

Appendix D: Detailed Level of Service Methodology

Level of service analysis of the roadway system is necessary for the Lane County Transportation System Plan. This analysis allows assessment of our transportation system's performance. The methodology for the analysis comes from the 1994 Highway Capacity Manual. Certain assumptions were made for Lane County to reflect specific conditions and move away from more general assumptions. Two-lane rural roadways were assumed for the analysis. Therefore, multi-lane or urban roadways will require separate, more specific analysis techniques to determine *level of service*.

The operational function of two-lane, two-way rural roadways differs from multi-lane highways. Passing opportunities allow drivers to maintain their travel speed and therefore reduce travel time. On two-lane roadways, passing is only possible in the face of opposing traffic. As traffic volumes and passing demand increase, the volumes in the opposing direction also increase, reducing the opportunities to pass. When drivers experience delays due to reduced travel speeds and lack of passing opportunities, the *level of service* of the roadway deteriorates. The mixture of heavy vehicles in the traffic stream and steep roadway grades also limit passing opportunities and have the effect of reducing the *level of service*.

Level of service (LOS) is graded on a letter scale from A to F. A being the highest level of service and F being the lowest. At LOS A, traffic flows freely, selecting desired travel speeds with ample passing opportunities. At LOS F, traffic flow is forced, the traffic volume has exceeded the capacity of the roadway to handle it and there are no passing opportunities. LOS D is generally considered to be the lowest tolerable level of service for roadways. Roadway designs attempt to operate at LOS D in only the worst case situations and preferably at higher levels of service.

The Transportation Research Board (TRB) has defined the following definition for level of service:

- LOS A represents free flow. Individual users are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to maneuver within the traffic stream is extremely high. The general level of comfort and convenience provided to the motorist, passenger, or pedestrian is excellent.
- LOS B is in the range of stable flow, but the presence of other users in the traffic stream begins to be noticeable. Freedom to select desired speeds is relatively unaffected, but there is a slight decline in the freedom to maneuver within the traffic stream from LOS A. The level of comfort and convenience provided is somewhat less than at LOS A, because the presence of others in the traffic stream begins to affect individual behavior.

- LOS C is in the range of stable flow, but marks the beginning of the range of flow in which the operation of individual users becomes significantly affected by interactions with others in the traffic stream. The selection of speed is now affected by the presence of others, and maneuvering within the traffic stream requires substantial vigilance on the part of the user. The general level of comfort and convenience declines noticeably at this level.
- LOS D represents high-density, but stable, flow. Speed and freedom to maneuver are severely restricted, and the driver or pedestrian experiences a generally poor level of comfort and convenience. Small increases in traffic flow will generally cause operational problems at this level.
- LOS E represents operating conditions at or near the capacity level. All speeds are reduced to a low, but relatively uniform value. Freedom to maneuver within the traffic stream is extremely difficult, and it is generally accomplished by forcing a vehicle or pedestrian to “give way” to accommodate such maneuvers. Comfort and convenience levels are extremely poor, and driver or pedestrian frustration is generally high. Operations at this level are usually unstable, because even small increases in flow or minor perturbations within the traffic stream will cause breakdowns.
- LOS F is used to define forced or breakdown flow. This condition exists wherever the amount of traffic approaching a point exceeds the amount which can traverse it and queues begin to form. Operations within the queue are characterized by stopping and starting. Over and over, vehicles may progress at reasonable speeds for several hundred feet or more, then be required to stop. Level-of-service F is used to describe operating conditions within the queue, as well as the point of the breakdown. It should be noted, however, that in many cases once free of the queue, traffic may resume to normal conditions quite rapidly.

Level of service analysis for two-lane rural highways is found in Chapter 8 of the 1994 Highway Capacity Manual. Rural highways provide both mobility and accessibility for motorists. For major highways, the movement of traffic with a minimum of delay is its principal function. Although mobility is desirable, many highways provide the only means of access to an area. *Percent time delay*, the primary factor affecting highway level of service, reflects both mobility and accessibility. “Percent time delay is the average percent of the total travel time that all motorists are delayed in platoons while traveling a given section of highway”. The *average travel speed* and *capacity utilization* are secondary factors that determine *level of service*. The average travel speed reflects the mobility function and utilization of capacity reflects the accessibility function of the highway. On two-lane highways, the demand for passing increases as traffic volumes increase. Likewise, opportunities for passing decrease as traffic volumes in the opposite direction increase. When highway or traffic characteristics limit the ability to pass, vehicles are delayed and the *level of service* of the highway decreases.

The *terrain type* is one of several variables that must be defined in order to calculate road segment level of service. This analysis is for rural two-lane road segments and follows the methodology set forth on the 1994 Highway Capacity Manual. Our inventories currently provide most of the data necessary to determine roadway level of service, except for the *terrain type*. In order to enrich our inventory and facilitate the calculation of roadway level of service, we must also inventory the *terrain type*.

Terrain type is a factor affecting the roadway conditions and ultimately its operational capacity. The horizontal and vertical alignment of a highway varies due to the topography through which it is constructed. The effects of terrain on traffic flow are most apparent when trucks are included in the traffic stream. In more severe terrain, steeper grades and curves affect the operation of trucks. In particular, significant long grades and sharp curves slow trucks down and limit passing opportunities for cars. The overall effect of the *terrain type* can be a reduction in the capacity of the roadway and its *level of service*.

A general definition of *terrain type* from the 1994 Highway Capacity Manual follows.

- **Level Terrain:** Any combination of grades and horizontal and vertical alignment that allows heavy vehicles to maintain approximately the same speed as passenger cars; this terrain generally includes short grades of no more than 1 to 2 percent.
- **Rolling Terrain:** Any combination of grades and horizontal and vertical alignment that causes drivers of heavy vehicles to reduce speeds to substantially below those of passenger cars, but does not require operation at crawl speeds for any significant length of time.
- **Mountainous Terrain:** Any combination of grades and horizontal and vertical alignment that causes drivers of heavy vehicles to operate at crawl speeds for significant distances or frequent intervals.

Crawl speed is the maximum sustained speed that heavy vehicles can maintain on an extended upgrade of a given percent.

With these definitions in hand, we can classify our two-lane roadway segments into one of then three general terrain types (*level, rolling, or mountainous*). This classification provides the missing link in the calculation of our roadway system's *level of service*.

Other assumptions about the roadway include: *percent of no passing zones* in level, rolling and mountainous terrain; *directional split* of traffic volume; *lane width*; *heavy vehicles* in the traffic stream expressed as a percentage of trucks, recreational vehicles and buses; *design speed*; and the *design hour factor* relating the proportion of the average daily traffic volume expected to occur in the design hour.

- The *percent of no passing zones* are assumed to be 20% in level terrain, 40% in rolling terrain and 60% in mountainous terrain.
- The *directional split* of traffic is assumed to be 60%/40%.
- *Lane widths* are assumed to be 11 feet.
- *Heavy vehicles* in the traffic stream are estimated to be 5% for trucks, 2% for recreational vehicles and 0% for buses.
- The *design speed* of the roadway is assumed to be 60 miles per hour.
- The *design hour factor*, K , is assumed to be 0.10 and represents the proportion of the average daily traffic volume expected to occur in the design hour.

Rural Two-Lane Highway Level of Service Analysis
 1994 Highway Capacity Manual Methodology
 with assumptions for Lane County

The following tables and factors are used to calculate the roadway *level of service*. The final table, titled “*Maximum ADT vs. Level of Service*”, contains the maximum daily traffic volumes for each *level of service* for differing *terrain types* and *roadway widths*. The table is used by selecting the *terrain type* and *roadway width*. Then, compare the actual *daily traffic volume* to those in the table. The *level of service* is determined when the daily traffic volume does not exceed the tabulated volume.

(8-1) *Service Flow Rate* (vph), $SF_i = 2800(\text{vph}) \times (v/c)_i \times f_d \times f_w \times f_{hv}$

Volume/Capacity, (v/c) _i (Table 8-1)			
LOS	Percent No Passing		
	Level 20%	Rolling 40%	Mountainous 60%
A	0.12	0.07	0.04
B	0.24	0.19	0.13
C	0.39	0.35	0.23
D	0.62	0.52	0.40
E	1.00	0.92	0.82
F	-	-	-

Directional Split, f_d (Table 8-4) (60/40)= 0.94

Lane and Shoulder Width, f_w (Table 8-5) (11 foot Lanes)				
Usable Shoulder Width	LOS A-D	LOS E	Road Width	
0	0.49	0.66	18	(factors for 9 ft lanes)
0	0.54	0.71	19	(interpolated between 9&10 ft lanes)
0	0.58	0.75	20	(factors for 10 ft lanes)
0	0.62	0.79	21	(interpolated between 10&11 ft lanes)
0	0.65	0.82	22	
1	0.70	0.85	23	(interpolated)
2	0.75	0.88	24	
3	0.80	0.90	25	(interpolated)
4	0.85	0.92	26	
5	0.89	0.93	27	(interpolated)
>= 6	0.93	0.94	>= 28	

Heavy vehicle factor, f_{hv}

$$(8-2) f_{hv} = 1 / [1 + P_T(E_T-1) + P_R(E_R-1) + P_B(E_B-1)]$$

Assume percentage of trucks,

$$P_T (5\%) = 0.05$$

Assume percentage of recreational vehicles,

$$P_R (2\%) = 0.02$$

Assume percentage of buses,

$$P_B (0\%) = 0.00$$

<i>Passenger Car Equivalents, E,</i> for trucks recreational vehicles and buses (Table 8-6)				
	LOS	Level	Rolling	Mountainous
E_T	A	2.00	4.00	7.00
	B and C	2.20	5.00	10.00
	D and E	2.00	5.00	12.00
E_R	A	2.20	3.20	5.00
	B and C	2.50	3.90	5.20
	D and E	1.60	3.30	5.20
E_B	A	1.80	3.00	5.70
	B and C	2.00	3.40	6.00
	D and E	1.60	2.90	6.50

Heavy vehicle factor, f_{hv}			
LOS	Level	Rolling	Mountainous
A	0.93	0.84	0.72
B and C	0.92	0.79	0.65
D and E	0.94	0.80	0.61

Peak Hour Factor, PHF (Table 8-3)					
	Level of Service				
	A	B	C	D	E
PHF	0.91	0.92	0.94	0.95	1.00

Assume design hour factor, $K = 0.10$

Maximum ADT vs. Level of Service					
ADT _i (vpd) = [Service Flow Rate, SF _i (vph)] X PHF _i / K					
Level of Service					
Road Width	A	B	C	D	E
Level Terrain					
18	1311	2612	4338	7153	16357
19	1432	2852	4736	7810	17472
20	1552	3092	5134	8467	18588
21	1646	3279	5444	8977	19455
22	1739	3466	5754	9488	20322
23	1873	3732	6197	10218	21066
24	2007	3999	6639	10948	21809
25	2141	4265	7082	11678	22305
26	2275	4532	7524	12408	22801
27	2382	4745	7878	12992	23049
>=28	2489	4958	8233	13576	23296
Rolling Terrain					
18	688	1792	3373	5113	12826
19	751	1957	3683	5583	13701
20	814	2121	3992	6052	14575
21	864	2249	4233	6418	15255
22	913	2377	4474	6783	15936
23	983	2560	4818	7305	16519
24	1053	2743	5163	7826	17102
25	1123	2926	5507	8348	17490
26	1194	3109	5851	8870	17879
27	1250	3255	6126	9287	18073
>=28	1306	3401	6402	9705	18268
Mountainous Terrain					
18	340	1006	1818	2999	8717
19	371	1098	1985	3275	9312
20	403	1190	2152	3550	9906
21	427	1262	2281	3764	10369
22	451	1334	2411	3979	10831
23	486	1436	2597	4285	11227
24	521	1539	2782	4591	11623
25	555	1642	2968	4897	11887
26	590	1744	3153	5203	12152
27	618	1826	3301	5448	12284
>=28	646	1908	3450	5692	12416