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Analytic Memo Option 2: Rethinking LOS

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Don’t “Delay” Abandoning HCM: Rethinking Level of Service in Eugene

Executive Summary

The City of Eugene currently uses the Highway Capacity Manual (HCM) to evaluate the performance of its streets and intersections. This tool is focused on improving the level of service (LOS) for automobiles but does a poor job of measuring LOS for cyclists, pedestrians, and transit riders. To address this shortcoming, the transportation department conducted a study examining multi-modal level of service (MMLOS) standards in Eugene.

The transportation department compared two street intersections using the traditional LOS and the Urban Street Design Guidelines (USDG), a MMLOS adopted from Charlotte, NC. Staff found that the traditional LOS was inadequate for assessing streets due to its lack of consideration for other modes. However, staff also found limitations in Charlotte's USDG.

Staff chose the USDG rather than other MMLOS standards because this tool uses street design features as its primary metric. Street design is relatively simple to analyze compared to operational metrics such as bicycle and pedestrian volumes. However, staff found that the tool did not capture other important aspects of multimodal use, such as comfort and efficiency.

Staff anticipate that a nuanced MMLOS will provide a significant improvement over the standard LOS. For this reason, staff recommend that Eugene adopt a hybrid model based on the USDG as well as other MMLOS standards including the Pedestrian Environmental Quality Index (PEQI) and the Bicycle Environmental Quality Index (BEQI). By combining MMLOS metrics, Eugene can create a robust tool that analyzes many different aspects of street performance for all modes.

Introduction

A key function of the City of Eugene's Transportation Department is to assess street performance and identify areas for improvement. To do this, the department uses the Highway Capacity Manual (HCM), which outlines methods for determining level of service (LOS) for vehicles.

Although the HCM has been the industry standard for almost 70 years, other methods may offer a more robust examination of street performance because they take into account the perspectives of non-automobile transportation modes .[1] These multi-modal level of service (MMLOS) methods have the potential to reprioritize street space for pedestrians, cyclists, and transit riders.

This memo describes both the standard LOS as well as various MMLOS methods from early-adopter cities. Staff then use the standard LOS to show how this tool assesses street performance for two intersections: Coburg Road & Chad Drive and Willamette Street & 18th Avenue. Staff then analyze these same intersections using the MMLOS. The results of our study show that although both tools have limitations, adopting an MMLOS in Eugene that takes into account all modes through the lens of safety, comfort, and efficiency will help the city meet its transportation and climate goals.

Overview of the Traditional Level of Service

In 1950, the first-ever HCM was developed in response to post-World War II roadway expansion.[2] The 1950 HCM established measures to quantify the capacity for roadways and highways and was intended

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[1] Brozen, M; Black, T; Liggett, R (2014). "Comparing Measures and Variables in Multimodal Street Performance Calculations: What's a Passing Grade*?" Transportation Research Record: Journal of the Transportation Research Board, No. 2420*, Transportation Research Board of the National Academies, Washington, D.C., 2014, pp.1-14
[2] Highway Capacity Manual (2010). *Transportation Research Board.*

to assure that designs would result in the necessary infrastructure.[3] The concept of LOS, which is calculated by a ratio of service volume to designed capacity, was introduced in 1965 to measure street capacity for automobiles.[4] Since 1965, LOS metrics have been refined and broadened to include non-vehicle modes such as pedestrians, bicyclists, and transit riders.[5] However, transportation professionals do not often use the HCM to calculate LOS for non-motorized uses because these calculations are complex and heavily rely on operational data. While LOS provides a consistent system to encourage efficient vehicle travel, critics find that traditional LOS does not adequately account for the multi-variate experience of bike, pedestrian, and transit travel.[6]

The LOS system assigns a grade (A through F) based on vehicle delay at intersections, usually measured during weekday peak hours. Delay is measured as the difference between the actual travel time and what the travel time would be without other vehicles or traffic controls.[7] Lastly, vehicle LOS will necessarily worsen if other travel modes are prioritized.[8]

A grading system easily conflated with school grades and peak hour analysis both contribute to the development of roads that are overbuilt for nearly every hour of the day. LOS A indicates that drivers may travel at the posted speed; as delay increases, the grade gets worse.[9] LOS E indicates that a roadway is operating at or near the designed capacity.[10] While a roadway operating at or near capacity sounds appropriate, a 'failing' grade is not viewed positively. The desired objectivity of LOS, then, is

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[3] Highway Capacity Manual (2010).
[4] Ibid.
[5] Ibid.
[6] Brozen, M; Black, T; Liggett, R (2014); Milam, R (n.d.) "Transportation Impact Analysis Gets a Failing Grade" *Fehr & Peers.*
[7] Milam, R (n.d.).
[8] Ibid.
[9] Ibid.
[10] Ibid.

marred by subjective interpretations of ‘passing’ grades. Additionally, LOS grades are determined by transportation operations analyses that are conducted during the busiest time of day, the peak 15-minute traffic volume.[11] Is LOS A desirable during the 99th percentile of all vehicle travel on that road segment? The traditional LOS system indicates yes, but that road space will sit mostly vacant and underutilized for much of each day.

The objectivity of the traditional LOS system is also compromised by relying on “acceptable” levels of delay and congestion.[12] Local jurisdictions determine what is or is not acceptable which allows for context-dependent policies but undermines any opportunity for regional or national consistency.[13] While rural communities may maintain LOS C or better, suburban areas may have a different threshold and maintain LOS D or better.[14] Also, while measuring travel experience only in terms of delay is acceptable for vehicles, bicyclists, pedestrians, and transit riders are subject to more variables such as safety, comfort, and efficiency.

In prioritizing vehicle efficiency, the traditional LOS necessarily conflicts with improvements for bicyclists, pedestrians, and transit riders.[15] Reallocating space for safer and more enjoyable walking and biking or for enhanced transit service removes land area that can increase vehicle capacity.

While the traditional LOS provides a fairly consistent and understandable system for efficient vehicle movement, a nuanced MMLOS would better address the needs of non-vehicle users by measuring safety, comfort, and efficiency.

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[11] Milam, R (n.d.) “Transportation Impact Analysis Gets a Failing Grade” *Fehr & Peers.*
[12] Milam, R. (n.d.)
[13] Ibid.
[14] Ibid.
[15] Ibid.

Overview of Multimodal Level of Service

Planners and traffic engineers have developed several alternate LOS systems that include the roadway experiences of pedestrians, cyclists, and transit riders. These MMLOS metrics are a significant departure from the standard LOS but have the potential to provide a more thorough analysis of street performance for all users. Although not nearly as widely used as the standard LOS, MMLOS metrics have been used in many cities, including Charlotte, NC and San Francisco, CA. Eugene does not have a designated MMLOS metric, but the city's Transportation System Plan (TSP) does include street design guidelines that intend to support multimodal options.

MMLOS metrics vary both in the inputs they measure and the goals they advance. Most MMLOS systems focus on either improving safety, comfort, or aesthetic appeal for multimodal users.[16] They can measure a variety of inputs, including delay and design features such as signal timing. The following section describes two of the most common MMLOS metrics and discusses their strengths and weaknesses.

Charlotte, North Carolina

In 2007, the City of Charlotte adopted the Urban Street Design Guidelines (USDG) in response to the increase in congestion as a result of the community's rapid growth. The goal of these guidelines is to encourage complete streets and promote Smart Growth principles.[17] The USDG tool uses street design to measure safety rather than focusing on comfort and efficiency.

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[16] Brozen, M; Black, T; Liggett, R (2014)
[17] City of Charlotte. (2007). *Urban Street Design Guidelines*.

The USDG metric is used to measure performance for cyclists and pedestrians, but does not measure performance for transit riders. Another shortcoming of the USDG is that the tool is designed to measure intersections but not street links.[18]

Although the USDG metric is limited to measuring intersections and does not factor in transit riders' experiences, this tool effectively measures safety and is simple to implement as it includes few operational inputs.[19]

San Francisco, California

The City of San Francisco developed the Bicycle Environmental Quality Index (BEQI) and the Pedestrian Environmental Quality Index (PEQI) in 2007 to assess street intersection and road link performance. Like the USDG, this tool focuses on street design with the goal of improving safety for pedestrians and cyclists.[20]

The BEQI measures both street intersections and links. However, there are only three inputs that factor into intersection scores: whether or not vehicles can turn right on red, the presence or absence of bicycle lane striping, and the presence or absence of bicycle left turn lanes.[21] For road links, the tool is more robust and includes numerous inputs that fall into the categories of land use, vehicle traffic, intersection safety, perceived safety, and street design.[22]

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[18] Zuniga-Garcia, N., Ross, H., & Machemehl, R. (2018). Multimodal Level of Service Methodologies: Evaluation of the Multimodal Performance of Arterial Corridors. Transportation Research Record, 2672(15), 142-154.
[19] Brozen, M; Black, T; Liggett, R (2014)
[20] Ibid.
[21] Ibid.
[22] Zuniga-Garcia, N., Ross, H., & Machemehl, R. (2018)

The PEQI also measures both street intersections and links. For intersections, the PEQI includes many more inputs than the BEQI, including crosswalks, intersection lighting, signal countdowns, islands within the street crossing, high visibility crosswalks, curb ramps, and wait time, among others. For road links, the PEQI includes factors that fall into the same general categories as the BEQI.[23]

This tool is similar to Charlotte's USDG tool in that it mainly uses design inputs as metrics. However, it offers a more robust examination of street segments as whole, whereas the USDG only assesses intersections. Furthermore, the BEQI and PEQI both measure land use, perceived safety, and vehicle traffic, which are essential aspects of bicycle and pedestrian infrastructure that relate to efficiency and comfort.

Eugene, Oregon

Although Eugene does not use MMLOS analysis of street segments, the city was an early adopter of multimodal street design guidelines. In 1999, the city adopted *Design Standards and Guidelines for Eugene Streets, Sidewalks, Bikeways and Accessways,* which requires that new streets and street modifications include design features aimed at increasing cycling, walking, and riding transit.[24]

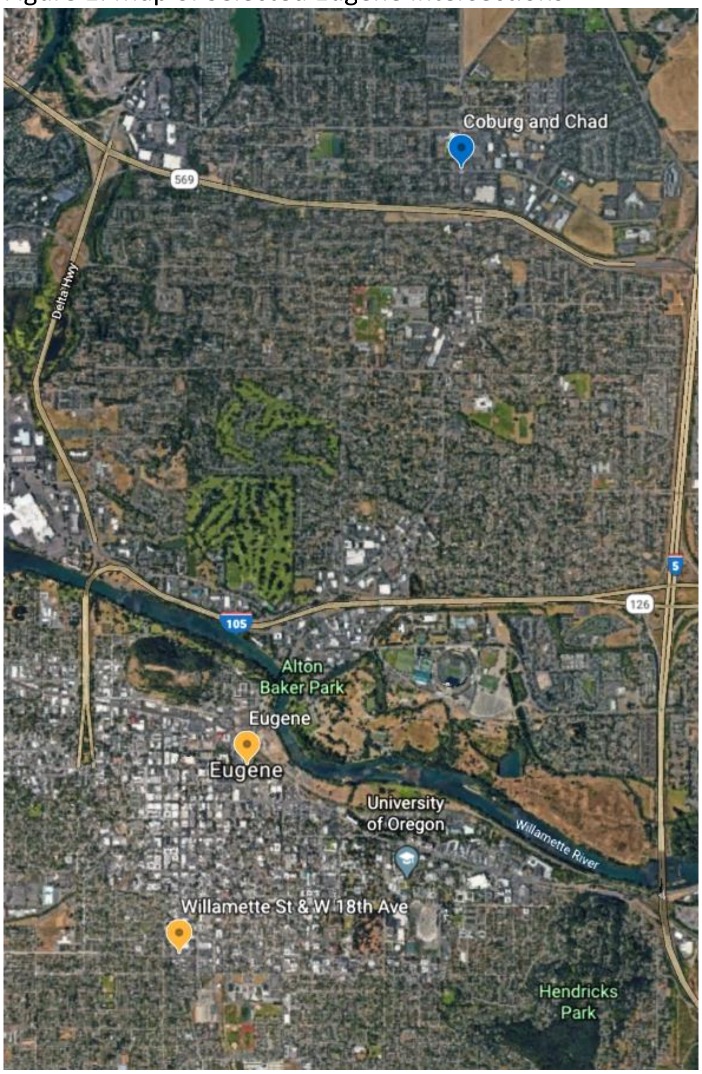
Eugene Roadway Evaluation

Staff determined two intersections to evaluate using the Highway Capacity Manual and Charlotte's USDG. Staff selected one under-performing intersection as well as one high-performing intersection to

[23] Zuniga-Garcia, N., Ross, H., & Machemehl, R. (2018)
[24] City of Eugene. (2017). *"2035 Transportation System Plan."* https://www.eugene-or.gov/3941/Transportation-System-Plan.

evaluate how different LOS techniques would assess a variety of intersection types. Staff selected the intersection of Coburg Road & Chad Drive as our under-performing intersection. The intersection of Willamette Street and W 18th Avenue served as our high-performing intersection. The two locations can be seen on the map in Figure 1:

Figure 1: Map of Selected Eugene Intersections



Source: Google Maps

For images depicting the intersection of Coburg & Chad, reference **Appendix D**. For images depicting the intersection of Willamette & 18th, reference **Appendix E.**

Evaluation: Highway Capacity Manual

The method for calculating vehicle LOS for signalized intersections includes two main factors: delay and volume to capacity ratio (V/C ratio). **Appendix A** discusses the HCM methodology for determining delay and V/C ratios. Figure 2 shows how these two metrics relate to LOS ratings:

Figure 2: HCM Level of Service Performance Standards for Signalized Intersections

Control Delay per Vehicle (seconds per vehicle)	LOS at V/C Ratio ≤ 1	LOS at V/C Ratio > 1
≤ 10	A	F
> 10-25	B	F
> 20-35	C	F
> 35-55	D	F
> 55-80	E	F
> 80	F	F

Source: Federal Highway Administration

Because the Eugene TSP uses the HCM to determine intersection LOS, staff were able to use calculations made by Eugene's traffic engineers. Figure 3 shows how the HCM LOS scored both intersections:

Figure 3: HCM LOS Scores, Chad Dr. & Coburg Rd.; Willamette St. & W 18th Ave.

Intersection Name	Performance Standard			Intersection Performance Metrics			Meets Standard?
	Intersection Control	Jurisdiction	Performance Standard	LOS	Delay (s)	V/C	
Coburg Road & Chad Drive	Signal	City of Eugene	LOS D	E	72.1	0.68	No
Willamette Street & W 18th Avenue	Signal	City of Eugene	LOS E	B	18.8	0.70	Yes

Source: Eugene 2035 Transportation System Plan

The intersection of Coburg & Chad received an LOS of E. This does not meet the city's standard for the intersection, which is LOS D. The intersection's V/C ratio is .68, indicating that this intersection is well below its designed capacity. However, this intersection does not meet standards due to vehicle delay.

The intersection of Willamette & 18th performed better in the delay category, but is closer to its designed capacity (.70) than Coburg & Chad. Because of the short vehicle delay at this intersection, it received an LOS of B, which is well above its minimum performance standard of E.

Traffic engineers generally receive training on how to collect and analyze delay and V/C ratios, which is why this tool is often easier to implement than more innovative approaches. However, the HCM methodology is complex and involves many assumptions about vehicle speed and behavior. MMLOS metrics may actually be simpler to calculate and involve fewer assumptions, but the lack of training for engineers on MMLOS metrics may be a barrier to implementation.

Evaluation: Urban Street Design Guideline's MMLOS

Charlotte's 2007 USDG prioritizes safety for pedestrians and cyclists. Conducting evaluations with USDG metrics was straight forward and efficient. Necessary data can be collected from online tools and individual approach scores are added to an "approach total" and averaged to find the "intersection average."[25]

While ease of use is an advantage, the USDG's emphasis on safety leaves out important considerations about comfort and efficiency, leading to scores that seem incongruous with the built environment. Using these metrics, it is also difficult to account for differences on two different sides of one crosswalk; for example, Willamette St. becomes one-way south of 18th Ave. The following section outlines two intersection evaluations for motor vehicles, pedestrians, and bicycles.

[25] City of Charlotte (2007) "Urban Street Design Guidelines."

Motor Vehicles

As shown in Figures 4 and 5, all seven approaches (four from one intersection and three from another), are designated as "Condition 4." Per the Eugene TSP, the V/C for each intersection is below 0.90.[26] Staff assumed that this was recorded for both one AM and one PM hour. USDG Conditions (ranging 1-4) serve as thresholds for moving forward with LOS analysis for vehicle, pedestrian, and bike travel.[27]

Figure 4. USDG Road Condition Designation, Coburg Road & Chad Drive

Chad Dr. & Coburg Rd.	Westbound Approach (Chad Dr.)	Eastbound Approach (Chad Dr.)	Northbound Approach (Coburg Rd.)	Southbound Approach (Coburg Rd.)
Condition	4	4	4	4

Figure 5. USDG Road Condition Designation, Willamette Street & W 18th Avenue

Willamette St. & 18th Ave.	Southbound Approach (Willamette St.)	Northbound Approach (Willamette St.)	Westbound Approach (18th Ave.)	Eastbound Approach (18th Ave.)
Condition	4	-	4	4

Pedestrian

USDG pedestrian metrics include the following:

- Pedestrian crossing distance (measured in lanes)
- Left turn conflict (left turns into pedestrian path)
- Right turn conflict (right turns into pedestrian path)
- Pedestrian signal display (upraised hand, walking person, countdown)
- Corner radius

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[26] City of Eugene (2017) "2035 Transportation System Plan" https://www.eugene-or.gov/3941/Transportation-System-Plan.
[27] City of Charlotte (2007) "Urban Street Design Guidelines."

- Crosswalks (transverse or ladder markings)[28]

Staff evaluated the intersections using both Google Street View and Google Earth. Under these metrics, the intersection at Coburg & Chad receives **LOS C** and the intersection at Willamette & 18th receives **LOS B**. The full pedestrian matrices can be found in **Appendix B.**

Bicycle

USDG bicycle metrics include the following:

- Bike travel way and speed of adjacent traffic (whether a bike travels in a shared lane or dedicated bike lane; posted speed on roadway)
- Opposing vehicular left turn phase (protected or unprotected left turns)
- Stop bar location (all travelers stop at the same point or bikes stop ahead)
- Shared traffic lane or separate right turn traffic lane
- Right turns on red (allowed or prohibited)
- Intersection crossing distance (measured in number of lanes)[29]

Staff evaluated these intersections using both Google Street View and Google Earth. Under these metrics, the intersection at Coburg & Chad receives **LOS C** and the intersection at Willamette & 18th receives **LOS C**. The full bicycle matrices can be found in **Appendix C**.

[28] City of Charlotte (2007) "Urban Street Design Guidelines."
[29] City of Charlotte (2007)

Findings and Recommendations

Staff find that, on their own, neither the traditional LOS nor the USDG adequately encourage non-motorized use. Instead, staff recommend that the City of Eugene adopt a hybrid MMLOS that includes the USDG, the BEQI, and the PEQI as well as shift towards considering person throughput instead of vehicle throughput. The following section discusses findings from the traditional LOS analysis and the MMLOS analysis as well recommendations for implementation.

Traditional LOS

According to HCM metrics that measures delay, the intersection of Coburg & Chad is sub-standard for cars. The Eugene 2035 Transportation System Plan classifies Coburg Road as a priority for street design improvements due to its increasing congestion and discomfort for cyclists and pedestrians. Since Eugene adopted multimodal design guidelines in 1999, the intersection of Coburg & Chad may be performing appropriately from a design perspective, but needs to improve comfort, land use, and aesthetics.[30]

Under the same metrics, the intersection of Willamette & 18th meets standards for all modes. While vehicle delay is almost four times higher at Coburg & Chad, versus Willamette & 18th (72.1 seconds and 18.8 seconds, respectively), Willamette & 18th has a higher V/C ratio (.70 vs .68). Even though both intersections are under capacity, measuring delay results in a "failing" grade for Coburg & Chad. If Coburg & Chad is to improve LOS, the city would likely need to increase roadway capacity. Increased capacity can induce demand, but the current V/C also shows that increased capacity may not alleviate

[30] City of Eugene (2017) "2035 Transportation System Plan"

delay. In this way, V/C may be more helpful than delay in indicating road performance and preventing overbuilt and underutilized roadways.

Urban Street Design Guidelines (USDG) MMLOS

The USDG metrics have shortcomings for bicycle and pedestrian evaluations but interpret motor vehicle travel differently. Instead of assigning grades, the USDG metrics use conditions based only off V/C.[31] These conditions are more descriptive than evaluative, serving as a threshold for beginning LOS analysis. By shifting away from motor vehicle LOS grades, the USDG reduces the conflation between road system performance and a good report card. Instead, road conditions may inform bike and pedestrian infrastructure.[32]

While Willamette & 18th earns a "higher" grade than Coburg & Chad for pedestrians, the bicycle LOS is the same for both intersections. This is surprising given staff's perceived differences between the two intersections, and helps illustrate the USDG's shortcomings. In prioritizing safety, the USDG neglects to include metrics that measure bicyclist comfort and efficiency. The posted speed of 35 mph on Coburg may be safe, but the wide and straight road design encourages drivers to travel faster than the speed limit, leaving bicyclists feeling vulnerable. To account for the disparity between posted speed and actual speed of traffic, the USDG could lower speed thresholds. The USDG could also be more stringent on the crossing distance because of the land use and accessibility impacts of roadways with many lanes.

[31] City of Charlotte (2007) "Urban Street Design Guidelines"
[32] City of Charlotte (2007)

While the USDG effectively reframes motor vehicle LOS away from grading and provides strong design guidelines to improve bicyclist and pedestrian safety, the model is limited to intersections and inadequately measures bicyclist and pedestrian comfort and efficiency.

Recommendations

Based on our findings, staff recommend that the city adopt a nuanced MMLOS that includes metrics to evaluate the safety, comfort, and efficiency of all road users. The traditional LOS incentivizes increasing capacity to reduce delay. Capacity increases (such as adding lanes) both negatively impacts land use and the travel experience of other modes and also, due to induced demand, may not decrease delay.[33]

Creating and implementing a nuanced MMLOS could help Eugene achieve its defined climate and transportation goals. Specifically, staff recommend that Eugene adopt a hybrid model that incorporates the USDG, the Bicycle Environmental Quality Index (BEQI), and the Pedestrian Environmental Quality Index (PEQI). These three models are similar in their focus on design and safety, and staff recommend adding the BEQI and PEQI to provide a more robust examination of street segments that addresses bicyclist and pedestrian comfort and efficiency. The addition of PEQI/BEQI to an MMLOS system will help the city assess road links as well as intersections.

Notably, neither the USDG nor the BEQI/PEQI address transit use. Further research and analysis are necessary to evaluate develop a transit LOS for Eugene. These preliminary recommendations require further impact and feasibility analyses, but staff believe that a nuanced MMLOS will best address the travel needs of vulnerable road users to encourage more balanced travel demand.

[33] Downs, A. (2004). Still Stuck in Traffic: Coping with Peak-Hour Traffic Congestion.

Conclusion

The traditional LOS established an important foundation for evaluating roadway performance. As the analysis shows, though, the traditional metrics do not serve multimodal transportation needs and goals. A nuanced and inclusive multimodal LOS requires further study, but staff provide preliminary steps to improve the safety, comfort, and efficiency for all travelers.

Bibliography

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Appendix A: HCM Methodology for Calculating Intersection LOS

The method for calculating vehicle LOS for signalized intersections includes two main factors: delay and volume to capacity ratio (V/C ratio).

For signalized intersections, the HCM uses delay resulting from traffic signals as the main indicator for LOS. This type of delay is called control delay. Figure 6 describes the factors that contribute to control delay.

Figure 6: Control Delay Factors

Factor	Description
Slowing in advance of an intersection	Time spent deaccelerating to stop on a red light
Stopping on an intersection approach	Time spent stopped at an intersection
Moving up in the queue	Time spent moving forward after the light turns green
Acceleration to desired speed	Time spent accelerating after clearing an intersection

Source: Highway Capacity Manual 2010

The HCM also uses V/C ratios as a threshold for determining whether or not an intersection meets LOS standards. A ratio of 1.0 means that the intersection is at full capacity. A ratio of greater than 1.0 means that an intersection's volume is over its designed capacity, while a ratio of less than 1.0 means that the intersection is below capacity. If an intersection's vehicle volume is 1.0 or greater, the intersection receives an LOS of F.

V/C ratios are found by dividing vehicle volume by the intersection's capacity. Although this equation is simple, volume and capacity each have their own inputs. Vehicle capacity is defined by the HCM 2010 as "the maximum number of vehicles that can pass a given point during a specified period under prevailing roadway, traffic, and control conditions."[34]

Calculating volume involves counting the number of vehicles travelling in a designated time period. The most common way to calculate volume is to use flow rate, which shows the number of vehicles travelling per hour.

[34] Highway Capacity Manual (2010)

Appendix B: Pedestrian Evaluation

Figure 7: Coburg Road & Chad Drive Pedestrian LOS Calculations

Location: Chad Drive & Coburg Road	Westbound Approach (Chad Dr.)	Eastbound Approach (Chad Dr.)	Northbound Approach (Coburg Rd.)	Southbound Approach (Coburg Rd.)
Pedestrian Crossing Distance	5 Lanes	5 Lanes	3 Lanes	2 Lanes
Score	50	50	78	80
Signal Features				
Left Turn Conflict (left turns into pedestrian path)	Green Arrow Only, from 2+ lanes - with pedestrian phase	Green Arrow Only, from 2+ lanes - with pedestrian phase	Green Ball Only, from a single lane, with a pedestrian phase	Green Ball Only, from a single lane, with a pedestrian phase
Score	15	15	0	0
Right Turn Conflict (right turns into pedestrian path)	Green Ball from shared thru-right lane - with pedestrian phase	Green Ball from shared thru-right lane - with pedestrian phase	Green Ball from shared thru-right lane - with pedestrian phase	Green Ball from shared thru-right lane - with pedestrian phase
Score	0	0	0	0
Pedestrian Signal Display	Upraised Hand	Upraised Hand	Upraised Hand	Upraised Hand
Score	0	0	0	0
Corner Radius	28'	28'	28'	28'
Score	5	5	5	5
Right Turns on Red	Allowed	Allowed	Allowed	Allowed
Score	0	0	0	0
Crosswalks	Transverse	Transverse	Transverse	Transverse
Score	0	0	0	0
Approach Total	70	55	83	85
Approach LOS	C	C	B	B
Intersection Average	**73**			
Intersection LOS	**C**			

Figure 8: Willamette Street & 18th Street Pedestrian LOS Calculations

Location: Willamette Street & 18th Avenue	Southbound Approach (Willamette St.)	Northbound Approach (Willamette St.)	Westbound Approach (18th Ave.)	Eastbound Approach (18th Ave.)
Pedestrian Crossing Distance	3		2	2
Score	78		80	80
Signal Features				
Left Turn Conflict (left turns into pedestrian path)	Green Ball Only, from a single lane, with a pedestrian phase		Green Ball Only, from a single lane, with a pedestrian phase	Left Turn Prohibited
Score	0		0	15
Right Turn Conflict (right turns into pedestrian path)	Green Ball from shared thru-right lane - with pedestrian phase		Green Ball from shared thru-right lane - with pedestrian phase	Green Ball from shared thru-right lane - with pedestrian phase
Score	0		0	0
Pedestrian Signal Display	Walking Person		Walking Person	Walking Person
Score	0		0	0
Corner Radius	13'		13'	13'
Score	10		10	10
Right Turns on Red	Allowed		Allowed	Allowed
Score	0		0	0
Crosswalks	Transverse		Transverse	Transverse
Score	0		0	0
Approach Total	88		90	90
Approach LOS	B	N/A	B	B
Intersection Average	**89**			
Intersection LOS	**B**			

Appendix C – Bicycle Evaluation

Figure 9: Coburg Road & Chad Drive Bicycle LOS Calculations

Location: Chad Drive & Coburg Road	Westbound Approach (Chad Dr.)	Eastbound Approach (Chad Dr.)	Northbound Approach (Coburg Rd.)	Southbound Approach (Coburg Rd.)
Bike Travel Way & Speed of Adjacent Traffic	Bike Lane to Bike Lane - 25 mph	Bike Lane to Bike Lane - 35 mph	Bike Lane to Bike Lane - 35 mph	Bike Lane to Bike Lane - 35 mph
Score	80	70	70	70
Signal Features Opposing Vehicular Left Turn Phase	Green Arrow & Green Ball	Green Arrow & Green Ball	Green Ball Only from a single lane - with pedestrian phase	Green Ball Only from a single lane - with pedestrian phase
Score	5	5	0	0
Stop Bar Location	Vehicles & Bikes Stop at Same Point	Vehicles & Bikes Stop at Same Point	Vehicles & Bikes Stop at Same Point	Vehicles & Bikes Stop at Same Point
Score	0	0	0	0
Right Turning Traffic Conflict Shared Traffic Lane/Separate Right Turn Traffic Lane	Separate Right Turn Lane - Bike Lane Right of Right Turn Lane	Shared Thru-Right lane - no bike lane	Separate Right Turn Lane - Bike Left of Right Turn Lane	Separate Right Turn Lane - Bike Lane Right of Right Turn Lane
Score	-20	0	10	20
Right Turns on Red	Allowed	Allowed	Allowed	Allowed
Score	0	0	0	0
Intersection Crossing Distance	5 Lanes	5 Lanes	3 Lanes	2 Lanes
Score	-5	-5	0	0
Approach Total	70	70	80	50
Approach LOS	C	C	B	D
Intersection Average	**65**			
Intersection LOS	**C**			

Figure 10: Willamette Street & 18th Street Bicycle LOS Calculations

Location: Willamette Street & 18th Avenue	Southbound Approach (Willamette St.)	Northbound Approach (Willamette St.)	Westbound Approach (18th Ave.)	Eastbound Approach (18th Ave.)
Bike Travel Way & Speed of Adjacent Traffic	Bike Lane to Bike Lane - 25 mph		Bike Lane to Bike Lane - 25 mph	Bike Lane to Bike Lane - 30 mph
Score	80		80	70
Signal Features				
Opposing Vehicular Left Turn Phase	Green Ball Only from a single lane - with pedestrian phase		Green Ball Only from a single lane - with pedestrian phase	Green Ball Only from a single lane - with pedestrian phase
Score	0		0	0
Stop Bar Location	Vehicles & Bikes Stop at Same Point		Vehicles & Bikes Stop at Same Point	Vehicles & Bikes Stop at Same Point
Score	0		0	0
Right Turning Traffic Conflict				
Shared Traffic Lane/Separate Right Turn Traffic Lane	Separate Right Turn Lane - Bike Lane Right of Right Turn Lane		Separate Right Turn Lane - Bike Lane Right of Right Turn Lane	Separate Right Turn Lane - Bike Lane Right of Right Turn Lane
Score	-20		-20	-20
Right Turns on Red	Allowed		Allowed	Allowed
Score	0		0	0
Intersection Crossing Distance	3 Lanes		2 Lanes	2 Lanes
Score	0		0	0
Approach Total	60		60	50
Approach LOS	C	N/A	C	C
Intersection Average	57			
Intersection LOS	C			

Appendix D – Coburg Road & Chad Drive Images

Figure 11: Birds Eye View, Coburg Rd. & Chad Dr.

Source: Google Earth

Figure 12: Northbound on Coburg

Source: Google Earth

Figure 13: Southbound on Coburg

Source: Google Earth

Figure 14: Eastbound on Chad


Source: Google Earth

Figure 15: Westbound on Chad

Source: Google Earth

Appendix E – Willamette Street & 18th Avenue Images

Figure 16: Birds Eye View, Willamette St. & 18th Ave

Source: Google Earth

Figure 17: Northbound on Willamette (not possible, one-way)

Source: Google Earth

Figure 18: Southbound on Willamette

Source: Google Earth

Figure 19: Eastbound on 18th

Source: Google Earth

Figure 20: Westbound on 18th

Source: Google Earth