Modeling Intersection Delay in Static Assignment

May 11, 2016
Agenda

MOTIVATION
• Why do this?

KEY ISSUES
• Things to think about

METHODS
• Ways of doing it

SUMMARY
Motivation
Why bother?

GOOD REASONS
• Get speeds and delay right on arterials
  - Get emissions and vehicle operating costs right
  - Get routing right (better volumes, better paths for microsim)
• Represent rough benefits of different types of intersection control
  - Stop vs. Roundabout vs. Signal vs. Interchange

MAYBE NOT
• Test signal improvements (re-timing, coordination)
  - Better to use Synchro, HCS, or microsimulation
Key Issues
Solution Stability

REQUIREMENTS FOR EXISTENCE OF UNIQUE, FIXED POINT SOLUTION

- The network is strongly connected
- Demand is non-negative, finite, and either fixed or continuous and decreasing in cost
- The cost function is positive, continuous and increasing in demand

Source: D. Boyce
Trouble with Intersections

SIGNS – ESPECIALLY ACTUATED – VIOLATE CONDITIONS

- cost function must be positive, **continuous and increasing in demand**
- cost can decrease at signals with the same or increasing demand if
  - timing changes/adapts or
  - cross street demand decreases
- multiple equilibria possible
- difference between two runs could just be this

![Actuated Signal](image)

**Two Equilibria!**
So... Good enough?

DANGER OF REALISTIC TRAFFIC DYNAMICS

- Realistic signal operations, etc., can threaten solution stability and invalidate (legally for NEPA) alternatives analysis, benefit-cost, and emissions analyses

SO, INSTEAD...

- Most methods compromise between realism and solution stability
  - Make intersection delay as realistic as possible
  - While maintaining a stable solution
- Beware methods that don’t compromise!
Precision & Convergence

PRACTICAL CONSIDERATIONS

• Well converged solutions are important
  - Considerable noise in poorly converged results
  - Is 800 vph +/- 2,000 vph really helpful?
• Some methods of incorporating intersection delay can require much longer run times to achieve the same convergence – or may not be able to achieve good convergence at all
**Input Data**

**DATA HUNGRY?**

- Different methods require different data
  - Location of signals & roundabouts (maybe stops)
  - g/C ratios, cycle length
  - Phasing, turn bay lengths, etc.
Dependencies on Input Data

SELF-FULFILLING PROPHECIES

• Outcomes can be dependent on input assumptions (such as g/C, phasing, etc.) – even if the algorithm can adjust these
  - If the initial iteration has less delay for one movement, more demand gets assigned to it, so the algorithm maintains or increases the g/C / phasing ratio in favor of the movement…repeat ad infinitum
  - Not an issue in simpler schemes without phasing or variable g/C’s

Other Self-Fulfilling Prophecies

THERE IS TOO MUCH TRAFFIC FOR BILLY TO WALK TO SCHOOL; SO WE DRIVE HIM.
TO TRANSFER OR NOT TO TRANSFER

- Different methods have differing numbers and types of parameters
  - Some have observable parameters (e.g., cycle length, g/C)
  - All have calibration parameters
    » Some have well-established defaults
    » Others do not and may vary by location
- Ideal calibration requires having both travel time / delay and volume data for the same time periods
  - Travel time data now becoming more common – but often detailed (hourly / 15-min) counts are lacking
- Calibration can also be done by minimizing squared error versus counts in assignment
Methods
Overview of Methods

METHODS FOR INTERSECTION DELAY IN STATIC ASSIGNMENT

• Link / Approach-based
  - Link/Approach-based with Simple BPR form vdf
  - Link/Approach-based with “Double”/“Modified” BPR vdf
  - Others (Aashtiani et al.)

• Node Delay
  - IIT Logit Delay
  - TMODEL Node Delay

• HCM-based Volume-Dependent Turn Delays
  - Full HCM method
  - HCM approach method

• Others?
A SIMPLE METHOD

- Webster’s uniform control delay for free-flow conditions added to free-flow time for each approach
- BPR form volume-delay function used to represent flow-dependent delays (uniform, random arrival / incremental & overflow / queueing delays)

\[ d_0 = 0.5C \left(1 - \frac{g}{C}\right)^2 \]

\[ t = (t_0 + d_0) \left[ 1 + \alpha \left(\frac{v}{c}\right)^\beta \right] \]

NOTES

- Used in IN, KY, TN, AR, etc.
- Delay continuously increasing in demand
- Only requires intersection type (g/C can be assumed or input, etc.)
- Parameters (\(\alpha, \beta\)) different from freeways and vary by location
Link-based w/ “Double”/“Modified” BPR vdf

A PRETTY SIMPLE METHOD

• One BPR form volume-delay function for link / mid-block delay

\[ t_l = t_0 \left[ 1 + \alpha_l \left( \frac{v}{c} \right)^{\beta_l} \right] \]

• Another BPR form volume-delay function used to represent flow-dependent delays (uniform, incremental / random arrival & overflow/queueing delays)

\[ t_n = d_0 \left[ 1 + \alpha_n \left( \frac{v}{c} \right)^{\beta_n} \right] \]

NOTES

• Used in AZ, CA, AK

• Delay continuously increasing in demand

• Only requires intersection type (g/C can be assumed or input, etc.)

• Need four parameters, vary by location
Node Delay – IIT Logit

\[ t_n = p_1 d_0 \left[ 1 + \left( \frac{p_2}{1 + e^{(p_3 - p_4 \frac{v}{c})}} \right) \right] \]

A DIFFERENT METHOD

• Logit delay function (from IIT) – one for link delay, one for node delay

NOTES

• Used in NY, VT, NH
• Delay continuously increasing in demand
• Requires intersection / node capacities
  - Estimated at right from Synchro
• Requires lane configurations
• Fairly established parameters
HCM-based Volume-Dependent Turn Delays

A COMPLEX METHOD

- At each iteration, solve HCM for delay for each movement – update turn penalty to reflect this
- Can use full (critical movement) or simplified (approach) HCM method

NOTES

- Used in OH
- Delay NOT continuously increasing in demand with full HCM – mostly stable in practice, but…
  - Significant runtime increase
  - Limits convergence
  - Requires lane configurations
  - Fairly established parameters
Summary
## Methods and Issues

**AT THE RISK OF REALLY OVERSIMPLIFYING…**

<table>
<thead>
<tr>
<th>Method Type</th>
<th>Stable</th>
<th>Runtime / Convergence</th>
<th>Input Data Required</th>
<th>Self-Fulfilling Prophecy</th>
<th>Calibration</th>
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