td>$ 95,000</td>
</tr>
<tr>
<td>No. 8 – Salvaged Materials or Industrial By-Products</td>
<td>*</td>
</tr>
<tr>
<td>No. 9 – Select Crushed Material</td>
<td>$140,000</td>
</tr>
<tr>
<td>No. 10 – Select Crushed Material with Geogrid</td>
<td>$140,000</td>
</tr>
</tbody>
</table>

* = Highly variable depending on material and location.

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

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-inch **</td>
<td>100</td>
</tr>
</tbody>
</table>

** In at least one dimension.

Select Crushed material is crushed and screened aggregate with particles predominately larger than 1 1/2 inches, free of unconsolidated overburden materials, topsoil, organic materials, steel, and other deleterious materials, and will meet the gradation requirements shown in Table 15.3.
Table 15.3 Recommended Select Crushed Material Gradation

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-inch</td>
<td>90 - 100</td>
</tr>
<tr>
<td>1 1/2-inch</td>
<td>20 - 50</td>
</tr>
<tr>
<td>No. 10</td>
<td>0 - 10</td>
</tr>
</tbody>
</table>

Pit Run is an unprocessed aggregate material obtained from a gravel pit and will meet the gradation requirements shown in Table 15.4.

Table 15.4 Recommended Pit Run Gradation

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2 inch</td>
<td>0 - 50</td>
</tr>
</tbody>
</table>

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