TRAFFIC ATTACHMENT E

Measures of Effectiveness Criteria
Traffic: Performance Measures

Introduction

The Highway Capacity Manual\(^1\) and the Synchro 8 Software\(^2\) procedures document the methodology used for modeling levels of service, average vehicle delay, and volume-to-capacity ratios at both signalized and unsignalized intersections. Level of service is a measure of the operational quality of an intersection; level of service A is the highest, most efficient level, and level of service F is the lowest level. The operational quality of an intersection for the automobile mode is based on the average amount of time a vehicle is delayed. Levels of service are examined by 'lane group', the set of lanes allowing common movement(s) on an approach. Approaches to intersections are assigned primary directions for clarity as depicted on the traffic volume figures.

The Synchro 8 Software modeled results are applied to peak hour periods only. During off peak periods, which is the majority of the time, drivers typically will find operations better than the modeled peak hour results. During peak periods the experience of individual drivers can vary, because the model calculates average delay.

The current Highway Capacity Manual methodology regarding left turns on shared lanes has recently been modified and is not yet available. The Main Street Riverdale intersection is shown using Synchro 8’s Highway Capacity 2000 methodologies. Also the Current methodologies do not support coordinated intersections and thus levels of service at riverdale intersection that are time based coordinated should operate better than indicated.

Level of Service Criteria Signalized Intersections

When analyzing activity at signalized intersections, an understanding of the definition of level of service for the Automobile mode is essential:

Automobile Mode

Level of service can be characterized for the entire intersection, each intersection approach, and each lane group. Control delay alone is used to characterize level of service for the entire intersection or an approach. Control delay and volume-to-capacity ratio are used to characterize level of service for a lane group. Delay quantifies the increase in travel time due to traffic signal control. It is also a surrogate measure to driver discomfort and fuel consumption. The volume-to-capacity ratio quantifies the degree to which a phase’s capacity is utilized by a lane group. The following paragraphs describe each level of service.

Level of service A describes operations with a control delay of 10 seconds per vehicle or less and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is low and either progression is exceptionally favorable or the cycle length is very short. If it is due to favorable progression, most vehicles arrive during the green indication and travel through the intersection without stopping.

Level of service B describes operations with control delay between 10 and 20 seconds per vehicle and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is low and either progression is highly favorable or the cycle length is short. More vehicles stop than with Level of service A.

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\(^2\) Synchro 8, Computer software, Trafficware, Sugar Land, Texas, 2011.
Level of service C describes operations with control delay between 20 and 35 seconds per vehicle and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when progression is favorable or the cycle length is moderate. Individual cycle failures (i.e., one or more queued vehicles are not able to depart as a result of insufficient capacity during the cycle) may begin to appear at this level. The number of vehicles stopping is significant, although many vehicles still pass through the intersection without stopping.

Level of service D describes operations with control delay between 35 and 55 seconds per vehicle and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is higher and either progression is ineffective or the cycle length is long. Many vehicles stop and individual cycle failures are noticeable.

Level of service E describes operations with control delay between 55 and 80 seconds per vehicle and a volume-to-capacity ratio no greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is high, progression is unfavorable, and the cycle length is long. Individual cycle failures are frequent.

Level of service F describes operations with control delay exceeding 80 seconds per vehicle or a volume-to-capacity ratio greater than 1.0. This level is typically assigned when the volume-to-capacity ratio is very high, progression is very poor, and the cycle length is long. Most cycles fail to clear the queue.

A lane group can incur a delay less than 80 seconds per vehicle when the volume-to-capacity ratio exceeds 1.0. This condition typically occurs when the cycle length is short, the signal progression is favorable, or both. As a result, both the delay and volume-to-capacity ratio are considered when lane group level of service is established. A ratio of 1.0 or more indicates that cycle capacity is fully utilized and represents failure from a capacity perspective (just as delay in excess of 80 seconds per vehicle represents failure from a delay perspective).

Exhibit 18-4 lists the level of service thresholds established for the automobile mode at a signalized intersection.  

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3 From Transportation Research Board of the National Academies, HCM2010 Highway Capacity Manual, Washington D.C., Volume 3 page 18-6, 2010. Abbreviations and mathematical symbols have been replaced for reader clarity.
The New York State Department of Transportation (NYS DOT) generally seeks in urban areas for a level of service D or better (delay of 55 seconds or less for a signalized intersection) for all lane groups however:

In some cases, it may be necessary to accept level of service E or F on individual lane groups due to unreasonable costs or impacts associated with improving the level of service.4

**Level of Service Criteria for Two way Stop Controlled intersections**

The Highway Capacity Manual5 describes the level of service criteria as:

*Level of service for two way stop controlled intersections is determined by the computed or measure control delay. For motor vehicles, level of service is determined for each minor-street movement (or shared movement) as well as major-street left turns by using criteria given in Exhibit 19-1. Level of service is not defined for the intersection as a whole or for the major street-street approaches for three primary reasons: (a) major-street through vehicles are assumed to experience zero delay; (b) the disproportionate number of major-street through vehicles at a typical two way stopped controlled intersection skews the weighted average of all movements, resulting in a very low overall average delay for all vehicles; and (c) the resulting low delay can mask important level of service deficiencies for minor movements. As Exhibit 19-1 notes, level of service is assigned to the movements if the volume-to-capacity ratio for the movement exceeds 1.0, regardless of the control delay.*

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The level of service criteria for two-way stop-controlled intersections are somewhat different from the criteria used in Chapter 18 for signalized intersections, primarily because user perceptions differ among transportation facility types. The expectation is that a signalized intersection is designed to carry higher traffic volumes and will present greater delay than unsignalized intersection. Unsignalized intersections are also associated with more uncertainty for users, as delays are less predictable than they are at signals, which can reduce user's delay tolerance.

The [Highway Capacity Manual](https://manuals.trb.org/2010/Traffic/2010-Manual-on-Highway-Capacity/chap19.pdf) includes the following concerning level of service F at two-way stop-controlled intersection lane groups:

*Level of service F occurs when there are not enough gaps of suitable size to allow minor street vehicles to enter or cross through traffic on the major-street, resulting in long average control delays (greater than 50 seconds per vehicle). Depending on the demand on the approach, long queues on the minor approaches may result.*

*Level of service F may also appear in the form of drivers on the minor street selecting smaller-than-usual gaps...*  

*Even with a level of service F estimate, most low-volume minor-street approaches would not meet any of the Manual on Uniform Traffic Control Devices volume or delay warrants for signalization...*

*In some cases, the delay equations predict delays greater than 50 seconds for minor-street movements under very low volumes conditions on the minor street (fewer than 25 vehicles per hour). On the basis of the first term of the delay equation, the level of service F threshold is reached with a movement capacity of approximately 85 vehicles per hour or less, regardless of the minor-street movement volume.*

<table>
<thead>
<tr>
<th>Two Way Stop Delay (Unsignalized) Intersections Level of Service Criteria Automobile Mode For Lane Groups</th>
<th>Average Control Delay (Seconds Per Vehicle)</th>
<th>Volume-to-capacity Ratio less than or equal to one Level of Service</th>
<th>Volume-to-capacity Ratio greater than one Level of Service</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>less than or equal to 10</td>
<td>A</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>greater than 10 and less than or equal to 15</td>
<td>B</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>greater than 15 and less than or equal to 25</td>
<td>C</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>greater than 25 and less than or equal to 35</td>
<td>D</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>greater than 35 and less than or equal to 50</td>
<td>E</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>greater than 50</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

Modified from Transportation Research Board of the National Academies, HCM2010 Highway Capacity Manual, Washington D.C., Volume 3 page 19-2, Exhibit 19-1, 2010. Abbreviations and mathematical symbols have been replaced for reader clarity. Level of service is not calculated for major street approaches or for the intersection as a whole. Major Street through vehicles are assumed to experience no delay.

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6 From Transportation Research Board of the National Academies, HCM2010 Highway Capacity Manual, Washington D.C., Volume 3 page 19-40, 2010. Abbreviations and mathematical symbols have been replaced for reader clarity.
Model Limitations

The intersections of South Broadway, North Broadway, New Main Street and Palisades Avenue are two intersections functioning as a single signalized intersection. Although Synchro 8 can handle 5 legged intersections the 2010 highway capacity methodology cannot address all intersection configurations. As such the intersection has been modeled as a four-way intersection with Palisades Avenue and North Broadway being separate lanes of a single leg, and analyzed based on actual lane utilization. Likewise the Dock Street and Nepperhan Street are separated sufficiently to be normally treated as two separate intersections with Warburton Avenue. Based on the operations and at the request of the City, this location is being analyzed as a single intersection and based on the configuration Dock Street and Nepperhan Street are treated as a single leg.

Although some intersections are coordinated the Synchro 8 model and HCM 2010 methodologies have not yet fully intergraded coordination. Thus delays at coordinated intersections as Riverdale Avenue intersections may be less than indicated as all intersections are treated as uncoordinated.

The Highway Capacity and Quality of Service Committee has approved a change to HCM 2010 signalized intersection procedures to better address permitted left turns with shared lane operations. These approved changes have not yet been integrated into current analysis models. As such the Main Street intersection with Riverdale Avenue is analyzed using Synchro 8 HCM 2000 methodology.