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INTERSECTION LEVEL OF SERVICE AND PERFORMANCE DISCREPANCIES

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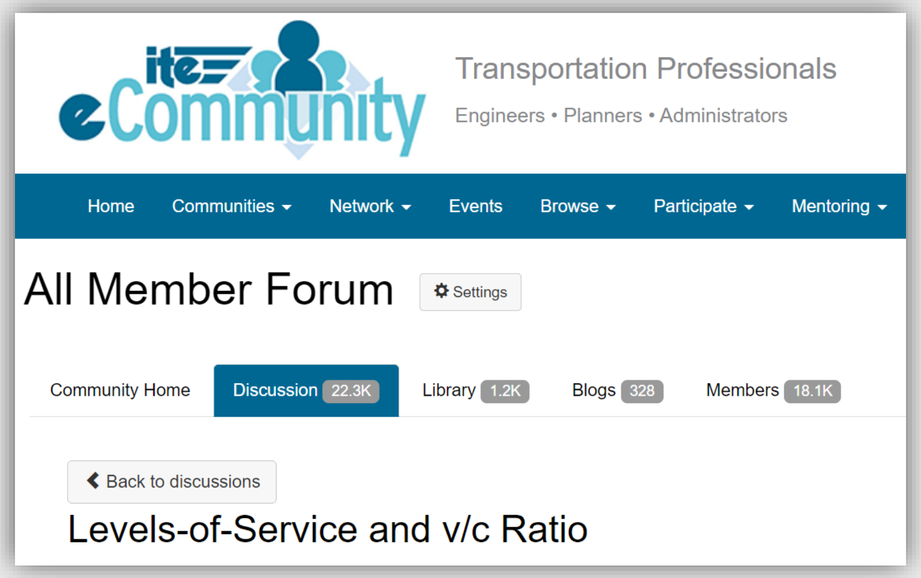
About this presentation

The main points of a paper prepared as a result of an ITE eCommunity Group discussion titled Levels-of-Service and v/c Ratio will be presented.

This discussion expressed concerns about a perceived discrepancy (or inconsistency) of low delay estimated at a high degree of saturation (volume / capacity, v/c ratio) leading to LOS F in HCM Edition 6, and attracted interesting comments.

The purpose of the paper is to discuss the questions raised and comments made in the ITE eCommunity Group discussion and offer detailed explanations regarding these.

ITE eCommunity Discussion Group. Levels-of-Service and v/c Ratio. https://bit.ly/2QAesP8



Concerns expressed by users of HCM

- *"… the traffic flow breakdown typically begins to occur when demand exceeds capacity (i.e. v/c > 1.0), which logically has been associated with LOS F".*

- *"To complicate matters, there are cases where a turning movement / lane group is calculated to be a delay of 100+ seconds (LOS F) while the v/c ratio is 0.80 (significantly less than 1.0)."*

- *"… because the v/c ratio is greater than 1.0, then … vehicles cannot make it through the traffic signal in one cycle length period. But if that were the case, would not the delay calculations reflect that as well?"*

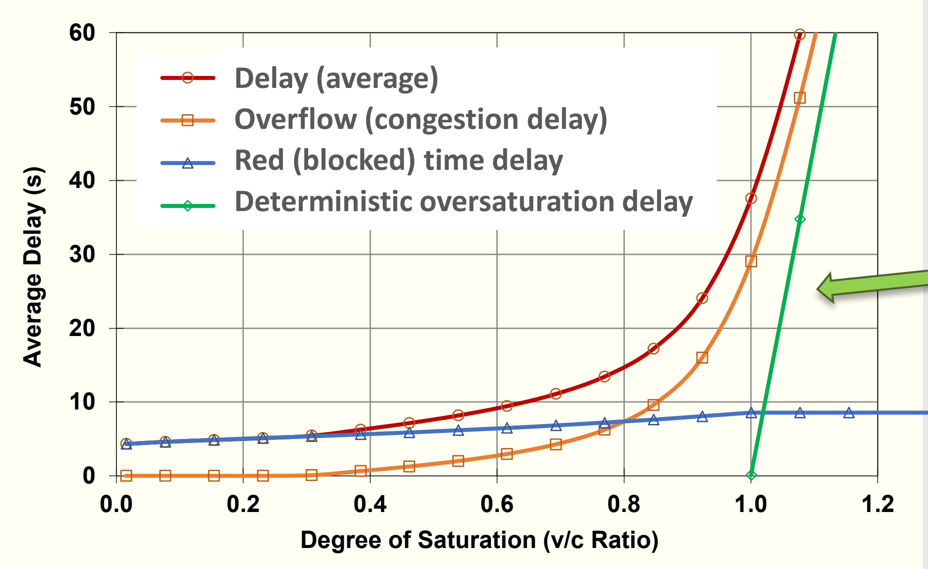
- *"If there is disparity between the calculated delay and the v/c ratio, … perhaps there could be a less abrupt transition."*

- *"… if the capacity of the project is of an issue, v/c is more important than delay."*

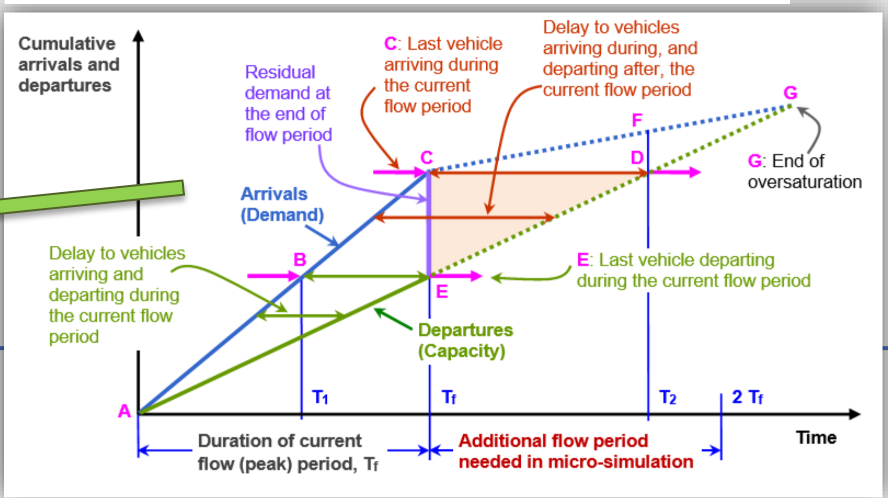
These questions and comments will be addressed in the following slides.

Average delay and v/c ratio (degree of saturation)

❖ **Analytical delay models**, such as the one used in the **HCM**, are derived considering **both undersaturated and oversaturated conditions** with a **smooth non-linear transition** between these conditions.



Deterministic oversaturation delay model



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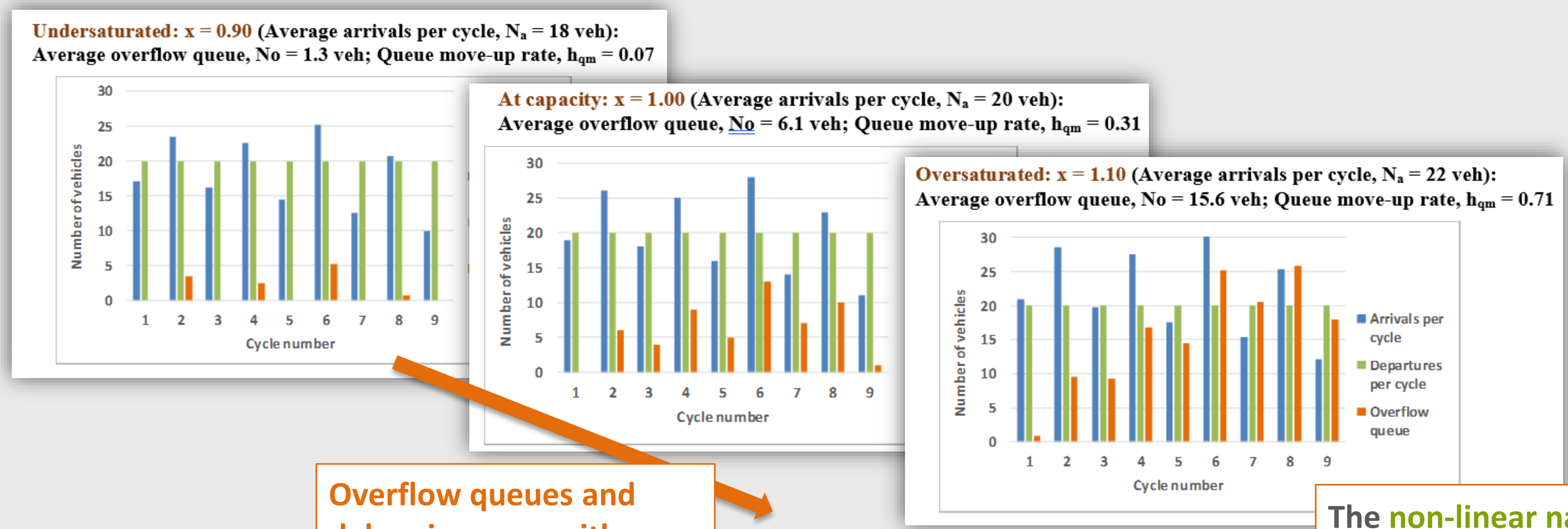
Steady (non-linear) increase of overflow queues

Overflow examples for different v/c ratios (capacity = 20 veh/cycle)



Overflow queues and delays increase with increasing v/c ratio (both undersaturated and oversaturated conditions)

The non-linear nature of delay, i.e. the high rate of increase in delay near capacity (near x = 1) is because of the overflow queues.

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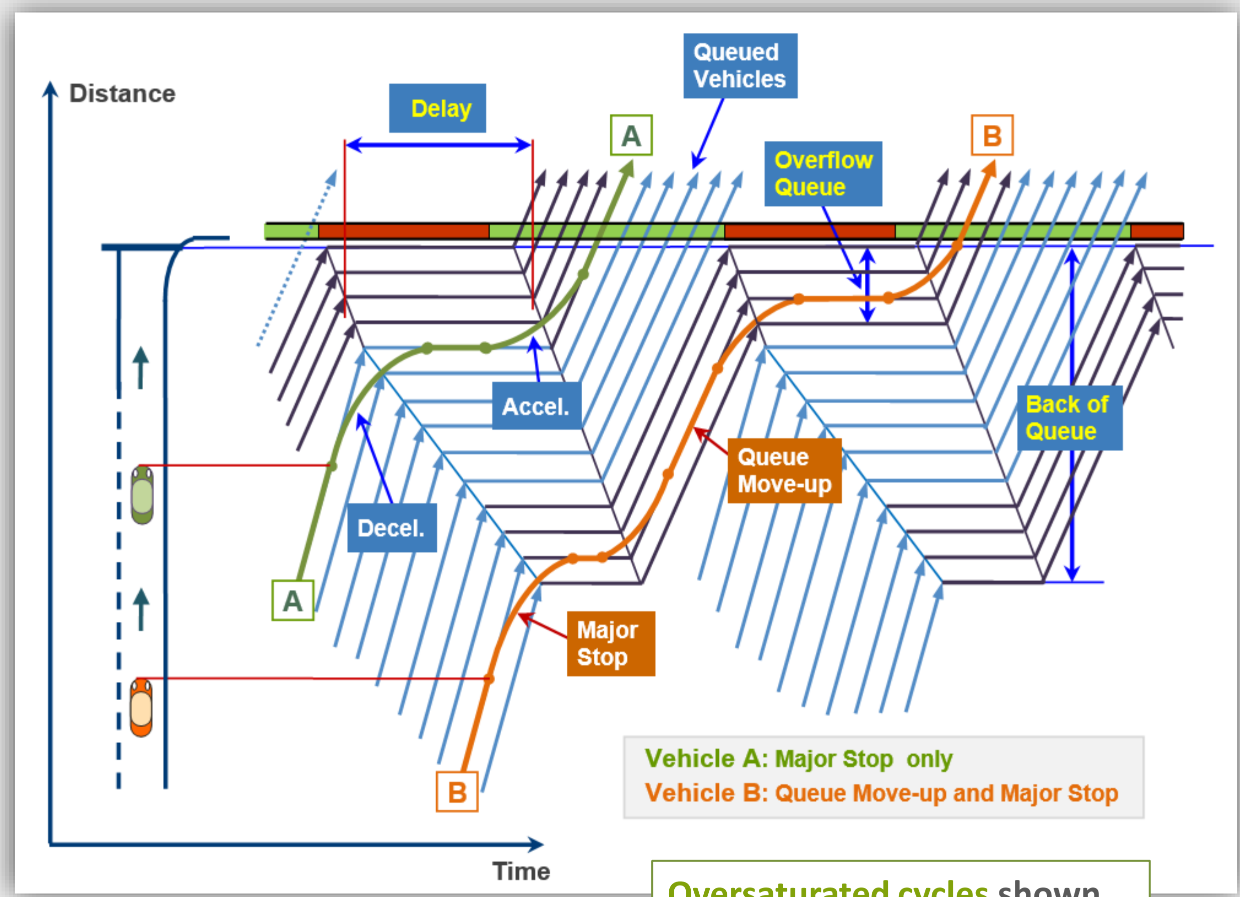
Overflow concept for delay, queue and stops

HCM does not use the overflow concept in performance equations and does not include a model for stops.

The SIDRA delay, back of queue and stop rate equations for all types of intersection are based on the use of the overflow concept.

The average queue move-up rate is related to overflows and is a good indicator of how many cycles it takes to depart from the queue.



Oversaturated cycles shown

Major Stop: Deceleration from Approach Cruise Speed to zero speed, and acceleration to Saturation Speed.

Queue Move-up: Acceleration to Queue Move-up speed and deceleration to zero speed.

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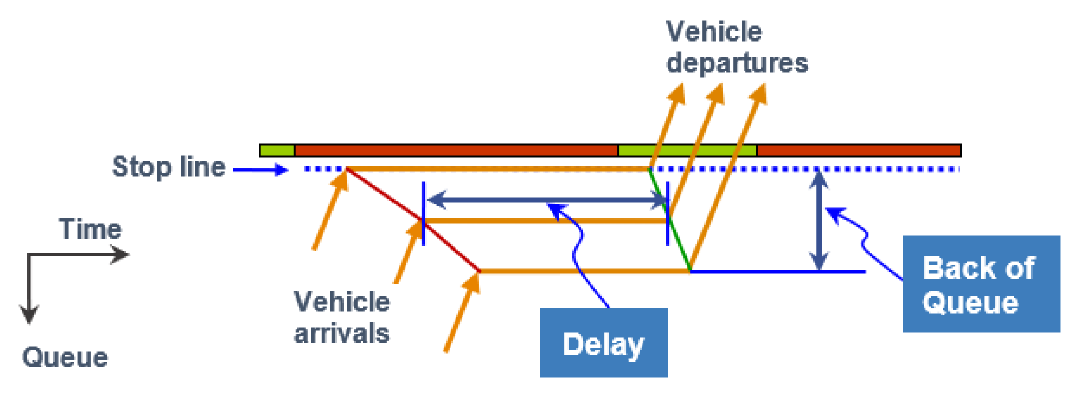
Long delay with low v/c ratio and short queue

Delay and v/c ratio (degree of saturation) are not necessarily consistent in terms of magnitude.

Short back of queue associated with a low v/c ratio and large average delay:

This occurs with long red (small green / unblocked time ratio) and low arrival flow conditions.

For roundabouts and two-way sign control, this case occurs under high circulating / opposing flow and low entry flow conditions.



Undersaturated cycle shown

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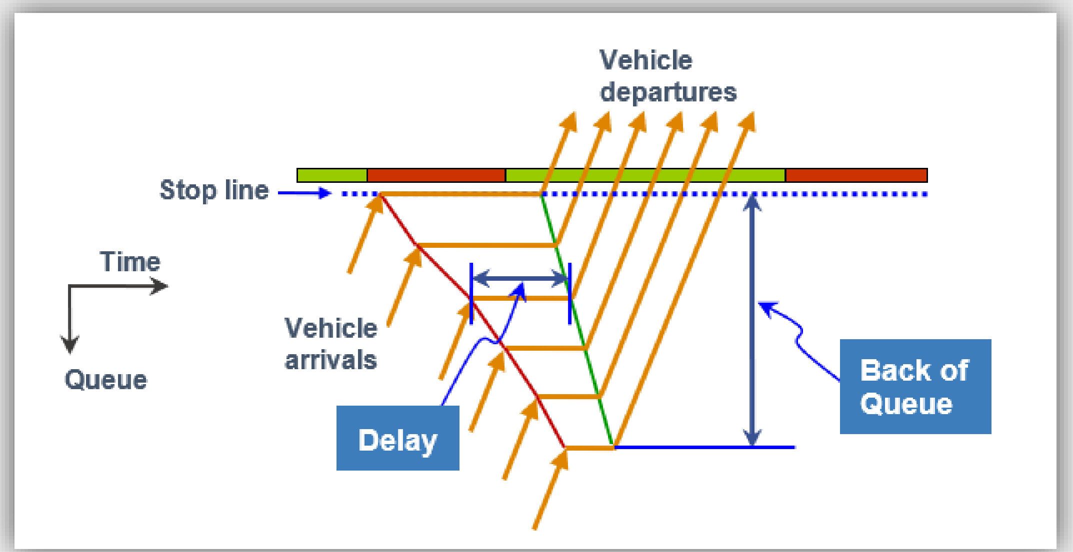
Short delay with high v/c ratio and long queue

Long back of queue associated with a high v/c ratio and short average delay:

This occurs with short red (large green / unblocked time ratio) and high arrival flow conditions.

For roundabouts and two-way sign control, this case occurs under low circulating / opposing flow and high entry demand flow conditions.

The large back of queue represents a moving queue formed by a heavy arrival flow.

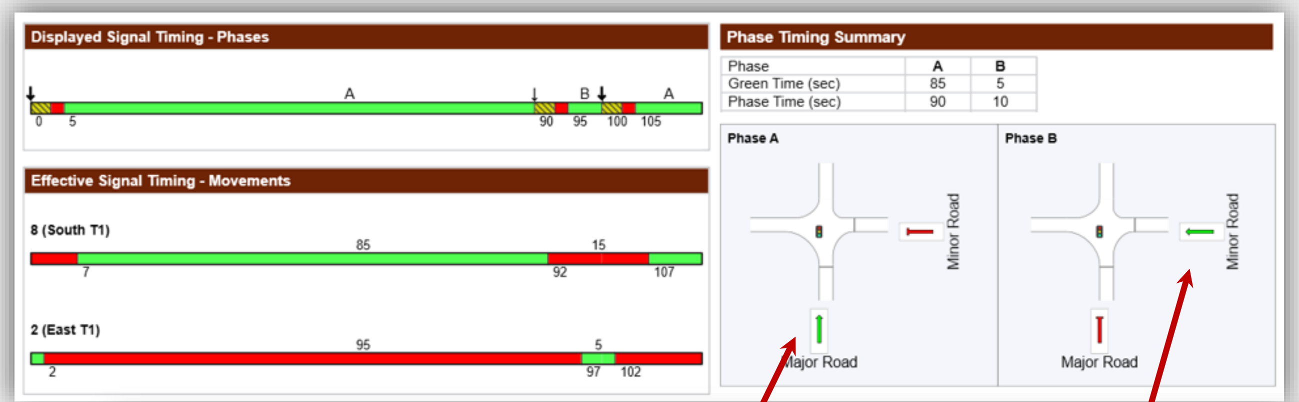


Undersaturated cycle shown

A basic example

This basic SIDRA INTERSECTION 9.0 example is given to show both cases of

- long back of queue and high v/c ratio with a low average delay, and
- short back of queue and low v/c ratio with a large average delay.



Movement >>	Northbound		Westbound
Arrival flow rate	1665 veh/h	1600 veh/h	60 veh/h
v/c Ratio (Degree of Saturation)	1.03	0.99	0.63
Average delay	38.0 s	27.3 s	58.2 s
Level of Service			
HCM (Table 1)	F	C	E
Delay only	D	C	E
Combined Delay & v/c Ratio	F	E	E
Average back of queue	1714 ft (522 m)	1496 ft (456 m)	50 ft (15 m)
Average overflow queue	22.3 veh	17.6 veh	0.4 veh
Queue move-up rate	0.38	0.26	0.12

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Adding the v/c Ratio to Level of Service

The use of delay only in defining levels of service for capacity conditions (x = 1) and undersaturated conditions (x < 1) leads to the expectation that other performance parameters like degree of saturation, overflow queue or queue move-up rate representing cycle failures, stop rate and back of queue are well correlated with delay.

An abrupt change to Level of Service F overriding any low delay values that may be associated appears to be inconsistent because of the lack of correlation between delay and degree of saturation in this case.

A long delay at a high v/c ratio includes the effect of "congestion delay" but a high delay at a low v/c ratio is a result of long red time with low likelihood of overflow delays (cycle failures).

The average delay for the analysis period itself cannot explain these.

Adding the degree of saturation to Level of Service evaluation is helpful with this in mind.

The method shown in the next slide provides smooth transitions between LOS grades with changing v/c ratio as opposed to an abrupt change at v/c ratio greater than 1.0 in the HCM method.

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Combined Delay and Degree of Saturation (v/c Ratio) method for Level of Service

Delay and Degree of Saturation (v/c Ratio) method for Level of Service:
SIDRA Method based on a proposal by Berry (1987)

Level of Service	Control delay per vehicle in seconds (d) (*including geometric delay*)			Degree of Saturation (v/c Ratio) (x)
	Signals	"SIDRA Roundabout LOS" option	Sign Control	
A	d ≤ 10	d ≤ 10	d ≤ 10	0 < x ≤ 0.85
B	10 < d ≤ 20	10 < d ≤ 20	10 < d ≤ 15	0 < x ≤ 0.85
C	20 < d ≤ 35	20 < d ≤ 35	15 < d ≤ 25	0 < x ≤ 0.85
D	35 < d ≤ 55	30 < d ≤ 50	25 < d ≤ 35	0 < x ≤ 0.85
	0 < d ≤ **55**	0 < d ≤ **50**	0 < d ≤ **35**	0.85 < x ≤ **0.95**
E	**55** < d ≤ 80	**50** < d ≤ 70	**35** < d ≤ 50	0 < x ≤ 0.95
	0 < d ≤ 80	0 < d ≤ 70	0 < d ≤ 50	**0.95** < x ≤ 1.00
F	80 < d	70 < d	50 < d	**1.00 < x**

LOS Target (level D)

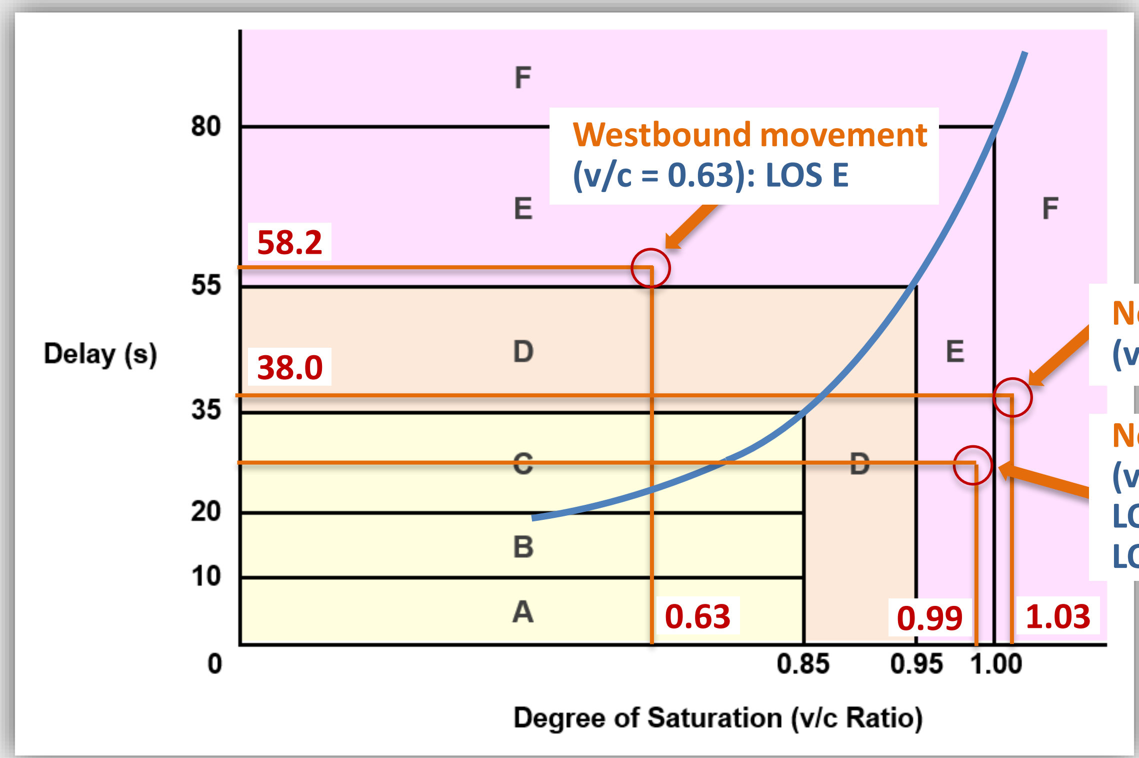
- **LOS thresholds vary by intersection type.**
- **Only delay is considered for approaches and intersection.**

BERRY, D.S. (1987). Using the volume-to-capacity ratios to supplement delay as criteria for levels of service at traffic signals. *Transportation Research Record* 1112, pp 23-28

Combined Delay and Degree of Saturation (v/c Ratio) method for Level of Service

The Combined Delay and Degree of Saturation (v/c Ratio) method for Level of Service provides **smooth transitions between LOS grades with changing v/c ratio** as opposed to **an abrupt change** at v/c ratio greater than 1.0 in the HCM method.

Three points with LOS E and LOS F as in the simple example are shown.



The blue curve indicates the non-linear characteristic of a general delay function.

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Conclusions

Level of Service is a **simple measure** used to assess traffic conditions. It cannot be expected to correlate well with other performance measures.

For good assessment of intersection performance, modelers should pay attention to **delay, back of queue** and **degree of saturation** rather than just the level of service.

Number of signal cycles to clear, overflow queue, queue move-up rate and **stop rate** are useful measures as well.

In the **ITE eCommunity discussion**, there seemed to be a consensus about **driver perception of overflows**.

Conclusions

Different road users (car drivers, large truck drivers, pedestrians, cyclists) may or may not perceive all these performance measures as "good service" or "bad service" at all types of intersection and under all traffic conditions.

For example, queue lengths and blockage of upstream lanes are important for closely-spaced intersections, and stop-starts would be important on high-speed arterial roads with high truck volumes.

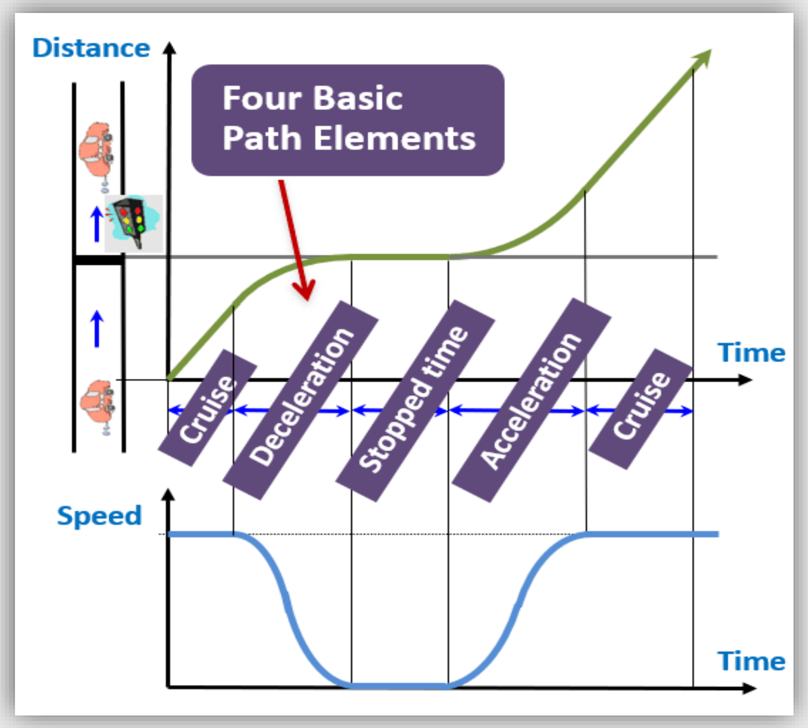
Conclusions

However, note that HCM does not model:

- stop rate, queue move-up rate, overflow queue and number of signal cycles to clear, or
- back of queue for roundabouts and sign-controlled intersections.

Modeling of stop-starts is essential for environmental assessments using energy and emission estimates.

It is recommended that these are considered for future HCM editions. It is also recommended that the level of service method which combines delay and degree of saturation (v/c ratio) is considered for inclusion in future HCM editions.



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END OF PRESENTATION

Thank you!