Development of TSP warrants considering vehicular emissions and variability in traffic demand.

Zeeshan Abdy

Supervisor: Bruce R. Hellinga

Dec 2006
Signalized intersections

Traffic Signal Warrants
- Volume (vehicular and pedestrian)
- School crossing
- Crash experience
- Signal coordination and roadway network

*Note: 115 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 80 vph applies as the lower threshold volume for a minor-street approach with one lane.
Introduction

- Highway Capacity Manual (HCM) and Canadian Capacity Guide (CCG) delay based procedure
- Signal design objective
- Volume and Delay relation

Input Parameters
- Geometric
- Traffic Volume
- Signal
- Peak Hour Factor
- Saturation Flow rate
- Capacity
- v/C

Performance Measures
- Delay
- LOS
- Queue
Motivation

- Degree of Variability
- Impact on intersection delay
- Design and evaluation methods
- Performance variation
Motivation

- Transit Signal Priority (TSP)
  - Preferential treatment to Transit vehicle (person delay)
  - Expense to cross street customers
  - Average performance

- TSP impact on delay with day to day variability

- TSP impact on vehicle emission

- Best Scenario to apply TSP
## Objectives

### Overall

Develop a TSP warrant methodology based on the developed relationships that can be used by transit agencies to aid in TSP implementation decisions.

### Specific

1. Quantify, on the basis of empirical data, the day to day variation in peak hour volume, PHF, and base saturation flow rate.
2. Develop an analytical relationship that reflects the day to day variation of peak hour demand, peak hour factor and base saturation flow rate.
3. Develop a signal analysis and design methodology that is based on the existing HCM and/or CCG methods, but which explicitly considers day to day variability. This methodology will also address the implications for field data collection (e.g. turning movement counts).
4. Examine the impact that TSP parameters, control strategies, signal timings, and variation in traffic demand have on TSP performance.
5. Develop a relationship between TSP performance measured in terms of delays and emission impacts. This relationship will help in assessing TSP impacts from an environmental perspective.
6. Develop a TSP warrant methodology based on the developed relationships that can be used by transit agencies to aid in TSP implementation decisions.
Transit Signal Priority

Figure 12: Illustration of Green extension process
Transit Signal Priority

Analytical models
- Weighted delay model Sunkari et al., (1995)
- Spare green time Skabardonis (2000)

Priority Strategies
- Offline
- Online (active, adaptive)
# Transit Signal Priority

**Literature Review**

- Traffic Volume
- Cycle length
- Signal Phasing
- Transit Arrival phase
- Transit demand
- TSP Strategies
- Bus Stop and Detector location
- Emissions
Day-to-day variability

- Sullivan research for PHV
  - COV for City of Malwauke was found (4.8% to 15.5%) mean of 8.9%.
  - A 10% increase in design hour volume (above the average) would result in 15% failure rate.
  - Specifically for intersection operating at LOS D, a 10% increase in traffic volumes would cause deterioration to LOS E or LOS F, about 15% of the time.
- Tarko model for PHF > Results > Problems


Tarko Model PHF
TSP Emissions

- Stop and go condition
- Waiting (Delay) times for non prioritized approach
- Reducing delay and reducing emissions
- No guidance for TSP implementation in terms of emission.
Framework to establish TSP warrant methodology

1. Empirical distribution of input parameters
2. TSP Studies in Literature
3. Scenarios of Interest $S_1, S_2, \ldots, S_n$
4. Day-to-day variability in traffic demand $V_1^S, V_2^S, \ldots, V_n^S$
5. VAP Code
6. VISSIM
7. Batch Processing complete?
8. Vehicle emission model
9. Delay $D_1^S, D_2^S, \ldots, D_n^S$
10. TSP warrant methodology
   - Statistical Models
   - Field Observations
Warrant development [9, 10]
Scenarios of Interest (2,3)

TSP studies in literature > Scenario of Interest

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road way geometry and Traffic Signal system</td>
<td>Impact of Pedestrian movement, Variability in day-to-day traffic peak hour volume, peak hour factor and base saturation flow rate.</td>
</tr>
<tr>
<td>Transit System</td>
<td>Bus Headway or frequency Impact on emissions</td>
</tr>
<tr>
<td>Signal operation</td>
<td>Cycle length, c/g ratio, v/c ratio, Control strategy and restriction on TSP calls, Impact on emissions.</td>
</tr>
</tbody>
</table>

\[
S_b = P_m^1, P_m^2, \ldots, P_m^N \quad \text{No TSP} \quad (17)
\]
\[
S_n = P_m^1, P_m^2, \ldots, P_m^N \quad \text{With TSP} \quad (18)
\]

where:
- \( S_b \) = Base Scenario of interest,
- \( S_n \) = Alternate \( n^{th} \) Scenario of interest,
- \( P_m^N \) = Selected parameter \( N \) from Table 8 for \( m \) parameter combination.
Day-to-Day variability (1,4)

Day-to-day variability in PHV, charts results and discussions
Day-to-Day variability (1,4)

Day-to-day variability in PHV, charts results and discussions

Day-to-Day variability in PHV, charts results and discussions
Day-to-Day variability (1,4)

Day-to-day variability in PHF, Base saturation flow rate

![Graph showing day-to-day variability in PHF and base saturation flow rate.](image)
Vehicle Actuated programming, batch and post processing (5,6,7)

VAP, Batch processing, Post processing units
Vehicle Emission Model (8)

\[ MOE_e = \sum_{i=0}^{3} \sum_{j=0}^{3} (L^e_{i,j} u^i a^j) \quad \text{for } a \geq 0 \]  
\[ MOE_e = \sum_{i=0}^{3} \sum_{j=0}^{3} (M^e_{i,j} u^i a^j) \quad \text{for } a < 0 \]

where:

- \( MOE_e \) = instantaneous fuel consumption (l/s) or emission rate (mg/s)
- \( L^e_{i,j}, M^e_{i,j} \) = regression model coefficient for MOE ‘e’ at speed power ‘i’ and acceleration power ‘j’
- \( u \) = instantaneous vehicle speed (km/h),
- \( a \) = instantaneous vehicle acceleration (km/h/s)
Development of Warrant methodology (9, 10)

Statistical models
TSP warrant methodology
Step by step procedure for practitioners.
Future Tasks

1. Quantification of variability in base saturation flow rate estimation
2. Investigation and/or development of HCM methodology based on day-to-day variability
3. Calibration and Validation of Simulation Model
4. Development and processing of Scenarios of Interest
5. Development of Comprehensive Vehicle Actuated Programming (VAP) code
6. Validation of Emission Model
7. Development of relationship for TSP in terms of delay and emission
8. Development of TSP warrant methodology based on the developed relationships