TRANSPORTATION RESEARCH SYNTHESIS

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Right and Left Turn Lane Warrants

Introduction

The genesis of this project stems from a perception by city and county engineers that there is a lack of guidance relative to the installation of right and left turn lanes along local road systems. An initial review found The *Minnesota Department of Transportation (MnDOT) Road Design Manual (RDM)* has guidance for when turn lane installation is warranted along the State's roadway system, but the focus is reconstruction. Many times separated turning and through volumes are required in order to determine whether or not a turn lane is needed, as well as to determine the length of the turn lane. This lack of guidance for local systems may cause some agencies to miss out on opportunities to build turn lanes when needed, to work with the zoning (permitting) authority and/or to have a developer pay for the cost of a turn lane as part of their development project.

CH2M HILL was asked to conduct a literature review to determine what existing turn lane guidance is available and being used by different agencies. The review focused on six key areas that local agencies are concerned with and encounter when deploying turn lanes on their road systems and include both long-term and short-term scenarios.

Consistent with MnDOT Transportation Research Syntheses, the objective of this project is to search existing literature and how it relates to the topic of providing guidance for installing right and left turn lanes along local systems, but not about developing new guidance. The summary of those findings are below, along with suggested next steps, followed by the individual literature results.

Summary

There are national and local guidelines available that provide guidance on turn lane installation. Seventeen documents were reviewed, focusing on six relevant areas to turn lane installations on local roads. The six focus areas included:

1. Corridor Design/Redesign (Long-Term)
2. Development Driven (Short-Term)
3. Problem Oriented, Safety, Operations, Maintenance and Removal
4. Access Management
5. Functional Systems
6. Pedestrian and Bicycle Considerations

Most of the documents only discussed specific focus areas and not the full range of review options. Figure 1 demonstrates a breakout of each document reviewed and the quality of information provided in each document regarding the six focus areas.

Corridor Design (Long-Term)

Corridor Design (Long-Term) turn lane information was prevalent among twelve of the seventeen documents. *MnDOT's RDM, North Dakota Department of Transportation's (NDDOT) Turn Lane Guidance* and *Federal Highway Administration's (FHWA) Signalized Intersection Guide* provided the most information on the topic.

In general, left turn lanes should be considered during development of reconstruction projects at ALL median openings if most intersections on a corridor will have them. At rural, multi-lane intersections, turn lanes should generally be provided at every public road intersection. Other turn lane locations are based on through, opposing and turning traffic volumes and speed in various references. In addition, designers are asked to consider seasonal variations in traffic volumes to determine the appropriate design with little guidance as to where in the seasonal fluctuations should be chosen.
Most of the guidance and recommendations are intended for the State highway system and are based on traffic turning volumes, typically in design (20) year forecasts. This type of detailed forecast is frequently unknown along the local road systems and in developing areas, creating decision making challenges for designers of projects on local systems.

Development Driven (Short-Term)

Development Driven (Short-Term) turn lane guidance was not as frequently discussed as long-term, corridor design solutions, but was mentioned in six of the seventeen documents. *Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)* provided the most information on the topic.

Development and redevelopment projects should address the need for turn lanes as part of an impact analysis of traffic operations and it was suggested that developers should provide right turn lanes that are expected to generate over 100 trips a day. *Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads* suggests an analytical process for identifying candidate locations for turn lanes based on two approaches – the operations analysis of land development/redevelopment and consideration of functional systems.

Document	Corridor Design (Long-Term)	Development Driven (Short-Term)	Problem Oriented (Safety, Ops, Maint & Removal)	Access Management	Functional Systems	Ped/Bike Considerations	Notes
Road Design Manual	●	○	◑	○	○	○	
AASHTO Green Book	◔	○	○	◔	●	○	
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)	◑	◑	○	○	●	○	
Highway Safety Manual	◔	○	○	○	○	○	
Highway Capacity Manual	◔	◔	○	○	◔	○	
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads	◔	○	◔	○	○	○	
Safety Effectiveness of Intersection Left- and Right-Turn Lanes (FHWA)	○	○	◑	○	○	○	
Left-Turn Lane Installation Guidelines (TTI)	◔	○	○	○	○	○	
NDDOT Guidelines for the Installation of Turn Lanes along State Highways	●	◔	○	○	○	○	
FHWA Signalized Intersections: Informational Guide	●	○	◔	○	◔	○	
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	◔	○	○	○	◑	○	
Dakota County 2030 Transportation Plan	◔	○	○	●	◔	○	
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)	○	○	○	●	◔	○	
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines	○	◔	◔	○	◔	○	*Close median opening if it meets signal warrant, but bad spacing does NOT allow install
Intersection Channelization Design Guide	◔	○	○	○	◔	○	
City of Rochester Zoning Ordinance and Land Development Manual	○	◑	○	○	○	○	
Scott County Traffic Impact Analysis Process	○	◑	○	○	○	○	

● = Excellent Info ◕ = Fair Info ◑ = Some Info
◔ = Little Info ○ = No Info

Figure 1 - Literature Overview

The issue with development driven turn lanes is that zoning (permitting) authority typically falls to Cities, while Counties and MnDOT have no authority (with the exception of Dakota County) in the permitting and zoning process to hold the developer accountable for installing and paying for a turn lane.

Problem Oriented, Safety, Operations, Maintenance and Removal (of Turn Lanes)

Problem oriented, safety, operations, maintenance and removal turn lane solutions are mentioned briefly in five of the seventeen documents with the most comprehensive analysis in the *MnDOT RDM* and *FHWA's Safety Effectiveness of Turn Lanes.*

The literature suggests that left turn lanes should be provided at all public road median crossovers, non-public access to high traffic generators and at hazardous locations determined by MnDOT's District Traffic Engineer. Other turn lanes should be provided at locations determined by the agency traffic engineer in consideration of safety, capacity and traffic volumes. The need for right turn lanes should consider a cost to install versus savings benefit based on average daily traffic (ADT) volumes and right turning traffic volumes.

The City of Tucson Access Management literature recommends closing a median if an arterial intersection with a less public road or private driveway meets the volume warrant threshold for a signal, but the spacing is determined to be undesirable for the installation of the signal.

There are proven safety benefits associated with both left and right turn lanes. The *Highway Safety Manual* states that left turn lane installations generally reduce crashes by 4 percent to 58 percent, while right turn installation can reduce crashes by 4 percent to 41 percent.

While the safety benefits of turn lanes are proven, guidance for how to identify and retrofit locations appearing to have problems was not mentioned in any of the literature. It is a benefit to agencies to identify turn lane installation locations early on in the scoping process to qualify for funding these locations.

Access Management

Access management guidance was provided in three of the seventeen documents with the *Dakota County 2030 Transportation Plan* and the *MnDOT Access Management Manual* providing the most in depth information.

Uncontrolled development is discouraged and by controlling development and access points, traffic operations improve. MnDOT provides guidance for access management based on divided versus undivided highways and utilizing trips per day. It has also been demonstrated on the Minnesota State and secondary rural system that crashes increase with increased access density along a corridor. This concept is similar around the country and, therefore, most of the recommendations are based on judicious use of median openings and access points.

However, it needs to be noted that both MnDOT and county highway departments face considerable challenges enforcing decisions to manage access because they are not the zoning authority and have only rarely purchased rights of access from abutting properties.

Functional Systems

Turn lanes related to roadway functional class was mentioned in nine of the seventeen documents, with the most comprehensive analysis in *AASHTO's A Policy on Geometric Design of Highways and Streets* and *Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads*.

Turn lanes are typically desirable along higher functioning roadways. Principal arterials should have left turn lanes, minor arterials should have left turn lanes with most intersections, collectors should have left turn lanes at intersections with principal arterials and a hybrid of other intersections. Turn lanes are also desirable on 2-lane, high speed roadways.

Most of the guidance for turn lanes using functional systems is inferred and still subject to engineering judgment.

Pedestrian and Bicycle Considerations

In all of the literature, there was no mention of pedestrian and bicycle considerations when it came to turn lane warrants. It is known, however, that there are tradeoffs in terms of pedestrian and bicycle facilities versus turn lanes from a roadway width and operations perspective. Channelized turn lanes can create a safety refuge for pedestrians. However, the more lanes a pedestrian or bicycle has to cross, increases the chance for the bicycle or pedestrian to be hit.

Suggested Next Steps

The members of the Technical Advisory Panel (TAP) suggested that the most useful immediate next step would be to develop a decision tree(s) that lists the key factors an agency should consider during the evaluation process of determining whether or not a turn lane should be constructed at a particular location (Right and Left Turn Lane Warrants Toolbox – attached at back). An additional benefit of the decision tree concept is that it could not only document a thought process, but also at the bottom line, identify either an existing resource/document already available to assist engineers in their evaluation of turn lane needs or identify gaps that represent opportunities for further research efforts.

The review of the literature dealing with turn lane needs combined with comments from the TAP suggests both a basic outline for the decision process and an initial list of the key factors that should be considered. It appears that the decision tree would actually consist of four trees (State System Segments, State System/Intersections, Local System/Segments and Local System/Intersections) and six levels (System, Segment or Intersection, Long-Term or Short-Term, Supporting Analysis, Data Needs and Existing Resource or Research Opportunity). A description of, and the rationale in support of these levels is provided in the following paragraphs.

System

The distinction between state and local systems addresses the fact that there is frequently a difference in function, volume and funding. In addition, the literature search found substantial guidance available for state highways, but very little for roadways on local systems. Further, it was important to the TAP not to be forced to use guidelines for state highways because equivalent guidelines for local roadways do not exist and the state guidelines do not acknowledge differences in needs between the systems.

Segment or Intersection

The distinction between segments and intersections suggests that the thought process, for example, twenty intersections along a ten-mile segment should be different than the process if only the needs for a single intersection are being considered. It appears that the issue of uniformity/consistency is of much greater importance when considering the need for turn lanes at multiple locations along a segment than when considering a single intersection.

Long-Term or Short-Term

Long-term roadway needs are typically addressed during reconstruction and because of funding limitations, most highway agencies are on a reconstruction cycle of more than 50 years. This extended road life suggests two critical considerations related to determining the need for turn lanes; forecasts of future traffic because of the need to maintain a reasonable quality of operation far beyond the traditional 20 year design life assumed for most projects and consistency in the use of turn lanes even though the actual need may not occur until years in the future (corn field today vs. 200 home subdivision 10 years from now).

When addressing short-term issues (maintenance, safety and development), it may not be as important to address consistency (with nearby intersections) or long-term traffic forecasts because there would still be the ability to do that during a future reconstruction project.

Supporting Analysis

The various types of technical analyses that support an agency's determination of the need for turn lanes are mostly uniform (safety, operations and consistency), with differences related to data needs and the depth of analysis. For example, the operational analysis associated with long-term reconstruction projects should include a more in-depth and rigorous analysis of traffic operations than would be needed to support a maintenance overlay. The rigorous analysis operations would likely be *Highway Capacity Manual* based (SYNCHRO) while the less rigorous analysis could use ADT vs. Level of Service estimates (Figure 2). The more rigorous analysis supports the need to address design issues over the extended life of reconstruction projects and can also provide insight about specific turn lane design features, such as recommended length of a turn lane. The length of a turn lane should accommodate deceleration plus storage, which is an output of rigorous operations analysis. It also suggests that more rigorous analysis is required for development driven projects to provide better documentation

and support for recommended turn lane additions to the system since cost sharing is frequently an issue.

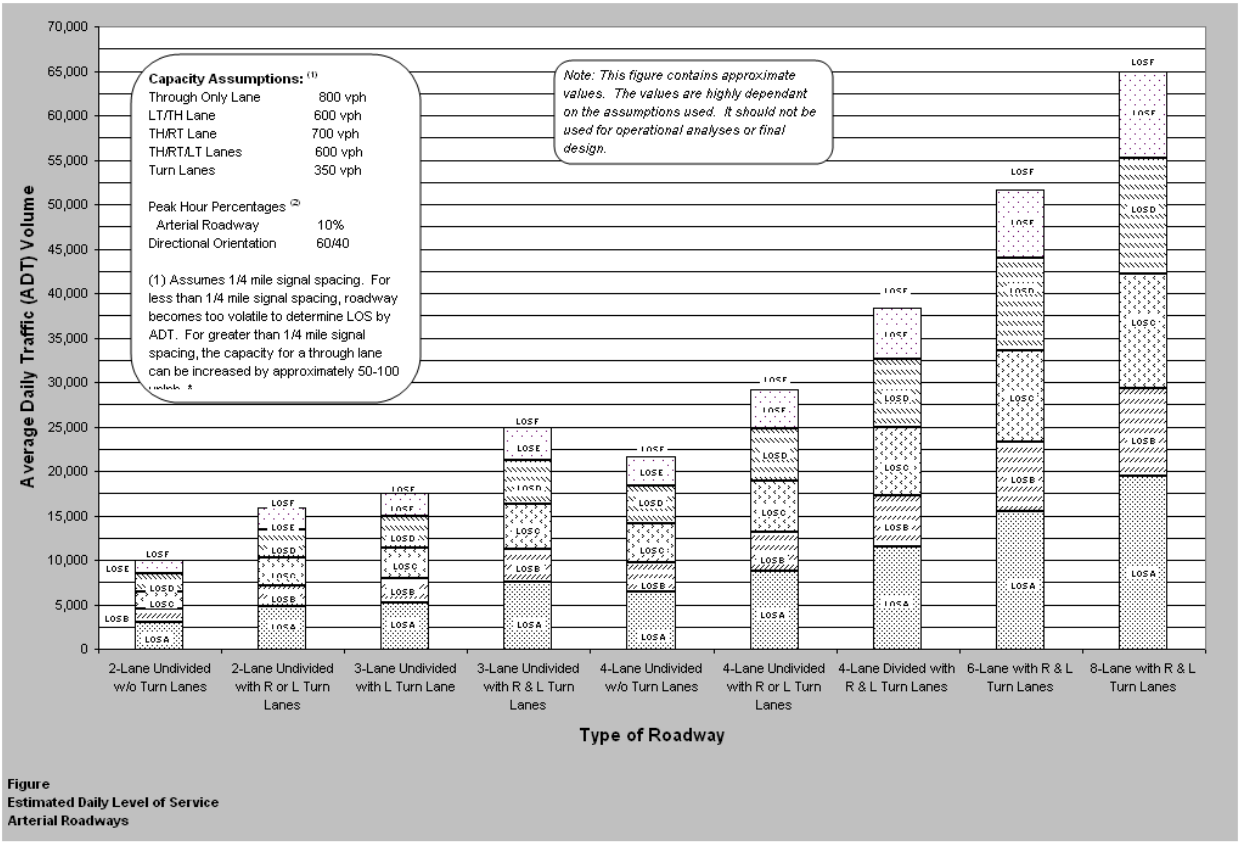


Figure 2 - ADT vs. Level of Service Estimate

A final issue related to supporting analyses deals with the consideration of consistency in the installation of turn lanes. It is suggested that achieving consistency among similar intersections along a given segment is an extremely important consideration as part of the long-term analysis of needs associated with reconstruction, but is less of an issue for short-term projects.

Data Needs

The data needs are typically roadway and traffic characteristics and are more documentation of the input to the technical analyses than differentiators and are common across the decision trees. The basic roadway, traffic and environmental characteristics to consider in determining a turn lane warrant are documented in Table 1 below.

Table 1 - Data Needs to Consider for Turn Lane Warrants

Characteristic	Long-Term	Short-Term
Roadway		
- Functional Class	X	
- Cross Section		X
- Speed Limit	X	X
- Terrain	X	X
- Access Density	X	X
- Ped/Bike Accommodations	X	X
Traffic		
- Existing ADT	X	X
- Forecast ADT	X	
- Peak Hour Volume	X	X
- Peak Hour Turning Volumes	X	X
- % Heavy Commercial	X	X
- Number of Ped/Bikes	X	X
Intersection Control		
- Through/STOP	X	X
- All-Way STOP	X	X
- Signal	X	X
- Roundabout	X	X
Area/Environment		
- Rural	X	X
- Urban	X	X
- Central Business District	X	X
- Commercial	X	X
- Residential	X	X
Cost/Right-of-Way	X	X

Existing Research or Research Opportunity

The bottom line of each decision tree identifies either the existing resource relating to documentation of turn lane needs for a specific set of system, segment or intersection and long- or short-term conditions or an opportunity for additional research to fill a gap.

The conclusion of the effort to develop an initial set of four decision trees resulted in the bottom line identification of 17 existing reference documents that provide guidance for determining turn lane needs and 3 gaps that represent opportunities for new research as indicated in Table 2.

Table 2 - Decision Tree Summary and Conclusions

	State System	Local System	
	Segment/Intersection	Segment	Segment/Intersection
	Long-Term/Short-Term	Long-Term	Short-Term/Intersection Long-Term
	Technical Analysis		
Existing References	Road Design Manual	Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)	Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)
	AASHTO Green Book	Highway Safety Manual	Highway Safety Manual
	Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)	Highway Capacity Manual	Highway Capacity Manual
	Highway Safety Manual	MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads	MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads
	Highway Capacity Manual	Left-Turn Lane Installation Guidelines (TTI)	Left-Turn Lane Installation Guidelines (TTI)
	MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads	Dakota County 2030 Transportation Plan	Dakota County 2030 Transportation Plan
	Left-Turn Lane Installation Guidelines (TTI)	City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines	City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines
	NDDOT Guidelines for the Installation of Turn Lanes along State Highways	Intersection Channelization Design Guide	Intersection Channelization Design Guide
	FHWA Signalized Intersections: Informational Guide	City of Rochester Zoning Ordinance and Land Development Manual	City of Rochester Zoning Ordinance and Land Development Manual
	Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	Scott County Traffic Impact Analysis Process	Scott County Traffic Impact Analysis Process
	Dakota County 2030 Transportation Plan		
	MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)		
	City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines		
	Intersection Channelization Design Guide		
	City of Rochester Zoning Ordinance and Land Development Manual		
	Scott County Traffic Impact Analysis Process		
Gaps/Research Opportunities	MnDOT developer driven guidelines	Specific MN documents adopted for long-term warrants on local systems	Specific MN documents adopted for long-term warrants on local systems
	MnDOT short-term guidelines (i.e., what to do as part of a maintenance overlay vs. reconstruction)	Specific short-term MN documents adopted on local systems	Specific short-term MN documents adopted on local systems
	MnDOT guidelines for how to identify problem locations that may warrant turn lanes	Development driven document adopted for use on local systems (Scott County and City of Rochester could be used as models)	Development driven document adopted for use on local systems (Scott County and City of Rochester could be used as models)
	Pedestrian & Bicycle Considerations	How to identify problem locations that may warrant turn lanes	How to identify problem locations that may warrant turn lanes
	Warrants based on crash history & characteristics	Pedestrian & Bicycle Considerations	Warrants based on traffic control device
		Warrants based on crash history & characteristics	Pedestrian & Bicycle Considerations
			Warrants based on crash history & characteristics
		NOTE: While there is some information on desired topics in these references, it is up to the local agency as to whether they want to use, for example, City of Tucson, AZ or create their own, more localized warrants. If agencies would like locally based references, there are more gaps in the information. Agencies can also defer to the State system references if they choose.	

There appears to be a sufficient amount of existing information to suggest when and where turn lanes should be deployed as part of reconstruction projects along the State highway system. However, there is little guidance relating to any short term situations and there are legitimate questions about relevancy of the guidance to local systems and availability of detailed forecasts to support the required analysis.

Information that is readily available to all agencies is roadway functional classification. Based on this and the existing literature, it seems feasible to create a flow chart and matrix using the existing literature and industry knowledge to assist in determining turn lane warrants. Table 3 shows an example of what one of these matrices could be. In this case, the example is a rural, high speed, 2-lane, undivided roadway. Additional matrices would likely be needed to include various road types, including rural, urban, multi-lane, 2-lane, high speed, low speed, divided and undivided.

Table 3 – EXAMPLE: Rural, High Speed, 2-Lane, Undivided Roadway Turn Lane Warrants

Major Street Functional Classification	Cross Street Functional Classification					
	Principal Arterial	Minor Arterial	Major Collector	Minor Collector	Local	Private
Principal Arterial	LTL RTL	LTL RTL	LTL RTL	LTL RTL	Access Not Recommended LTL RTL	Do Not Allow Access
Minor Arterial	LTL RTL	LTL RTL	LTL RTL	LTL RTL	Min. LTL RTL	Do Not Allow Access
Major Collector	LTL RTL	LTL RTL	Min. LTL Min. RTL	Min. LTL Min. RTL	Min. RTL	Min. RTL
Minor Collector	LTL RTL	LTL RTL	Min. LTL Min. RTL	Min. LTL Min. RTL	Min. RTL	Min. RTL
Local	LTL	Min. LTL	Min. LTL	Min. LTL	Paved Shoulder	Paved Shoulder
Private	Do Not Allow Access	Do Not Allow Access	None	None	None	None

Definitions:
LTL = Left Turn Lane
Min. LTL = Minimum Length Left Turn Lane
RTL = Right Turn Lane
Min. RTL = Minimum Length Right Turn Lane

In addition to turn lane warrants by functional classification, if turning traffic volumes and other directional volumes are known, turn lane warrants by volume could also be used based on guidance from the literature.

In the long term, the *MnDOT RDM* could be updated by adding functional class to turn lane warrants in order to address some of the problems that local agencies come across during the

design process to help them work with stakeholders on their projects and install turn lanes when they are warranted.

There is also a need to consider developing separate guidance for local systems given that the *MnDOT RDM* is for State highways and reconstruction projects. Local agencies frequently are involved in turn lane decisions involving problem locations, safety, operations, maintenance and removal issues. This guidance could be provided through MnDOT State Aid or through the MnDOT Research division with short-term warrants that are not addressed through the *MnDOT RDM* or current MnDOT State Aid guidelines.

When considering the need for turn lanes along Minnesota's local road systems, the literature search found a variety of documents that could be used by county and city engineers in their deliberations. These documents include guidelines for state highways (which may not reflect conditions along local roadways), guidelines that partly address the issues common to local systems (AASHTO's Policy on the Geometric Design of Highways and Streets) or provide a fairly comprehensive discussion of guidelines based on the characteristics, practices and ordinances in other states (City of Tucson Transportation Access Management guidelines). In these cases it is important for cities and counties in Minnesota to understand that none of these documents have been officially adopted for use on any local roadway and therefore should be considered no more authoritative than any other research report. From a risk management perspective, local agencies should recall that Minnesota has very good tort law that provides a great deal of protection against claims of negligence through discretionary and official immunity. Discretionary immunity basically covers implementation that is policy driven and this suggest that if an agency is going to use a particular set of turn lanes guidelines for their system, consideration should be given to having their elected body adopt it as part of an ordinance regulating activities including land development and roadway construction and maintenance. Official immunity applies to decisions made by agency staff based on documented engineering studies. The decision trees developed and documented in this TRS provide a reasonably comprehensive list of the roadway and traffic characteristics that should be considered and the technical analyses that would support decisions about implementation. As a result, these decision trees provide a good outline for what would reasonably be included and documented in an engineering study supporting the determination of the need for turn lanes along local roadways.

Literature Review

MnDOT Road Design Manual (2000)

The *MnDOT RDM* is Minnesota's main document with standards and guidelines on roadway design. The *MnDOT RDM* "establishes uniform policies and procedures for the Minnesota Department of Transportation" and can be used for other roadway jurisdictions within the state [1].

Corridor Design/Redesign (Long-Term)

The *MnDOT RDM* states that at urban intersections, on divided highways, left and right turn lanes should be provided at all locations where a paved crossover will be constructed (except

for freeway emergency crossovers). Right turn lanes should also be provided at locations with no crossover as determined by the District Traffic Engineer in consideration of safety, capacity and traffic volumes.

At rural intersections, turn lanes in general should be provided at every public road intersection along a stretch of highway if most intersections on the stretch will have them. On multi-lane, rural highways, right and left turn lanes should be provided at all public access intersections or if an access point serves an industrial, commercial or any substantial trip generator (including more than three residences). On 2-lane, rural highways, right turn lanes should be provided when the forecast ADT exceeds 1,500 vehicles per day (vpd) and the design speed exceeds 45 MPH at public road access points, accesses to high traffic generating industrial and commercial land uses and accesses serving more than ten residences. Left turn lanes should be provided when the access is to a public road, an industrial tract or a commercial center.

Problem Oriented, Safety, Operations, Maintenance and Removal

For preservation projects, at urban intersections, left turn lanes should be provided at all public road median crossovers, non-public access locations generating high traffic volumes, locations determined to present excessive hazard, locations determined by the District Traffic Engineer in consideration of safety, capacity and traffic volumes and where a median opening is planned or exists and its continued existence is justified regardless of what access point it serves. Right turn lanes should be provided at public road intersections or at locations determined by the District Traffic Engineer in consideration of safety, capacity and traffic volumes.

AASHTO's A Policy on Geometric Design of Highways and Streets (2011)

AASHTO's *A Policy on Geometric Design of Highways and Streets (Green Book)* "contains the current design research and practices for highway and street geometric design" [2]. Many state design manuals are based off of this comprehensive reference manual.

Corridor Design/Redesign (Long-Term)

The Green Book has guidelines for left turn lanes on two-lane highways based on volumes and speeds. Left turn lanes are desirable at intersections along arterials to increase capacity and safety. The use of indirect left turn lanes is supported to improve safety along divided roadways. In general, the desirability of left turn lanes cannot be overemphasized.

Table 9-23. Guide for Left-Turn Lanes on Two-Lane Highways (*10*)

Metric					U.S. Customary				
	Advancing Volume (veh/h)					Advancing Volume (veh/h)			
Opposing Volume (veh/h)	5% Left Turns	10% Left Turns	20% Left Turns	30% Left Turns	Opposing Volume (veh/h)	5% Left Turns	10% Left Turns	20% Left Turns	30% Left Turns
60-km/h Operating Speed					40-mph Operating Speed				
800	330	240	180	160	800	330	240	180	160
600	410	305	225	200	600	410	305	225	200
400	510	380	275	245	400	510	380	275	245
200	640	470	350	305	200	640	470	350	305
100	720	515	390	340	100	720	515	390	340
80-km/h Operating Speed					50-mph Operating Speed				
800	280	210	165	135	800	280	210	165	135
600	350	260	195	170	600	350	260	195	170
400	430	320	240	210	400	430	320	240	210
200	550	400	300	270	200	550	400	300	270
100	615	445	335	295	100	615	445	335	295
100-km/h Operating Speed					60-mph Operating Speed				
800	230	170	125	115	800	230	170	125	115
600	290	210	160	140	600	290	210	160	140
400	365	270	200	175	400	365	270	200	175
200	450	330	250	215	200	450	330	250	215
100	505	370	275	240	100	505	370	275	240

Source - AASHTO's A Policy on Geometric Design of Highways and Street

It is also noted that the *Highway Capacity Manual* indicates exclusive left turn lanes at signalized intersections should be installed where exclusive left turn phasing is provided and where left turn volumes exceed 100 vehicles/hour. Double left turn lanes should be considered where left turn volumes exceed 300 vehicles/hour.

Access Management

At intersections, channelizing islands serve the following purposes: separation of conflicts, control of angle of conflict, reduction in excessive pavement areas, regulation of traffic & indication of proper use of intersections, arrangements to favor predominant turning movement, protection of pedestrians, protection & storage of turning & crossing vehicles, and location of traffic control devices.

Limiting left turns along divided roadways to intersections through the use of medians (and the judicious use of median openings) discourages uncontrolled development and access to the highway while promoting improved traffic operations.

Functional Systems

On collector roads and streets, left turn lanes should be added where practical when a median opening exists. A 4-lane rural facility should have adequate median width to provide for protected left turn lanes.

On rural and urban arterials, the liberal use of high type intersections (turn lanes) and interchanges is highly desirable on arterials that do not have fully controlled access. Adequate turning widths with acceleration and deceleration tapers will provide a minimum

design for minor intersections on a minor arterial. Auxiliary turning lanes and adequate turning widths should generally be provided where arterials intersect with other public roads.

On urban arterials, medians are desirable and left turn lanes are always desirable. During high pedestrian hours, right turn restrictions may be warranted. Left turn demands should be accommodated as much as possible, although if it's not feasible, trying to divert traffic away could create other problems, but may work.

Left turning traffic should be removed from through lanes whenever practical, ideally at driveways and street intersections along major arterial & collector roads whenever left turns are permitted (crash reduction 20-65%). Establish left turn lanes where volumes are high enough or where safety considerations warrant them.

Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)

Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (incorporated into the *MnDOT Turn Lanes Policy*) is "a resource to assist local agencies in their efforts to better design, operate and maintain their system of roads and highways" [3]. The practices and policies are consistent with national research and are intended primarily for new construction.

Corridor Design/Redesign (Long-Term)
Turn lanes should be provided at major traffic generators on undivided and divided highways based on two approaches – operations analysis of development/redevelopment and functional systems.

Development Driven (Short-Term)
Development and redevelopment projects should address the need for turn lanes as part of an impact analysis of traffic operations. Developers should provide right turn lanes at their expense at all public road access points and private entrances serving commercial or industrial property that is estimated to generate over 100 trips per day. Left turn or bypass lanes should be provided if other similar access points along the same segment of roadway have left turn or bypass lanes.
Functional Systems
The use of left turn lanes is suggested based on the concept of functional hierarchy.

Principal Arterials should have full length left turn lanes at intersections with Minor Arterials, Collectors and Local Streets (if allowed and no access from private driveways).

Minor Arterials should have full length left turn lanes at intersections with Principal Arterials and Minor Arterials and a hybrid minimum length left turn lane (lower cost) at intersections with Collectors and Local Streets.

Collectors should have full length left turn lanes at intersections with Principal Arterials and hybrid minimum length left turn lanes at intersections with Minor Arterials and other Collectors.

Major Street Functional Classification	Cross Street Functional Classification				
	Principal Arterial	Minor Arterial	Collector	Local Street	Private Driveway
Principal Arterial	LTL	LTL	LTL	LTL (N.R)	N.A.
Minor Arterial	LTL	LTL	Min LTL	Min LTL	Paved Shoulder
Collector	LTL	Min LTL	Min LTL	Paved Shoulder	Paved Shoulder
Local Street	LLT	Min LLT	Paved Shoulder	Paved Shoulder	Paved Shoulder

Source: MnDOT Turn Lanes Policy

AASHTO's Highway Safety Manual (2010)

"The *Highway Safety Manual (HSM)* is a resource that provides safety knowledge and tools in a useful form to facilitate improved decision making based on safety performance" [4]. The *HSM* presents tools to quantitatively determine safety effects of various geometric implementations in roadway design.

Corridor Design/Redesign (Long-Term)

Providing left and right turn lanes on both rural 2-lane and multi-lane roads are associated with crash reduction (20-50% for left turn lanes and 5-15% for right turn lanes). On multi-lane urban and suburban arterials, divided roadways have the lowest expected crash frequency and providing left turn lanes is associated with crash reduction (10-50%).

The *HSM* states that "methods are provided to integrate quantitative estimates of crash frequency and severity into planning, project alternatives analysis, and program development and evaluation, allowing safety to become a meaningful project performance measure"[4]. This suggests that the guidance is primarily intended to be applied during corridor design/redesign (it appears to be assumed that safety analysis is already being conducted as part of projects specifically focused on responding to safety deficiencies).

TRB's Highway Capacity Manual (2010)

The *Highway Capacity Manual (HCM)* provides "a set of methodologies, and associated application procedures, for evaluating the multimodal performance of highway and street facilities in terms of operational measures and one or more quality-of-service indicators" [5].

Corridor Design/Redesign (Long-Term)

HCM analysis can indicate when the addition of a turn lane will result in acceptable level of service, but is not sufficient justification by itself for installing a turn lane. Values are provided to determine delays due to turning vehicles based on number of intersections. If the turn bay has adequate queue length, no delay is experienced. The *HCM* can model turn lane effects on signalized and unsignalized intersections, however, there is currently no model for the effects of turn lanes on highway speeds. Equations are provided for maximum queue, flow, capacity, delay due to turns, etc. The *HCM* provides 4 checks for determining if a left turn phase is needed: if there is more than 1 turn lane on approach, if there are more than 240 vehicles/hour, if the crossproduct of the left turns and opposing mainline vehicles is greater than the chart provided, or by comparing the left turn volume with "sneaker" capacity and equivalent factors.

Functional Systems

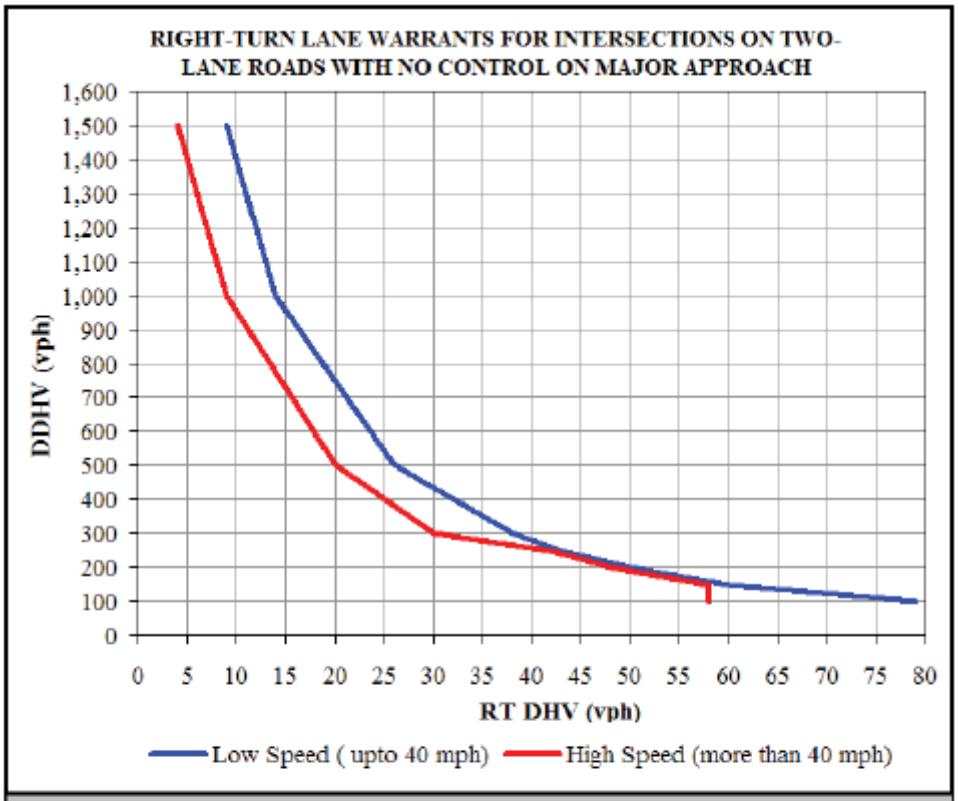
Turn lanes are desirable at selected locations on 2-lane highways to reduce delays to through vehicles caused by turning vehicles and to reduce crashes.

Warrants for Right-turn Lanes/Treatments on Two-lane Roads (2008)

The *Warrants for Right-turn Lanes/Treatments on Two-lane Roads* project analyzed "geometric, speed, volume, and crash data for a broad range of conditions with the ultimate objective of establishing bases for warrants for right-turn lanes on two-lane roads where major approach did not have any controls" [6].

Corridor Design/Redesign (Long-Term)

Warrants for right turn lanes were developed based on establishing traffic volume thresholds for design hour volumes on the main highway and hourly right turn volumes that attempt to strike a balance between the cost of installing the turn lane and the operational and safety savings resulting from the right turn lane. If the right turn lane costs $20,000 to install, the combination of 200 through vehicles and 60 right turning vehicles per hour would warrant the installation of the tight turn lane. If the right turn lane costs $50,000, the use of right turn lanes would begin to be warranted at through volumes exceeding 600 vehicles per hour. (See Chapter 6 – Development of Warrants for charts – sample below.)



Minimum Right-turn DHV (vph) Required to Warrant a Right-turn Lane
(Right-turn Lane Cost = $20,000 / Cost of Fuel = $3)

Speed	DDHV (vph)							
(mph)	100	150	200	250	300	500	1,000	1,500
≤ 40	79	60	50	43	38	26	14	9
> 40	58	58	48	42	30	20	9	4

Figure 6.7. Right-turn lane warrants for intersections (fuel cost $3/gallon, delay cost $13/hr, right-turn lane cost $20,000).

Source: Warrants for Right-turn Lanes Treatments on Two-lane Roads

Problem Oriented, Safety, Operations, Maintenance and Removal

Operational costs savings resulting from right turn lanes were identified, however, the savings primarily accrue at Average Daily Traffic (ADT) volumes greater than 10,000 vehicles per day and with right turn volumes exceeding 25%. Annual safety cost savings resulting from right turn lanes at intersections and driveways were identified, however, the savings primarily accrue at ADT's greater than 5,000 vehicles per day and right turn volumes exceeding 25%. (See Chapter 6 – Development of Warrants for charts.)

Right turns can result in rear end, sideswipe, right angle and right turn conflicts. Many of these crashes are associated with operating speeds, surface conditions, weather conditions, turn treatments and driver inattention.

Right turn lanes variably increase safety, more so at commercial and public driveways than intersections. Right turn special treatments are less critical than left turn treatments.

FHWA's Safety Effectiveness of Intersection Left- and Right-Turn Lanes (July 2002)

FHWA's *Safety Effectiveness of Intersection Left- and Right-Turn Lanes* report reviewed a "before-after evaluation of the safety effects of providing left- and right-turn lanes for at-grade intersections" [7].

Problem Oriented, Safety, Operations, Maintenance and Removal
Improved versus unimproved intersections were compared with the installation of left and/or right turn lanes or turn lane lengthening. Two-way STOP and signalized intersections were analyzed, however, intersections to shopping centers or schools were eliminated since peak hour volumes vary, only turn lanes at Thru-STOP intersections on major roads were considered and at signals, any approach was included.

At unsignalized intersections, adding a left turn lane at a rural intersection produced a 28% crash reduction for 4-legged and 44% crash reduction for 3-legged intersections. In urban, unsignalized locations, a 27% crash reduction was observed at 4-legged and 33% for 3-legged intersections. Adding a right turn lane at these locations produced an overall 14% crash reduction (27% on individual approaches) in rural locations.

At signalized locations, adding a left turn lane in an urban location reduced crashes by 10% on 4-legged intersections. A right turn lane reduced crashes by 4% in an overall intersection and by 18% on each individual approach leg.

Adding turn lanes on both approaches is expected to reduce crashes by not quite double that of one leg. No reliable statistics were found for lengthening a turn lane. Turn lanes in rural areas were found to have a higher crash reduction than urban.

Left-Turn Lane Installation Guidelines (2003)

The report on *Left-Turn Lane Installation Guidelines* "reviewed eight selected techniques and a number of criteria present in state manuals" to determine the best methods to use for left-turn lane installation warrants [8].

Corridor Design/Redesign (Long-Term)
While it is not specifically mentioned, the guidelines appear to suggest consideration during corridor design/redesign. Left turn lanes are suggested along 2-lane highways at intersections where the product of opposing through volume and percent left turns exceed threshold values for 30 MPH, 50 MPH and 70 MPH.

Table 5. Guidelines for Installing Left-Turn Lanes on Two-Lane Highways.

Vo	Percent Left Turns		
	10	20	40
30 mph (50 km/h)			
800	197	148	121
700	217	162	133
600	238	178	146
500	261	196	160
400	286	215	175
300	314	236	193
200	345	259	211
100	380	285	232
0	418	313	256
50 mph (80 km/h)			
800	153	115	94
700	168	126	103
600	184	138	113
500	202	152	124
400	222	166	136
300	244	183	149
200	268	201	164
100	294	221	180
0	323	243	198
70 mph (110 km/h)			
800	88	66	54
700	97	73	59
600	106	80	65
500	117	88	71
400	128	96	78
300	141	105	86
200	154	116	95
100	170	127	104
0	187	140	114

Source: Left-Turn Lane Installation Guidelines

Problem Oriented, Safety, Operations, Maintenance and Removal

Other research indicates that Left Turn Lanes are associated with reduced crashes (7%-48%) and reduced delays.

NDDOT's Guidelines for the Installation of Turn Lanes along State Highways (2011) [9]

The NDDOT created guidelines for when to install turn lanes along state highways, providing guidance for turn lane criteria, turn lane offsets, cost participation and timing of turn lane, turn lane design and turn lane maintenance.

Corridor Design/Redesign (Long-Term)

Turn lane criteria is broken out based on speed limits at non-controlled approaches to intersections.

On uncontrolled, higher speed (greater than or equal to 50 MPH) approaches, the following criteria come into play:

Volume Criteria

1) 2-Lane Rural Highways with Speed > 50 MPH – for uncontrolled approaches, turn lanes are suggested when the major corridor Average Daily Traffic (2-way) is greater

than 750 vehicles per day and the left or right turn movement (one direction) is greater than 125 vehicles per day.

2) Multi-Lane Highways with Speed > 50 MPH – for uncontrolled approaches, turn lanes are suggested when the major corridor Average Daily Traffic (2-way) is greater than 750 vehicles per day and the left or right turn movement (one direction) is greater than 75 vehicles per day.

Crash Criteria

1) For uncontrolled approaches, turn lanes are suggested where there have been two crashes in three years or three crashes in five years of types that are susceptible to correction by a turn lane.

Engineering Judgment

1) For uncontrolled approaches, a turn lane is suggested based on engineering judgment at locations identified in traffic operations studies.

On uncontrolled, lower speed (less than or equal to 45 MPH) approaches, the following criteria come into play:

Engineering Judgment

1) For controlled approaches of any approach with posted speed < 45 MPH, turn lanes are suggested based on engineering judgment at locations identified in traffic operations studies.

Development Driven (Short-Term)

Turn lanes may be installed at locations that do not meet any of the technical criteria if requested and if the requestor agrees to pay 100% of the turn lane installation costs.

FHWA's Signalized Intersections: Informational Guide (August 2004)

FHWA's *Signalized Intersections: Informational Guide* "is a comprehensive document that contains methods for evaluating the safety and operations of signalized intersections and tools to remedy deficiencies" [10]. Treatment review ranged from low-cost measures such as signal timing to high-cost measures such as grade separation.

Corridor Design/Redesign (Long-Term)

Exclusive left turn lanes are generally based on left turning volume and opposing traffic volumes, intersection design and safety implications. An exclusive left turn lane should be investigated when the left turn volumes exceed 100 turning vehicles per hour and dual left turn lanes when volumes exceed 300 turning vehicles per hour.

Exclusive right turn lanes reduce the amount of green time needed for through lanes and reduces the impedance between slower right turning vehicles and through traffic. Exclusive right turn lanes should be considered when the right turn volume and adjacent through lane volume exceeds 300 vehicles per hour.

Items to consider when adding left turn lanes include functional class, prevailing approach speeds, intersection capacity, proportion of approach vehicles turning left, volume of opposing through traffic, design conditions and crash history with turning vehicles.

Consider right turn lanes based on vehicle speeds, turning and through volumes, truck percentage, approach capacity, desire to provide right turn on red operations, type of highway, arrangements/frequency of intersections, crash history involving right turns, pedestrian conflicts and right of way.

Problem Oriented, Safety, Operations, Maintenance and Removal
Separating conflict points at intersections by adding turn lanes will increase capacity and safety.

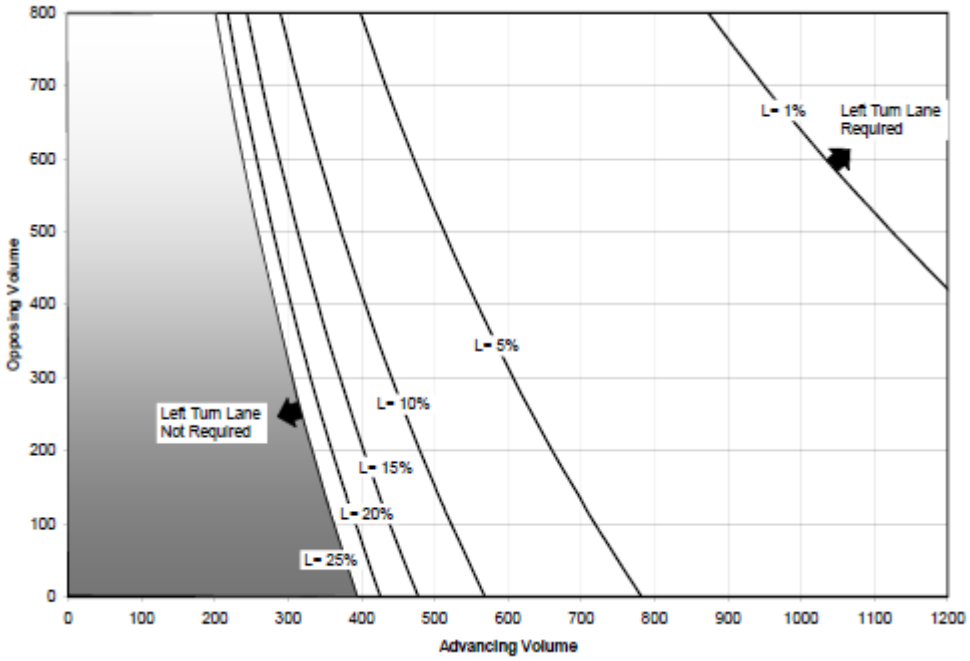
Functional Systems
Consider left turn lanes for higher functioning class facilities (arterials & principal arterials).

Auxiliary Turn Lanes

The Kentucky Transportation Center did a project on "criteria for the design and justification of auxiliary turn lanes" [11].

Corridor Design/Redesign (Long-Term)
Left turn lanes should be provided at all median openings along divided roadways, all non-stopping approaches of rural arterials and collectors or all other approaches where required on the basis of capacity and safety.

Functional Systems
Left turn lanes should be provided at intersections along arterials and collectors with major approaches at signalized intersections, STOP controlled approaches when indicated by capacity analysis or considered as a safety countermeasure, or on uncontrolled approaches on undivided roads where the product of opposing and advancing volume exceeds specified thresholds for 1%, 5%, 10%, 15%, 20% and 25% left turns.



Inputs

- *L = Percent Left-Turns*
- *Advancing Volume = Through + Left + Right-Turn Traffic*
- *Opposing Volume = Through + Left + Right-Turn Opposing Traffic*

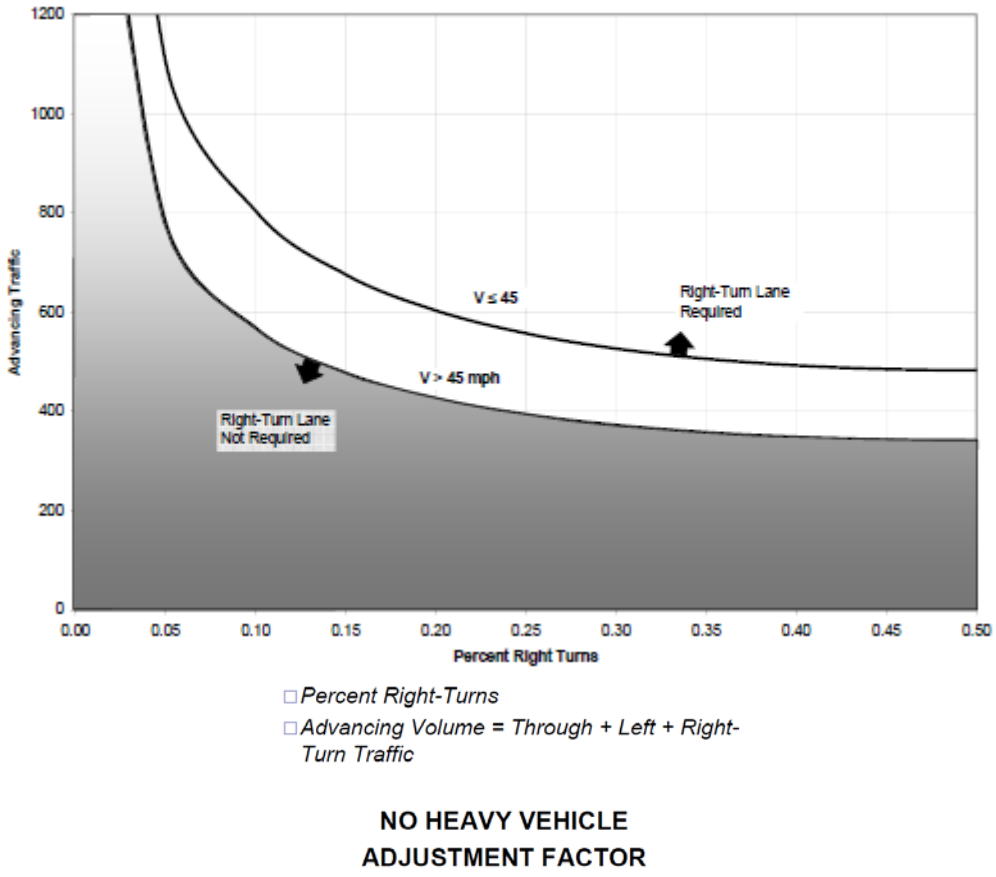
Heavy Vehicle Adjustment Factor

$v_A' = v_A[1+P_{HV}(E_{HV})]$

- v_A' = Adjusted advancing traffic volume
- v_A = Unadjusted advancing traffic volume
- P_{HV} = Percent heavy vehicles
- E_{HV} = Passenger car equivalency factor
  = 0.00035 (v_O) (two-lane facilities)
  = 0.0007 (v_O) (four and six-lane facilities)
- v_O = Opposing traffic volume

Source: Auxiliary Turn Lanes

Right turn lanes should be provided at uncontrolled approaches along arterials and collectors and where the product of the advancing volume and percent right turn volume exceeds specified thresholds for speeds under 45 MPH and 45 MPH and greater.



Source: Auxiliary Turn Lanes

Dakota County 2030 Transportation Plan (June 2012)

The Dakota County 2030 Transportation Plan "consists of six goals with desired outcomes, products or services provided by the transportation system" [12]. Goals are supported by "strategies, policies and performance measures" [12].

Corridor Design/Redesign (Long-Term)

On undivided highways, speed is considered and access spacing guidelines are reduced for low speed, higher volume roadways. There is a greater flexibility for partial access on high volume roads.

Access Managment

Dakota County has an access management policy and reviews access needs through corridor studies, traffic reviews of specific development proposals and a County Plat Commission to identify the type and best location of access that should be permitted. Data is required for developments so that the County can understand the impacts, operation needs and improvements. From this, the County can then stipulate the specific access spacing requirements through the Plat Commission and specify the best location and requirements for access through the permitting process.

The County reviews the design and plans the right number of access points and conflicting maneuvers to result in minimal delay, improved traffic movement and safety of the system. It is recognized that specific corridor access plans may supersede the guidelines and access should be provided from lower functioning roadways when practical.

Left turns may necessitate the removal or modification of partial access intersections in order to have good visibility. Accesses within 1,000 feet of an intersection make it difficult to accommodate turn lane tapers, storage areas and weaves.

Functional Class

Spacing and access guidelines are based on functional class, speed and ADT as demonstrated in Table 10 from the plan.

Table 10: Dakota County Access Guidelines (Spacing and Configuration)

Road Type (A)	Posted or Design Speed	Projected 2030 Average Daily Traffic	Full Movement Intersection	Partial Movement Intersection (B)
Principal Arterial	All	All	½ mile	¼ mile (C)
Divided Highway	All	> 35,000	½ mile	¼ mile (C)
	All	< 35,000	¼ mile	⅛ mile
Undivided Highway	(≤ 40 mph)	All	⅛ mile	N/A
	(≥ 45 mph)	> 1,500	¼ mile	N/A
	(≥ 45 mph)	< 1,500	Allowed per (D)	N/A

(A) Road type refers to the anticipated future roadway cross-section and functional classification.

(B) Partial Movement intersections do not allow left turns from the minor street to the major street or movements straight across the major street. Movements that are allowed will be based on engineering study.

(C) Right-in/right-out access may be permitted *at approximately ⅛ mile* for public or private (See Note #3) streets if the County determines the access improves the overall safety and/or efficiency of the transportation system.

(D) Private street or driveway access requests will be considered based on engineering judgment and the following factors: location, distance from other driveways and intersections, alignment with other access points, easement/access rights that allow widespread usage and system connectivity, the potential to combine accesses, visibility, adjacent land use, and other operational/safety issues.

N/A – Not Applicable to undivided roadway segments.

Access Spacing Notes:

1. These are minimum access spacing guidelines. The County may require accesses be spaced at distances greater than the minimums considering conditions specific to any County highway segment.
2. County roadways with full movement access spacing of ½ mile are shown in Figure 31. Considerations include regional transitways, adopted studies, principal arterials, system continuity and projected ADT > 35,000.
3. Access to County roadways is typically provided through public street connections. Private access will be considered along the County roadway system based on engineering assessment of the function and use of the private access point in consideration of the spacing criteria.
4. Specific corridor access plans or project designs developed through a public process and adopted by the County Board shall supersede these guidelines.
5. Medians may be added or median openings may be removed or modified at any time by the County to address safety and/or operational issues identified through engineering review.
6. Where there is opportunity for access on more than one public roadway, access shall be provided from the lower-function roadway, unless deemed impractical by the County. To support the objectives of system efficiency and connectivity, access to the higher-function County roadway may be allowed in addition to the lower-function roadway, provided there is adequate distance to accommodate access based on these access guidelines.

Source: ***Dakota County 2030 Transportation Plan***

MnDOT Access Management Manual [13]

MnDOT created an access management policy for state trunk highways that is outlined in this manual. Turn lane guidance and examples are in chapter three.

Access Management

Turn lane guidelines on divided trunk highways include:

1) Left turn lanes on all public street connections and median openings (except freeway emergency crossovers)
2) Right turn lanes on all public street connections, residential driveways serving 6 or more units and driveways with more than 50 trips/day
3) Right turn lane treatments (modification to shoulder, i.e., widening the paved shoulder, removing conflicting striping and shoulder rumble strips, prohibiting on-street parking on the widened shoulder and adding pavement thickness on the shoulder) at all field entrances, residential driveways and driveways with less than 50 trips/day

Turn lane guidelines on undivided trunk highways include:

1) Left or right turn lanes where there is a site-specific geometric or safety concern, indicated by turn lane warrants 1 through 8 or if traffic volumes meet warrant 9
2) Consider bypass lanes when left turn lane is warranted but construction is not practical at T intersections
3) Consider right turn lanes/bypass lanes at 4-leg intersections after all other solutions are found to be impractical and the cross street volume is low

Below are the nine turn lane warrants for undivided trunk highways and apply to both left and right turn lanes.

1) Passing Lane/Climbing Lane – at high volume driveways (greater than 100 trips/day) and all public street connections on highway segments where passing or climbing lanes are present in the approach/direction.
2) Limited Sight Distance/Terrain – at all locations with inadequate stopping sight distance or on short vertical curves or steep grades.
3) Railroad Crossings – at high volume driveways and public crossings where the railroad is parallel to the highway and vehicles queue into thru-lanes.
4) Signalized Intersections – at all locations.
5) Heavy-Vehicle Traffic – at high speed locations (45 MPH or greater) where heavy-vehicle turning volume is greater than or equal to 15 vehicles per hour for a least 8 hours per day for 4 months in a year.
6) School Entrances – at all locations on high speed roads.
7) Crash History – at high volume driveways and public streets that demonstrate a history of crashes suitable to correction by turn lane (typically 3 correctible/year) or where adequate trial of other methods have failed.
8) Corridor Crash Experience – at locations where corridor crashes are high and corridor consistency is needed.
9) Vehicular-Volume Warrant – At locations that satisfy criteria in the table provided.

Figure 3.40: Warrant 9 for Left-Turn Lanes

2-Lane Highway AADT	4-Lane Highway AADT	Cross Street or Driveway ADT	Turn Lane Requirement
1500 to 2999	3000 to 5999	> 1500	Left-turn lane warranted
3000 to 3999	6000 to 7999	> 1200	Left-turn lane warranted
4000 to 4999	8000 to 9999	> 1000	Left-turn lane warranted
5000 to 6499	10,000 to 12,999	> 800	Left-turn lane warranted
≥ 6500 AADT	≥ 13,000 AADT	101 to 400 > 400	Left-turn lane or bypass lane Left-turn lane warranted

Highway AADT one year after opening
Posted speed 45 mph or greater

Figure 3.41: Warrant 9 for Right-Turn Lanes

2-Lane Highway AADT	4-Lane Highway AADT	Cross Street or Driveway ADT	Turn Lane Requirement
≥ 1500 AADT	≥ 3000 AADT	> 100	Right-turn lane warranted

Highway AADT one year after opening
Posted speed 45 mph or greater

Source: MnDOT Access Management Manual

Turning movement restriction guidelines are provided based on sight distance, volumes, access point, etc.

Functional Systems
Intersection spacing is recommended based on facility type and functional class.

City of Tucson, AZ Access Management Guidelines (2011)

The City of Tucson, Arizona put together access management guidelines in order to "enable access to land uses while maintaining roadway safety and mobility through controlling access location, design, spacing and operation" [14].

Development Driven (Short-Term)
Guidelines have been adopted as ordinance and are applicable to all public and private development. Traffic impact analysis is required and must include a turn lane analysis that addresses turn lane needs.

Problem Oriented, Safety, Operations, Maintenance and Removal
Median openings should be closed when traffic volumes exceed MUTCD thresholds for traffic signal installations, but signal spacing is not sufficient to provide safe and efficient operation.

Access Management
When necessary for the safe and efficient movement of traffic, access points may be required to be designed for right turns in and out only.

Functional Systems
Left turn lanes are required along arterial roadways at intersections and driveways where the product of opposing hourly volume of through and left turns exceeds specified thresholds for 30, 40 and 55 MPH. Right turn lanes are required along arterials at intersections and

driveways where the product of one direction of through traffic and the volume of right turns exceeds specified thresholds for 40, 50 and 60 MPH.

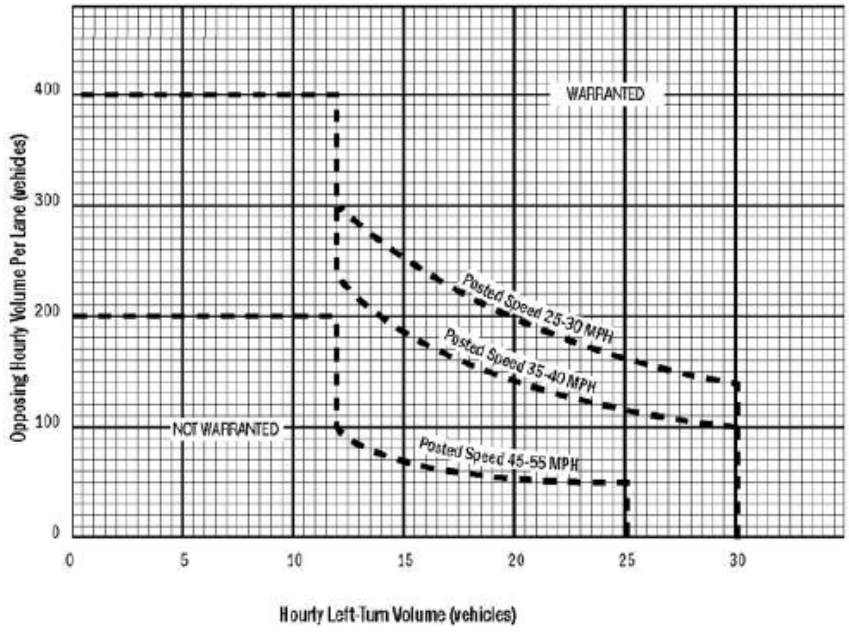


Figure 5-1 – Left Turn Lane Warrant[13]

Source: City of Tucson, AZ Access Management Guidelines

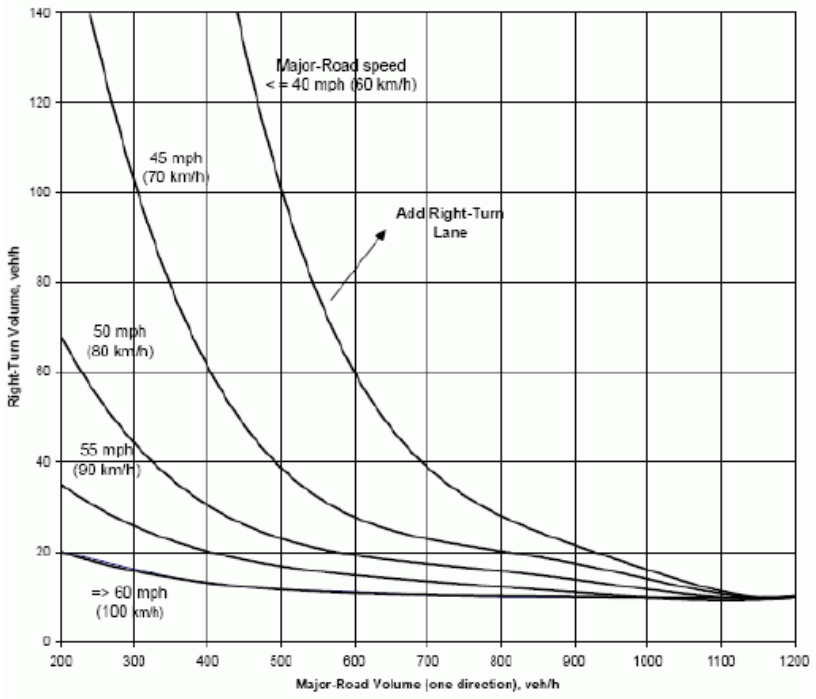
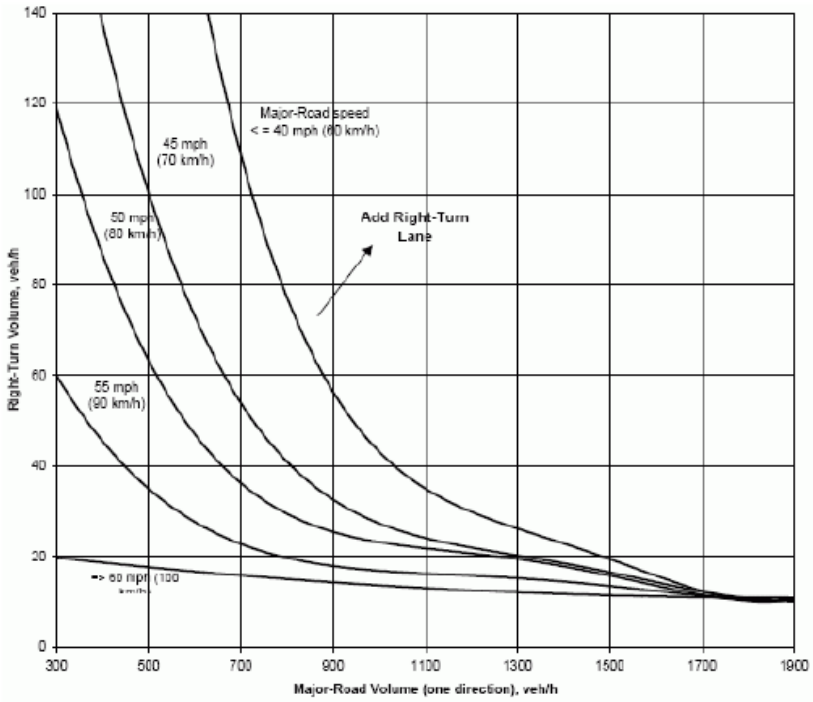


Figure 5-2 – Right Turn Lane Guidelines for Two-Lane Roadway[14]

Source: City of Tucson, AZ Access Management Guidelines



Note: Existing roadway constraints may restrict the ability or need to install turning lanes. Traffic Engineering may require a traffic engineering analysis to support alternative recommendations for the installation of turning lanes.

Figure 5-3 – Right Turn Guidelines for Four-Lane Roadways[15]

Source: City of Tucson, AZ Access Management Guidelines

Intersection Channelization Design Guide (1985)

The *Intersection Channelization Design Guide* incorporates "information, illustrations, and guidelines on the current state of the art for channelization" [15].

Corridor Design/Redesign (Long-Term)
Left turn lanes should be considered at ALL median openings on divided, high-speed highways. Left turn lanes are recommended on through approaches to intersections where the product of through, opposing and left turn volumes exceed specified thresholds. Left turn lanes on minor approaches should be provided based on analysis of capacity and operations of the intersection.

Functional Systems
Left Turn Lanes should be provided on ALL through approaches of primary, high-speed rural highways at intersections with other arterials and collectors.

City of Rochester Zoning Ordinance and Land Development Manual (February 5, 2014)

The *City of Rochester Zoning Ordinance and Land Development Manual* has ordinances for the City of Rochester's planning and zoning activities [16].

Development Driven (Short-Term)

Ordinance 61.520 (to 61.529) describes traffic impact studies required for land rezoning, development or amendment to the Land Use Plan. The ordinance clearly describes scenarios when a traffic impact study or traffic analysis is required for a proposed development. Standards for traffic service include capacity, level of service, number of access points, residential street impact, traffic flow and progression, vehicle storage, internal circulation and safety. The ordinance lays out who within the zoning agencies should be contacted (engineers, council, zoning administrator, etc) to determine the scope of the study, the process for review and preparation of the study, report findings. If staff finds the proposed development will not meet applicable service level standards, staff shall recommend actions by the applicant such as, reduce the size of the development, dedicate right-of-way for improvements, construct new streets, etc. Negotiations based on the conclusions are held with the City Council to create and implement a Development Agreement detailing the applicant's responsibilities and the City's responsibilities for implementing identified mitigation measures.

Scott County Traffic Impact Analysis Process (April 2005, DRAFT)

The draft *Scott County Traffic Impact Analysis Process* report outlines guidelines and procedures to "assist developers through an approval process by outlining the requirements and level of detail of traffic analysis that is expected based on the type and intensity of the proposed development" [17].

Development Driven (Short-Term)

A draft policy describes the need for a traffic impact study when a development is proposed and establishes level of service thresholds and requirements for minimum projected level of service on roadways with and without the development. Early coordination with County staff is encouraged to review the scope of the traffic study. A traffic impact study process is established that includes documentation of existing conditions, estimation of site traffic generation, safety analysis, documentation of expected post-development conditions and comparison of pre and post development to determine operational and safety impacts caused by site generated traffic and if the performance measure thresholds have been exceeded.

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Right and Left Turn Lane Warrants Toolbox

Why Use The Toolbox?

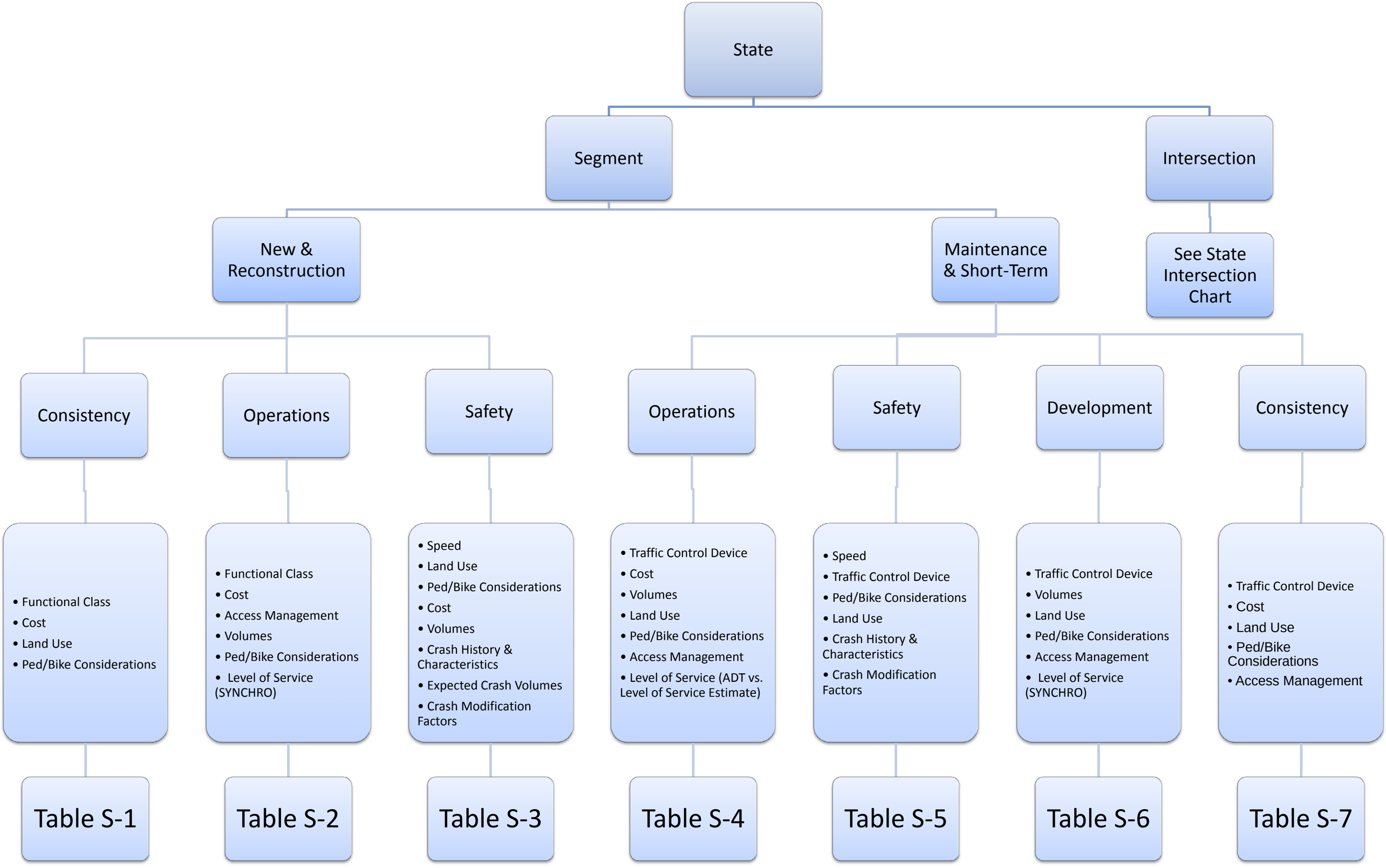
This toolbox uses decision trees (flow charts) to help identify items to consider when deciding whether or not a turn lane is warranted at a particular location on your agency's system. The decision trees lead to existing references that can be used to analyze particular locations and determine whether or not a turn lane is justified in a location.

How to Use the Toolbox?

1) Is the location on the State or local system? Locate the proper starting decision tree (State or Local)
2) Is an entire segment with multiple intersections being reviewed (segment) or only one intersection (intersection)?
3) Is the project new/reconstruction or maintenance/short-term? Continue down the decision tree as appropriate.
4) Why is the segment or intersection being constructed (supporting analysis)? Identify if the concern is mostly consistency, operations, safety or development.
5) Review the data needs to consider for the supporting analysis of interest. Based on TAP input, items are prioritized in these data needs lists based on importance in determining a turn lane warrant. This list is not all inclusive and other items may be considered or prioritized based on the specific locations.
6) Locate the referenced table (after the decision trees) to see a listing of references available from the TRS
7) References are listed in order of highest level of information available. As references are reviewed from top to bottom and left to right (data needs priorities), if one of those suggests a turn lane is warranted, no further analysis may be necessary.
8) If no references are available, a GAP in information is noted in each table.
9) Exercise engineering judgment in all cases.

Disclaimer

This toolbox is not all-inclusive and still requires engineers to exercise their judgment in the decision making process in all cases relating to the determination as to whether or not turn lanes should be installed. It is up to the individual agencies to determine whether the decision trees and listed references are appropriate for the agency's use and turn lane warrants. It is not suggested that these decision trees and tables are complete and include all possible technical analyses. Other turn lane warrant considerations and references may be available. The purpose of the TRS and this toolbox is to serve as a synthesis of pertinent completed research to be used for further study and evaluation by MnDOT and their partners in local road agencies. This TRS does not represent the conclusions of either CH2M HILL or MnDOT.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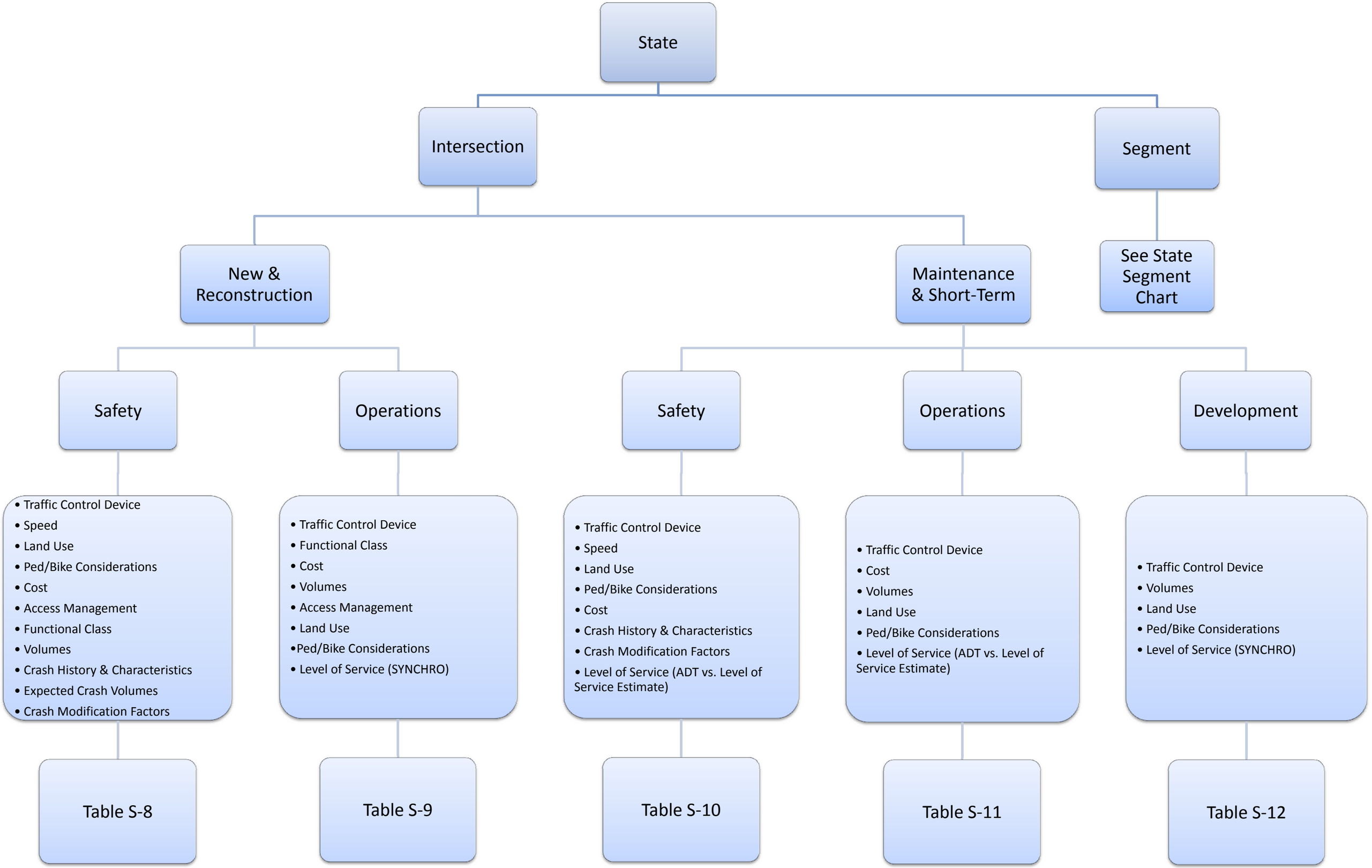
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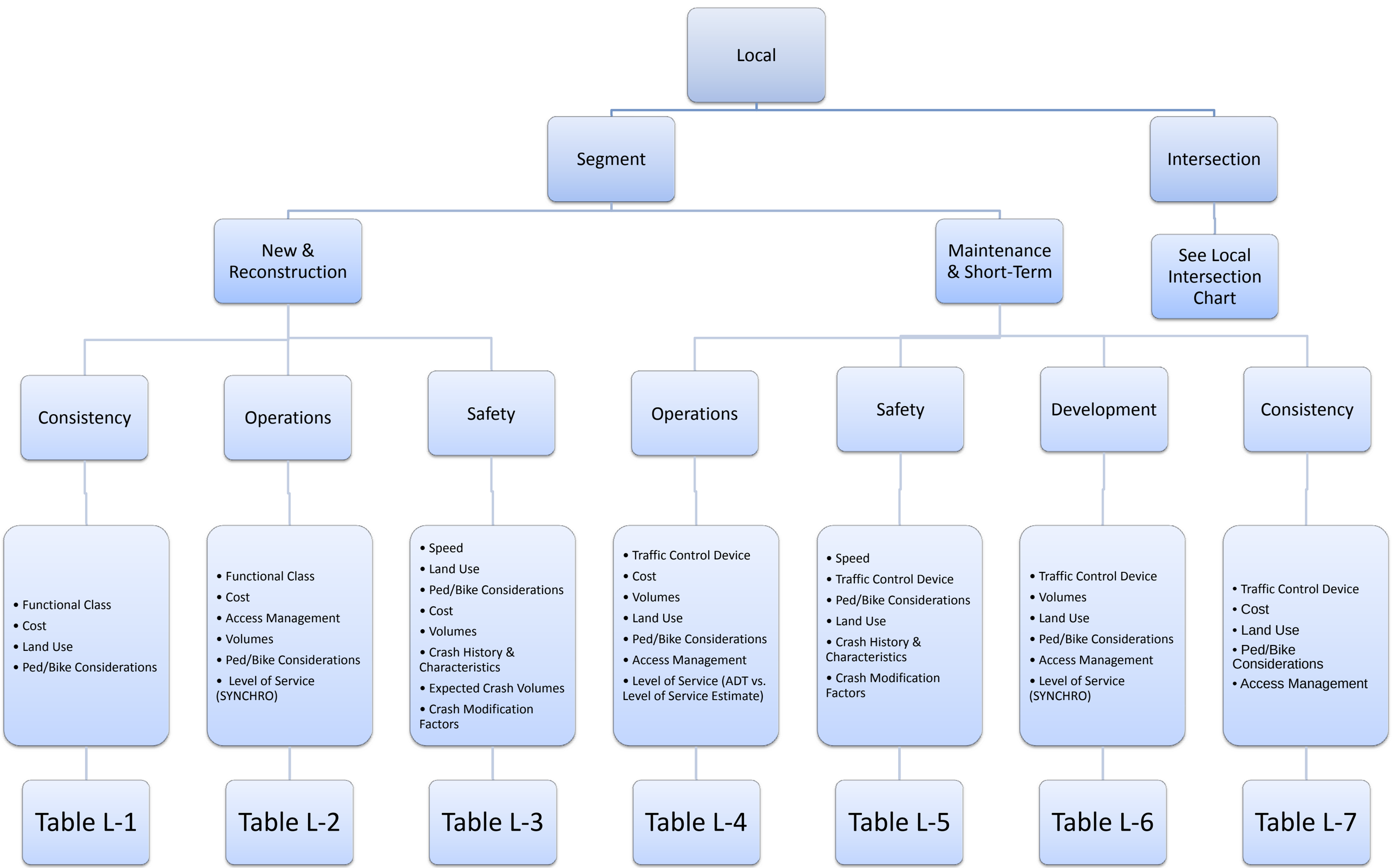
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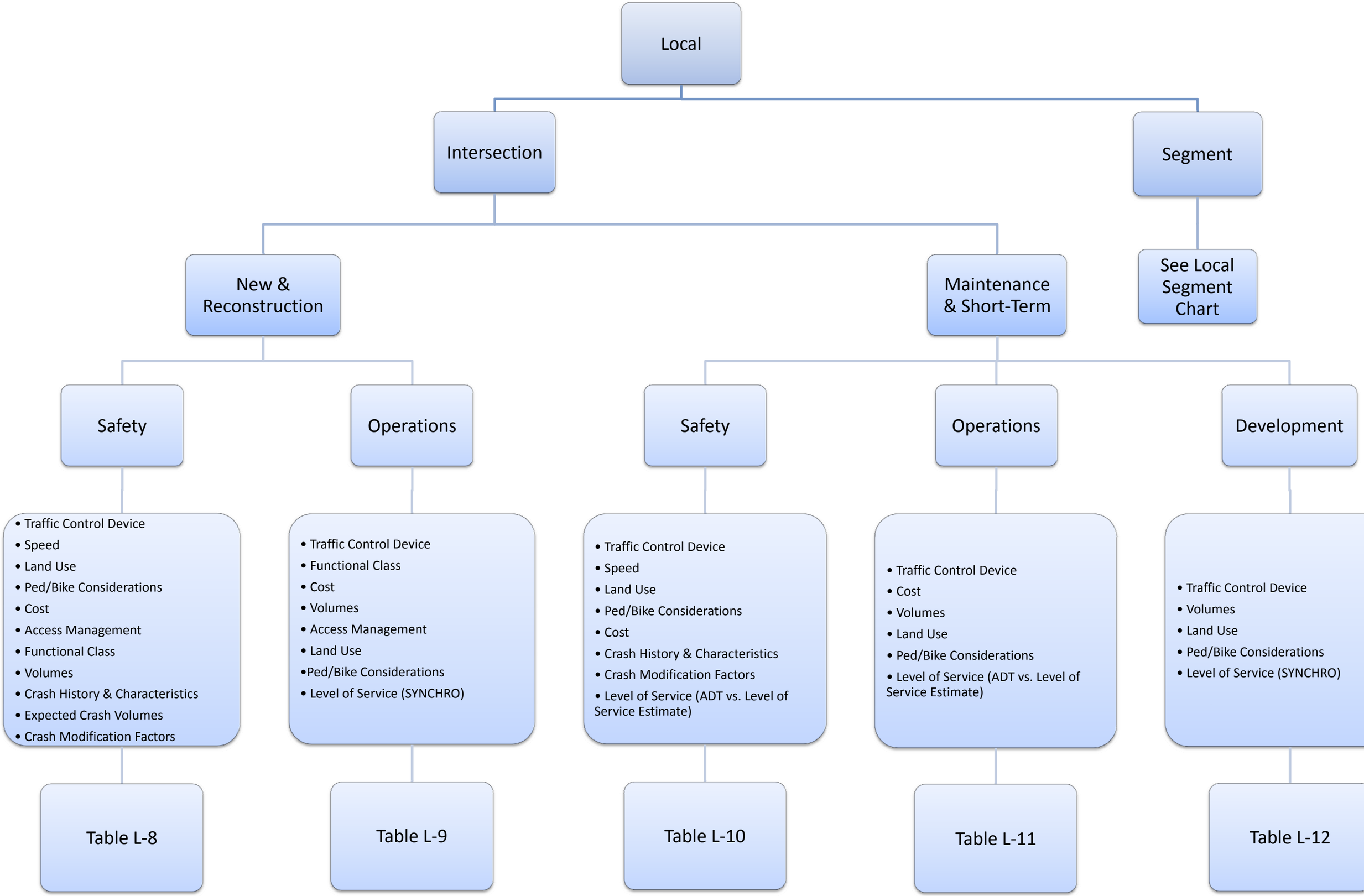
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Table S-1

Document	Functional Class	Cost	Land Use	Ped/Bike Considerations	Notes
Road Design Manual	X			GAP	Section 5-3.01 & 5-4.01
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)	X		X		Pg 30 - Turn Lanes Policy
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)	X		X		Ch. 3.4.9
AASHTO Green Book	X				Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X				
Intersection Channelization Design Guide	X				
FHWA Signalized Intersections: Informational Guide	X				Ch. 12
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads		X			Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X		Ordinance 61.520
Scott County Traffic Impact Analysis Process			X		

Table S-2

Document	Functional Class	Cost	Access Management	Volumes	Ped/Bike Considerations	Level of Service (SYNCHRO)	Notes
Road Design Manual	X			X	GAP		Section 5-3.01 & 5-4.01
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)	X			X			Pg 30 - Turn Lanes Policy
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)	X		X	X			Ch. 3.4.9
AASHTO Green Book	X			X			Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X			X			
Intersection Channelization Design Guide	X			X			
FHWA Signalized Intersections: Informational Guide	X			X			Ch. 12
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads		X		X			Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X		X		X	Ordinance 61.520
Dakota County 2030 Transportation Plan			X			X	Ch. 7
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines			X				
Left-Turn Lane Installation Guidelines (TTI)				X			Table 5
NDDOT Guidelines for the Installation of Turn Lanes along State Highways				X			
Scott County Traffic Impact Analysis Process						X	
Highway Capacity Manual						X	Vol. 3

Table S-3

Document	Speed	Land Use	Ped/Bike Considerations	Cost	Volumes	Crash History & Characteristics	Expected Crash Volumes	Crash Modification Factors	Notes
Road Design Manual	X		GAP		X	Many generically state to consider a turn lane if there's a safety problem, however no specific warrant thresholds			Section 5-3.01 & 5-4.01
AASHTO Green Book	X				X				Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X				X				
Intersection Channelization Design Guide	X				X				
Left-Turn Lane Installation Guidelines (TTI)	X				X				Table 5
NDDOT Guidelines for the Installation of Turn Lanes along State Highways	X				X				
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines	X								
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)		X			X				Pg 30 - Turn Lanes Policy
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)		X			X				Ch. 3.4.9
City of Rochester Zoning Ordinance and Land Development Manual		X		X	X				Ordinance 61.520
Scott County Traffic Impact Analysis Process		X							
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads				X	X				Ch. 6
FHWA Signalized Intersections: Informational Guide					X				Ch. 12
Highway Safety Manual							X	X	Vol. 2 - Predictive Vol. 3, Ch. 14 - Intersections (CMF)

Table S-4

Document	Traffic Control Device	Cost	Volumes	Land Use	Ped/Bike Considerations	Access Management	Level of Service (ADT vs. Level of Service Estimate)	Notes
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)	X		X	X	GAP	X	See Figure 2 in TRS: Right and Left Turn Lane Warrants	Ch. 3.4.9
AASHTO Green Book	X		X					Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X		X					
NDDOT Guidelines for the Installation of Turn Lanes along State Highways	X		X					
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads		X	X					Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X	X				Ordinance 61.520
Road Design Manual			X					Section 5-3.01 & 5-4.01
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)			X	X				Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide			X					
FHWA Signalized Intersections: Informational Guide			X					Ch. 12
Left-Turn Lane Installation Guidelines (TTI)			X					Table 5
Scott County Traffic Impact Analysis Process				X				
Dakota County 2030 Transportation Plan						X		Ch. 7
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines						X		

Table S-5

Document	Speed	Traffic Control Device	Ped/Bike Considerations	Land Use	Crash History & Characteristics	Crash Modification Factors	Notes
Road Design Manual	X		GAP		Many generically state to consider a turn lane if there's a safety problem, however no specific warrant thresholds		Section 5-3.01 & 5-4.01
AASHTO Green Book	X	X					Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X	X					
Intersection Channelization Design Guide	X						
Left-Turn Lane Installation Guidelines (TTI)	X						Table 5
NDDOT Guidelines for the Installation of Turn Lanes along State Highways	X	X					
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines	X						
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)		X		X			Ch. 3.4.9
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)				X			Pg 30 - Turn Lanes Policy
City of Rochester Zoning Ordinance and Land Development Manual				X			Ordinance 61.520
Scott County Traffic Impact Analysis Process				X			
Highway Safety Manual						X	Vol. 3, Ch. 14 - Intersections (CMF)

Table S-6

Document	Traffic Control Device	Volumes	Land Use	Ped/Bike Considerations	Access Management	Level of Service (SYNCHRO)	Notes
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)	X	X	X	GAP	X		Ch. 3.4.9
AASHTO Green Book	X	X					Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X	X					
NDDOT Guidelines for the Installation of Turn Lanes along State Highways	X	X					
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads		X					Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X			X	Ordinance 61.520
Road Design Manual		X					Section 5-3.01 & 5-4.01
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)		X	X				Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide		X					
FHWA Signalized Intersections: Informational Guide		X					Ch. 12
Left-Turn Lane Installation Guidelines (TTI)		X					Table 5
Scott County Traffic Impact Analysis Process			X			X	
Dakota County 2030 Transportation Plan					X	X	Ch. 7
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines					X		
Highway Capacity Manual						X	Vol. 3

Table S-7

Document	Traffic Control Device	Cost	Land Use	Ped/Bike Considerations	Access Management	Notes
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)	X		X	GAP	X	Ch. 3.4.9
AASHTO Green Book	X					Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X					
NDDOT Guidelines for the Installation of Turn Lanes along State Highways	X					
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads		X				Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X			Ordinance 61.520
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)			X			Pg 30 - Turn Lanes Policy
Scott County Traffic Impact Analysis Process			X			
Dakota County 2030 Transportation Plan					X	Ch. 7
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines					X	

Table S-8

Document	Traffic Control Device	Speed	Land Use	Ped/Bike Considerations	Cost	Access Management	Functional Class	Volumes	Crash History & Characteristics	Expected Crash Volumes	Crash Modification Factors	Notes
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)	X		X	GAP		X	X	X	Many generically state to consider a turn lane if there's a safety problem, however no specific warrant thresholds			Ch. 3.4.9
AASHTO Green Book	X	X					X	X				Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X	X					X	X				
NDDOT Guidelines for the Installation of Turn Lanes along State Highways	X	X						X				
Road Design Manual		X					X	X				Section 5-3.01 & 5-4.01
Intersection Channelization Design Guide		X					X	X				
Left-Turn Lane Installation Guidelines (TTI)		X						X				Table 5
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines		X				X						
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)			X				X	X				Pg 30 - Turn Lanes Policy
City of Rochester Zoning Ordinance and Land Development Manual			X		X			X				Ordinance 61.520
Scott County Traffic Impact Analysis Process			X									
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads					X			X				Ch. 6
Dakota County 2030 Transportation Plan						X						Ch. 7
FHWA Signalized Intersections: Informational Guide							X	X				Ch. 12
Highway Safety Manual										X	X	Vol. 2 - Predictive Vol. 3, Ch. 14 - Intersections (CMF)

Table S-9

Document	Traffic Control Device	Functional Class	Cost	Volumes	Access Management	Land Use	Ped/Bike Considerations	Level of Service (SYNCHRO)	Notes
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)	X	X		X	X	X	GAP		Ch. 3.4.9
AASHTO Green Book	X	X		X					Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X	X		X					
NDDOT Guidelines for the Installation of Turn Lanes along State Highways	X			X					
Road Design Manual		X		X					Section 5-3.01 & 5-4.01
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)		X		X		X			Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide		X		X					
FHWA Signalized Intersections: Informational Guide		X		X					Ch. 12
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads			X	X					Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual			X	X		X		X	Ordinance 61.520
Left-Turn Lane Installation Guidelines (TTI)				X					Table 5
Dakota County 2030 Transportation Plan					X			X	Ch. 7
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines					X				
Scott County Traffic Impact Analysis Process						X		X	
Highway Capacity Manual								X	Vol. 3

Table S-10

Document	Traffic Control Device	Speed	Land Use	Ped/Bike Considerations	Cost	Crash History & Characteristics	Crash Modification Factors	Level of Service (ADT vs. Level of Service Estimate)	Notes
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)	X		X	GAP		Many generically state to consider a turn lane if there's a safety problem, however no specific warrant thresholds		See Figure 2 in TRS: Right and Left Turn Lane Warrants	Ch. 3.4.9
AASHTO Green Book	X	X							Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X	X							
NDDOT Guidelines for the Installation of Turn Lanes along State Highways	X	X							
Road Design Manual		X							Section 5-3.01 & 5-4.01
Intersection Channelization Design Guide		X							
Left-Turn Lane Installation Guidelines (TTI)		X							Table 5
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines		X							
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)			X						Pg 30 - Turn Lanes Policy
City of Rochester Zoning Ordinance and Land Development Manual			X		X				Ordinance 61.520
Scott County Traffic Impact Analysis Process			X						
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads					X				Ch. 6
Highway Safety Manual							X		Vol. 3, Ch. 14 - Intersections (CMF)

Table S-11

Document	Traffic Control Device	Cost	Volumes	Land Use	Ped/Bike Considerations	Level of Service (ADT vs. Level of Service Estimate)	Notes
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)	X		X	X	GAP	See Figure 2 in TRS: Right and Left Turn Lane Warrants	Ch. 3.4.9
AASHTO Green Book	X		X				Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X		X				
NDDOT Guidelines for the Installation of Turn Lanes along State Highways	X		X				
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads		X	X				Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X	X			Ordinance 61.520
Road Design Manual			X				Section 5-3.01 & 5-4.01
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)			X	X			Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide			X				
FHWA Signalized Intersections: Informational Guide			X				Ch. 12
Left-Turn Lane Installation Guidelines (TTI)			X				Table 5
Scott County Traffic Impact Analysis Process				X			

Table S-12

Document	Traffic Control Device	Volumes	Land Use	Ped/Bike Considerations	Level of Service (SYNCHRO)	Notes
MnDOT Access Management Manual (http://www.dot.state.mn.us/accessmanagement/resources.html)	X	X	X	GAP		Ch. 3.4.9
AASHTO Green Book	X	X				Ch. 9 - Intersections
Auxiliary Turn Lanes (SPR Project: Criteria for the Design and Justification of Auxiliary Turn Lanes)	X	X				
NDDOT Guidelines for the Installation of Turn Lanes along State Highways	X	X				
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads		X				Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X		X	Ordinance 61.520
Road Design Manual		X				Section 5-3.01 & 5-4.01
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)		X	X			Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide		X				
FHWA Signalized Intersections: Informational Guide		X				Ch. 12
Left-Turn Lane Installation Guidelines (TTI)		X				Table 5
Scott County Traffic Impact Analysis Process			X		X	
Highway Capacity Manual					X	Vol. 3
Dakota County 2030 Transportation Plan					X	Ch. 7

Table L-1

Document	Functional Class	Cost	Land Use	Ped/Bike Considerations	Notes
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)	X		X	GAP	Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide	X				
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads		X			Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X		Ordinance 61.520
Scott County Traffic Impact Analysis Process			X		

Table L-2

Document	Functional Class	Cost	Access Management	Volumes	Ped/Bike Considerations	Level of Service (SYNCHRO)	Notes
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)	X			X	GAP		Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide	X			X			
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads		X		X			Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X		X		X	Ordinance 61.520
Dakota County 2030 Transportation Plan			X			X	Ch. 7
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines			X				
Left-Turn Lane Installation Guidelines (TTI)				X			Table 5
Scott County Traffic Impact Analysis Process						X	
Highway Capacity Manual						X	Vol. 3

Table L-3

Document	Speed	Land Use	Ped/Bike Considerations	Cost	Volumes	Crash History & Characteristics	Expected Crash Volumes	Crash Modification Factors	Notes
Intersection Channelization Design Guide	X		GAP		X	Many generically state to consider a turn lane if there's a safety problem, however no specific warrant thresholds			
Left-Turn Lane Installation Guidelines (TTI)	X				X				Table 5
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines	X								
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)		X			X				Pg 30 - Turn Lanes Policy
City of Rochester Zoning Ordinance and Land Development Manual		X		X	X				Ordinance 61.520
Scott County Traffic Impact Analysis Process		X							
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads				X	X				Ch. 6
Highway Safety Manual							X	X	Vol. 2 - Predictive Vol. 3, Ch. 14 - Intersections (CMF)

Table L-4

Document	Traffic Control Device	Cost	Volumes	Land Use	Ped/Bike Considerations	Access Management	Level of Service (ADT vs. Level of Service Estimate)	Notes
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads	GAP	X	X		GAP		See Figure 2 in TRS: Right and Left Turn Lane Warrants	Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X	X				Ordinance 61.520
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)			X	X				Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide			X					
Left-Turn Lane Installation Guidelines (TTI)			X					Table 5
Scott County Traffic Impact Analysis Process				X				
Dakota County 2030 Transportation Plan						X		Ch. 7
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines						X		

Table L-5

Document	Speed	Traffic Control Device	Ped/Bike Considerations	Land Use	Crash History & Characteristics	Crash Modification Factors	Notes
Intersection Channelization Design Guide	X	GAP	GAP		Many generically state to consider a turn lane if there's a safety problem, however no specific warrant thresholds		
Left-Turn Lane Installation Guidelines (TTI)	X						Table 5
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines	X						
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)				X			Pg 30 - Turn Lanes Policy
City of Rochester Zoning Ordinance and Land Development Manual				X			Ordinance 61.520
Scott County Traffic Impact Analysis Process				X			
Highway Safety Manual						X	Vol. 3, Ch. 14 - Intersections (CMF)

Table L-6

Document	Traffic Control Device	Volumes	Land Use	Ped/Bike Considerations	Access Management	Level of Service (SYNCHRO)	Notes
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads	GAP	X		GAP			Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X			X	Ordinance 61.520
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)		X	X				Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide		X					
Left-Turn Lane Installation Guidelines (TTI)		X					Table 5
Scott County Traffic Impact Analysis Process			X			X	
Dakota County 2030 Transportation Plan					X	X	Ch. 7
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines					X		
Highway Capacity Manual							Vol. 3

Table L-7

Document	Traffic Control Device	Cost	Land Use	Ped/Bike Considerations	Access Management	Notes
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads	GAP	X		GAP		Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X			Ordinance 61.520
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)			X			Pg 30 - Turn Lanes Policy
Scott County Traffic Impact Analysis Process			X			
Dakota County 2030 Transportation Plan					X	Ch. 7
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines					X	

Table L-8

Document	Traffic Control Device	Speed	Land Use	Ped/Bike Considerations	Cost	Access Management	Functional Class	Volumes	Crash History & Characteristics	Expected Crash Volumes	Crash Modification Factors	Notes
Intersection Channelization Design Guide	GAP	X		GAP			X	X	Many generically state to consider a turn lane if there's a safety problem, however no specific warrant thresholds			
Left-Turn Lane Installation Guidelines (TTI)		X						X				Table 5
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines		X				X						
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)			X				X	X				Pg 30 - Turn Lanes Policy
City of Rochester Zoning Ordinance and Land Development Manual			X		X			X				Ordinance 61.520
Scott County Traffic Impact Analysis Process			X									
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads					X			X				Ch. 6
Dakota County 2030 Transportation Plan						X						Ch. 7
Highway Safety Manual										X	X	Vol. 2 - Predictive Vol. 3, Ch. 14 - Intersections (CMF)

Table L-9

Document	Traffic Control Device	Functional Class	Cost	Volumes	Access Management	Land Use	Ped/Bike Considerations	Level of Service (SYNCHRO)	Notes
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)	GAP	X		X		X	GAP		Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide		X		X					
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads			X	X					Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual			X	X		X		X	Ordinance 61.520
Left-Turn Lane Installation Guidelines (TTI)				X					Table 5
Dakota County 2030 Transportation Plan					X			X	Ch. 7
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines					X				
Scott County Traffic Impact Analysis Process						X		X	
Highway Capacity Manual								X	Vol. 3

Table L-10

Document	Traffic Control Device	Speed	Land Use	Ped/Bike Considerations	Cost	Crash History & Characteristics	Crash Modification Factors	Level of Service (ADT vs. Level of Service Estimate)	Notes
Intersection Channelization Design Guide	GAP	X		GAP		Many generically state to consider a turn lane if there's a safety problem, however no specific warrant thresholds		See Figure 2 in TRS: Right and Left Turn Lane Warrants	
Left-Turn Lane Installation Guidelines (TTI)		X							Table 5
City of Tucson Update to Ordinance 9823 Transportation Access Management Guidelines		X							
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)			X						Pg 30 - Turn Lanes Policy
City of Rochester Zoning Ordinance and Land Development Manual			X		X				Ordinance 61.520
Scott County Traffic Impact Analysis Process			X						
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads					X				Ch. 6
Highway Safety Manual							X		Vol. 3, Ch. 14 - Intersections (CMF)

Table L-11

Document	Traffic Control Device	Cost	Volumes	Land Use	Ped/Bike Considerations	Level of Service (ADT vs. Level of Service Estimate)	Notes
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads	GAP	X	X		GAP	See Figure 2 in TRS: Right and Left Turn Lane Warrants	Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X	X			Ordinance 61.520
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)			X	X			Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide			X				
Left-Turn Lane Installation Guidelines (TTI)			X				Table 5
Scott County Traffic Impact Analysis Process				X			

Table L-12

Document	Traffic Control Device	Volumes	Land Use	Ped/Bike Considerations	Level of Service (SYNCHRO)	Notes
MnDOT LRRB 2008-25 Warrants for Right-turn Lanes/Treatments on Two-lane Roads	GAP	X		GAP		Ch. 6
City of Rochester Zoning Ordinance and Land Development Manual		X	X		X	Ordinance 61.520
Minnesota's Best Practices and Policies for Safety Strategies on Highways and Local Roads (MnDOT Turn Lanes Policy)		X	X			Pg 30 - Turn Lanes Policy
Intersection Channelization Design Guide		X				
Left-Turn Lane Installation Guidelines (TTI)		X				Table 5
Scott County Traffic Impact Analysis Process			X		X	
Highway Capacity Manual					X	Vol. 3
Dakota County 2030 Transportation Plan					X	Ch. 7