A STUDY ON DESIGN VOLUME FOR A CLUSTER OF TRAFFIC FLOW
WITH CONSIDERATION OF ITS VARIATIONS

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Abstract In this paper signal control parameters and design volume are investigated
with consideration of variations in traffic volume using the non-linear programming method.
Traffic volume data for the analysis are collected by detectors at the signalized intersection in
Tokyo. A simple and practical method of clustering for traffic volume is also checked.

1. Introduction
The fixed-time signal control (esp. multiple-program control) is still widely used.
SHIKATA, KATAKURA and MOROBOSHI\(^1\) divided a whole day's volumes into several patterns by the
clustering analysis and found that the total delay decreases with the increase of no. of
patterns. Yet they took the 85-percentile volume as design volume in evaluating delay.

2. Data collection and reduction
It is better to take the four-arm intersection where less congestions occur. The intersection of
Yotuya 3-chome, Tokyo, was chosen. The data are outputs from detectors which is collected for
every 15-min. from 5:00 am to 11:00 pm for four
months. Total 98 weekdays was used for analysis.
Fig. 1 shows the transition history for the
average 15-min. volumes of a whole day. It was
found the the 15-min volumes obey normal
distribution approximately.

3. Optimum signal parameters
It is appropriate to take delay minimization as
objective function for undersaturated condition.
For delay evaluation, the famous F.V.Webster's
formula\(^2\) and the 1985 H.C.M. formula\(^3\) are
usually considered. Since the former
overestimates delay for higher degree of
saturation, the latter is taken here.

Here we define the optimum signal parameters
(cycle length & green splits) as those which give
the minimal total delay for a whole cluster of
traffic volume and the design volume as that
giving the optimum parameters.

The objective function here is the total delay
(TD) with the consideration of variations of
traffic volume for a given cluster.

\[ TD = \int \int \int D_1(q_1, C, g_1) dq_1 dq_2 \]

where \( f \) is joint pdf of maximum direction volumes
\( q_1 \) & \( q_2 \); \( N \) is no. of 15-min. volumes in a cluster;
g_1 is green split defined by effective green over
cycle length. So there exists

\[ g_1 + g_2 = 1 \]  

Since total delay (TD) is just function of
signal parameters \( C \) and \( g_1 \) or \( g_2 \), determination
of parameters can be replaced by the following
optimization problem.

\[ TD = F(C, g_1) \rightarrow \text{Min.} \]

\[ C_{min} \leq C \leq C_{max} \]

\[ G_{min} \leq g_1 \leq G_{max} \]

Here \( C_{min} C_{max} G_{min} \) and \( G_{max} \) are
determined from particular conditions of each
intersection, e.g. geometric condition and safety
consideration, etc.

It was found that TD is convex in practical
area of \( C \) and \( g_1 \) plane for any given cluster.
Fig. 2 shows the convexity for all the 15-min.
volumes \( n=72 \). Values in each contour are the
total delay. The normal NLP methods such as
conguage direction method and Davidson's method
via Fletcher and Powell (the DFP method) are all
not so effective because the contours show the
straight and narrow ridges with the increase of
N. Problem \( (4) \) was solved successfully by the
method of the continued PARTAN (Parallel
Tangents) search\(^4\).

4. Design volume

For \( n=1 \) in \( (1) \), optimum cycle length can be
determined\(^1\). The following formula is based on
2-phase signal control and loss time of 6sec.

\[ C=5.98\exp(2.73\lambda +1.21\lambda +\alpha) \]  \hspace{1cm} (4)

where \( \lambda \) and \( \lambda + \alpha \) are the normalized direction flow per 15 min. Green splits are obtained by followings:

\[ g_1 = \frac{\lambda}{\lambda + 1 - \frac{1}{L/C}}; \quad g_2 = \frac{\lambda}{\lambda + 1 - \frac{1}{L/C}} \]  \hspace{1cm} (5)

From (5), we can get

\[ \frac{g_1}{g_2} = \frac{\lambda}{\lambda + \alpha} \]  \hspace{1cm} (6)

From (4) and (6), we can determine the design volumes \( Q_1, Q_2 \) for a given cluster of volume uniquely \( Q_1 \leq Q_2 \).

\[ Q_1 = \frac{\ln(C/5.98)}{6.07 \times 10^{-3}(1+1.21g_2/g_1)} \]  \hspace{1cm} (7)

\[ Q_2 = \frac{\ln(C/5.98)}{6.07 \times 10^{-3}(1+1.21g_2/g_1)} \]

5. Clustering of traffic volume

The problem is to divide the 15-min. volume series of whole day into \( n \) clusters which give the minimal total delay assuming that design volume of each cluster is one of the 15-min. volumes. The result is shown in Fig. 1 for \( n=4 \). Table 1 shows the signal parameters and average delays of each cluster by this approximate method. Also shown in the table are the optimum parameters from NLP method described in 1 and the design volumes. The difference is negligible. The reason is that the 15-min volume series do not variate abruptly. Fig. 1 15-min volume series and its clustering.

So the assumption of the approximate method is reasonable at least as far as this problem is concerned.

6. Conclusions

Signal control parameters were investigated through NLP method based on minimal delay criterion with the consideration of variations of traffic flow. Design volume was also checked. At last an approximate method of volume clustering was also checked and found to be practical in engineering.

References:


Table 1 Parameters and average delays for each cluster

<table>
<thead>
<tr>
<th>Cluster</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle</td>
<td>30.0/28.8</td>
<td>64.8/64.9</td>
<td>58.1/58.2</td>
<td>43.3/43.9</td>
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<tr>
<td>Split 1</td>
<td>37.3/37.7</td>
<td>46.8/46.8</td>
<td>42.6/42.9</td>
<td>46.9/46.9</td>
</tr>
<tr>
<td>Des vol</td>
<td>6.81/6.78</td>
<td>23.0/23.0</td>
<td>19.2/19.2</td>
<td>12.6/12.6</td>
</tr>
<tr>
<td>(111,122)</td>
<td>(183,173)</td>
<td>(161,176)</td>
<td>(160,134)</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2 convexity of total delay in cycle and split

<table>
<thead>
<tr>
<th>Cycle (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.000/00</td>
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<tr>
<td>6.50/00</td>
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<td>1.000/00</td>
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