

City of Concord

Technical Standards Manual

Article VIII

Traffic Impact Analysis (TIA)

Appendix G

Pedestrian and Bicycle Intersection LOS Methodology



G.1 INTRODUCTION

The following Level of Service (LOS) methodology was developed by the City of Charlotte, North Carolina to assess pedestrian and bicyclist comfort and safety while crossing signalized street intersections. The results can be weighed against motor vehicle LOS to balance user needs and priorities at an intersection. Pedestrian and bicyclist LOS is based on crossing comfort and safety compared to motor vehicle LOS, which is based on driver delay. While delay is a factor to pedestrians and bicyclists, crossings that appear unsafe or imposing result in people avoiding those intersection crossings. Efforts to improve motor vehicle LOS typically include the addition of extra lanes or signal timing enhancements that are generally perceived to negatively affect pedestrians and bicyclists. Resources used to prepare this methodology include FHWA's *Pedestrian Facilities Users Guide*, ITE's *Traffic Control Devices Handbook*, FDOT's *Point Level of Service Report* dated August 2001 and Portland's *Pedestrian Design Guide*. The LOS methodologies for pedestrians and bicyclists are presented as separate analysis techniques since major impediments are different for pedestrians and bicyclists.

G.2 PEDESTRIAN INTERSECTION LOS

A. Signalized Intersection Parameters and Their Relative Importance

The primary impediments to comfort and safety for pedestrians at signalized intersections are crossing distance and conflicts with turning vehicles. Vehicle volumes and speeds are factors as well, but these are tempered by the presence of the traffic signal, its phasing and/or physical characteristics of the intersection. For example, tight corner radii can slow the speed of right-turning vehicles, and right and left turn volume conflicts can be reduced or eliminated by signal phasing. These design factors affect pedestrian's perceived comfort and safety.

This methodology identifies those key elements or features that enhance or reduce pedestrian perceptions of comfort and safety and then weighs them relative to one another by a point system.

B. Key Intersection Parameters

1. Pedestrian Crossing Distance

Crossing distance is the primary crossing obstacle for pedestrians and therefore receives the greatest weight in this methodology—accounting for more than half of all possible points. The shorter distance a pedestrian has to walk to cross a street, the easier and more comfortable it is perceived to be. For example, a crossing distance equivalent to two or three lanes rates a minimum LOS C, exclusive of any other features. By contrast, a crossing of six to seven lanes generally falls in the LOS E to F range, exclusive of any other features. For wide crossings, where there is a greater probability that pedestrians might fail to make it across the entire roadway in the signal time provided, LOS can be improved noticeably if there is a median wide enough to serve as refuge. Crossing distance should be measured along the marked crosswalk, or if unmarked, the assumed path one would take to cross the street. The crossing distance for streets with medians is the total distance to cross the street, including the median width. For streets with right-turn porkchop islands, the crossing distance is that required to reach the far intersection corner minus the distance within the porkchop island.

2. Signal Phasing and Timing

This is the most intricate of the categories and accounts for nearly 20 percent of the total points. It is rated according to the type and level of crossing information provided to the pedestrian and whether the signal phasing minimizes or eliminates conflicts between pedestrians and turning vehicles.

Dedicated left-turn phasing is generally perceived as a benefit to pedestrians if accompanied by pedestrian signals that inform pedestrians when they can cross without a conflict with left-turning vehicles. With a dedicated left-turn signal phase but no pedestrian signal, pedestrians have greater risk exposure because motorists are less likely to yield when they have a green arrow than when they have a solid green ball indication. This situation is viewed negatively.

Right turns are rated according to lane configuration and signal phasing. Points cannot be gained from this subcategory but can be lost if overlap phasing is used and no pedestrian signals are present. Similar to dedicated left-turn phasing, motorists are less likely to yield to pedestrians when they have a green arrow than when they have a solid green ball indication.

Points can be attained by the presence of pedestrian signals, provided vehicle conflicts are reduced and/or information is given by the signals that show pedestrians how much time is available for them to cross the street (countdown signals). Additional points can be obtained by timing the pedestrian phases for slower walk speeds if countdown pedestrian signals are used. Pedestrian phase times based on slower walk speeds without countdown signals are not perceived by pedestrians and therefore do not receive extra points.

3. Corner Radius

A corner radius is rated according to its potential effects on right-turning vehicle speeds and any increased walking distance for the pedestrian. A smaller corner radius will generally lead to slower right-turn speeds and will help minimize the crosswalk distance. Negative points are given for very large corner radii. If the effective radius for right-turning vehicles is significantly larger than the actual radius of the pavement edge (as might be the case where on-street parking is allowed near intersection corners), the effective radius should be considered. For simplicity, no distinction is made between radius distance and its effect on vehicle-turning speeds onto a street with either a single lane or multiple lanes. Also, the effect of intersection angle on vehicle-turning speeds is not directly incorporated into this methodology. Corner radius ranks third for points among the rated intersection features.

4. Right-Turns-On-Red

There are differing views as to the safety benefits of prohibiting right-turns-on-red. Since prohibiting right-turns-on-red eliminates a possible conflict between pedestrians and motorists, its effect is rated. The Right-Turns-On-Red and Crosswalk (below) features each account for 5 percent of the possible points.

5. Crosswalk

The presence and design features of a crosswalk are both rated. Marked crosswalks may help raise awareness to motorists of the possibility of pedestrians crossing the street. Enhanced crosswalks are perceived as being more visible and therefore somewhat more effective than simple transverse markings.

6. Traffic Flow Direction

Points are given to account for situations where there are no left or right turn traffic conflicts, such as for one-way streets or intersections. Note, however, that points are subtracted for the departure leg of a one-way street, if that street intersects with a two-way street. This accounts for the increased risk to pedestrians caused by their exposure to turning traffic for the entire crossing distance of the road, instead of just a portion of the crossing distance (such as is the case for crossing a two-way street).

C. Intersection Features Not Rated

There are several other intersection features which are not rated, that should be considered for pedestrian comfort and safety. Among these features are sight lines, lighting, pavement condition, signing, curb extensions, and ADA features such as accessible ramps and signals. These features are not included in the pedestrian LOS determination in an effort to focus on the major elements previously described.

D. Pedestrian LOS Matrix

The summation of total points for all six intersection pedestrian parameters for a particular intersection approach provides the LOS for that approach. Adding all approach points and dividing by the number of approaches provides the overall intersection LOS. More points equate to a higher LOS.

When applying this methodology, it is important to remember that for a particular intersection approach, the feature being assessed is the one that affects or creates conflicts with the pedestrian crossing. For example, vehicle-turning movements from the street adjacent to the crossing are the turns to be considered. This is true for both right and left turns.

1. Pedestrian Crossing Distance			
Crossing Distance	Typical Number of Travel Lanes	Median Presence	Points
Less than 30 feet	2	None	60
30 feet to 40 feet	3	No median or less than 4 feet	53
41 feet to 52 feet	4	No median or less than 4 feet	42
		Narrow median (4 feet to 6 feet)	45
		Median refuge (6 feet or more)	48
53 feet to 64 feet	5	No median or less than 4 feet	30
		Narrow median (4 feet to 6 feet)	35
		Median refuge (6 feet or more)	43
65 feet to 76 feet	6	No median or less than 4 feet	15
		Narrow median (4 feet to 6 feet)	22
		Median refuge (6 feet or more)	35
77 feet or more	7+	No median or less than 4 feet	0
		Narrow median (4 feet to 6 feet)	10
		Median refuge (6 feet or more)	25
2. Signal Phasing and Timing			
A. Left turn phasing			
A1.	No protected left turn phase	No pedestrian phase	0
A2.	No protected left turn phase	With pedestrian phase	4
A3.	Protected/Permissive phase	No pedestrian phase	-5
A4.	Protected/Permissive phase	With pedestrian phase	6
A5.	Protected/Prohibited phase	No pedestrian phase	-2
A6.	Protected/Prohibited phase	No pedestrian phase w/ dual left turn lanes	-5
A7.	Protected/Prohibited phase	With pedestrian phase	10
A8.	No left-turn conflict	(Tee intersection or one-way)	See Parameter 6
B. Right Turn Traffic (Lane Configuration and Signal Phasing)			
B1.	Shared thru/right lane	No pedestrian phase	0
B2.	Shared thru/right lane	With pedestrian phase	0
B3.	Exclusive right-turn lane No overlap phase	No pedestrian phase	0
B4.	Exclusive right-turn lane No overlap phase	With pedestrian phase	0
B5.	Exclusive right turn lane Overlap phase	No pedestrian phase	-10
B6.	Exclusive right turn lane Overlap phase	With pedestrian phase	0
B7.	Dual right turn lanes No overlap phase	No pedestrian phase	-10
B8.	Dual right turn lanes No overlap phase	With pedestrian phase	0

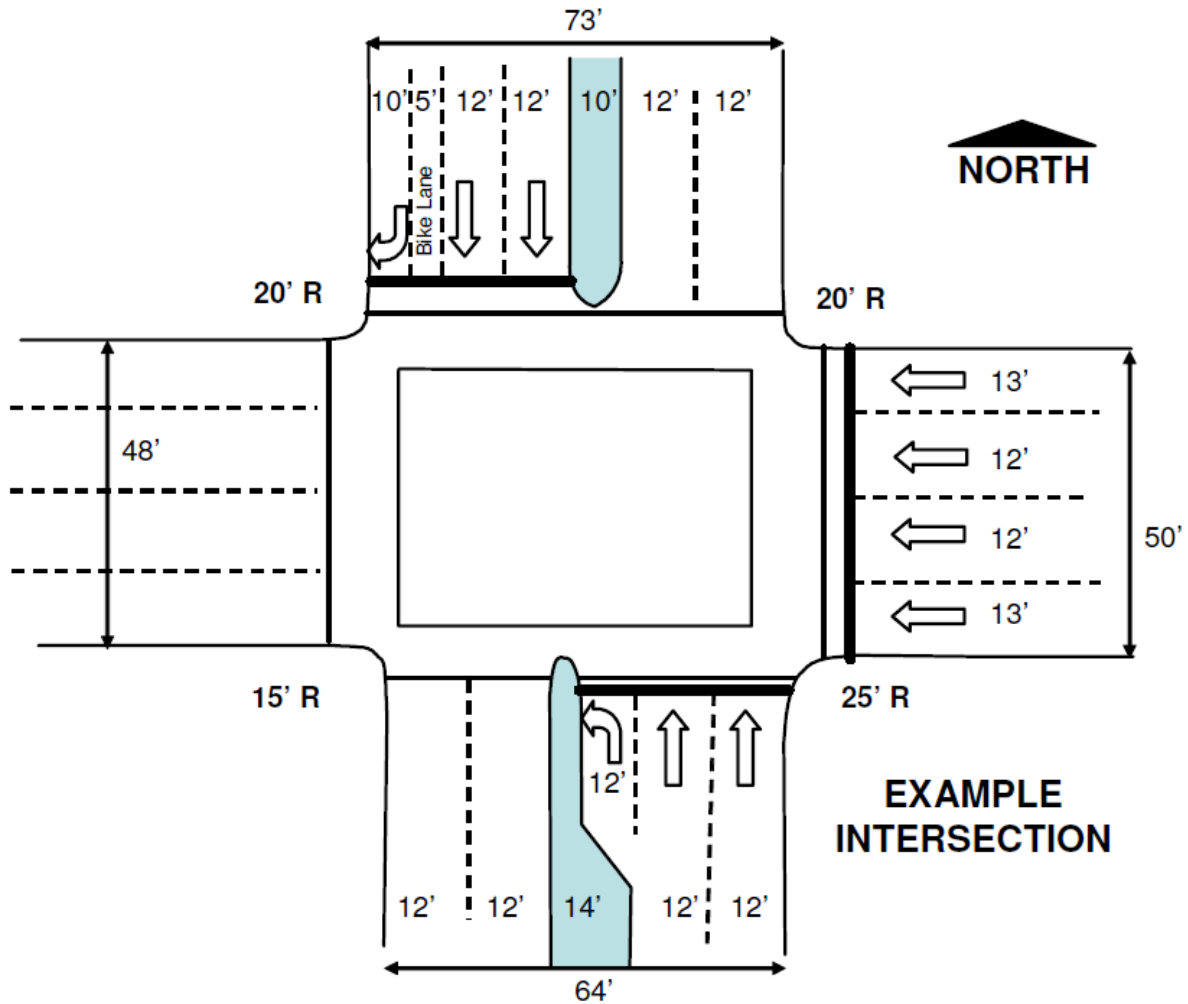
B9.	Dual right turn lanes Overlap phase	No pedestrian phase	-15
B10.	Dual right turn lanes Overlap phase	With pedestrian phase	0
B11.	No right turn conflict	(Tee intersection or one-way)	See Parameter 6
C. Pedestrian Signal Display			
C1.	Pedestrian phase with conventional style display (walk / flashing don't walk)		0
C2.	Pedestrian phase with countdown display		5
C3.	Leading pedestrian phase (Peds start crossing before vehicles on adjacent street) – Conventional display		4
C4.	Leading pedestrian phase (peds start crossing before vehicles on adjacent street) – Countdown display.		7
C5.	Pedestrian walk speeds		
	4.0 ft/sec or faster		0
	3.5 ft/sec		1
	3.0 ft/sec		2
3. Corner Radius			
A.	Radius up to 20'		11
B.	Radius of 21' to 35'		5
C.	Radius of 36' to 50'		0
D.	Radius larger than 50'		-5
E.	Compound Curve		
E1.	Without Channel Island		-5
E2.	With Channel Island		0
F.	Channel Island Slip Lane Design		
F1.	Yield Controlled		2
F2.	Signal Controlled		8
G.	No Corner Radius (Tee Intersection)		11
4. Right Turns on Red			
A.	Allowed		0
B.	Prohibited		5
5. Crosswalk			
A.	No Marked Crosswalk		0
B.	Marked Crosswalk		
B1.	Transverse markings (perpendicular to traffic flow)		3
B2.	Diagonal/Longitudinal markings (between transverse markings)		5
C.	Textured/Colored Crosswalk Surface		5
6. Traffic Flow Direction			
A.	Pedestrian Crossing of Two-way Street		0

B. Pedestrian Crossing of One-way Street (or Tee intersection without left/right-turn conflicts)		
B1.	Approach crossing where the only pedestrian/vehicle conflicts are from right-turning vehicles (no left-turn conflicts)	15
B2.	Approach crossing where the only pedestrian/vehicle conflicts are from left-turning vehicles (no right-turn conflicts)	15
B3.	Approach crossing where there are no pedestrian/vehicle conflicts	30
B4.	Departure leg of a one-way street with three or more lanes that intersects with a two-way street (pedestrian exposed to both left- and right-turn vehicle conflicts for entire crossing distance)	-10
B5.	Departure leg of a one-way street with three or more lanes that intersects with a two-way street (pedestrian exposed to both left- and right-turn vehicle conflicts for entire crossing distance), but the left-turn conflict minimized by Protected/Prohibited left-turn phase on the adjacent street, and pedestrian crossing is controlled by ped signals.	-3

Pedestrian LOS based on total points

<u>LOS</u>	<u>Total Points</u>
A	84 or greater
B	68-83
C	52-67
D	35-51
E	18-34
F	less than 18

INTERSECTION PEDESTRIAN LOS WORKSHEET EXAMPLE



Parameters	Approach Crossing			
	Northbound	Eastbound	Southbound	Westbound
1. Pedestrian Crossing Distance	64 feet 5 lanes (4 TH, 1 LT and a 4 foot median)	48 feet 4 lanes (4 shared/TH, no median)	73 feet 5 lanes (4 TH, 1 RT and a 10 foot median)	50 feet 4 lanes (4 shared/TH, no median)
Score	35	42	35	42
2. Signal Features:				
2A. Adjacent LT Traffic	No protected turn phase with ped. phase	Dedicated permitted LT phase with ped.	No LT conflict-intersects with one-way	No LT conflict-intersects with one-way
Score	4	6	--	--

2B. Right Turn Traffic	No conflict (one-way Street—see Parameter 6)	No conflict (one-way Street- see Parameter 6)	Rt Trn Ln, No overlap, w/ Ped Phase	Shared Right-Thru, w/ Ped Phase
Score	--	--	0	0
2C. Pedestrian Signal Display	Ped. phase with countdown signals	Ped. phase with countdown signals	Ped. phase with countdown signals	Ped. phase with countdown signals
Score	5	5	5	5
3. Corner Radius	25 feet	15 feet	20 feet	20 feet
Score	5	11	11	11
4. Right Turns On Red	No RTOR – one-way street	No conflict – one-way Street	Allowed	Allowed
Score	5	5	0	0
5. Crosswalk	Painted markings perpendicular to traffic flow	Painted markings perpendicular to traffic flow	Painted markings perpendicular to traffic flow	Painted markings perpendicular to traffic flow
Score	3	3	3	3
6. Traffic Flow Direction	Intersects with one-way street (No RT conflict)	Departure leg crossing one-way street intersects with two-way street (LT not protected)	Intersects with one-way street (no LT conflict)	Approach leg crossing of one-way street (no LT conflicts)
Score	15	-10	15	30
Approach Total	72	62	69	91
Approach LOS	B	C	B	A
Ave Intersection Score	73			
Ave Intersection LOS	B			
LOS	Total Points	LOS	TOTAL POINTS	
A	84 or greater	D	35-51	
B	68-83	E	18-34	
C	52-67	F	less than 18	

INTERSECTION PEDESTRIAN LOS - BLANK WORKSHEET

Parameters	Approach Crossing			
	Northbound	Eastbound	Southbound	Westbound
1. Pedestrian Crossing Distance				
Score				
2. Signal Features:				
2A. Adjacent LT Traffic				
Score				
2B. Right Turn Traffic				
Score				
2C. Pedestrian Signal Display				
Score				
3. Corner Radius				
Score				
4. RTOR				
Score				
5. Crosswalks				
Score				
6. Traffic Flow Direction				
Score				
Approach Total				
Approach LOS				
Ave Intersection Score				
Ave Intersection LOS				
LOS	Total Points	LOS	TOTAL POINTS	
A	84 or greater	D	35-51	
B	68-83	E	18-34	
C	52-67	F	less than 18	

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G.3 BICYCLE INTERSECTION LOS

A. General

The major impediments to the comfort and safety of bicyclists at signalized intersections are somewhat different than those for pedestrians. Traffic signal features, potential conflicts with turning vehicles, and a desire for physical space in the roadway (separation from automobile traffic lanes) are prominent issues for bicyclists, with intersection crossing distance playing a minor role. Since bicyclists share space with, and travel alongside motor vehicles, the speed of traffic is also a factor.

The key parameters of signalized intersections that enhance or reduce the perceived comfort and safety of bicyclists are identified and assigned points according to how well they meet the objectives.

B. Key Intersection Parameters

1. **Signal Phasing and Timing**—Features that remove potential vehicular left-turn conflicts from the path of bicyclists and features that place bicyclists before motorists (in time and space) are rated as desirable. Signal phasing and timing accounts for 40 percent of the possible points.
2. **Roadway Space for Bikes**—Bicycle travel space, separated from the outside vehicular travel lane, is viewed as highly desirable. Marked bike lanes are the preferred method of accommodating in-street bike operations. There is a difference of opinion among bicyclists concerning the desirability of wide outside travel lanes (13 to 14 feet) compared to standard width travel lanes (10 to 12 feet). Because wide outside travel lanes provide extra clearance between bicyclists and motorists, this methodology rates wide outside lanes as better than standard lanes. Ratings are assigned according to how space is allocated in advance of the intersection (approach leg) as well as how it is allocated beyond the intersection (departure leg). This feature accounts for 30 percent of the possible points.
3. **Right-Turn Conflict Treatment**—This parameter addresses the potential conflict involving motorists turning right and bicyclists traveling straight ahead at an intersection approach. The preferred method of resolving this conflict is for bicyclists to use the traffic lane if it is shared with traffic, or if there is a separate right turn lane, motorists should merge right with bicyclists that are traveling straight ahead. Points are awarded if there is no right- turn conflict with motorists. If there is a conflict, either no points are awarded or points are taken away, depending on whether the bicyclist or motorist is required to merge.
4. **Approach Speed of Traffic**—As previously mentioned, vehicular traffic speeds affect bicyclist's comfort and safety. For simplicity, the posted speed limit is used as a measure.
5. **Right-Turns-On-Red**—This is another potential source of conflict between bicyclists and motorists. Bicyclists can easily appear to blend into the background when a motorist is looking to turn right on red because motorists are often looking for larger vehicles.
6. **Intersection Crossing Width**—Crossing distance is a less important factor for bicyclists than for pedestrians, but the risk of exposure in an intersection is worthy of rating.

C. Intersection Features Not Rated

There are several other intersection features which are not rated that should be considered for bicyclist safety and comfort. Among these features are sight lines, roadway lighting, pavement condition, and street signing. To obtain meaningful results, a limited number of primary features are rated. Rating too many features dilutes the results and tends to make features nearly indistinguishable in their relative importance.

D. Bicycle LOS Matrix

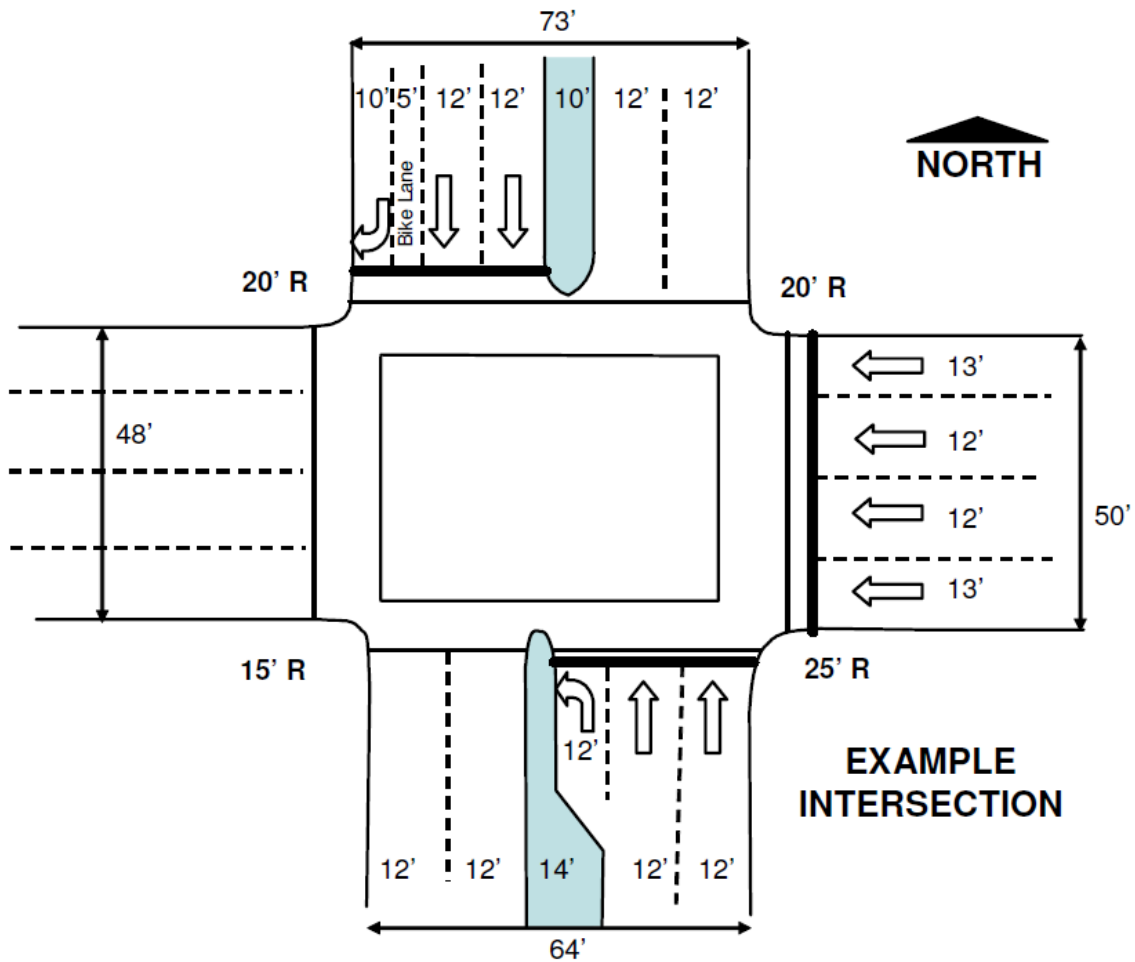
Adding the points of all six parameters for a particular intersection approach yields the LOS for that approach. Adding all approach points and dividing by the number of approaches yields the overall intersection LOS. More points equate to higher LOS.

1. Signal Phasing and Timing		Points
A. Bicycle Phase		
A1.	No leading bicycle phase	0
A2.	Leading bicycle phase (cyclists given green seconds before other traffic – requires bike display, bike lane, and bike detection)	12
B. Signal Timing		
B1.	Green and yellow clearance time based on vehicular speeds	0
B2.	Green and yellow clearance time based on bicycle speeds	6
C. Stop Bar Location		
C1.	Shared stop bar (motorists and bikes at common point)	0
C2.	Advanced stop bar or bike box (bikes stop closer to intersection than motorists)	10
D. Vehicular Left Turn Phases (opposing cyclists)		
D1.	None	0
D2.	Leading Protected/Permissive	6
D3.	Protected/Prohibited	12
D4.	No left turn conflict (Tee intersection or one-way)	15
2. Roadway Space for Bikes		
Approach Leg		Departure Leg
Ride in vehicle travel lane (roadway 12 feet or less in width)	Ride in vehicle travel lane	0
	Ride in widened outside lane	10
	Ride in bike lane or shoulder (4 feet min)	15
Ride in widened outside lane (roadway 13 to 14 feet wide)	Ride in vehicle travel lane	10
	Ride in widened outside lane	20
	Ride in bike lane or shoulder (4 feet min)	25
Ride in bike lane or shoulder (4 feet min. width)	Ride in vehicle travel lane	15
	Ride in widened outside lane	25
	Ride in bike lane or shoulder (4 feet min)	30
3. Right Turn Conflict Treatment		
A. No right turn conflict (Tee intersection or one-way)		15
B. No separate vehicular right turn lane		0
C. Separate vehicular right turn lane		
C1.	With bike lane to left of vehicular right turn lane (Figure 9c-3 of 2000 MUTCD)	0
C2.	No bike lane	-5
C3.	Curb lane drops as vehicular right turn lane with bike lane to left of vehicular right turn lane (Figure 9c-4 of 2000 MUTCD)	-10
C4.	Curb lane drops as vehicular right turn lane, no bike lane	-15
C5.	Bike lane to right of vehicular right turn lane	-25
4. Approach Speed of Traffic (85th percentile speed if known, otherwise posted speed limit)		
A. High Speed (45 mph or more)		-15
B. Moderate Speed (35-40 mph)		0
C. Low speed (30 mph or less)		15

5. Right Turns On Red	
A. Allowed	0
B. Prohibited	5
6 Intersection Crossing Width	
A. Less than 36 feet (typically up to 3 travel lanes)	10
B. 37 feet to 60 feet (approximately 5 travel lanes)	5
C. Greater than 61 feet (approximately 6+ travel lanes)	0

Bicycle LOS based on total points

<u>LOS</u>	<u>Total Points</u>
A	84 or greater
B	68-83
C	52-67
D	35-51
E	18-34
F	less than 18



Parameters	Approach Crossing			
	Northbound	Eastbound	Southbound	Westbound
1A. Signal Phasing/Timing Features	No leading bicycle phase	Not applicable (one-way street)	No leading bicycle phase	No leading bicycle phase
Score	0	--	0	0
1B. Signal Timing	Based on auto speeds	--	Based on auto speeds	Based on auto speeds
Score	0	--	0	0
1C. Stop Bar Location	Vehicles and bikes at same location	--	Vehicles and bikes at same location	Vehicles and bikes at same location
Score	0	--	0	0

1D. Opposing Vehicle Left Turn Phases	No left-turn conflict	--	Protected/Permissive	No left-turn conflict
Score	15	--	6	15
2. Bike Space on Street (Approach/Departure Leg)	Auto travel lane to auto travel lane: 12 foot outside lane		Bike lane to auto travel lane: 12 foot outside lane	Widened auto travel lane to 12 foot auto travel lane
Score	0	--	15	10
3. Right-Turning Traffic Conflict: Shared traffic lane/Separate right-turn lane	No right turn conflict (intersects with one-way street)		Separate right-turn lane that drops, bike lane according MUTCD	Shared TH/right-turn lane- no bike lane
Score	15	--	-10	-5
4. Speed of Intersection Approach	35 mph		35 mph	35 mph
Score	0	--	0	0
5. Right Turn on Red	Allowed		No right-turn conflict (intersects with one-way street)	Allowed
Score	0	--	5	0
6. Intersection Crossing Distance	50 feet		48 feet	73 feet
Score	5	--	5	0
Approach Total	35	--	21	20
Approach LOS	D		E	E
Ave Intersection Score	25			
Ave Intersection LOS	E			
LOS	Total Points	LOS	TOTAL POINTS	
A	84 or greater	D	35-51	
B	68-83	E	18-34	
C	52-67	F	less than 18	

INTERSECTION BICYCLE LOS - BLANK WORKSHEET

Parameters	Approach Crossing			
	Northbound	Eastbound	Southbound	Westbound
1A. Signal Phasing/Timing Features				
Score				
1B. Signal Timing				
Score				
1C. Stop Bar Location				
Score				
1D. Opposing Vehicle Left-Turn Phases				
Score				
2. Bike Space on Street (Approach/Departure Leg)				
Score				
3. Right-Turning Traffic Conflict: Shared traffic lane/Separate right-turn lane				
Score				
4. Speed of Intersection Approach				
Score				
5. Right-Turn-on-Red				
Score				
6. Intersection Crossing Distance				
Score				
Approach Total				
Approach LOS				
Ave Intersection Score				
Ave Intersection LOS				
LOS	Total Points	LOS	TOTAL POINTS	
A	84 or greater	D	35-51	
B	68-83	E	18-34	
C	52-67	F	less than 18	