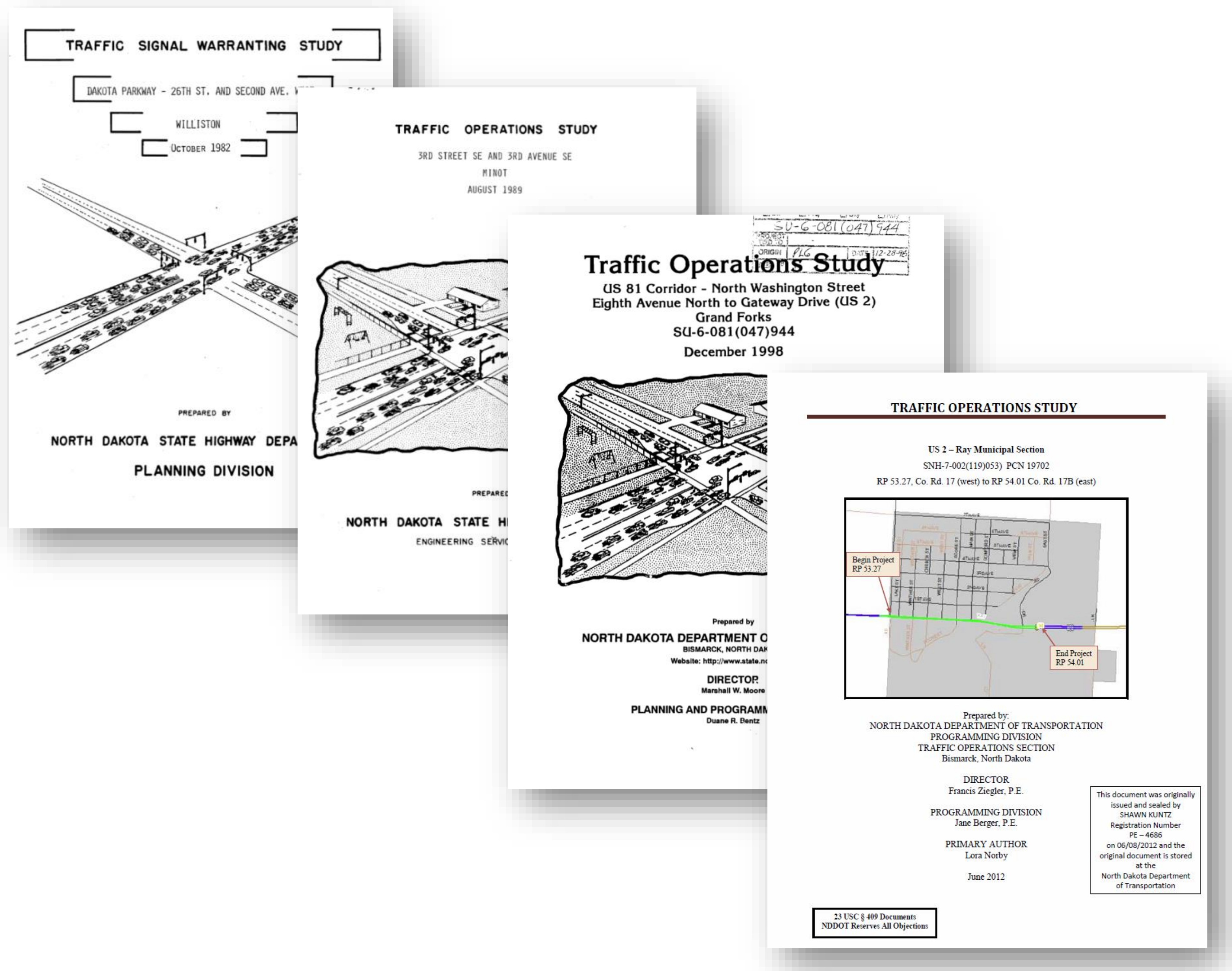
NDDOT TRAFFIC OPERATIONS MANUAL



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North Dakota Department of Transportation
Programming Division
Traffic Operations Section
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Table of Contents

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
MUTCD	Manual on Uniform Traffic Control Devices (2009 Edition)
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
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):

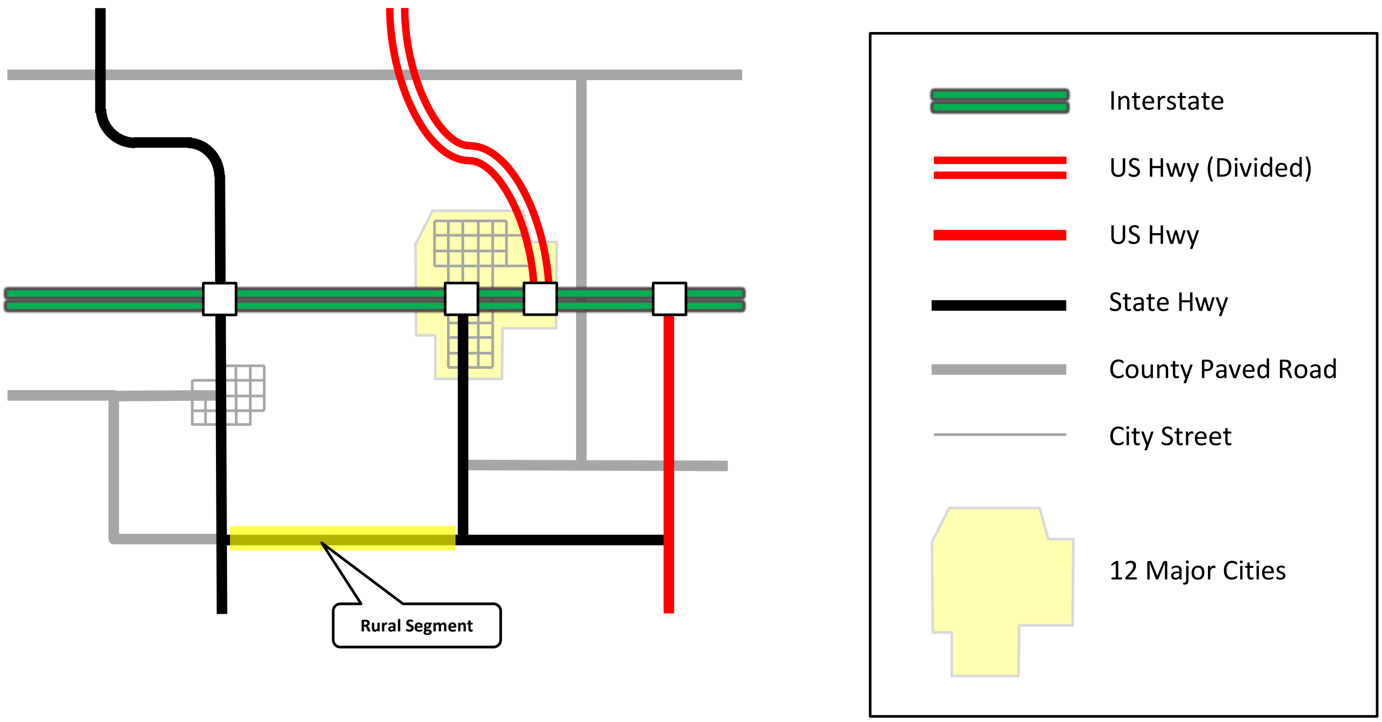
- Documentation and manual references, references to previous studies
- Location (project limits, roadway name, reference points, name of city, etc.). A location map may be helpful to the reader. Often NDDOT will put a location map on the cover of the traffic operations study document.
- Project number/PCN (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:

23 USC § 409 Documents
NDDOT Reserves All Objections

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.

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).

RURAL SEGMENTS (2-LANE)



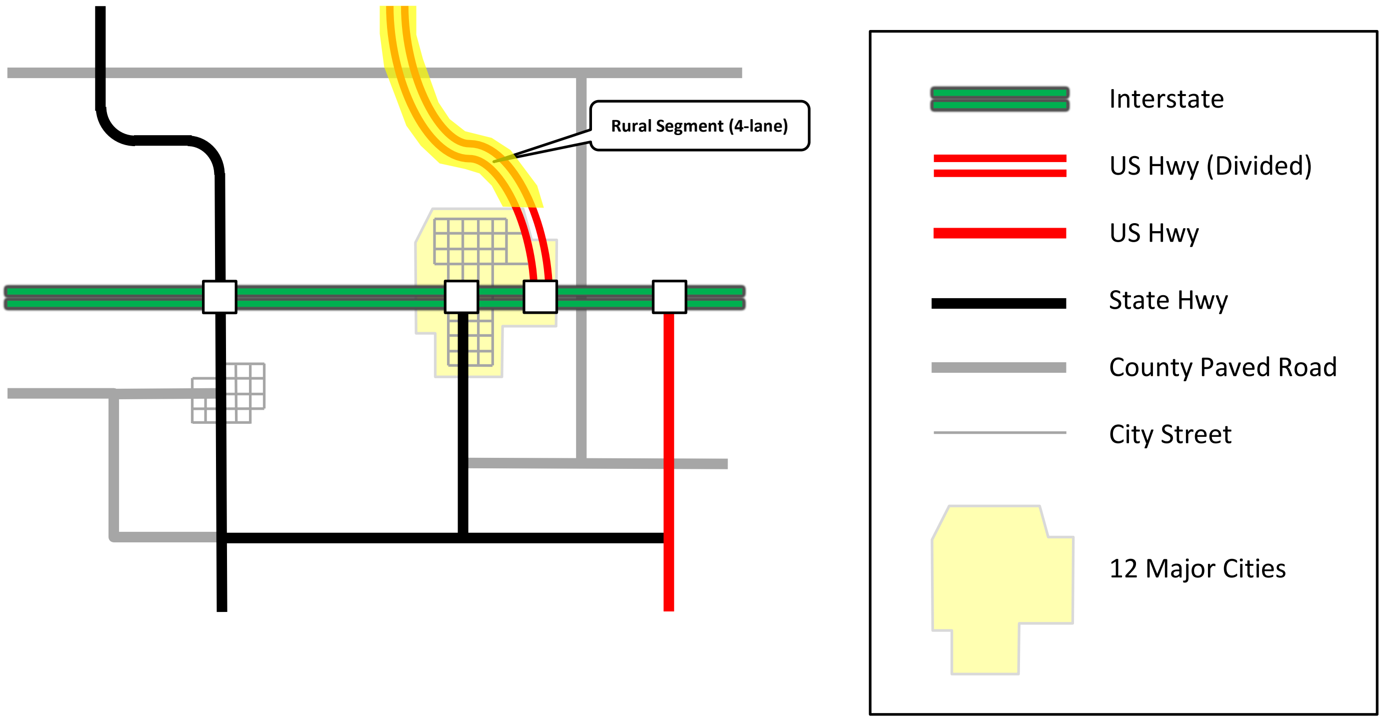
A traffic study of a rural segment on a 2-lane highway typically contains the following:

- ☐ 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
- ☐ Surrounding land use
- ☐ Capacity analysis – see chapter 15 of the HCM[1] for two-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
- ☐ Summary of recommendations

References:

1. TRB, *"Highway Capacity Manual, Sixth Edition,"* October 2016.
2. NDDOT, *"Lighting Warrant Policy"*, March 2015.

RURAL SEGMENTS (4-LANE)



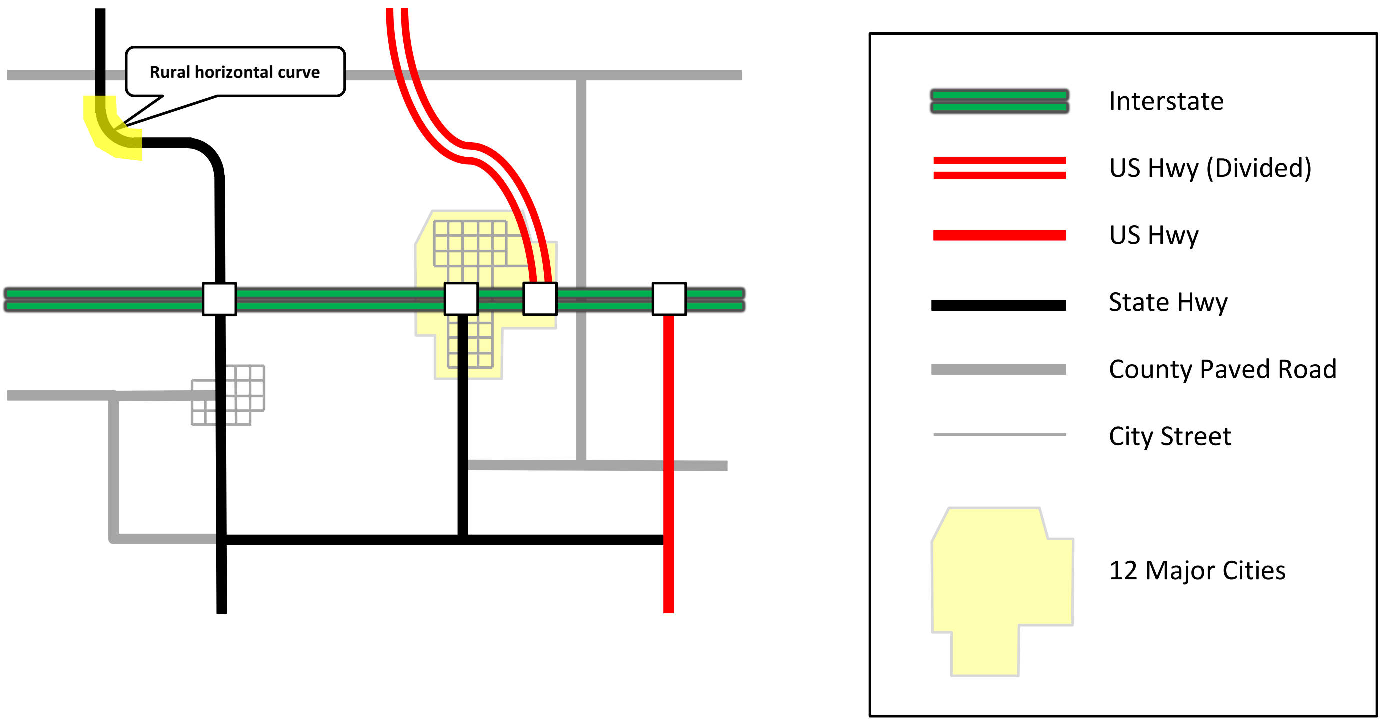
A traffic study of a rural segment on a multi-lane highway typically contains the following:

- ☐ 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
- ☐ Summary of recommendations

References:

1. TRB, *"Highway Capacity Manual, Sixth Edition,"* October 2016.
2. NDDOT, *"Lighting Warrant Policy"*, March 2015.

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

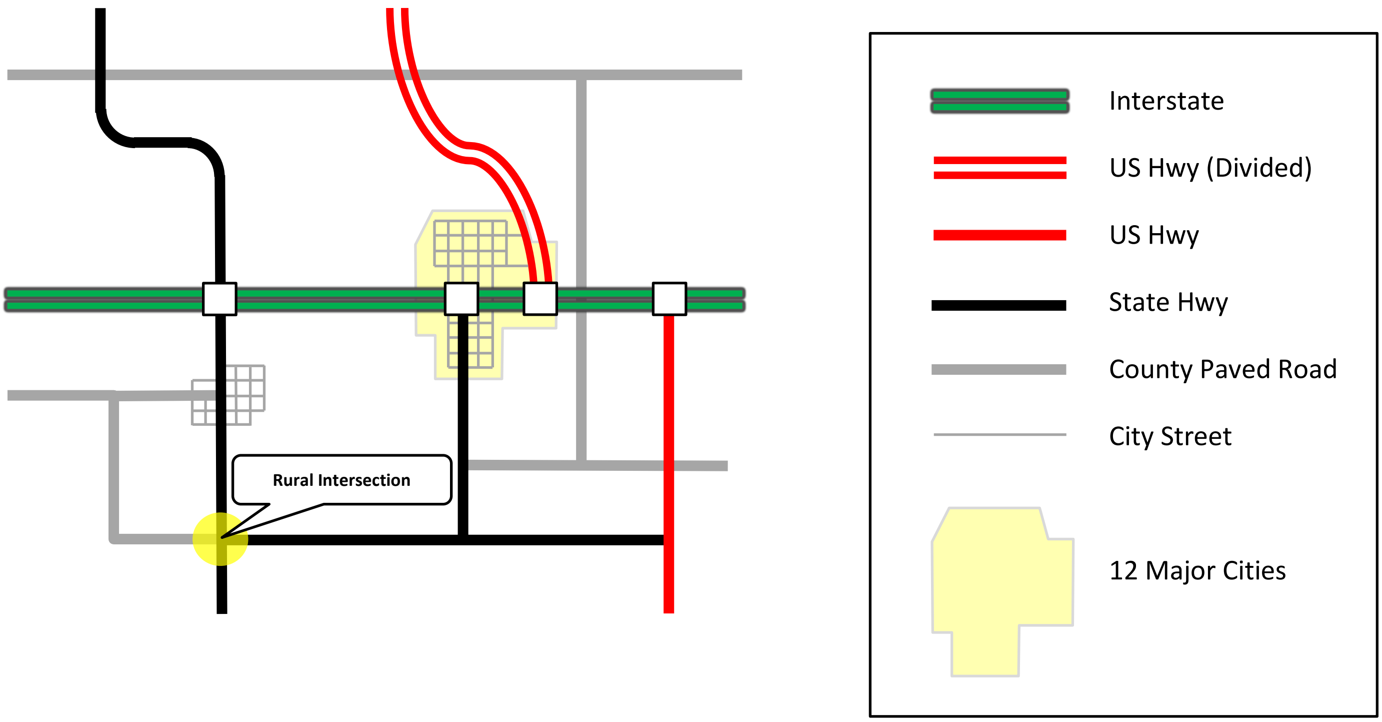
A radial-T intersection project involves the removal of skewed intersection(s) on a curve. The curve is on the major roadway and the reconstruction project brings the minor road into the curve at a 90° angle.

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



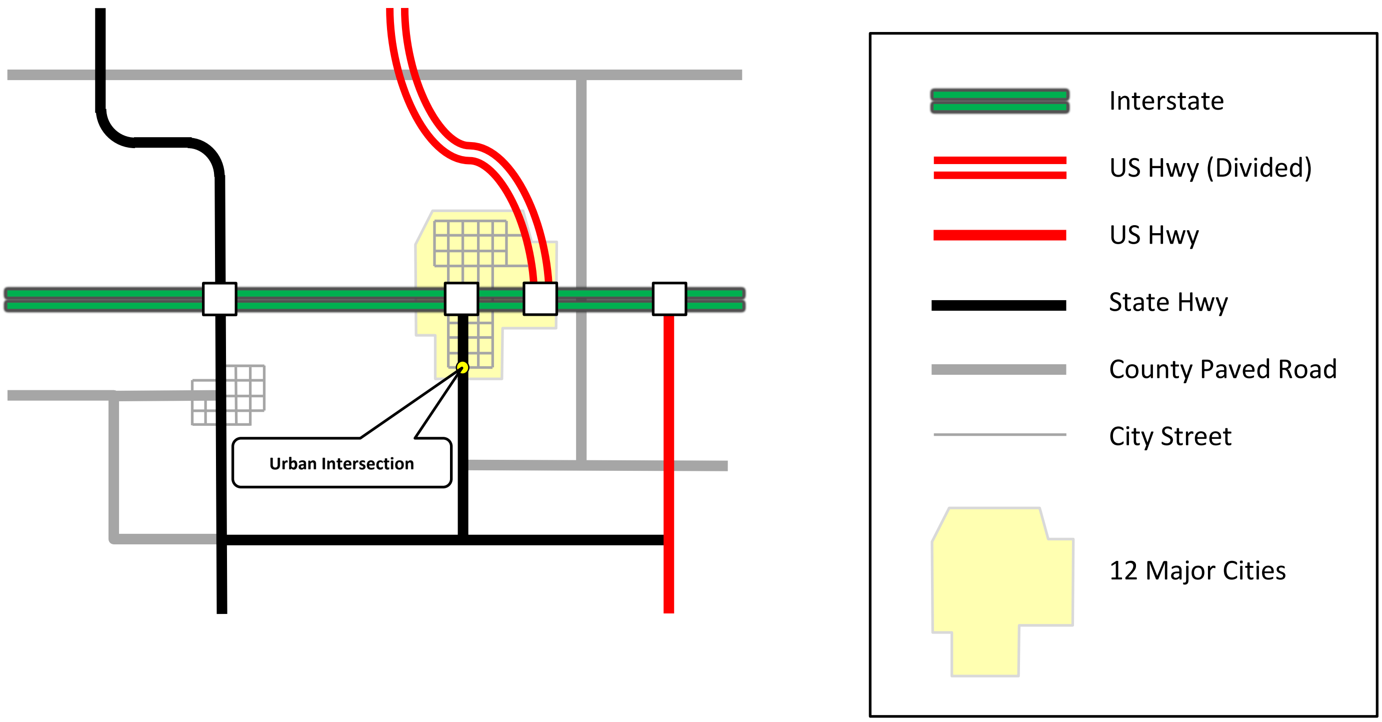
Rural intersections may be a subset of a larger traffic study for a roadway segment or are sometimes their own study. Intersections that should be studied are state highways, CMC routes, or paved county roads. Items specific to the analysis of rural intersections in a traffic study:

- 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)
- 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:
1. TRB, *"Highway Capacity Manual, Sixth Edition,"* October 2016.
2. NDDOT, *"Lighting Warrant Policy"*, March 2015.
3. NDDOT, *"Installation of Do Not Enter and Wrong Way signs at Stop Controlled Divided Highway Intersections"*, July 2011.

URBAN INTERSECTIONS



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
- If the intersection is being evaluated for signal warrants, 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
- Summary of recommendations

References:

1. TRB, *"Highway Capacity Manual, Sixth Edition,"* October 2016.
2. NDDOT, *"Lighting Warrant Policy"*, March 2015.

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.[1]" 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[2].

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[3]. 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.

Temporary Traffic Control

A "work zone safety and mobility[4]" 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.

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:

1. NDDOT, *"Speed Limit Guidelines"*, September 2015.
2. NDDOT, *"NDDOT Guidelines for the Use of Dynamic Speed Display Signs on the State Highway System"*, November 2010.
3. NDDOT, *"Guidelines for New Development Adjacent to the ND State Highway System"*, June 2012.
4. NDDOT, *"Workzone Safety & Mobility"*, February 2007.

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 traffic control (two-way stop, all-way stop, signal, roundabout, 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

<u>NDDOT Guidance on LOS</u>
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].

<u>References:</u>

1. TRB, *"Highway Capacity Manual, Sixth Edition,"* October 2016.
2. TRB, *"NCHRP Report 650: Median Intersection Design for Rural High-Speed Divided Highways"*, 2010. (page 149)
3. FHWA Memo, "Level of Service on the National Highway System", May 6, 2016.

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.)
- 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)

<u>Crash severity (from HSM[1] page 3-4):</u>

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

<u>References:</u>

1. AASHTO, *"Highway Safety Manual"*, 2010.

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.

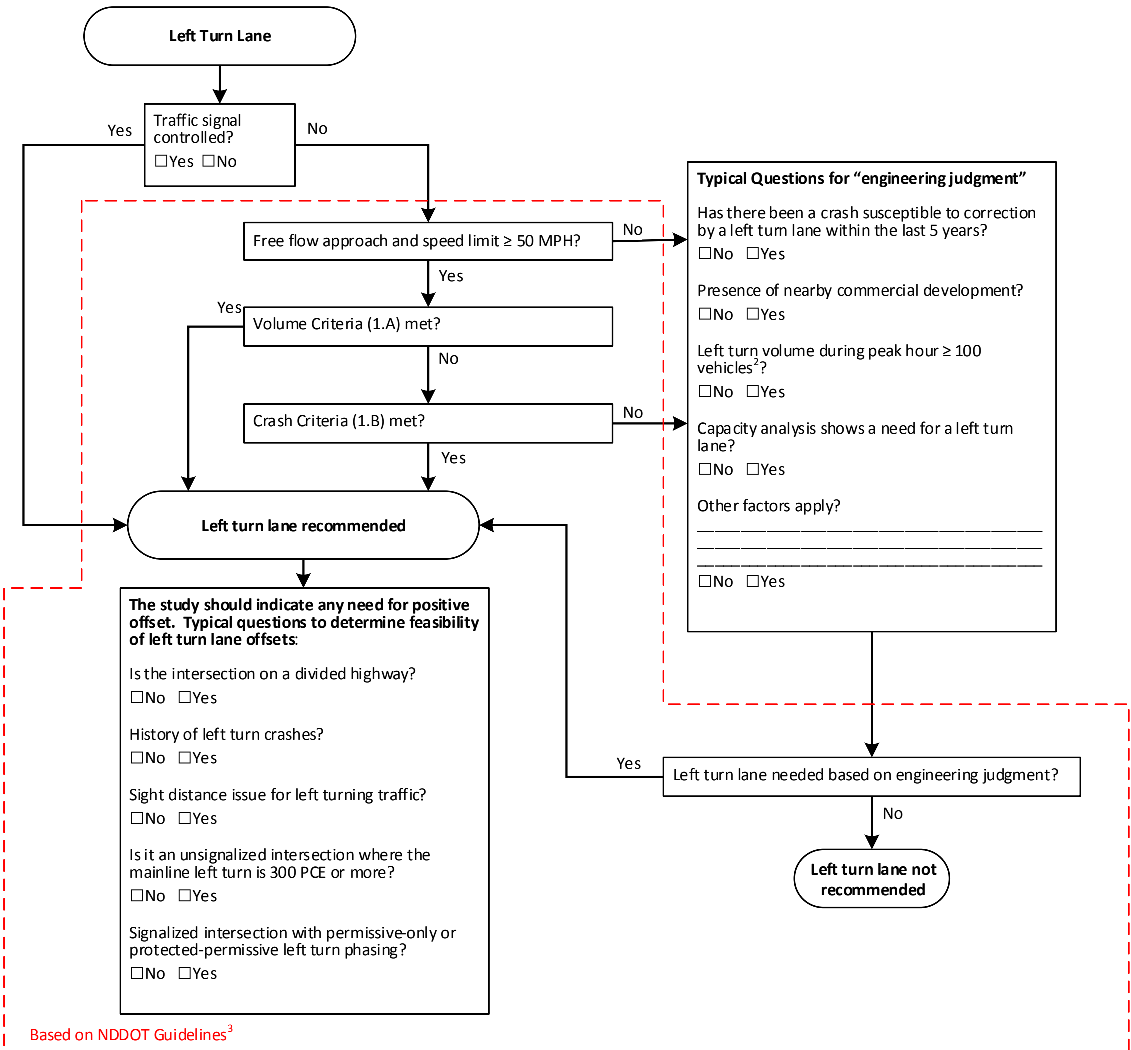
References:

1. NDDOT, *"Lighting Warrant Policy"*, March 2015.
2. AASHTO, *"Roadway Lighting Design Guide"*, October 2005.

LEFT TURN LANE

In designing an intersection, left-turning traffic should be removed from the through lanes, whenever practical[1]. Left turn lanes should be considered at the planning and preliminary design stages of any new signalized intersection[2]. However, it is not cost effective to install a left turn lane at every roadway intersection. The flowchart below may be used to determine whether a left turn lane should be recommended in the traffic study. The flowchart is primarily based on the NDDOT guidelines[3].

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



Dual left turn lanes should be considered if the left turn volumes exceed 300 vehicles per hour[1]. Dual *receiving* lanes are necessary and need to be at least 15 feet wide where dual left turn lanes are used.

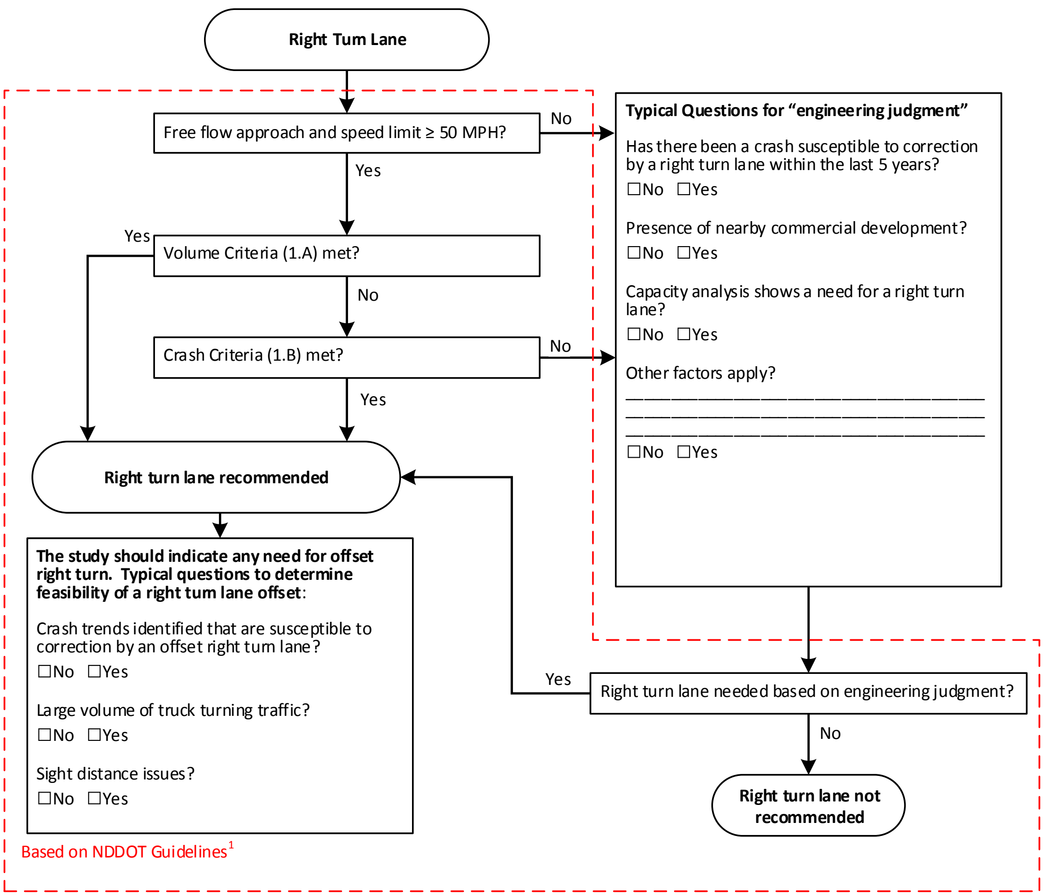
References:

1. AASHTO, *"A policy on Geometric Design of Highways and Streets,"* 2011 (Section 9.7.3)
2. TRB, *"NCHRP Report 279: Intersection Channelization Design Guide"*, November 1985. (page 48)
3. NDDOT, "*Guidelines for the Installation of Turn Lanes along State Highways*," July 2014.

RIGHT TURN LANE

The flowchart below may be used to determine the whether a right turn lane should be recommended in the traffic study. The flowchart is primarily based on the NDDOT guidelines[1].

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



References:

1. NDDOT, "*Guidelines for the Installation of Turn Lanes along State Highways*," July 2014.

TURN LANE LENGTH

If a traffic operations study recommends a *new* turn lane, any other *existing* turn lanes at that intersection are recommended to be upgraded to meet current design standards (such as extending the turn lane to provide more storage or deceleration distance). *Existing* turn lanes at an intersection not receiving a *new* turn lane do not need to be rebuilt to meet current design standards unless stated in the traffic operations study.

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[1]. 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[1]) 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[1].

Traffic Signal

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

- The 95th percentile queue distance of *turning* vehicles (based on the capacity analysis) rounded up to the nearest 25 ft
- The average queue distance of the *adjacent* through lane (based on the capacity analysis) rounded up to the nearest 25 ft
- Approach speed[2]:

  25 mph 125 ft
  30 mph 150 ft
  35 mph 225 ft
  40 mph 300 ft
  45 mph 375 ft
  50 mph 450 ft
  55 mph 525 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)

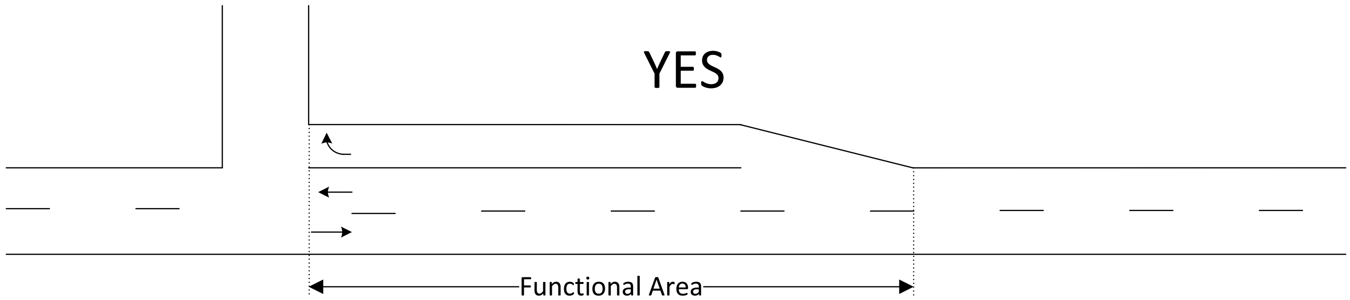
Most turn lanes are 100 feet full-width length at stop or yield controlled approaches. If the capacity analysis is LOS F, the 95th percentile length may be much longer and is not a practical recommendation. If it is likely that a traffic signal would be warranted within 20 years, the recommended full-width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

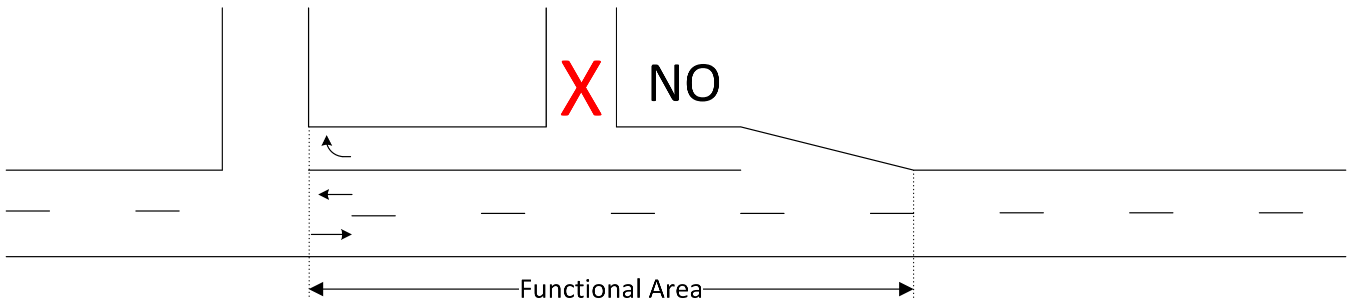
References:

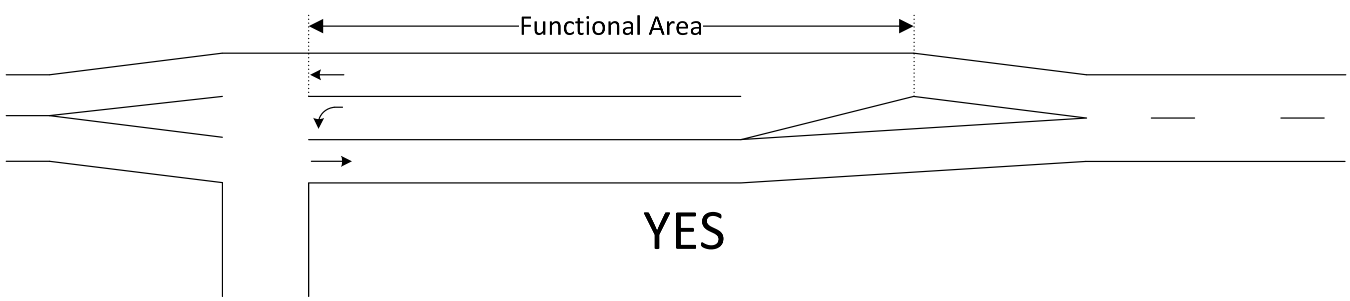
1. NDDOT, *"Design Manual,"* May 5, 2015. (Section III-03.05.01)
2. These distances adapted from Exhibit 16-18: Transportation Research Board, *"Access Management Manual, 2nd Edition,"* 2014.

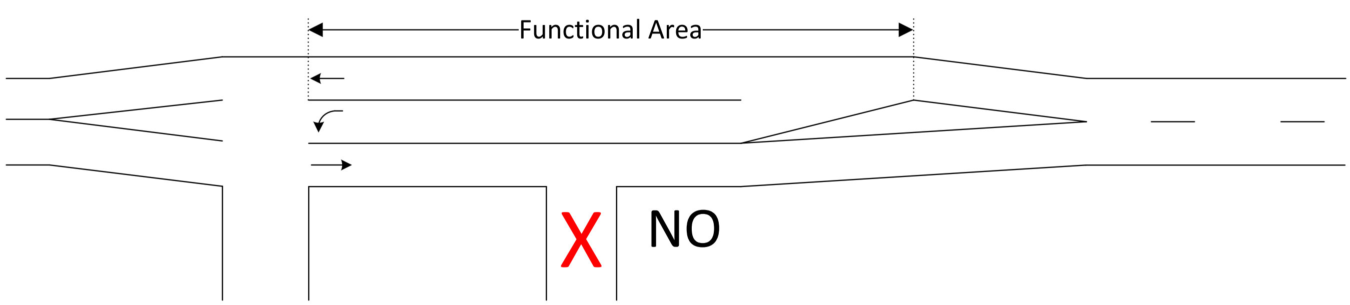
ISSUES TO CONSIDER WITH TURN LANE RECOMMENDATIONS

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









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:

1. TRB, *"NCHRP Report 500 Volume 5: A Guide for Addressing Unsignalized Intersection Collisions"*, 2003. (page V-23)
2. TRB, *"NCHRP Report 650: Median Intersection Design for Rural High-Speed Divided Highways"*, 2010. (page 107)
3. NDDOT, *"Memorandum: 6th Ave SW Approach"*, January 4, 2005.

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[1]. 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:

1. TRB, *"NCHRP Report 650: Median Intersection Design for Rural High-Speed Divided Highways"*, 2010 (page 1)

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. To prevent unexpectedly short green times, the green portion of the split should be at least 8 seconds, even for left turn movements. Please note, the green portion of the split is different than the "Min Green" setting in the controller. With coordinated-actuated operations, low volume minor movements can still gap out prior to using the entire green portion of the split.

NDDOT phase number convention

Where the major road runs east-west:

ϕ1	ϕ2 →	ϕ3 ↳	ϕ4 ↑
ϕ5 ⤴	ϕ6 ←	ϕ7 ↰	ϕ8 ↓

Where the major road runs north-south:

ϕ1 ↰	ϕ2 ↓	ϕ3	ϕ4 →
ϕ5 ↳	ϕ6 ↑	ϕ7 ⤴	ϕ8 ←

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 phase type

Determination of the left turn phasing type should be based on the flowchart from exhibit 4-16 of the Signal Timing Manual[1]. The NDDOT allows the use of flashing yellow arrows which allow more flexibility for left turn phasing.

References:

1. FHWA, *"Signal Timing Manual, 2nd Edition"*, 2015.

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[1]." The preferred traffic signal removal process should follow the process shown below.

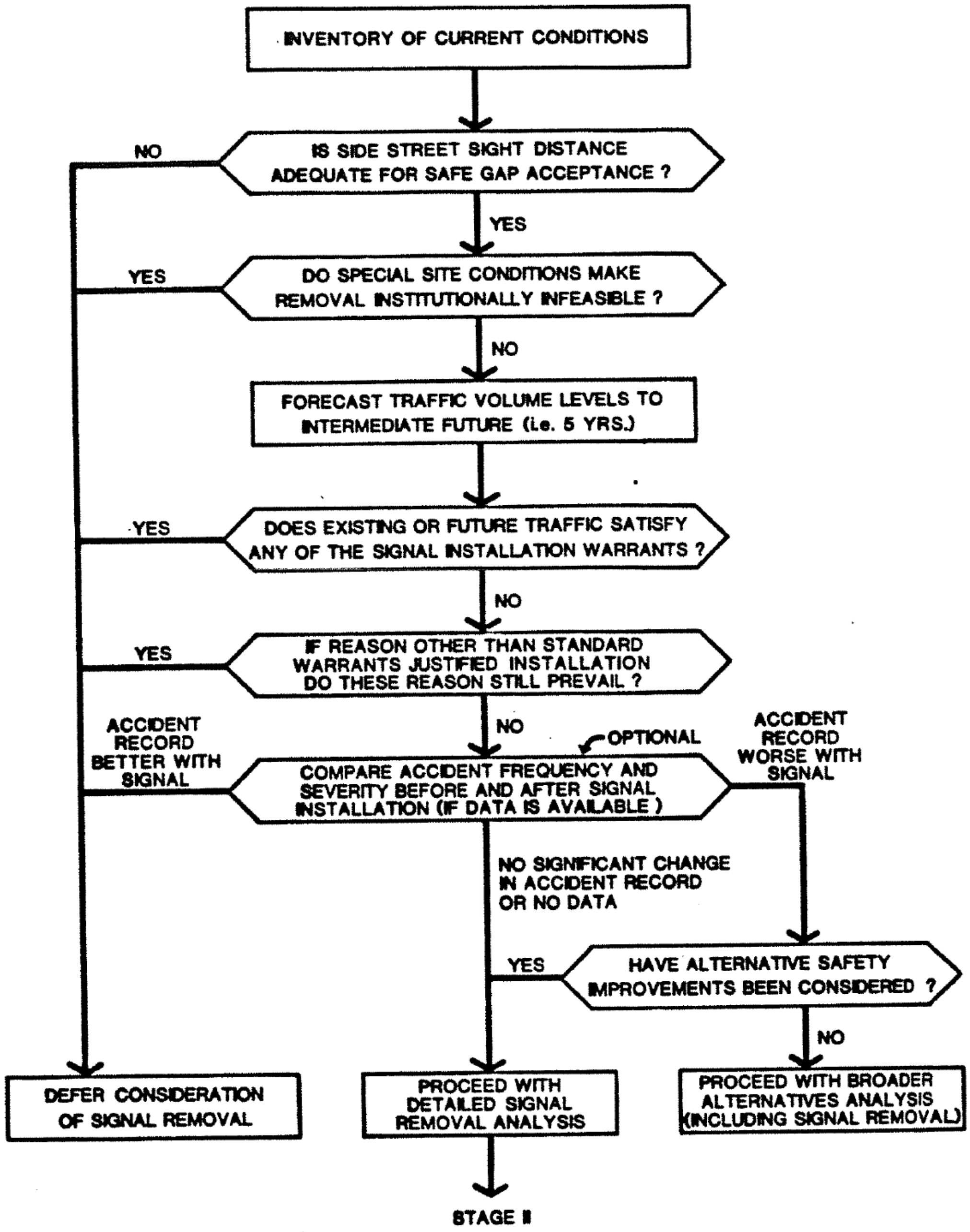


Figure 1. Signal Removal Decision Process
Stage I - Preliminary Screening

From FHWA[2]

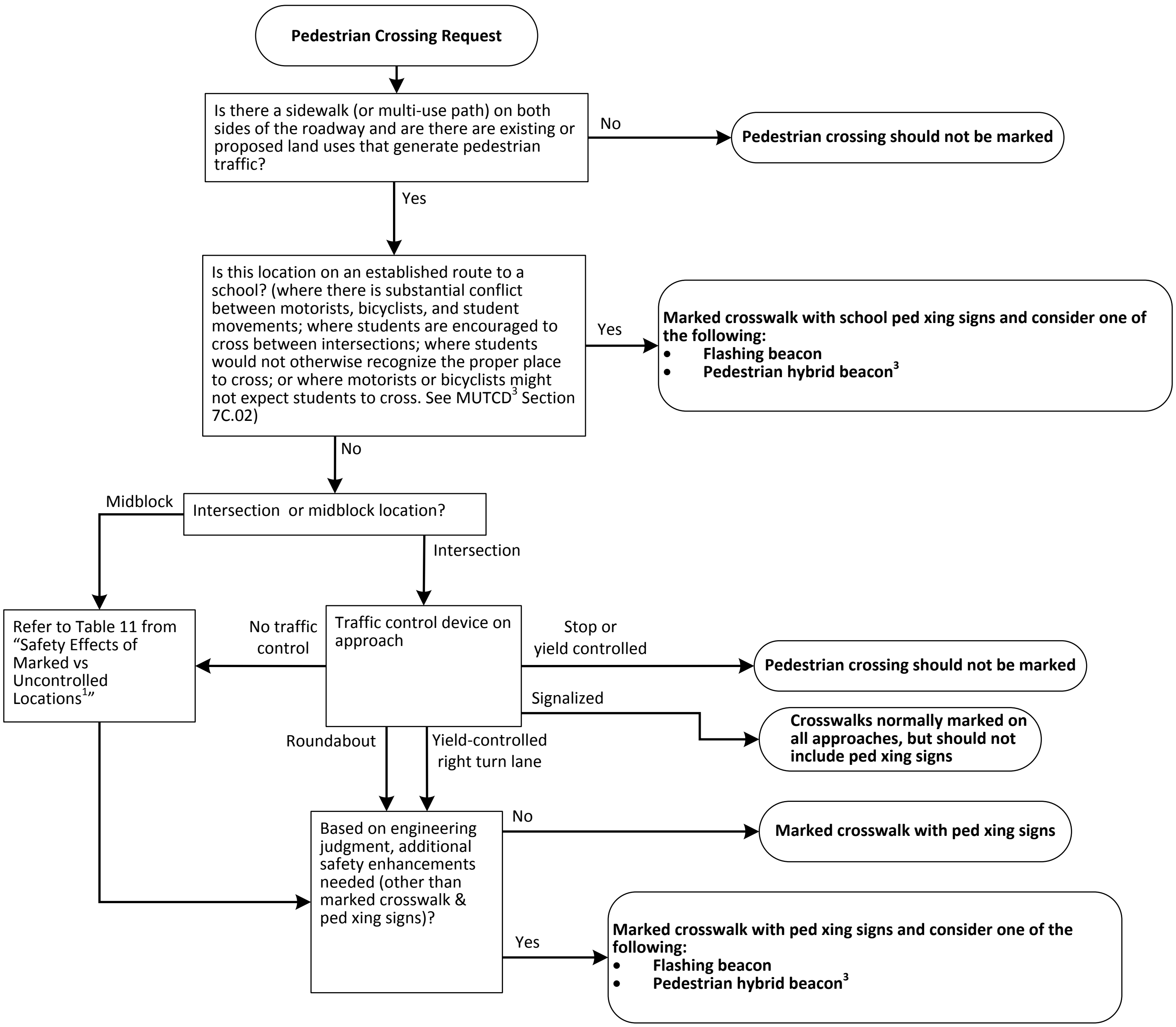
References:

1. ITE, "*Guidelines for the Activation, Modification, or Removal of Traffic Control Signals*", 2005.
2. FHWA, *"User Guide For Removal of Not Needed Traffic Signals"*, November 1980.

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[2]. 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, "Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations", September 2005.
2. NDDOT, "Design Manual," July 28, 2014. (Appendix III-10B)
3. FHWA, "Manual on Uniform Traffic Control Devices", 2009.