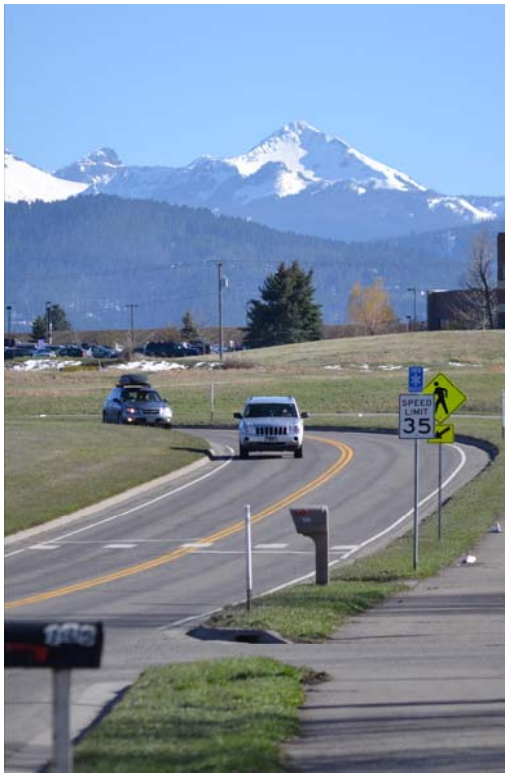
Traffic Operations Standards and Best Practices

Technical Memorandum



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prepared by:
Robert Peccia & Associates
www.rpa-hln.com

prepared for:
City of Bozeman & Montana Department of Transportation

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ABBREVIATIONS/ACRONYMS

ADT	Average Daily Trips
DPW	Department of Public Works
FDOT	Florida Department of Transportation
LOS	Level of service
QOS	Quality of Service
TDM	Transportation Demand Management
TSM	Transportation System Management
v/c	Volume to capacity ratio
V/S	Volume to service ratio
VMT	Vehicle miles traveled

Traffic Performance Measures

1.0. INTRODUCTION

The City of Bozeman's current intersection standards for development are based on the intersection level of service (LOS) during the peak hours. The *Bozeman Code of Ordinance*[1] states:

4. *Level of service standards.* All arterial and collector streets and intersections with arterial and collector streets shall operate at a minimum level of service "C" unless specifically exempted by the subsection. [LOS] values shall be determined by using the methods defined by the most recent edition of the Highway Capacity Manual. A development shall be approved if the LOS requirement are met in the design year, which shall be a minimum of 15 years following the development application review or construction of mitigation measures if mitigation measures are required to maintain LOS. Intersections shall have a minimum acceptable LOS of "C" for the intersection as a whole.

    a. Exception: If an intersection within the area required to be studied by section 28.41.060.A.12 does not meet LOS "C" and the intersection has been fully constructed to its maximum lane and turning movement capacity, then a LOS of less than "C" is acceptable.

    b. Exception: The review authority may accept an LOS of less than "C" at a specific intersection if:

        (1) A variance to allow a lesser LOS was approved not more than two years prior to the date an application for development being reviewed is determined to be adequate for review;

        (2) The request was made in writing with the application; and

        (3) The circumstances are in the professional judgment of the review authority substantially the same as when the variance was granted.

This standard, however, may be unreasonable for some intersections for a variety of reasons. As an example, the intersection of Main Street and North 7th Avenue is constrained by the available right-of-way at the intersection. If the intersection LOS was to become sub-standard, few options are available to improve the intersection. As such, context based LOS standards may be required for the City of Bozeman. This study seeks to identify context based traffic performance standards that allow flexibility.

Context based traffic performance standards aim to consider more than just one aspect—vehicle delay—of an intersection. These aspects include, but are not limited to, safety, volume, duration of peak hours, scale of importance, and prioritization or functional class of the intersection and its component roadways. This study presents a review of the best practices on the subject of traffic performance measures.

2.0. STATE OF PRACTICE REVIEW

The following review, while not exhaustive, presents the state of the practice for setting traffic performance standards. Traffic performance standards for many municipalities were found within their respective development concurrency plans. Detailed discussion for each source is presented in the following subsections.

2.1. PIERCE COUNTY, WASHINGTON

Pierce County, Washington extends between Tacoma and Mount Rainer National Park. The Department of Public Works Traffic Section published the *Transportation Concurrency Management System* guide in 2015[2]. Within the guide, they recommend the use of a volume over service level (V/S) for measuring the performance of roadways. The service level for a roadway is similar to the capacity measure but is based on a set rubric for road size. **Table 2.1** reproduces the arterial service thresholds published in the guide.

Table 2.1: Arterial Service Thresholds

Service Threshold (S)			
Travel Lanes (Both Directions)		Without Turn Channelization	With Turn Channelization
Urban	2	14,800	18,700
	3	20,800	28,200
	4	29,700	37,600
	6	45,000	56,300
Rural	2	13,700	17,300
	3	27,400	34,800

The volume portion of the V/S ratio is determined from the average annual daily traffic on a given roadway. Projected V/S ratios are determined through the use of travel demand models. The growth between the existing and projected year models is applied to the existing traffic counts. The guide states, "This procedure is intended to minimize the impact of individual link based forecasting errors that are inevitable in almost all travel demand models."

This method can be applied to entire roadways by taking the average V/S of all the component links weighted based on the length of the link. The resulting V/S ratios are then compared to the service standards to determine whether a particular segment is above the threshold. The standard is set at a daily V/S of 1.05.

Mitigation of service threshold deficiencies require financial commitment to address the issues within six years. The guide defines "implementation within six years" as "that a contract for full construction of the roadway capacity improvements must have been executed by the County within six years of the time that the concurrency violation occurred." Six mitigation strategies are outlined in the guide: 1) increase arterial capacity, 2) prohibit/phase development activities, 3) revise service standards, 4) revise service thresholds, 5) ultimate capacity, and 6) other strategies. Methods 1) and 2) are self-explanatory, the remaining four options are further discussed in the following paragraphs.

Revision of service standards would amount to allowing a higher V/S for identified segments. It is also possible to exempt certain roadways from concurrency. This, however, may be unpopular with the public as it could greatly reduce mobility on these facilities. Given that traffic volumes vary daily, weekly, and seasonally, it may be reasonable to refine the current Service Standard methodology.

Revision of service thresholds could be pursued, but would likely involve using new guidelines and/or professional judgment to modify one or more data inputs that go into the calculation of the thresholds. The current thresholds are based on information from the late 1990's. The Guide further states, "Any proposal to revise the thresholds should be based on sound traffic operational analysis and/or refinement of existing methodologies. It should also reflect the nature or road and/or traffic characteristics in the County."

Ultimate capacity could be used in situations where higher density development and a focus on multimodal transportation is desired. Ultimate capacity scenarios may also occur when the county council determines that excessive expenditure of public funds is not warranted for the purpose of making further improvements on certain arterials. Feasible alternatives, however, must be provided as a means to mitigate the congestion on the designated corridor.

Other strategies is a blanket category for transportation demand management (TDM) and transportation system management (TSM) options. While TDM and TSM improvements are generally worth pursuing, it would be very difficult to prove that they would reduce traffic enough to bring any deficient concurrency segments into compliance.

2.2. Boulder, Colorado

The City of Boulder, Colorado lists transportation service standards in their Design and Construction Standards[3]. Chapter 2 of the *Design and Construction Standards* relates to transportation design. The transportation service standards require a discussion and analysis assessing

the impacts of development on the existing and projected transportation system within the study area with respect to the following traffic impact and mitigation objectives:

1. **Transportation Master Plan Objectives**: TMP service standards' objectives include the following:
    a. No long-term growth in auto traffic over current levels described as a 0 percent increase in vehicle miles traveled.
    b. Reduction in single-occupant vehicle travel to 25 percent of total trips.
    c. Continuous reduction in mobile source emission of air pollutants, and no more than 20 percent of roadways congested at LOS F.
2. **Level of Service Design Guide**: LOS standards objectives include:
    a. Minimum LOS D design guide for peak hour conditions for all movements. Project impacts that maintain LOS D or better for all intersections and street segments may not be required to provide LOS-related traffic mitigation improvements.
    b. LOS E and lower peak hour conditions require the implementation of one or more transportation management strategies consistent with the goals and objective of the TMP. A transportation management strategy plan required to address and mitigate these conditions may include travel demand management, land use intensity reduction, site design, layout and access modifications, parking reduction measures, or transportation infrastructure improvements.

2.3. San Diego County, California

Transportation and traffic guidelines for San Diego County, California are given in the *Guidelines for Determining Significance*[4]. This document states, "New development shall provide needed roadway expansion and improvements on-site to meet the demand created by the development, and to maintain a LOS C on circulation element roads during peak traffic hours. New development shall provide off-site improvements designed to contribute to the overall achievement of LOS D on circulation element roads." Simply stated, roadways and intersections within and adjacent to the development must reach at least LOS C. Roadways and intersection that are impacted by the development must operate at LOS D or better.

The Department of Public Works presents the LOS standards for roadways in their Public Roads Standards[5]. The standards presented are based on the average daily vehicle trips on a given road. These standards are reproduced in **Table 2.2**.

The Guidelines list eight standard mitigation options if a corridor does not meet LOS requirements:

1) Traffic signal improvements
2) Physical road improvements
3) Street re-striping and parking restrictions
4) Fair share contributions

5) TDM – implementation of these measures will require monitoring on an on-going basis
6) Traffic safety/hazard mitigation for pedestrians or bicyclists
7) Alternative transportation
8) Project phasing

If a proposed project results in a significant traffic impact, mitigation for the traffic impact must be proposed. If mitigation is infeasible or impractical, the technical, economic, and physical reasons for the infeasibility must be detailed to support a statement of overriding considerations.

Table 2.2: Average Daily Vehicle Trips

Mobility Element Roads			Levels of Service				
Road Classification		# of Travel Lanes	A	B	C	D	E
Expressway		6	<36,000	<54,000	<70,000	<86,000	<108,000
Prime Arterial		6	<22,200	<37,000	<44,600	<50,000	<57,000
Major Road	w/ Raised Median	4	<14,800	<24,700	<29,600	<33,400	<37,000
	w/ intermittent turn lanes	4	<13,700	<22,800	<27,400	<30,800	<34,200
Boulevard	w/ raised median	4	<18,000	<21,000	<24,000	<27,000	<30,000
	w/ intermittent turn lanes	4	<16,800	<19,600	<22,500	<25,000	<28,000
Community Collector	w/ Raised Median	2	<10,000	<11,700	<13,400	<15,000	<19,000
	w/ Continuous left turn lane	2	<3,000	<6,000	<9,500	<13,500	<19,000
	w/ intermittent turn lane	2	<3,000	<6,000	<9,500	<13,500	<19,00
	w/ passing lane	2	<3,000	<6,000	<9,500	<13,500	<19,000
	no median	2	<1,900	<4,100	<7,100	<10,900	<16,200
Light Collector	w/ raised median	2	<3,000	<6,000	<9,500	<13,500	<19,000
	w/ continuous left turn lane	2	<3,000	<6,000	<9,500	<13,500	<19,000
	w/ intermittent turn lane	2	<3,000	<6,000	<9,500	<13,500	<19,000
	w/ passing lane	2	<3,000	<6,000	<9,500	<13,500	<19,000
	no median	2	<1,900	<4,100	<7,100	<10,900	<16,200
	w/ reduced shoulder	2	<5,800	<6,800	<7,800	<8,700	<9,700
Minor Collector	w/ raised median	2	<3,000	<6,000	<7,000	<8,000	<9,000
	w/ intermittent turn lane	2	<3,000	<6,000	<7,000	<8,000	<9,000
	no median	2	<3,000	<6,000	<7,000	<8,000	<9,000
Non-mobility Element Roads			Levels of Service				
Residential Collector		2	-	-	<4,500	-	-
Rural Residential Collector		2	-	-	<4,500	-	-
Residential Road		2	-	-	<1,500	-	-
Rural Residential Road		2	-	-	<1,500	-	-
Residential Cul-de-Sac or Loop Road		2	-	-	<200	-	-

2.4. Spokane, Washington

The City of Spokane Levels of Service Standards/Concurrency Management System is outlined in a report published in 2000[6]. The report proposed a LOS program that establishes different standards for different areas of the city. Much of the proposed system is meant to be used as a tool to direct or control development. To be effective in this goal, LOS standards must reflect the land use strategy. For example, areas where development is desired, the LOS standards can be relaxed.

Three basic LOS systems were suggested and modeled. The first is simply a flat LOS of D or better. The second system defines LOS targets based on land use and the corridors connecting the different areas of the city. A LOS of C would be required for areas and routes with no mixed-use centers or corridors. LOS D would be allowed on major routes that connect residential areas to areas with mixed-use or the central business district. A LOS E would be allowed in areas and on segments in the central business district.

The third standard would be region based. The central business district would be allowed to operate at LOS E. The next region would be adjacent to the central business district would be LOS D. Areas on the edge of town would allow an LOS C. The third method would not take land use into account.

Each of the above methodologies were modeled and compared to one another. It was determined that the cost to mitigate the deficient roadways was highest with the flat LOS D standard and less expensive under the other two options. The second and third option resulted in roughly equal costs.

Ultimately, Spokane utilizes a combination of the above approaches. According to the City of Spokane's *Administrative Policy and Procedure*, intersection LOS standards vary with intersection location[7]. For signalized intersections in the downtown and central business districts, LOS of F not to exceed 90 seconds of delay is acceptable at arterial intersections. Areas within Types 1, 2, and 4 areas—retail centers and corridors—may not exceed LOS F with greater than 85 seconds of delay. For all other intersection on arterial roadways, LOS of E or better is required; LOS of D or better is required for all collectors.

Unsignalized intersections are to have a LOS of E or better according to the Policies. Individual approach movements are analyzed at all unsignalized intersections, including two-way stop-controlled and all-way stop-controlled intersections. Lower LOS may be allowed by the department based on major and minor movement queue length, delay, and volume to capacity ratio.

Developments causing LOS to drop below the relevant standard are given five mitigations options:

1) Mitigate impacts such that the LOS of the transportation facility meets or exceeds the relevant LOS standard;
2) Do not proceed with development or modify or phase the development proposal,

3) Delay the development until a programmed project is included in the Six-Year Comprehensive Street Program which adds sufficient capacity to the impacted transportation facility;
4) Participate in a voluntary agreement with the City; or
5) Pay an appropriate transportation impact fee.

2.5. Wisconsin Department of Transportation

The Wisconsin Department of Transportation published LOS recommendations in their *Traffic Impact Analysis Guidelines*[8]. These guidelines recommended that roadway and/or intersection improvements may be required under the following conditions:

1. If specific movements on the roadway segment and/or roadway intersection are expected to operate at LOS C or better and have a volume to capacity (v/c) ratio less than 1.0 in the horizon year(s) without the development but operate at LOS D or worse with a v/c ratio greater or equal to 1.0 with the development. In this case, improvements shall be proposed to bring the LOS from D or worse to LOS C and a v/c ratio less than 1.0.
2. If specific movement on the roadway segment and/or roadway intersection are expected to operate below LOS C and/or above a v/c ratio of 1.0 in the horizon year(s) without development, but operate at an even lower LOS with the development. In this case, improvements shall be proposed to maintain the amount of delay (in seconds per vehicle) expected to occur without the development using Highway Capacity Manual methodology.

The guidelines, however, do allow the regional traffic engineer to determine locations and situation that LOS D may be acceptable. With respect to roundabouts, the regional engineer needs to be consulted when a roundabout is operating at LOS C or lower. Furthermore, if an approach or lane is operating with LOS D or lower, the regional engineer needs to determine if that LOS is acceptable. The guide further states that roundabout capacity analysis should be performed using the most current version of the Highway Capacity Manual.

2.6. Vancouver, Washington

The City of Vancouver, Washington has a concurrency program that consists of three basic elements; 1) level of service standards that are affordable and consistent with the City's land use plan, 2) system monitoring and management to maintain adopted levels of service, and 3) development impact review to determine whether proposed development will cause levels of service to decline below adopted standards[9]. The city measures LOS on arterial corridors based on the free-flow speed of traffic. Additionally, if a corridor is fully built out, or as the manual states, "constructed to ultimate capacity", mitigation efforts turn to safety, access management and circulation, and transportation demand management. Roadways that are constructed to ultimate capacity are defined as those that have been built to full urban standards with sidewalks, bike lanes, travel lanes appropriate to its designation, intersection capacity consistent with the roadway cross section, and state of the art traffic control.

Each of the facilities within the arterial street network is assigned a target average peak hour travel speed. Some facilities are broken into sections with different target speeds. According to the *Vancouver Comprehensive Plan*, the target average peak hour travel speeds range from 10 to 15 miles per hour[10].

System monitoring and management is conducted at least annually, according to the concurrency program standards. Both speeds and traffic volumes are measured. Growth from expected development is taken into account to preempt possible level of service issues that may be caused by growth and development. The City groups its major corridors into four categories.

- **Category 1**: Transportation concurrency corridors are presumed to operate within acceptable LOSs between corridor LOS measurements and are not specifically evaluated with each development application.
- **Category 2**: Transportation concurrency corridors are presumed to operate within acceptable LOSs between corridor LOS measurements where the near-future LOS is over 15 percent above the adopted LOS standard for the corridor.
- **Category 3**: Transportation concurrency corridors operating at close to the adopted LOS will likely require additional analysis either by the Director or by the development applicant.
- **Category 4**: Those corridors designated by City Council as built to ultimate capacity.

Mitigation for congestion is required for any developments. Developments impacting Category 4 corridors are deemed to satisfy transportation concurrency where the proposed development complies with the corridor management plan and demonstrates consistency with the corridor's person trip capacity.

2.7. Florida Department of Transportation

The Florida Department of Transportation (FDOT) published the 2009 *Quality/Level of Service Handbook* to define their methodology for approaching system operations[11]. The handbook seeks to utilize both quantitative and qualitative measured to define transportation system operations. Quantitative measures are those that directly measure an aspect of the transportation system, for example, LOS and vehicle delay. Quantitative measures are meant to gauge traveler-based perceptions of the operations of the facility. The handbook presents the concept of quality of service (QOS) as a user's perception of how well a transportation service or facility operates. LOS, as defined by the handbook, is the qualitative stratification of the QOS.

The handbook recommends using a holistic approach to QOS and LOS for a given system by simultaneously measuring for auto, pedestrian, bike, and transit modes. However, simply combining the resultant LOS for each mode into a single score is discouraged because of the interrelated nature of the component LOS scores. Four major cautions are cited in the handbook:

1) No professionally accepted or scientifically valid technique exists for combining the LOS for the various modes.

2) Simply weighting each of the modes by the number of users would, in most cased, result in using the LOS for the automobile mode.
3) The functional classification/purpose of the facility may favor one mode over the other.
4) The travel patterns for each mode are generally distinct.

The handbook recognizes that the Highway Capacity Manual is the foremost authority on automobile LOS. For bicycle and pedestrian LOS, a score is determined based on multiple aspects of the road/sidewalk environment. The score is then used to determine a LOS. Transit LOS is based on the headway between busses. Details for the determination of LOS using the methodologies presented in the handbook are beyond the scope of this document. However, FDOT does distribute software to determine LOS for all modes.

The handbook presents FDOT's standards for LOS as D or better in urban areas and C in rural areas for both roadway segments and signalized intersections. The handbook warns against basing intersection LOS on only the through movement as it is possible to get an acceptable LOS if other movements are allowed to have a decreased LOS. Non-automobile modes are not given an LOS target, rather local goals and facility context need to be assessed.

2.8. Emeryville, California

The Emeryville, California *General Plan* gives the city's policies on transportation LOS[12]. Emeryville has opted to focus on multi-modal transportation. As such, they have chosen to eschew the traditional LOS model in favor of the QOS model presented by FDOT. Their justification for this approach is that it allows for greater development flexibility to take advantage of land use density and diversity which have been shown to increase multi-modal usage of the transportation network.

The plan presents policies for the overall circulation system. Included in these policies is the following statement, "A [QOS] standard that seeks to optimize travel by all transportation modes shall be developed and used to measure transportation performance. The City does not recognize [LOS] as a valid measure of overall transportation operations, and sets no maximum or minimum acceptable LOS levels, with the exception of streets that are part of the regional Congestion Management Agency network. LOS shall not be used to measure transportation performance in environmental review documents for any other purpose unless it is mandated by another agency over which the City has no jurisdiction, and then it shall only be used for the purposes mandated by that agency." Additionally, a policy stating that traffic impact fees can be used for bicycle, pedestrian, and transit improvements is included, "so that development pays its fair share toward a circulation system that optimizes travel by all modes." A street system policy requiring all private developments and public infrastructure projects to provide adequate right-of-way for all transportation modes is also listed.

2.9. Arlington, Texas

The City of Arlington, Texas *Thoroughfare Development Plan* lists the city's LOS standards as C or D except in specific areas where slower moving traffic will help to create a vibrant, safe, and pedestrian-friendly environment[13]. The city does not use intersection LOS, rather, corridor LOS is used based on v/c ratios. The following issues related to the adjustment of the roadway system are given:

1) A roadway that is projected to experience traffic volumes greater than its capacity may need to be adjusted to allow for increased capacity.
2) A roadway that is planned for increased capacity improvement without the backing of increased traffic volume projections should be adjusted to match the demand.
3) A roadway may require increased capacity, but expansion may be limited to site-specific constraints such as right-of-way. In this instance, improvements on parallel facilities and throughout the entire network should be examined to mitigate demand.
4) Increased use of alternated modes of transportation, such as transit or bicycling, could reduce vehicular demand on thoroughfare roadways over time.

The City of Arlington emphasizes flexible design for major roads. As stated in the *Thoroughfare Development Plan*, "Flexible design allows for transportation planners and roadway designers to create unique characteristics specific to individual corridors."

2.10. Snohomish County, Washington

Snohomish County, Washington uses an ultimate capacity standard for arterials that are built to their final size[14]. The ultimate capacity standard is applied to a roadway "when the county council determines that excessive expenditure of public funds is not warranted for the purpose of making further improvements on certain arterial units, the county council may designate, by motion, following a public hearing such arterial unit as being at ultimate capacity." After a road has been designated as having ultimate capacity, TSM and TDM actions are used to improve or maintain the QOS on the roadway. The objectives of the ultimate capacity methodology is given in **Table 2.3**.

Table 2.3: Ultimate Capacity Objectives

GMA Objective in RCW 36.70A.020	How the use of Ultimate Capacity relates to the GMA objective
Urban growth. Encourage development in urban areas where adequate public facilities and services exist or can be provided in an	Designation of certain arterials as ultimate capacity will enable increased density of both residential and commercial development in the surrounding (and immediate) areas served by the arterials to increase the viability of more efficient modes of
Reduce sprawl. Reduce the inappropriate conversion of undeveloped land into sprawling, low-density development.	Snohomish County's adopted GMA Comprehensive Plan identifies the areas suitable for higher density urban development. Without designations of ultimate capacity on arterials in these areas (once they have been improved to a certain level), concurrency restrictions can prevent the increased densities of development necessary to fully achieved these higher densities, forcing growth into lower density areas or even outside the urban growth area.
Transportation. Encourage efficient multimodal transportation systems that are based on regional priorities and coordinated	Efficient multi-modal systems depend upon high density residential and commercial
Permits. Applications for both state and local government permits should be processed in a timely and fair manner to	Determination of ultimate capacity streamlines concurrency determinations for developments impacting such arterials.
Public facilities and services. Ensure that those public facilities and services necessary to support development shall be adequate to serve the development at the time the development is available for occupancy and use without decreasing current service levels below locally established minimum standards.	All developments impacting arterials designated as ultimate capacity would still be subject to concurrency, but the determination of ultimate capacity would effectively establish a lower level of service standard and shift the focus to multimodal transportation. Developments impacting ultimate capacity facilities are required to meet [TSM] requirements (e.g. access control) and either meet revised (more intensive) [TDM] requirements, or meet criteria for transit compatibility. Determinations of ultimate capacity also include commitments to additional road improvements, TSM actions, and/or TDM actions by the County. Examples might include access control, periodic signal coordination, signal upgrades, and support for

Snohomish County establishes LOS standards based on average daily trip (ADT) thresholds. The thresholds for roadways that are not designated as ultimate capacity are generally low and only arterials with relatively low volumes will meet the standard. Conversely, roads that have been designated as ultimate capacity, the thresholds are high and are intended to be difficult, but not impossible, to exceed. **Table 2.4** presents the threshold values used by Snohomish County with respect to minimum levels of service.

Table 2.4: Transportation Level of Service Standard: Average Daily Trip Thresholds

Thresholds Measured as Number of Daily Trips (ADT)	Road Not Designated as Ultimate Capacity		Road Designated as Ultimate Capacity	
Number of Lanes	Rural Arterial Unit	Urban Arterial Unit	Rural Arterial Unit	Urban Arterial Unit
2	4,000	7,000	18,000	22,000
3	5,000	9,000	27,000	33,000
4	7,000	12,000	36,000	44,000
5	n/a	15,000	45,000	55,000
6	n/a	16,000	54,000	66,000
7	n/a	21,000	63,000	77,000

Snohomish County gives the following criteria for designating a roadway as reaching ultimate capacity

1) Initiated by a recommendation from the Public Works Director
    - Upon Completion of an engineer's report
    - Based on criterial in code and Department of Public Works (DPW) rules
2) Ultimate capacity is a County Council determination
    - By motion following a public hearing
    - When excessive expenditure of public funds would not be warranted for making further improvements
    - When arterial is designated ultimate capacity, a different LOS standard would apply, which would effectively allow much reduced travel speed.
3) Criteria for DPW recommendations and Council Designation
    - Either road is totally improved consistent with long-range plan
    - Road is partially improved but certain constraints preclude additional cost effective improvements
4) If road is only partially improved, then
    - Number of general-purpose travel lanes (excluding turn lanes) is consistent with the adopted transportation element
    - Adequate provisions are made to accommodate pedestrian and bicycle demand
    - If the source of delay is another agency's facility, then the approach to that facility is totally improved consistent with long-range plan
5) Developments impacting ultimate-capacity arterials would be required to:
    - Provide access management and circulation provisions, and either
        - Provide TDM, or

- Meet the criteria for transit compatibility

6) Designation by Council to include a commitment by the County to
    - Complete any known improvements needed to address safety issues
    - Complete an access management and circulation plan
    - TSM actions, access management improvements, and/or TDM actions for the purpose of improving efficiency, preserving roadway capacity, and improving operations

2.11. Fort Collins, Colorado

LOS standards for the City of Fort Collins, Colorado are given in their *Multimodal Transportation Level of Service Manual*[15]. Context sensitivity is stated in the Manual as, "[LOS] standards do not exist as stand-alone measures, but are part of a system of goal, objectives and standards. They are interpreted by the public and by elected decision makers in the context of current and future issues, trends, conditions, expectations, and perceptions and they require a system of measurement." Along this line of reasoning, LOS standards are presented for vehicular, pedestrian, bicycle, and transit modes, each with their respective criteria. The relevant vehicular LOS standards are presented in the following paragraphs.

The basic structure of Fort Collins' LOS standards is based on facility type and adjacent land use. LOS standards are given for both roadways (**Table 2.5**) and intersections (**Table 2.6**). Two special circumstances that may require unique treatment are identified as "Constrained Corridors" and "Backlogged Facilities." The Manual defines these two situations as:

- Constrained Corridors – These are segments of the street network which are physically constrained from further widening or major reconstruction. The constraint may be caused by the proximity of buildings or by environmental conditions (e.g., the presence of a wetland or riparian corridor).
- Backlogged Facilities – These are roadway segments which currently operate below the LOS standards in [**Table 2.5**]. These roadways are normally adjacent to developed properties and are not expected to be improved in future development.

Identification of both constrained corridors and backlogged facilities are identified on city maps. Each situation may require investment in non-motorized infrastructure to mitigate congestion and LOS issues.

Table 2.5: Roadway LOS Standards

Roadway Functional Classification	Land Use (from structure plan)			
	Commercial Corridors	Other Corridors Within:		
		Mixed Use Districts	Low Density Mixed Residential	All other Areas
Major Arterial	E	E*	D	D
Arterial	E	E*	D	D
Minor Arterial	E	E*	C	D
Collector	D	D*	C	D
Connector	n/a	C*	B	C

** Corridors within mixed use districts may fall below the LOS level indicated. In such cases, the City will provide for mitigation of congestion through alternatives to motor vehicle travel.*

Table 2.6: Intersection LOS Standards

Intersection Type	Land Use (from structure plan)			
	Commercial Corridors	Other Corridors Within:		
		Mixed Use Districts	Low Density Mixed Residential	All Other Areas
Signalized Intersections	D	E*	D	D
Stop Sign Control (arterial/local)	n/a	E*	E*	E
Stop Sign Control (collector/local)	n/a	C	C	C

** Intersections falling below LOS E will require identification of specific strategies for mitigation of congestion through alternatives to motor vehicle travel*

Street oversizing fees are collected prior to the issuance of building permits. These fees are coordinated with the City's overall transportation LOS standards and with its capital improvement planning. Proposed developments which would not meet motor vehicle LOS standards without additional investment in roadway infrastructure must be evaluated in light of the City's fee provisions. For such projects, the relationship between LOS standards and the street oversizing fee program, including the anticipated sharing of costs for roadway investments and the timing of such improvements, should be established as part of early review and should be explicitly addressed at the beginning of a development project.

2.12. Bellingham, Washington

The City of Bellingham, Washington defines its LOS standards in the *Development Guidelines & Improvement Standards*[16]. LOS standards are simply states as, "Level of service 'C' will be the peak-hour design objective for all movements, and under no circumstance will less than level of service 'D' be accepted for site- and non-site traffic including existing traffic at build out of the study area." The standards state that the current version of the Highway Capacity Manual or Transportation Research Board *Circular 212* methods be used to calculate LOS.

Bellingham uses a multimodal transportation concurrency policy[17]. The city is broken into 23 concurrency service areas. Within these areas, established concurrency measurement points are used to determine LOS on an annual basis. For pedestrian and bicycle concurrency, the degree of completeness is used rather than capacity measurements. As system of "person trip credits" is used to determine the multimodal capacity of each concurrency service area.

When a new development application is made, a determination must be made that there are enough person trips available to serve the development. If there are not enough person trips available, then the developer would be required to fund and construct bicycle, pedestrian, transit, and automobile improvements to ensure adequate person trips are available. This approach allows the City to focus on more than just peak hour traffic volumes. The concurrency policy states, "It is important to realize that, with the exception of the 'rush hour' commute, our multimodal transportation system works quite will." Changing user perception and expectations about rush hour automobile traffic congestion and their travel and mobility decisions and behavior is the goal of these policies.

2.13. Eugene, Oregon

Eugene, Oregon presents its LOS standards in the *Eugene 2035 Transportation System Plan*[18]. The LOS criteria vary depending upon where in the city the roadway is located:

1) LOS F within Eugene's Downtown Traffic Impact Analysis Exempt Area
2) LOS D elsewhere

Eugene's Downtown Traffic Impact Analysis Exempt Area is best characterized as the downtown core of Eugene. Additionally, this portion of Eugene is space constrained.

The *Transportation System Plan* further states that, "In some cases, it may not be possible or desirable to meet the designated mobility target or LOS standard. In those cases, an alternative mix of strategies such as land use, transportation demand management, safety improvements or increased use of active modes may be applied."

System-wide transportation system improvements are given for direction for a wide range of actions that reduce the need to construct new roadway capacity improvements. Examples of such actions include the following:

- Reconfigure roadway accesses to minimize traffic conflicts at intersections;
- Limit parking near signalized intersection to increase intersection capacity;
- Coordinate and operate traffic signals to improve traffic progression;
- Relocate driveways and improve local street connections to direct traffic away from overburdened intersections and intersection where side-street capacity is limited in order to optimize traffic progression on arterial and collectors;
- Improve turning-radii at intersections that are heavily used by trucks to avoid lane blockages;
- Install raised medians to reduce traffic conflicts; and
- Improve accesses so that traffic can enter or exit the highway with minimal disruptions of flow.

Even with the above actions, significant components of the roadway system are forecast to fall below acceptable LOS standards. Where management actions have failed to produce acceptable LOS, construction projects to add roadway capacity must be considered.

2.14. Pocatello, Idaho

The City of Pocatello, Idaho follows its *Traffic Impact Study Guidelines* for LOS criteria[19]. Based on intersection LOS, the criteria are based on the existing LOS without development and projected LOS with development. If the existing LOS is A, B, or C prior to development, then the minimum acceptable projected LOS with development shall be LOS C for all movements within a specific intersection. If, however, the existing LOS is D, E, or F, then the minimum acceptable projected LOS shall be equal to the LOS without development.

Mitigation requirements are jurisdiction specific. At a minimum, for each significant impact (drop in LOS) identified in the results section, the report must discuss feasible measures to avoid or reduce the impact to the system. To be considered adequate, measures should be specific and feasible. The report should also identify who is responsible for each measure. Any existing facility which does not meet criteria prior to the TIS should be identified. For developments that cause a facility to operate at an unacceptable LOS, measures should be identified for which the developer would be 100 percent responsible. If a development causes a significant impact at a facility which is directly accessed, the developer should be responsible for an equitable share. The development's equitable share is defined as its percentage of the facility's total traffic.

If a development causes a facility not directly accessed but within the study area to have significant impact or operate below the acceptable LOS, then the proposed development should pay a fair share of mitigation measures identified.

2.15. Raleigh, North Carolina

LOS standards for Raleigh, North Carolina are found in *The 2030 Comprehensive Plan for the City of Raleigh*[20]. The LOS standards are stated as Policy T 2.10: "Maintain [LOS] 'E' or better on all roadways and for overall intersection operation at all times, including peak travel times, unless maintaining this LOS would be infeasible and/or conflict with the achievement of other goals."

In addition to LOS standards, the Plan gives policies on when additional lanes can be added to a roadway. The Plan states that additional lanes should be added only after the roadway has exceeded 20 percent of its full capacity and all other alternative approaches have been considered. Furthermore, roadway improvements should increase vehicle dispersion and circulation, not just capacity. Use of bicycle, pedestrian, and transit LOS is also recommended.

2.16. College Station, Texas

LOS standards for College Station, Texas are found in their municipal code[21]. The code focuses on development related impacts to the transportation network. A standard of LOS D or better is given. If a new development will cause the LOS to degrade below a D, there are four mitigation options listed:

1) Modifying the density or intensity of land use, such as a reduction in square footage or the percentage of commercial use to result in traffic levels meeting LOS D or better
2) Phasing approval and construction of a project until additional roadway capacity becomes available;
3) Improving the access plan by dealing with features such as overall sire arrangement, the placement and design features of access points, provision of additional access points to roadway not immediately adjacent to the property, provision of alternate controls, or adjustments in the site circulation system;
4) Making off-site improvements including the construction of additional lanes, increases in storage lane capacities, or modification of signalization, to list some examples.

Mitigation is required where the development is contributing five percent or more of the total traffic at locations failing to meet LOS D or better. Adequate mitigation shall be determined by the appropriate reviewing body as to whether acceptable LOS will be met by the mitigation effort.

3.0. SUMMARY

Traffic performance measure policies are used to assist in determining when a given facility or intersection needs to be upgraded or improved. Establishing a fixed performance target can lead to forcing expensive upgrades that may have limited benefit. As such, care must be taken in determining a performance standard that is suitable for a given context.

Many of the agency policies that were reviewed focused on corridor, instead of intersection, performance measures. Travel time and v/c ratios were commonly used measures of performance. For some locations, travel time is measured for each link that makes up a given facility. For others, travel time between selected origins and destinations are used. For the municipalities that use v/c, capacity is set by policy based on facility size and functional usage. Commonly, a v/c less than 1.0 is considered acceptable.

Total volume on a given facility is used by some agencies. Some of the agencies establish threshold values for LOS (i.e. a value for LOS A, B, C, etc.), other agencies set a single threshold for passing or failing. For the agencies that use letter grades, LOS thresholds range based on facility size and function but generally LOS D and better is considered acceptable.

Free flow travel speed targets were used by a few agencies. Free flow speed target values are established by policy for roadway segments. An advantage cited for using free flow speed is the ability for the agency to measure it relatively easily.

While most agencies focused on automobile traffic, some utilize a holistic approach that accounts for multiple travel modes. When looking at multiple travel modes, the interrelated nature of the modes needs to be taken into account. Caution should be used when combining all modes of travel based on the volume of each mode. When this is done, it is often the case that the high volume of automobiles will dominate.

The concept of ultimate capacity, or establishing a point at which little to no more improvement in service can be realized through capacity improvements, is used to varying levels by some agencies. This concept allows city planners and leaders to establish a hard limit to the size and extent of certain roadways. When a facility is determined to be at ultimate capacity, funds are used for transportation demand management and transportation system management instead of capacity and infrastructure. **Table 3.1** presents a brief summary of the traffic performance metrics used by agencies reviewed in this document.

Table 3.1: Summary of Findings

Agency	Metric	Threshold	Notes
Pierce County, Washington	Volume to Service V/S ratio (similar to v/c)	V/S < 1.05	
Boulder, Colorado	Average daily trips (roadway)	LOS D or LOS E with TSM/TDM	
San Diego County, California	Average daily trips (roadway)	LOS C within development LOS D outside development	LOS thresholds vary based on size and functional class
Spokane, Washington	Intersection Delay	Delay no worse than 90 seconds in CBD Delay no worse than 85 seconds in retail areas/corridors LOS E or better on signalized arterial intersections LOS D or better on signalized collector intersections LOS E on unsignalized intersections	
Wisconsin DOT	Intersection Delay Roadway v/c	LOS C v/c < 1.0	
Vancouver, Washington	Roadway Free-flow speed	Established for each segment based on functional class and location	Measured annually along with volume
Florida DOT	Varies	Varies	Outlines a holistic approach to measuring multimodal LOS
Emeryville, California	Varies	No set targets	Utilizes the Florida DOT model No targets were set to ensure flexibility
Arlington, Texas	Roadway v/c	LOS C or D	Areas where slow speed and pedestrian traffic are allowed to have lower LOS
Snohomish County, Washington	n/a	n/a	Ultimate capacity policies that designate a facility as fully built.
Fort Collins, Colorado	Roadway v/c Intersection Delay	Varies by functional class	Have provisions for constrained and backlogged facilities
Bellingham, Washington	Roadway v/c	LOS C or D	Uses a "person trips available" method for multimodal capacity
Eugene, Oregon	Roadway v/c	LOS F in downtown, LOS D elsewhere	
Pocatello, Idaho	Intersection Delay	LOS C or better	
Raleigh, North Carolina	Intersection Delay	LOS E	If it is infeasible to build out of poor LOS, alternative mitigation options are allowed
College Station, Texas	Roadway v/c	LOS D	

Mitigation of transportation deficiencies varies between the reviewed agencies. Many agencies require developers to share the financial burden, however, the options available to the developers varies. For some agencies, increasing capacity is the last option to be considered. Investment in multi-modal transportation is preferred to expanding vehicle capacity in many locations. Some agencies have different requirements based on what portion of the city is being impacted. For example, Eugene, Oregon has designated its downtown area as a "Traffic Impact Exempt" area allowing for LOS F for vehicular modes.

Ultimate capacity designation is used by many cities. These routes, as designated by the respective city councils, are often space constrained and have been built to the extent that is reasonable. Other times, it may not be desirable to expand the corridors further due to land use, functional class, neighborhood character, etc. Again, investment in multi-modal infrastructure is needed to address the capacity needs of the areas.

4.0. RECOMMENDATIONS

A desire has been expressed to reevaluate current standards and to determine if changes are necessary to better mitigate impacts from development. The previous sections provide a discussion and comparison of what other communities have in place for development standards. While no single reviewed standard may be directly applicable to Bozeman, the review does provide some ideas for modifications to Bozeman's existing development standards.

The City of Bozeman's current development standards provide requirements for intersection performance based on LOS. The existing standards require developers to submit traffic impact studies documenting existing and projected conditions for traffic conditions adjacent to the development. This approach relies on intersection LOS to measure the impact of developments and often results in a narrowly focused view of the transportation system. Impacts from development are felt throughout the community, not just at adjacent intersections. The current standards are often unattainable due to funding or other constraints, and in some cases, may be undesirable.

Standards based on intersection LOS provide a microscopic approach to reviewing traffic operations. Intersection LOS is a simplistic approach to evaluate intersection performance in terms of vehicle delay and does not factor in alternative travel modes nor does it provide a realistic picture of the overall transportation system. Intersection LOS is often based on a single hour, or peak hours, for which the system is most congested. A more macroscopic approach to improving the transportation system, not just reducing peak hour delay at single intersections, should be taken to improve conditions for all users.

Investment in other parts of the transportation network may be more appropriate than trying to fix intersections near new development. Some areas of town require more infrastructure investment than others. For example, a residential development on the outskirts of town where current infrastructure is lacking would be more costly to the community than the same size and type of development in an area

where infrastructure is already built to current standards. Older areas of town are already built up and have constraints which limit the ability to add vehicle capacity. These areas are likely at their ultimate capacity. Undeveloped areas, however, require higher investment costs to provide new infrastructure. Other approaches to improving travel conditions, such as providing for active transportation modes and TDM strategies, should be encouraged to help reduce impacts, delay, and improve safety for all users.

Instead of requiring developers to develop traffic impact studies, it may be desirable, and simpler, to evaluate based solely on the type, location and size of the development. Ultimately, the goal is to develop the transportation network to the standards contained in the Bozeman TMP. For those roadways already built to recommended standards, no further infrastructure investment is needed. Focus can instead be put on improving accommodations for active travel modes and implementing TDM strategies. For other areas, significant costs are likely needed to improve infrastructure to meet current standards. These costs increase the further out development occurs. Standards focusing on the specifics of the development, not just on a set threshold for adjacent intersection, would allow for a holistic approach to improving the transportation system.

5.0. REFERENCES

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