Date: 3/12/2022
To: Bill Cisco, Chair, Interrupted Flow Subcommittee, TRB Committee on Highway Capacity and Quality of Service
From: Jim Bonneson
Re: Proposed modifications to the urban streets computational engine.

Reported Issue

Kittelson & Associates Inc (KAI) was recently using the HCS Urban Streets software to evaluate the operation of two-lane two-way streets with short (i.e., 400-ft) signal spacing, as might be found in a central business district (CBD). It was noted that the discharge flow profile for the three upstream movements at the signalized intersection feeding the segment were not matching expectations and the predicted travel speed was too slow. Inquiry with McTrans staff confirmed that they were implementing the procedures exactly as rendered in the HCQSC Urban Streets Computational Engine (USCE), Version 8.29 (i.e., the current version).

I recreated the KAI CBD example in my copy of USCE V8.29. The issue is in the calculation of the discharge rate and time interval associated with each discharge period for each of the three upstream movements (L,T,R) that feed the downstream intersection. Each upstream discharge flow is influenced by the subject approach's left-turn mode (prot, perm, prot-perm), lane use (excl, shared), and number of lanes. These calculations are in the ComputeDischargeProfile subroutine.

Background

As you know, the "HCM" approach to quantifying the effect of signal coordination on operations is to compute the pattern of arrivals at the downstream intersection using the upstream discharge profile for each of the three upstream movements. This computation is illustrated in Figure 1.

The issue is that the departure flow profile calculations in the ComputeDischargeProfile subroutine are simplistic such that they do not precisely model permissive filtering and shared lane discharge flows. In most cases, this simplicity does not bias the predicted performance measures because of the following three traits:

1. For typical segment lengths, platoons tend to be sufficiently spread out that they arrive at the downstream signal throughout the cycle length.
2. Mid-segment flows are typically present and they are assumed to be uniformly spread over the cycle length.
3. The USCE maps discharge flows into an arrival flow profile at the downstream intersection (see Figure 1) and use it to compute the "proportion of arrivals on green". This proportion is computed using the arrival volume during green (as shown in the shaded area of Figure 2). Thus, the use of this proportion to describe the arrival profile essentially converts the arrival profile into a simple step function (arrivals on green, arrivals on red) for delay calculation. In other words, even if we predict the "perfect" upstream discharge profile procedure to predict the downstream arrival profile, we mask all of this accuracy by converting the profile into the relatively simple and less precise step function for delay calculation.

For these reasons, the computed "proportion arrivals on green" from the "simple" departure flow profile calculations provide reasonable delay and travel speed estimates for street segments that are either longer (say > 1000 ft) or have some mid-segment flows entering/exiting.

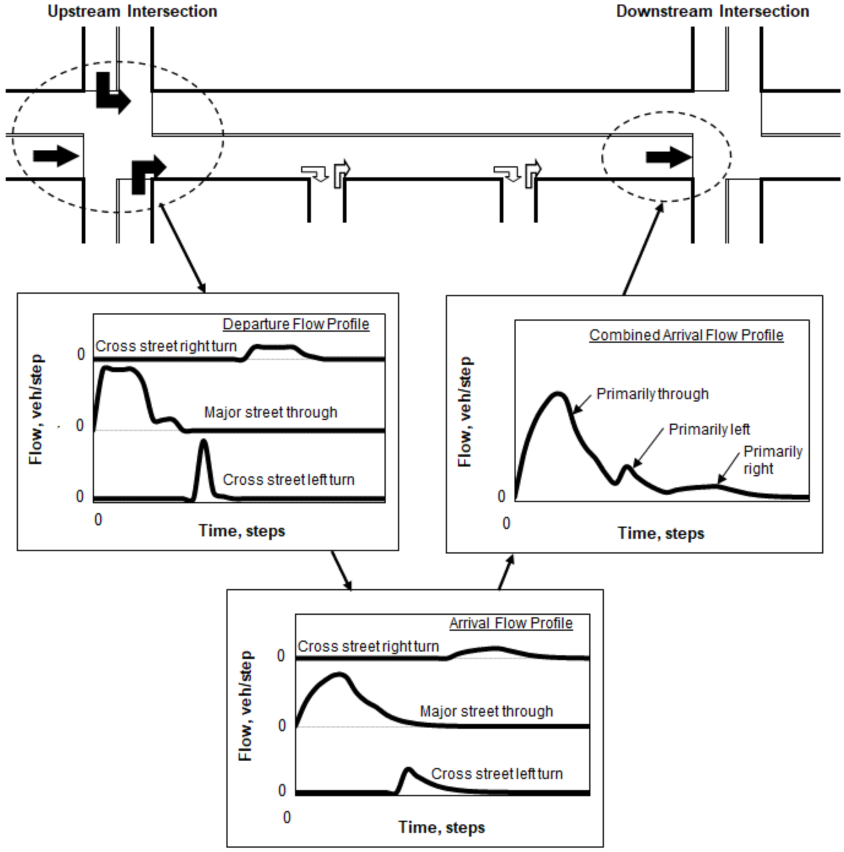

Figure 1. Arrival Flow Profile Estimation.

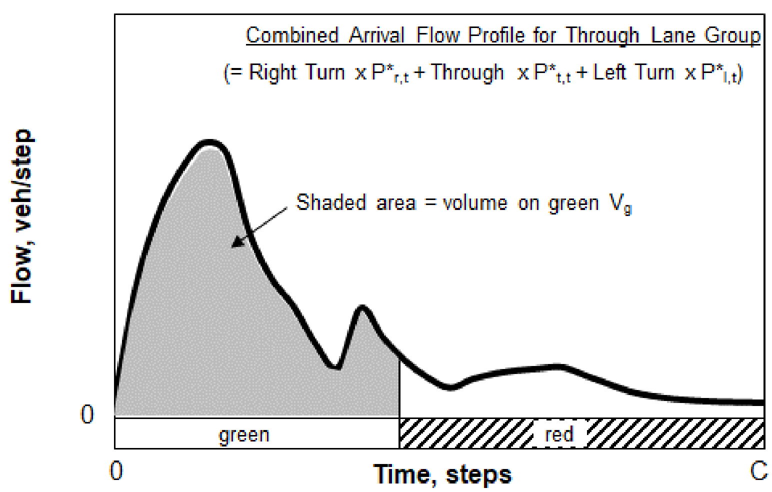

Figure 2. Proportion of Arrivals on Green.

That said, the short-segment-and-no-mid-segment-flows case brought up by KAI represents a case where the simplistic departure flow profile calculations may not be adequate. In this regard, I have made changes to the ComputeDischargeProfile subroutine to provide more realistic profiles for all combinations of left-turn model (protected sat flow, permissive filtering), phase sequence (lead, lag), and lane use (exclusive, shared) for each of the three upstream movements (L,T,R) that feed the downstream intersection.

Evaluation of Changes

The modified departure flow profile calculations in the ComputeDischargeProfile subroutine were used to re-examine the original CBD case for which the issues were identified by KAI. The results are shown in the second column of Table 1. The modifications increased the predicted travel speed in the coordinated (eastbound) direction by 17%. The speed in the non-coordinated direction also increased (by 41%). This was the expected outcome because the segment length was short and there were no mid-segment flows to mitigate the simplistic discharge routines in Version 8.29.

Table 1. Evaluation of Modified Discharge Profile Calculations.

	Results for Selected Street Settings		
	Original KAI	**Modified KAI**	**Modified HCM Example Problem**
Segment length, ft	400	1800[a]	1800
Segments	6	6	2[b]
Mid-segment access pts.	none	none	2
Through lanes	2	2	4
Speed limit, mph	30	30	35
Cycle length, s	120	120	100
Coordinated direction:	Eastbound	Eastbound	Eastbound
Left-turn mode E-W:	Prot/perm.	Prot/perm.	Protected
Left-turn mode N-S:	Prot/perm.	Prot/perm.	Prot/perm.
EB thru. volume, vph:	800	800	1210
Wb thru. volume, vph:	650	650	1210
Version 8.29 Results			
EB travel speed, mph:	7.75	21.0	24.0
Version 8.30 Results			
EB travel speed, mph:	9.04	21.5	24.0
	+17%	+2%	--
Comparison of Travel Speed in EB (coordinated) Travel Direction, mph			
Version 8.29	7.75	21.0	24.0
Version 8.30 beta	9.04	21.5	24.0
Percent Change:	+17%	+2%	--
Comparison of Travel Speed in WB (non-coordinated) Travel Direction, mph			
Version 8.29	5.31	20.8	24.0
Version 8.30 beta	7.48	17.6	24.0
Percent Change:	+41%	-15%	--

a – Modified KAI has 1800 ft segment length. Offset modified to maintain perfect progression in eastbound travel direction.

b – Same as Example Problem 1 in Chapter 30 but expanded to two 1800-ft segments.

The segment length for the KAI case was increased from 400 ft to 1800 ft and the offsets changed to maintain perfect progression in the eastbound direction. The results of this evaluation are shown in column 3 of Table 1. The speed in the coordinated direction increased by 2% as expected. It decreased in the non-coordinated direction because maintenance of perfect progression in the eastbound direction had a larger negative effect on progression quality in the non-coordinated direction (relative to that for the 400 ft segment length).

The fourth column of Table 1 shows the impact of the modifications to the street segment used in Example Problem 1 of HCM Chapter 30. In fact, there was no impact to the predicted travel time for the example problem because the segment is relatively long and has mid-segment flows.

Impact to HCM Text

The modifications to the USCE ComputeDischargeProfile subroutine do not affect the text used to describe this routine in the HCM (notably, Section 3 of Chapter 30). That is, implementation of the proposed modifications in the committee's version of the USCE would not require changes to the text of the current HCM.