IV-65 A STUDY ON DESIGN VOLUME FOR A CLUSTER OF TRAFFIC FLOW WITH CONSIDERATION OF ITS VARIATIONS

Jian XING : Student Member, Univ. of Tokyo
Masaki KOSHI : Regular Member, Univ. of Tokyo
Masao KUWAHARA : Regular Member, Univ. of Tokyo

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 undersatuated 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 satuation, 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.

$$TD=\sum_{i=1}^{N} \int \int [D_1(q_1,C,g_1)*q_1+ D_2(q_2,C,g_2)*q_2]*f_{q1,q2}(q_1,q_2)\, dq_1dq_2 \quad (1)$$

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

$$g_1+g_2=1-L/C \quad (2)$$

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

$$\begin{aligned} &TD=F(C,g_1) \rightarrow \text{Min.} \\ &C_{min} \leqq C \leqq C_{max} \quad (3) \\ &G_{1min} \leqq G_1=g_1*C \leqq G_{1max} \end{aligned}$$

Here $C_{min}, C_{max}, G_{1min}$ and G_{1max} are determined from particular conditions of each intersection, e.g. geometric condition and safety consideration, etc.

It was found that TD is convex in pratical 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 congujate-direction mathod and Davidon'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.

$$C=5.98EXP(2.73(\lambda_1+1.21\lambda_2)) \qquad (4)$$

where λ_1 and λ_2 are the normalized direction flow per 15 min. Green splits are obtained by followings:

$$g1=\frac{\lambda_1}{\lambda_1+\lambda_2}(1-L/C);\ g2=\frac{\lambda_2}{\lambda_1+\lambda_2}(1-L/C) \qquad (5)$$

From (5), we can get

$$\frac{g_1}{g_2}=\frac{\lambda_1}{\lambda_2} \qquad (6)$$

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

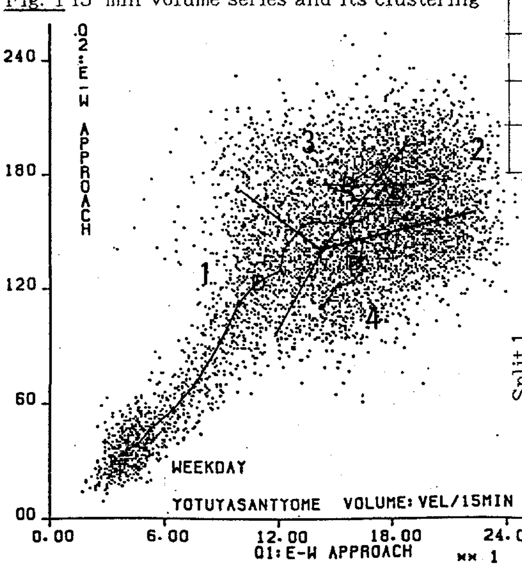
$$Q_1=\frac{\ln(C/5.98)}{6.07\times10^{-3}(1+1.21g_2/g_1)}$$

$$Q_2=\frac{\ln(C/5.98)}{6.07\times10^{-3}(1.21+g_1/g_2)} \qquad (7)$$

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

Fig. 1 15-min volume series and its clustering



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:

1. S. SHIKATA, M. KATAKURA and K. MOROBOSHI : A method for establishing split patterns of pretimed control in consideration of variation in traffic volume, Proceedings of infrustructure planning, No.9, 1986 (in Japanese)

2. F.V. WEBSTER : Traffic signal settings, Road res. tech. paper no.39,1958, Road Reseach Lab.

3. Highway Capacity Manual, Special Report 209, 1985, Transp. Res. Board.

4. D.A. PIEREE, Optimization theory with applications, Dover, 1986.

Tabble 1 Parameters and average delays for each cluster
Note: */**: *-- obtained by approx. method; **-- obtained by NLP method;

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

Fig. 2 convexity of total delay in cycle and split