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List of Acronyms and Short Names

AADT Average Annual Daily Traffic
DSDS Dynamic Speed Display Sign
EPDO Equivalent Property Damage Only
FHWA Federal Highway Administration
FYA Flashing Yellow Arrow
HSIP Highway Safety Improvement Program
HSM Highway Safety Manual
ICWS Intersection Conflict Warning System
ITS Intelligent Transportation Systems
LPI Leading Pedestrian Interval
LRSP Local Road Safety Program
NDDOT North Dakota Department of Transportation
NHS National Highway System
PCE Passenger Car Equivalent
RCUT Restricted Crossing U-Turn (intersection)
REF95 NDDOT internal database to catalog traffic operations requests
SDOT State Department of Transportation (acronym used by FHWA)
SHSP Strategic Highway Safety Plan
SRSP State Road Safety Program
TAADT Truck Average Annual Daily Traffic
TRB Transportation Research Board
TWSC Two-way stop controlled (intersection)
TRAFFIC OPERATIONS OVERVIEW

This manual describes typical NDDOT practice for traffic operations work. It is meant to be used as a guideline only and not be a substitute for engineering judgment. This manual is not meant to replace or conflict with commonly accepted references such as the MUTCD, Green Book, Highway Capacity Manual, Highway Safety Manual, Access Management Manual, etc. The checklists, flowcharts and tables were created to encourage a consistent decision making process.

Traffic operations studies provide recommendations for traffic control, need for turn lanes, lighting, signals, beacons and other safety improvements.

NDDOT has adopted the 2009 Manual on Uniform Traffic Control Devices. A traffic control analysis should determine whether traffic control devices are needed along the project corridor and should ensure existing devices meet current MUTCD and NDDOT standards. Traffic control devices include signs, markings, traffic signals, and flashing beacons.

A typical traffic study should describe the following items (some items may not apply to all studies):

- Documentation and manual references
- Reference previous studies or other related studies (safety analyses, planning documents, etc.)
- Location (project limits, roadway name, reference points, name of city, etc.). A location map may be helpful to the reader. Often NDDOT will put a location map on the cover of the traffic operations study document.
- Project number/PCN (if applicable)
- Description of the proposed work
- Proposed construction year
- Identify the study intersections
- Length of study area
- Assumptions
- Summary of recommendations
- Appendix materials and support documentation
- Every page should have a 409 stamp:

In 1987, Congress determined that federal record keeping requirements were subjecting state transportation agencies to inappropriate litigation and stifling the open discussion of safety issues. Congress enacted 23 United States Codes (U.S.C.), Section 409, to remedy these problems.

Railroad Coordination

Traffic operations studies should evaluate railroad crossings within the project area. If a railroad crossing is outside of the project limits or where a railroad runs parallel to the study segment, the following statement from FHWA¹ applies:

Where a railroad-highway grade crossing is physically located “near” a terminus but outside of the project limits, FHWA recommends that the SDOT evaluate and determine the adequacy of warning devices if one or both of the following conditions exist:

1. A Grade Crossing Advance Warning Sign for the crossing is located within the project limits in accordance with the Manual on Uniform Traffic Control Devices (MUTCD) Part 8, Section B8.06; and/or
2. An intersection traffic control signal within the project limits is or will be linked to the railroad crossing’s flashing light signal and gate.

The following pages describe in further detail the items needed in the traffic study depending on the element being studied. These checklists can be used to write traffic studies for NDDOT projects. Often, projects are a combination of several of these elements (such as a rural highway segment includes rural intersections and horizontal curves).

References:

A traffic study of a rural segment on a 2-lane highway typically contains the following:

- Traffic data – average annual daily traffic (AADT), truck average annual daily traffic (TAADT) – describe how and when it was collected, also indicate the projected 20-year forecasted traffic volumes
- Roadway speed limit(s) – describe any speed zones, provide beginning and ending reference points (on state system)
- Roadway geometry (number of lanes, presence of passing lanes, typical section, lane widths, shoulder widths, etc.)
- Highway performance classification
- Functional classification
- Describe horizontal/vertical alignment
- Presence of railroad crossings – identify the use of rail lines as freight and/or passenger. If known, supply the number of crossings that occur daily at that location
- Surrounding land use
- Capacity analysis – see chapter 15 of the HCM for two-lane highways analysis
- Crash history and analysis
- Lighting warrants (refer to table 4 of Lighting Warrant Policy)
- Cross reference HSIP – check SRSP or LRSP documents for recommended safety improvements of rural roadway segments based on risk assessments
- Existing or planned pedestrian accommodations, bike routes, bus stops
- Summary of recommendations

References:
A traffic study of a rural segment on a multi-lane highway typically contains the following:

- Traffic data – average annual daily traffic (AADT), truck average annual daily traffic (TAADT) – describe how and when it was collected, also indicate the projected 20-year forecasted traffic volumes
- Roadway speed limit(s) – describe any speed zones, provide beginning and ending reference points (on state system)
- Roadway geometry (number of lanes, typical section, lane widths, shoulder widths, etc.)
- Highway performance classification
- Functional classification
- Describe horizontal/vertical alignment
- Presence of railroad crossings
- Surrounding land use
- Capacity analysis – see chapter 12 of the HCM\(^1\) for multi-lane highways analysis
- Crash history and analysis
- Lighting warrants (refer to table 4 of Lighting Warrant Policy\(^2\))
- Cross reference HSIP – check SRSP or LRSP documents for recommended safety improvements of rural roadway segments based on risk assessments
- Existing or planned pedestrian accommodations, bike routes, bus stops
- Summary of recommendations

References:
RURAL HORIZONTAL CURVES

Curves are often a subset analysis of a larger traffic study for a roadway segment. Items specific to the analysis of horizontal curves in a traffic study:

- Curve radius and evaluation of signing based on the design manual\(^1\)
- Presence of intersection(s) along the curve
- Presence of a “visual trap” (where the line of sight makes the roadway appear to continue straight but the main highway actually has a curve)
- Cross reference HSIP – check SRSP or LRSP documents for recommended safety improvements of rural horizontal curves based on risk assessments

Radial-T

A radial-T intersection project involves the removal of skewed intersection(s) on a curve. The curve is on the major roadway and the reconstruction project brings the minor road into the curve at a 90° angle.

Although this type of configuration is common in North Dakota, the traffic operations study should look at each location on a case-by-case basis. All options should be analyzed when looking at a location for a potential radial-T project.

References:

1. NDDOT, “Design Manual”. August 2013. (Section III-09.04)
RURAL INTERSECTIONS

Rural intersections may be a subset of a larger traffic study for a roadway segment or are sometimes their own study. Intersections that should be studied are state highways, CMC routes, or paved county roads. Items specific to the analysis of rural intersections in a traffic study:

- AADT and TAADT on all approaches. A “turning movement diagram” that shows the daily volumes of through and turning movements is necessary
- Existing type of intersection control (TWSC, AWSC, Signal, Roundabout, etc.)
- Intersection capacity analysis – see chapter 20 of the HCM\(^1\) for TWSC, chapter 21 for AWSC, chapter 22 for roundabouts, chapter 19 for signals
- Intersection related crash history and analysis
- Turn lanes (need to add left or right turn lanes, determine length of turn lanes)
- Recovery Approaches (or need for them)
- Signal Warrants (only for high volume locations)
- Lighting warrants (refer to tables 5 and 6 of the Lighting Warrant Policy\(^2\))
- Intersections with existing overhead mounted flashing beacons should be recommended for removal (see page 18)
- Cross reference HSIP – check SRSP or LRSP documents for recommended safety improvements of rural intersections based on risk assessments
- Alternative options for the configuration of the intersection (such as a radial-T – see previous page)
- Existing or planned pedestrian accommodations, bike routes, bus stops
- Summary of recommendations

NDDOT has adopted a policy\(^3\) on the installation of Do Not Enter and Wrong Way signs at stop controlled divided highway intersections.

References:
Items specific to the analysis of urban intersections in a traffic study:

- Existing type of intersection control (TWSC, AWSC, Signal, Roundabout, etc.)
- AADT and TAADT on all approaches. A “turning movement diagram” that shows the daily volumes of through and turning movements is necessary
- For signal warrant evaluation, a turning movement count at the intersection for a minimum of 12 hours is required. Typically, NDDOT collects a 16-hour turning movement count that begins at 6:00am and ends at 10:00pm. This timeframe will capture the eight highest traffic volume hours at most intersections that is needed for the MUTCD traffic volume warrants.
- Intersection capacity analysis – see chapter 19 of the HCM\(^1\) for TWSC, chapter 20 for AWSC, chapter 21 for roundabouts, chapter 18 for signals
- Intersection related crash history and analysis
- Turn lanes (need to add left or right turn lanes, determine length of turn lanes)
- Signal Warrants (where necessary)
- Lighting warrants (refer to tables 5 and 6 of the Lighting Warrant Policy\(^2\))
- Cross reference HSIP – check LRSP document for recommended safety improvements of urban intersections based on risk assessments
- Existing or planned pedestrian accommodations and/or bike routes
- Note any public transit infrastructure including bus stops, public transit signal infrastructure and transit specific pedestrian accommodations at or near urban study intersections.
- Summary of recommendations

References:
Traffic operations studies should include tables, drawings, maps, aerial photos or other graphics to help communicate the issues and analysis. The location map of the project is generally included early in the report, possibly on the title page as shown below.

Where the traffic study recommends changes to intersection geometry, a helpful graphic is an intersection “schematic” showing the layout of turn lanes with proposed lengths. This type of graphic is a helpful tool to reference during the design phase of a project. Shown below are some samples.
OTHER TYPES OF TRAFFIC STUDIES

Speed Studies
Speed studies collect and record vehicle speeds at a particular site. This data is used to determine the posted speed limits. “The posted speed limit should be within 5 mph of the 85th percentile speed of free flowing traffic. If the posted speed is set lower than the 85th percentile speed, it shall not be set less than the 50th percentile speed.” Dynamic speed display signs are installed to provide a real-time dynamic display of a driver’s vehicular speed at a particular location where speeding has been determined and documented to be a safety problem.

Traffic impact studies for new developments
Special traffic studies are needed when there is a development proposed adjacent to or near the state highway system. Typically these studies include many of the items listed above but also require a calculation of the trip generation. Trip generation numbers are added to existing traffic volumes and the impact of the proposed development to the system is analyzed in these studies. Include pedestrian and bicycle trip generation in traffic impact analysis for new developments.

Temporary Traffic Control
A “work zone safety and mobility” analysis should be done for significant projects. A project is considered “significant” where it exceeds an estimated $3,000,000 in cost and is on the urban regional system that either goes through a Metropolitan Planning Organization (MPO) boundary or city over 25,000 in population. Traffic operations will analyze the existing level of service of the facility and compare that with the level of service under work zone traffic control. The traffic control plan is acceptable if the level of service is no less than two grades lower than the existing and traffic delays are less than 15 minutes. Describe the need for contractors and other personnel to maintain space for people walking and biking in construction zones.

Highway Safety Improvement Program
Infrastructure-related highway safety improvements are developed through the Highway Safety Improvement Program (HSIP). The program’s goal is to reduce fatalities and serious injuries. Applications for HSIP projects come from NDDOT districts, MPO’s, cities, counties and tribal governments. Potential HSIP projects may require special traffic studies to evaluate the proposed safety improvements. Projects can be created to address crash problems on a particular roadway or at intersections (reactive). Projects may also be developed on a “systemic” basis where a roadway or intersection has a high number of risk elements (proactive).

References:
CAPACITY ANALYSIS

Capacity analysis should follow the procedures of the Highway Capacity Manual\(^1\). The author should note any software program used during the capacity analysis. NDDOT uses HCS and/or Synchro-Simtraffic. However, NDDOT does not adopt or recommend any specific software for capacity analysis.

For study intersections with turning movement data, NDDOT uses the four highest consecutive 15-minute periods as the peak hour.

Typical items from the capacity analysis:
- Determine the number of traffic lanes needed, including the need for any turning lanes (see turn lane section) or passing lanes.
- Recommend the type of intersection geometry/traffic control (two-way stop, all-way stop, signal, roundabout, RCUT, etc.)
- Establish signal phasing, timing, and coordination needs (if applicable, see traffic signals section)
- Identify operational problems (provide guidance to relocate or close driveways near intersections, consolidate driveways or other access points, etc.)
- Establish the “level of service” (LOS) for each intersection to be studied and when appropriate, the entire arterial or roadway segment. Include pedestrian and bicycle level of service in the capacity analysis.

NDDOT Guidance on LOS

The capacity analysis is one factor to determine the recommended geometric design. The NDDOT guidance is to meet or exceed an overall LOS D under 20-year projected automobile traffic.

Further guidance on LOS can be found from Table 2-5 of the Green Book. However, “The recommended values in the Green Book are regarded by FHWA as guidance only.”\(^3\)

Normally the report discusses the study intersections’ operation with the proposed lane geometry under the 20-year projected volumes. Some studies may require analysis of both existing and proposed lane geometry. If an intersection does not currently meet signal warrants, but is likely to with the future volumes, a signalized capacity analysis (on proposed geometry) of the 20-year projected volumes should be included in the study. This does not mean a signal has to be a recommendation in the study, but this will inform the reader that the proposed geometry (turn lanes) will be adequate for future conditions. If a two-way stop control intersection is calculated at LOS F for the minor street approaches, and the likelihood of meeting signal warrants within 20 years is low, it is not necessary to determine the necessary geometry to meet NDDOT LOS guidance.

Projected traffic volumes are based on a yearly growth factor that may be obtained from the NDDOT Roadway Data Section. In urban MPO areas, traffic volumes may be obtained from citywide traffic models.

For rural areas, a 20-year volume projection can be used for capacity analysis. Note that two-way stop controlled rural expressway intersections tend to experience safety issues long before they experience congestion\(^2\).

References:

**CRASH ANALYSIS**

The evaluation of crash history may help to identify existing problems. The crash analysis section of the study may identify alternatives to help reduce potential crashes. Recommendations such as installing rumble strips, adding or modifying signing/striping, changing horizontal/vertical alignment are examples of possible countermeasures. Safety improvements must consider all road users (pedestrians, bicycles, etc.).

Traffic operations studies require the collection of crash data. For local governmental agencies and consultants this data will be provided by NDDOT using the email request format shown below:

I am requesting crash data for the past X years for X Avenue from X Street to X Street and all links in between (see attached map).

I recognize this crash data is considered to be exempted from disclosure pursuant to 23 USC § 409, and can be used only with the understanding that the City of X or its agents will not release or transfer it, nor will it be used for anything other than the intended purpose as a part of a safety study or safety improvement project.

This data will be used by our staff with the City of X, and/or acting as its agent, in the development of a study.

Several crash analysis items that are discussed in a traffic study:

- Beginning and ending dates of crash data gathered (Use 5 years for rural locations and a minimum of 3 years for urban locations)
- Total number of crashes
- Breakdown of the common crash types (how many angle, rear-ends, etc.)
- Note any crashes involving pedestrians and or bicyclists
- Describe crash patterns relating to weather, roadway conditions, light vs. dark, etc.
- Crash summary sheets, statistics, intersection crash diagrams (usually included as an appendix)
- Possible countermeasures
- Note if the study area is listed on any NDDOT crash listings – rural intersection high crash list or urban intersection high crash list,
- Indicate severity of the segment(s) referenced from the latest state highway segment crash map. This map shows the weighted crashes per mile in one of four categories (0-10, 10-25, 25-40, 40-265).
- Highway Safety Manual\(^1\) expected number of crashes (optional)

**Crash severity (from HSM\(^1\) page 3-4):**

- K  Fatal – (one or more persons died within 30 days)
- A  Incapacitating Injury
- B  Non-incapacitating Injury
- C  Possible Injury
- O or PDO  No Injury / Property Damage Only

References:

LIGHTING

The traffic study should indicate need for new lighting or upgrades to existing lighting. Refer to NDDOT Lighting Warrant Policy\(^1\) to determine where lighting is needed.

Lighting design is based on AASHTO guidelines\(^2\).

Guidelines for the Installation of Banners on Light Standards

- Banners cannot interfere with any official traffic control devices.
- Banners must not look like a traffic control device.
- Under the Highway Beautification Act of 1965, it is illegal for any private or commercial business to advertise on highway right-of-way. The banners can not contain any form of advertising for private or commercial business.
- There are no specified mounting height requirements for banners on light standards at this time. A distance of 10 feet from the bottom of the banner to allow for pedestrians and vehicles to pass under is recommended. Mounting brackets should be hinged and allow for rotation if the banner is struck.
- The maintenance of the banners and mounting hardware would be the responsibility of the local road authority. The NDDOT will not be responsible for any banners.
- The manufacturer or the owner of the light standard/utility pole must verify that the pole is structurally sound to support the banner.
- Recommend that they only be installed within city limits and in a reduced speed zone.

References:

LEFT TURN LANE

The flowchart below may be used to determine whether a left turn lane should be recommended in the traffic study.

<table>
<thead>
<tr>
<th>Type of Project</th>
<th>Turn lane warrants based on:</th>
</tr>
</thead>
<tbody>
<tr>
<td>New/Reconstruction</td>
<td>Projected 20-year traffic</td>
</tr>
<tr>
<td>Major Rehabilitation</td>
<td>Projected 20-year traffic</td>
</tr>
<tr>
<td>Structural Improvement</td>
<td>Projected 20-year traffic</td>
</tr>
<tr>
<td>Minor rehabilitation</td>
<td>Current traffic</td>
</tr>
<tr>
<td>Preventive Maintenance</td>
<td>Current traffic</td>
</tr>
<tr>
<td>No project planned (REF95 request)</td>
<td>Current traffic</td>
</tr>
<tr>
<td>New Development</td>
<td>Projected traffic for opening year of development</td>
</tr>
</tbody>
</table>

Approach traffic control

- Speed limit ≤ 45 MPH
- Speed limit ≥ 50 MPH

Stop, Yield

Signal

Left turn lane recommended*

Refer to Green Book² Figures 9-35, 9-36, 9-37

Guidance met?

Typical Questions for “engineering judgment”

- Has there been a crash susceptible to correction by a left turn lane within the last 5 years?
- Capacity analysis shows a need for a left turn lane?
- Other factors apply?

Left turn lane recommended*

Left turn lane based on engineering judgment?

Left turn lane not recommended

"The study should indicate any need for positive offset. Typical questions to determine feasibility of left turn lane offsets:

- Is the intersection on a divided highway?
- History of left turn crashes?
- Sight distance issue for left turning traffic?
- Is it an unsignalized intersection where the mainline left turn is 300 PCE or more?
- Signalized intersection with permissive-only or protected-permissive left turn phasing?

References:
RIGHT TURN LANE
The flowchart below may be used to determine whether a right turn lane should be recommended in the traffic study.

<table>
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</tr>
</tbody>
</table>

References:
TURN LANE LENGTH

Locations where turn lane warrants are met:

If the turn lane warrants are met at a location where a turn lane does not exist, then recommend a new turn lane be built.

If there are existing turn lanes at the same location that do not meet design standards, and do meet turn lane warrants, then recommend to extend these turn lanes to meet design standards.

If there is a turn lane at this same location that does not meet design standards and does not meet turn lane warrants, then do not recommend to extend.

Locations where turn lane warrants are not met:

If there are existing turn lanes at a location that do not meet design standards and/or do not meet turn lane warrants, then do not recommend the turn lanes to be extended.

If there are conditions where engineering judgment may need to be exercised, then the engineer may make a recommendation to build new or extend existing turn lanes as long as proper justification is made.

Uncontrolled Approach
An uncontrolled turn lane is defined as any turn lane in which no traffic signals or signs are used to control traffic movement within the turn lane. Details on the design of the turn lane geometry can be found in the NDDOT Design Manual Section III-03.05.01. The storage distance (L4) is the most important value that is needed by readers of the traffic operations study. The storage length procedure is described below. Other turn lane design elements (L1, L2, L3, L5 from the NDDOT Design Manual) may be necessary in the development of a traffic study.

Right turn lane at uncontrolled approach
L4 = 0 feet – This applies to most cases, the traffic operations study should describe reasoning if a longer storage length is recommended.

Left turn lane at uncontrolled approach
L4 = the highest of the following:

- The 95th percentile queue distance of turning vehicles (based on the capacity analysis)
- 100 feet

The study should indicate if a left turn lanes are to be designed with a positive offset and if right turn lanes are to be designed with an offset (these items relate to providing proper sight distance).
**Controlled Approach**

For a turn lane on an approach that is controlled by a stop sign, yield sign or traffic signal, the traffic operations study will indicate the recommended “full-width length” of the turn lane.

**Traffic Signal**

The recommended length of the turn lane at a signalized intersection should take into account impacts to nearby intersections and the overall area context. The traffic study should describe methods used such as capacity analysis, traffic modeling, etc. As a guideline, the full-width length recommendation is generally the highest of the following:

- The 95th percentile queue distance of turning vehicles rounded up to the nearest 25 ft or
- The average queue distance of the adjacent through lane rounded up to the nearest 25 ft or
- Approach speed:
  - 25 mph 75 ft
  - 30 mph 75 ft
  - 35 mph 100 ft
  - 40 mph 150 ft
  - 45 mph 200 ft
  - 50 mph 265 ft
  - 55 mph 335 ft

**Stop Sign or yield sign**

The full-width length recommendation is typically the highest of the following:

- 100 feet
- 95th percentile queue distance of turning vehicles (based on the capacity analysis)

Most turn lanes are 100 feet full-width length at stop or yield controlled approaches. If the capacity analysis is LOS F, the 95th percentile length may be much longer and is not a practical recommendation. If it is likely that a traffic signal would be warranted within 20 years, the recommended full-width length may be determined using the signalized approach method.

References:

1. NDDOT, “Design Manual,” May 5, 2015. (Section III-03.05.01)
ISSUES TO CONSIDER WITH TURN LANE RECOMMENDATIONS

The NDDOT practice is to discourage accesses within the functional area of the turn lanes. Some examples are shown below.

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YES

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NO

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FUNCTIONAL AREA

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FUNCTIONAL AREA

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FUNCTIONAL AREA

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FUNCTIONAL AREA

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FUNCTIONAL AREA

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FUNCTIONAL AREA

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FUNCTIONAL AREA

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FUNCTIONAL AREA

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FUNCTIONAL AREA

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FUNCTIONAL AREA
ACCELERATION LANES

An acceleration lane is an auxiliary or speed-change lane that allows vehicles to accelerate to highway speeds before entering the through-traffic lanes of a highway\(^1\).

NDDOT will consider installation of a median acceleration lane (MAL) at intersections on divided highways where all of the following criteria\(^2\) are met:

1. There is a significant history of rear-end or sideswipe crashes
2. Intersection sight distance is inadequate for left-turning traffic entering the divided highway
3. There is a high volume of left-turning trucks (75 or more per day) entering the divided highway.

Acceleration lanes are generally not installed in urban areas on non-interstate roadways. The NDDOT has found through past history that they are ineffective because motorists generally choose not to use them\(^3\).

References:
OVERHEAD FLASHING BEACON

Recent information obtained from NDDOT engineering and safety partners is leading the department away from the use of overhead flashing beacons. Review of existing information indicates no proven crash reduction after installation of these devices. Other countermeasures are available to reduce intersection crashes that have the potential to be more effective.

The overhead flashing beacon removal process is as follows:

1. Existing overhead flashing beacons are identified by District Engineers and Traffic Operations
2. Traffic operations identifies intersection treatments after the beacon is removed. Typically the base treatments include the following items:
   a. Destination light (NDDOT Lighting warrant 6C is met)
   b. Stop bar
   c. “STOP AHEAD” pavement markings
   d. Larger stop sign (36” x 36” or larger) with higher retroreflective sheeting
   e. Stop-ahead sign (W3-1)
   f. Intersection rumble strips
   g. Double arrow sign (for T-intersections only)
3. If the intersection is determined to have a severe crash history and/or identified as a “high risk” in the SRSP, additional 2nd tier treatments may be considered in addition to the base treatments:
   a. Flashing beacon stop sign or flashing LED stop sign
   b. Intersection warning sign(s) on the major road – such as W2-1, W2-2
4. If the district engineer agrees with the proposed treatments, the intersection improvements will be programmed into the STIP either through a standalone HSIP project, or integrated into other programmed projects.
5. Where traffic operations and the district engineer agree that more substantial improvements are needed (beyond the 1st and 2nd tier treatments), a traffic operations study should be done to look at other countermeasures (ICWS, J-Turn, Roundabout, etc.).
TRAFFIC SIGNAL WARRANTS

The decision on whether or not to do a signal warrant analysis at a study intersection should be based on engineering judgment. Intersections where the product of the highest major road AADT times the highest minor road AADT is greater than 20,000,000, it is possible that MUTCD warrants may be met. This “rule of thumb” may be used for planning purposes but should not be used to recommend signal installation.

Any recommendation for installation of a traffic signal should have documentation on what MUTCD warrants are met. The NDDOT form SFN 7924 should be used to document a signal warrant analysis. This form may be supplemented with printouts from any software or spreadsheet programs used to analyze the warrants. Meeting signal warrants does not in itself require the installation of a traffic signal. Traffic signals in rural areas are discouraged for several reasons including violation of driver expectations and difficulty in servicing and maintaining signals in remote locations. If an intersection does not meet signal warrants based on current traffic but is close, it is helpful to decision makers if the author identifies the approximate year a signal may be needed.

When performing a traffic signal warrant analysis, engineering judgment should be used to determine what portion of minor-street right-turning traffic to include. Volume modifications should be documented and explained in the warrant analysis. If the minor-street approach has an existing exclusive right turn lane and right-turning traffic is able to turn onto the major-street with minimal conflict, then the right turn volume is excluded from the warrant analysis. Some points to consider when determining if traffic is able to turn with minimal conflict include, but are not limited to:

- Unsignalized capacity analysis results
- Intersection sight distance
- Crash history
- Truck volumes
- Pedestrian conflicts

If the minor-street approach does not have an exclusive right turn lane, then the right turn volume is typically included in the warrant analysis. However, if it is feasible to install an exclusive right turn lane and right-turning traffic is able to turn onto the major-street with minimal conflict, then the right-turn volume is excluded from the warrant analysis.

References:
TRAFFIC SIGNAL ANALYSIS

Traffic studies that examine existing signalized intersections or where a traffic signal is recommended typically supply the following information:

- Existing signal timing (cycle length, split times, yellow timing, all-red timing, pedestrian crossing timing and coordination settings such as offset, etc.).
- Analysis of optimized timings for current traffic and future traffic on the proposed roadway geometry.
- Recommended signal timing plan(s).
- Time-of-day plans, time-space diagrams, and coordination timings for coordinated signals.
- Recommended left turn type (permissive, protected-permissive, protected, or variable).
- Need for new controller or detection equipment.

When determining splits for coordination timings and time-space diagrams, the splits consist of the green, yellow, and all-red time. Splits are programmed into the controller as whole numbers only, no decimals.

**NDDOT phase number convention**

Where the major road runs east-west:  

<table>
<thead>
<tr>
<th>φ1</th>
<th>φ2</th>
<th>φ3</th>
<th>φ4</th>
</tr>
</thead>
<tbody>
<tr>
<td>φ5</td>
<td>φ6</td>
<td>φ7</td>
<td>φ8</td>
</tr>
</tbody>
</table>

Where the major road runs north-south:  

<table>
<thead>
<tr>
<th>φ1</th>
<th>φ2</th>
<th>φ3</th>
<th>φ4</th>
</tr>
</thead>
<tbody>
<tr>
<td>φ5</td>
<td>φ6</td>
<td>φ7</td>
<td>φ8</td>
</tr>
</tbody>
</table>

Note: On major north-south roads in the City of Minot, use phase 1 for SBL, phase 2 for NB, phase 5 for NBL, phase 6 for SB.

**Left turn phases**

The flowchart on the following page may be used to determine the left turn phasing type. The flowchart is based on exhibit 4-16 of the Signal Timing Manual. The minimum split for left turn phases should be 13 seconds. If protected-permissive left turn phasing is used, the protected portion may be omitted during off-peak times (such as when the left turn volumes do not satisfy the criteria for protected-permissive left turn phasing). Left turn flashing yellow arrow heads should be recommended for new signals except where there is limited sight distance or no exclusive left turn lane.

References:

**LEFT TURN PHASING TYPE**

**Are any of the following true?**

A. \( V_s \times V_a > 200,000 \)?

B. Two or more left-turn lanes on subject approach

C. Four or more through lanes on opposing approach

D. The number of left-turn related crashes \( (C_{lt}) \) has been equaled or exceeded

<table>
<thead>
<tr>
<th># of left-turn movements on subject road</th>
<th>Crash Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Year</td>
</tr>
<tr>
<td>One</td>
<td>( C_{lt} = )</td>
</tr>
<tr>
<td>Two</td>
<td>( C_{lt} = )</td>
</tr>
</tbody>
</table>

**Are either of the following true?**

A. The left-turn sight distance is less than the minimum sight distance to oncoming vehicles \( (SD_s) \) and cannot be corrected?

B. The 85th percentile speed (or speed limit) of opposing traffic is greater than 45 mph

<table>
<thead>
<tr>
<th>Speed Limit (mph)</th>
<th>SD (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>200*</td>
</tr>
<tr>
<td>30</td>
<td>240*</td>
</tr>
<tr>
<td>35</td>
<td>280*</td>
</tr>
<tr>
<td>40</td>
<td>320*</td>
</tr>
<tr>
<td>45</td>
<td>360*</td>
</tr>
<tr>
<td>50</td>
<td>400*</td>
</tr>
<tr>
<td>55</td>
<td>440*</td>
</tr>
</tbody>
</table>

**Are there 2 or less left-turning vehicles per cycle?**

<table>
<thead>
<tr>
<th>Cycle Length (sec)</th>
<th>Hourly equivalent to 2 veh/cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>120 vph</td>
</tr>
<tr>
<td>75</td>
<td>96 vph</td>
</tr>
<tr>
<td>90</td>
<td>80 vph</td>
</tr>
<tr>
<td>105</td>
<td>69 vph</td>
</tr>
<tr>
<td>120</td>
<td>60 vph</td>
</tr>
</tbody>
</table>

**Is the cross product \( (V_s \times V_a) \) greater than the value shown below?**

<table>
<thead>
<tr>
<th>Number of through lanes on opposing approach</th>
<th>( V_s \times V_a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33,000</td>
</tr>
<tr>
<td>2</td>
<td>66,000</td>
</tr>
<tr>
<td>3</td>
<td>66,000</td>
</tr>
</tbody>
</table>

**Has the number of left-turn related crashes \( (C_{lt+pp}) \) been equaled or exceeded?**

<table>
<thead>
<tr>
<th># of left-turn movements on subject road</th>
<th>Crash Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Year</td>
</tr>
<tr>
<td>One</td>
<td>( C_{lt+pp} = )</td>
</tr>
<tr>
<td>Two</td>
<td>( C_{lt+pp} = )</td>
</tr>
</tbody>
</table>

**Is the left-turn delay equal to: (a) 2.0 vehicle-hours or more, and (b) greater than 35 seconds per vehicle?**

**Permitted**

**Protected-Permitted**

**Protected**
REMOVAL OF TRAFFIC SIGNAL

A traffic study of an existing signalized intersection typically would not need to be analyzed for signal warrants. If it is questioned whether the signal in-place should be removed, refer to ITE’s “Guidelines for the Activation, Modification, or Removal of Traffic Control Signals”. The preferred traffic signal removal process should follow the process shown below.

![Signal Removal Decision Process Diagram](image)

Consider enhanced pedestrian and bicycle crossings when signals meet removal warrants.

References:
PEDESTRIAN CROSSWALKS

An engineering study is performed before a marked crosswalk is installed at a location away from a traffic signal or an approach controlled by a stop or yield sign. A city or local governmental agency must submit the request to ensure they support the project, because they will be required to assume the maintenance of the improvement after it is installed. After a request for a pedestrian facility is submitted to NDDOT, traffic operations staff will review the request to ensure the location meets guidelines for installing a pedestrian crossing. Typically this review involves looking at the number of pedestrians crossing the roadway, the width of the roadway, sidewalk connectivity leading to and from the proposed location and existing nearby pedestrian crossings.

A typical crosswalk consists of two 6” white lines. A continental style crosswalk may also be used when extra emphasis is needed; such as for midblock crosswalks, crosswalks across uncontrolled roadways, or crosswalks across a yield-controlled right turn lane at a signalized intersection (see continental crosswalk detail—NDDOT standard drawing D-762-1).

References:
1. FHWA, “Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations”, 2017
LED STOP SIGNS

LED Stop Sign

Are at least two or more of the following true?
A. Limited visibility on approach to the intersection
B. Documented history of crashes caused by failure to stop
C. Speed limit greater than 40mph on both minor and major road approaches
D. Previous stop sign on minor approach more than 5 miles away

Yes

Have three or more of the following conspicuity improvements been previously implemented?
A. Stop-ahead sign
B. Larger size stop sign (36" or larger)
C. Retroreflective red strip on stop sign post
D. "Stop Ahead" pavement markings & stop bar
E. Transverse rumble strips
F. Intersection lighting (destination or illumination)
G. Second STOP sign on left side

No

LED Stop Sign not recommended.

Yes

LED Stop Sign recommended