Efficient-band: a Novel Approach to Arterial Traffic Signal Optimization

Ying Wang

4/19/2018
Content

• Introduction
• E-band
• The following works
introduction
Figure 1. Space-time diagram showing greenbands. Inbound and outbound greenbands pass through signals $S_h$ and $S_l$. Quantities with bars refer to inbound direction; those without, outbound. Outbound rods are drawn solid and above inbound rods which are dashed. In the general case shown inbound and outbound rods need not coincide.

**MILP1**

\[
\begin{align*}
\text{max } b \\
\bar{b} = b
\end{align*}
\]

**MILP2**

\[
\begin{align*}
\text{max}(b + k\bar{b}) \\
(1 - k)\bar{b} & \geq (1 - k)kb
\end{align*}
\]

Is queue clearance time, an advance leaving time
MULTIBAND

\[ \max(b + kb) \]

\[ (1 - k)b \geq (1 - k)kb \]

\[ \text{MAX } B = \frac{1}{n - 1} \sum_{i=1}^{n-1} (a_i b_i + \bar{a}_i \bar{b}_i) \]

\[ a_i = \left( \frac{v_i}{s_i} \right)^p \quad \bar{a}_i = \left( \frac{\bar{v}_i}{\bar{s}_i} \right)^p \]
Max $\sum_{i=1}^{n-1}(a_i * b) + (\bar{a}_i * \bar{b}) + \sum_{j=1}^{p}[\sum_{i=1}^{N_e-N_s} a_{(o,d)}(i) * y_{N_s,N_e} + \sum_{i=1}^{N_s-N_e} a_{(o,d)}(i) * \bar{y}_{N_s,N_e}]$

$I$

$a_i = \frac{V_i}{S_i}$  $\bar{a}_i = \frac{V_i}{\bar{S}_i}$  $a_{od}(i) = \frac{V_{o,d}}{S_{o,d}}$  $\bar{a}_{od}(i) = \frac{V_{o,d}}{\bar{S}_{o,d}}$

$a^*$  $b^*$

$II$

Tianjin Chengjian University
Lighthill and Whitham

Lighthill and Whitham 1955， Federal Highway Administration. Traffic Flow Theory
My band’s shape
E-Band
Turn-in turn-out through traffic (OD)
On outbound direction:
Intersection 1: 1. \( q_{11th} \)
Intersection j: 1. \( q_{j-1rjth} \), 2. \( q_{j-1ljth} \), \ldots, 2j-3. \( q_{1rjth} \), 2j-2. \( q_{1ljth} \), 2j-1. \( q_{1thjth} \)

On inbound direction:
Intersection i: 1. \( \overline{q}_{ith} \)
Intersection j: 1. \( \overline{q}_{j+1rjth} \), 2. \( \overline{q}_{j+1ljth} \), \ldots, 2(i-j)-1. \( \overline{q}_{irjth} \), 2(i-j). \( \overline{q}_{iljth} \), 2(i-j)+1. \( \overline{q}_{ithjth} \)
\[ g_{jp5} = \frac{q_{jth}}{s_{th}} C, \quad g_{jp1} = \frac{\bar{q}_{jth}}{\bar{s}_{th}} C. \]

\[ g_{jp1}^{end} = g_{ip1}^{end} + \sum_{k=1}^{j-1} \bar{t}_{\text{segment } k}, \quad g_{jp5}^{end} = g_{ip5}^{end} + \sum_{k=1}^{j-1} t_{\text{segment } k}. \]

Where:

- \( g_{jpk} \) = the green time interval of phase \( k \).
- \( s_{th} \) = saturation flow rate of through lane on outbound direction of arterial.
- \( \bar{s}_{th} \) = saturation flow rate of through lane on inbound direction of arterial.
- \( g_{jpk}^{end} \) = the green end time spot of phase \( k \), a cyclic value.
- \( t_{\text{segment } k} \) = travel time of segment \( k \) on outbound direction of arterial, and
- \( \bar{t}_{\text{segment } k} \) = travel time of segment \( k \) on inbound direction of arterial.
- \( C \) = common cycle length, \( C \geq \max (C_j, j = 1,2, \ldots, i) \). \( C_j \) was the most optimal cycle length of isolated intersection \( j \) calculated by Webster’s model.
\[
\begin{align*}
\left\{
\begin{array}{l}
g_{jP_1}^{\min} = y_{j_1} \times C \\
g_{jP_1}^{\max} = C - (\max(y_{j_3} + y_{j_4}, y_{j_7} + y_{j_8}) + y_{j_2})C, j = 1,2,\ldots, i^* \\
g_{jP_5}^{\min} = y_{j_5} \times C \\
g_{jP_5}^{\max} = C - (\max(y_{j_3} + y_{j_4}, y_{j_7} + y_{j_8}) + y_{j_6})C, j = 1,2,\ldots, i^*
\end{array}
\right.
\]
\]
\[
g_{jP_1}^{\min} \leq g_{jP_1} \leq g_{1P_1}^{\max}, g_{jP_5}^{\min} \leq g_{jP_5} \leq g_{1P_5}^{\max}, i^*
\]

Where,\[^*
\]
y_{jk} = \text{critical flow ratio for phase } k \text{ of intersection } j, i^*
\]
g_{jk}^{\min} = \text{the minimal green time interval of phase } k, \text{ and, } i^*
\]
g_{jk}^{\max} = \text{the maximal green time interval of phase } k, i^*
On outbound direction:  

\[ W_j = \frac{\sum_{k=1}^{j-1} (q_{kr,jth} + q_{kl,jth})}{n \times s_{th}} \quad j = 2,3, ..., i, \quad W_1 = 0, \]

\[ A_j = 1 - \max (y_{j,3} + y_{j,4}, y_{j,7} + y_{j,8}) - y_{j,6} - W_j \quad j = 1,2, ..., i, \]

\[ B_j = \frac{q_{1th,jth}}{n \times s_{th}} \quad j = 1,2, ..., i, \]

\[ F_j = \frac{A_j}{B_j} \quad j = 1,2, ..., i, \]

\[ g_{\text{max}}^{\text{p5'}} = g_{\text{min}}^{\text{p5}} \times \min (F_1, F_2, ..., F_i), \quad g_{\text{min}}^{\text{p5}} \leq g_{\text{p5}} \leq g_{\text{max}}^{\text{p5'}}, \]

The maximum green time of phase 5 is made up by three parts:

\[ t_{j1} = B_j \times k \times C \quad 1 \leq k \leq \min (F_1, F_2, ..., F_i), \]

\[ t_{j2} = W_j \times C, \]

\[ t_{j3} = g_{\text{max}}^{\text{p5}} - t_{j1} - t_{j2}. \]
On outbound direction:

\[ \overline{W}_j = \sum_{k=1}^{j+1} \frac{(\overline{q}_{k,j+1} + \overline{q}_{k,j})}{\bar{n} \times \bar{s}_{th}} \quad j = 1, 2, \ldots, i - 1, \quad W_i = 0, \]

\[ \overline{A}_j = 1 - \max (y_{j,3} + y_{j,4}, y_{j,7} + y_{j,8}) - y_{j,2} - \overline{W}_j \quad j = 1, 2, \ldots, i, \]

\[ \overline{B}_j = \frac{\overline{q}_{j+1}}{\bar{n} \times \bar{s}_{th}} \quad j = 1, 2, \ldots, i, \]

\[ \overline{F}_j = \frac{\overline{A}_j}{\overline{B}_j} \quad j = 1, 2, \ldots, i, \]

\[ g_{iP1}^{\text{max'}} = g_{iP1}^{\text{min}} \times \min (\overline{F}_1, \overline{F}_2, \ldots, \overline{F}_i), \]

\[ g_{iP1}^{\text{min}} \leq g_{iP1} \leq g_{iP1}^{\text{max'}}, \]

The green time interval of phase 1 was made up by three-part:

\[ \overline{t}_{j1} = \overline{B}_j \times k \times C \quad 1 \leq k \leq \min (\overline{F}_1, \overline{F}_2, \ldots, \overline{F}_i), \]

\[ \overline{t}_{j2} = \overline{W}_j \times C, \]

\[ \overline{t}_{j3} = g_{iP1}^{\text{max'}} - \overline{t}_{j1} - \overline{t}_{j2}. \]
\[ \theta_{p1} = \frac{q_{th}}{s_{th} + \bar{q}_{th}} \, ^\circ \]

\[ \bar{\theta}_{p1} = \frac{\bar{q}_{th}}{s_{th} + \bar{q}_{th}} \, ^\circ \]

\[ a = \theta_{p1} \times t_{p1}^{end}, ^\circ \]

\[ \bar{a} = \bar{\theta}_{p1} \times t_{p1}^{end} \, ^\circ \]
\[ O_j = \frac{g_{jP5} - W_j \times C}{B_j \times C} \quad j = 1, 2, \ldots, i, \quad W_1 = 0, \]

\[ g_{1P5}' = g_{1P5}^{\text{min}} \times \min (O_j, \quad j = 1, 2, \ldots, i), \]

\[ g_{1P1}^{\text{start}} = g_{1P5}^{\text{start}} = g_{1P5}^{\text{end}} - g_{1P5}', \]

\[ \bar{O}_j = \frac{g_{jP1} - \bar{W}_j \times C}{\bar{B}_j \times C} \quad j = 1, 2, \ldots, i, \quad \bar{W}_1 = 0, \]

\[ g_{1P1}' = g_{1P1}^{\text{min}} \times \min (\bar{O}_j, \quad j = 1, 2, \ldots, i), \]

\[ g_{1P1}^{\text{start}} = g_{1P5}^{\text{start}} = g_{1P5}^{\text{end}} - g_{1P1}'. \]
• Did not think about pedestrian
• Did not think about the lost time.
Following work

1 Computer program
2 Comparison
3 Other type of NEMA
Thank you!