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Signal Control Algorithms of a One-Way Traffic Network

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Abstract

This paper studies signal control algorithms of a one-way traffic network from a deterministic control viewpoint. A signal control system is synthesized applying the feedback control of signal control parameters for the traffic network. The signal control system of the congestion length is described by a linear time-varying discrete dynamic system in the traffic network. Two signal control algorithms are presented to control the congestion lengths on an arterial; one is a "priority control algorithm", the other is a "balance control algorithm". In the priority control algorithm, the congestion lengths of the arterial direction are controlled prior to the other ones, and the three signal control parameters consisting of the cycle length, green split and offset are systematically controlled according to the variation of incoming volumes and queue lengths so as to minimize the sum of a control error function for the arterial direction. In the balance control algorithm, the two congestion lengths which cross each other on a road are controlled so as to become equal and minimize the sum of the control error function of both the arterial and the cross directions. A network signal control algorithm is presented for the traffic network using the concept of the balance control. From the simulation results in Fukuyama city, Japan, it is confirmed that the cycle lengths, green splits and offsets are systematically and sequentially controlled according to the variation of the incoming volumes and the queue lengths. The three signal control algorithms work well to control the congestion lengths so as to satisfy each performance criterion.

Key Words : volume balance, signal control system, signal control algorithms
one-way traffic network

1. Introduction

Automobiles play an essential role in transportation systems. In recent years, along with the increase of registered automobiles, the congestion has increased in traffic networks in Japan. The congestion has caused problems such as the increase of travel time, exhaust pollutions, and fuel consumption.

The signal control is an effective method to control the congestion of traffic networks. On-line signal control methods such as the SCOOT1), decentralized control2) and the STREAM3) have been presented to control the congestion in traffic networks. The SCOOT is a signal control technique which on-line control the three signal control parameters consisting of the cycle length, green split and offset so as to minimize vehicle delay. The gating is introduced to control the inflow of traffic into sensitive areas to prevent the formation of long queues or congestion4). The decentralized control is such an on-line signal control method that queue length perturbations at all signalized intersections of the network are asymptotically "balanced"; this is done by changing the nominal "signal-split" percentage of a cycle length using only a local knowledge of queue lengths at each signalized intersection. The STREAM is such a practical real-time signal control system that the three signal control parameters are independently controlled so as to reduce the delay and stops.

Since incoming volumes and queue lengths at each signalized intersection of traffic networks increase rapidly in rush hours, the three signal control parameters are desired to be controlled not independently but systematically. In this paper, the three signal control parameters are controlled systematically and sequentially according to the variation of the incoming volumes and the queue lengths.

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The signal control system is synthesized applying the feedback control of the congestion length for the traffic network. The volume balance is held at each signalized intersection of the traffic network for a certain sampling period. Based on the volume balance at each signalized intersection, the congestion mechanism is described quantitatively. The time of the beginning, continuance and disappearance of the congestion are evaluated from the volume balance. Based on the volume balance at each signalized intersection, and regarding the excess incoming volume as the state variable, the time-dependent characteristics of the congestion length are described by a linear time-varying discrete dynamic system. In this system, the outgoing volume is controlled by the three signal control parameters at the signalized intersection concerned. The control input, which is a function of three signal control parameters, is defined by the difference between the incoming volume and the outgoing volume. In this way, the signal control system of the congestion length is described by a linear time-varying discrete dynamic system. The three signal control parameters are controlled systematically so as to minimize the sum of the control error function in the traffic network.

Two signal control algorithms are presented to control congestion lengths on an arterial; one is a "priority control algorithm", the other is a "balance control algorithm". The main difference between the priority control algorithm and the balance control algorithm is as follows: The green splits and the cycle length are corrected for the arterial direction or the corresponding cross directions depending on a control index value. A network control algorithm is presented for a one-way traffic network based on the concept of the balance control.

The priority and the balance control algorithms of the congestion length are simulated at four signalized intersections on Route 2 in Fukuyama city, Japan. From the comparison of the simulation results between the two signal control algorithms, it is confirmed that the balance control algorithm works more effectively to reduce both the duration and the length of the congestion on the arterial. The network control algorithm is simulated in the traffic network consisting of twelve signalized intersections in Fukuyama city. The three signal control parameters are stepwise determined so as to minimize the sum of the control error function in the traffic network.

2. Signal Control System

The signal control system of the congestion length is synthesized in a one-way traffic network. The volume balance at each signalized intersection of the traffic network is written as follows.

$$\begin{aligned} x_e(i,j,m,l,k) = x_e(i,j,m,l,k-1) \\ +x_i(i,j,m,l,k) \\ -x_o(i,j,m,l,k) \end{aligned} \qquad (1)$$

$$\begin{cases} x_o(i,j,m,l,k) < c_x(i,j,m,l,k) \\ x_e(i,j,m,l,k) \geq 0 \end{cases} \qquad (2)$$

where i, j and m denote the location of each signalized intersection and the moving direction of motor cars (see Fig. 1), l and k denote a day of the week and time respectively. In the volume balance at each signalized intersection, it is assumed that the incoming volume $x_i(i,j,m,l,k)$ is measured, and the outgoing volume $x_o(i,j,m,l,k)$ is controlled by the three signal control parameters at the signalized intersection concerned.

$$\begin{aligned} x_i(i,j,m,l,k) - x_o(i,j,m,l,k) = f[c_y(i,j,m,l,k), \\ r_g(i,j,m,l,k), t_{off}(i,j,m,l,k)] \end{aligned} \qquad (3)$$

where $c_y(i,j,m,l,k)$, $r_g(i,j,m,l,k)$ and $t_{off}(i,j,m,l,k)$ denote the cycle length, green split and offset respectively. The control input $u(i,j,m,l,k)$ is defined by

$$\begin{aligned} u(i,j,m,l,k) \triangleq f[c_y(i,j,m,l,k), \\ r_g(i,j,m,l,k), t_{off}(i,j,m,l,k)] \end{aligned} \qquad (4)$$

The signal control system is then written as follows.

$$\begin{cases} x_e(i,j,m,l,k) = x_e(i,j,m,l,k-1) + u(i,j,m,l,k) \\ y_c(i,j,m,l,k) = l_m(i,j,m,l,k)x_e(i,j,m,l,k) \end{cases} \qquad (5)$$

The observation equation of the congestion length $y_c(i,j,m,l,k)$ is described in such a way that the state variable is multiplied by a "transformation factor" $l_m(i,j,m,l,k)$. If $x_e(i,j,m,l,k-1) = 0$ and we can find $u(i,j,m,l,k) \leq 0$, then we can transfer $x_e(i,j,m,l,k)$ to $x_e(i,j,m,l,k) = 0$. Therefore, provided that $x_e(i,j,m,l,k-1) = 0$ and $x_i(i,j,m,l,k) \leq x_o(i,j,m,l,k)$, the signal control system is controllable.

The signal control system of the congestion length is considered in the traffic network; in this control system, the reference input, control input and output are given by the permitted congestion length $l_r(i,j,m,l,k)$, three signal control parameters and congestion length respectively. In this way, the signal control system of the congestion length is synthesized at each signalized intersection (see Fig. 2). The purpose of the signal control system is to find such control input that it makes the following performance criterion minimize.

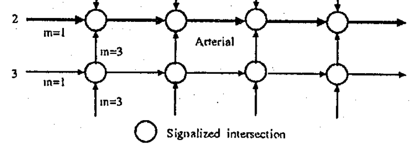

Fig. 1 One-way traffic network consisting of a rectangular grid of intersecting streets

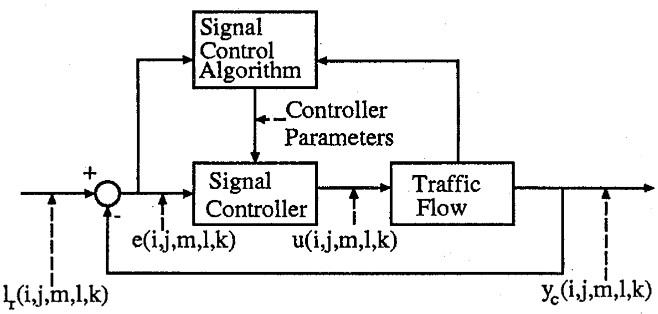

Fig. 2 Signal control system of congestion length at each signalized intersection

$$J_n(l,k) = \sum_{i=1}^{L}\sum_{j=1}^{N}\sum_{m=1}^{K} g(i,j,m,l,k) \tag{6}$$

where the control error function $g(i,j,m,l,k)$ and the control error $e(i,j,m,l,k)$ are defined by

$$g(i,j,m,l,k) \triangleq \begin{cases} 0 & e(i,j,m,l,k) \geq 0 \\ |e(i,j,m,l,k)| & e(i,j,m,l,k) < 0 \end{cases} \tag{7}$$

$$e(i,j,m,l,k) \triangleq l_r(i,j,m,l,k) - y_c(i,j,m,l,k) \tag{8}$$

3. Signal Control Algorithms

3.1 Priority control algorithm

The priority control of the congestion length means that the congestion lengths of the arterial direction are controlled prior to other ones, and the three signal control parameters are systematically and sequentially controlled so as to minimize the following performance criterion for the arterial direction on a road.

$$J_a(i,l,k) = \sum_{j=1}^{N} g(i,j,1,l,k) \tag{9}$$

Step 1. The parameters, control indexes and initial conditions are set for each signalized intersection.

Step 2. The incoming volume $x_i(i,j,m,l,k)$ is inputted, and the sampling time ΔT is equally set to the cycle length $c_y^{(n)}(i,j,m,l,k)$. The symbol $^{(n)}$ denotes the repetition times of computation.

Step 3. The incoming volume is recalculated by

$$\begin{aligned} &\acute{x}_i^{(n)}(i,j,m,l,k) \\ &= x_i^{(n)}(i,j,m,l,k) + x_e(i,j,m,l,k-1) \end{aligned} \tag{10}$$

Step 4. The capacity $c_x^{(n)}(i,j,m,l,k)$ is evaluated by summing up each lane capacity.

$$\begin{aligned} c_x^{(n)}(i,j,m,l,k) = c_{xl}^{(n)}&(i,j,m,l,k) \\ +c_{xs}^{(n)}&(i,j,m,l,k) \\ +c_{xr}^{(n)}&(i,j,m,l,k) \end{aligned} \tag{11}$$

$$\begin{cases} c_{xl}^{(n)}(i,j,m,l,k) = \\ \quad r_{gl}^{(n-1)}(i,j,m,l,k)\ c_{xl}(i,j,m,l,k) \\ c_{xs}^{(n)}(i,j,m,l,k) = \\ \quad r_{gs}^{(n-1)}(i,j,m,l,k)\ c_{xs}(i,j,m,l,k) \\ c_{xr}^{(n)}(i,j,m,l,k) = \\ \quad r_{gr}^{(n-1)}(i,j,m,l,k)\ c_{xr}(i,j,m,l,k) \end{cases} \tag{12}$$

where $c_{xl}(i,j,m,l,k)$, $c_{xs}(i,j,m,l,k)$, $c_{xr}(i,j,m,l,k)$ are the capacities and $r_{gl}(i,j,m,l,k)$, $r_{gs}(i,j,m,l,k)$, $r_{gr}(i,j,m,l,k)$ are the green splits, of left-turn-, straightforward- and right-turn-lanes respectively.

Step 5. The green time of each lane are evaluated by

$$\begin{cases} g_l^{(n)}(i,j,m,l,k) = \\ \quad c_y^{(n-1)}(i,j,m,l,k)\ r_{gl}^{(n-1)}(i,j,m,l,k) \\ g_s^{(n)}(i,j,m,l,k) = \\ \quad c_y^{(n-1)}(i,j,m,l,k)\ r_{gs}^{(n-1)}(i,j,m,l,k) \\ g_r^{(n)}(i,j,m,l,k) = \\ \quad c_y^{(n-1)}(i,j,m,l,k)\ r_{gr}^{(n-1)}(i,j,m,l,k) \end{cases} \tag{13}$$

Step 6. The excess incoming volume $x_e^{(n)}(i,j,m,l,k)$ is evaluated based on the volume balance.

$$\begin{aligned} &x_e^{(n)}(i,j,m,l,k) \\ &= \acute{x}_i^{(n)}(i,j,m,l,k) - x_o^{(n)}(i,j,m,l,k) \end{aligned} \tag{14}$$

$$\begin{cases} x_o^{(n)}(i,j,m,l,k) = \\ \quad \xi^{(n)}(i,j,m,l,k)c_x^{(n)}(i,j,m,l,k) \\ x_e^{(n)}(i,j,m,l,k) \geq 0 \end{cases} \tag{15}$$

where $\xi^{(n)}(i,j,m,l,k)$ is evaluated by taking the effective green time into account.

Step 7. The congestion length $y_c^{(n)}(i,j,m,l,k)$ is evaluated by

$$\begin{aligned} &y_c^{(n)}(i,j,m,l,k) \\ &= l_m(i,j,m,l,k)x_e^{(n)}(i,j,m,l,k) \end{aligned} \tag{16}$$

Proceed to Step8 for m=1, or return to Step2 for m=2. For m=3, let k=k+1 and return to Step2.

Step 8. If the control index $e^{(n)}(i,j,m,l,k) \geq 0$ is satisfied, we apply the green splits and the cycle length at optimum time values and proceed to Step11.

$$\begin{aligned} &e^{(n)}(i,j,m,l,k) \\ &= l_r(i,j,m,l,k) - y_c^{(n)}(i,j,m,l,k) \end{aligned} \tag{17}$$

Step 9. If $e^{(n)}(i,j,m,l,k) < 0$, the green splits are corrected by

$$\begin{cases} r_{gl}^{(n)}(i,j,m,l,k) = \\ \quad r_{gl}^{(n-1)}(i,j,m,l,k) + \Delta r_{gl}(i,j,m) \\ r_{gs}^{(n)}(i,j,m,l,k) = \\ \quad r_{gs}^{(n-1)}(i,j,m,l,k) + \Delta r_{gs}(i,j,m) \\ r_{gr}^{(n)}(i,j,m,l,k) = \\ \quad r_{gr}^{(n-1)}(i,j,m,l,k) + \Delta r_{gr}(i,j,m) \end{cases} \tag{18}$$

If $r_{gs}^{(n)}(i,j,m,l,k) > r_{gs,max}$, proceed to Step10.
If $r_{gs}^{(n)}(i,j,m,l,k) \leq r_{gs,max}$, return to Step4.
where $r_{gs,max}$ denotes the upper limit of the green split of the straightforward lane.

Step 10. The cycle length $c_y^{(n)}(i,j,m,l,k)$ is corrected by

$$\begin{aligned} &c_y^{(n)}(i,j,m,l,k) \\ &= c_y^{(n-1)}(i,j,m,l,k) + \Delta c_y(i,j,m) \end{aligned} \tag{19}$$

Return to Step2.

Step 11. The optimum relative offset $t_{off}(i,j,m,l,k)$ is evaluated by

$$\begin{aligned} &t_{off}(i,j,m,l,k) \\ &= \frac{d(i,j,m)}{v(i,j,m,l,k)} - \frac{q^{(n)}(i,j,m,l,k)}{\psi^{(n)}(i,j,m,l,k)} \end{aligned} \tag{20}$$

where $d(i,j,m)$, $v(i,j,m,l,k)$, $q^{(n)}(i,j,m,l,k)$ and $\psi^{(n)}(i,j,m,l,k)$ denote the link length, average speed, queueing number of motor cars while the signal at the downstream intersection has been red, and the saturation flow on the approach at the downstream intersection.

Step 12. The green time, green splits and cycle length are evaluated for the cross directions to the arterial direction based on the relationships among the signal control parameters at each signalized intersection. for j=1,2,..., N, m=2,3.

$$g_r^{(n)}(i,j,1,l,k) = c_y^{(n)}(i,j,1,l,k) r_{gr}^{(n)}(i,j,1,l,k) \tag{21}$$

$$\begin{aligned} r_{gs}(i,j,2,l,k) = p(i,j,2,l,k)[1 &- r_{gs}^{(n)}(i,j,1,l,k) \\ &- r_{gr}^{(n)}(i,j,1,l,k) \\ &- 2r_y(i,j,1,l,k) \\ &- 2r_c(i,j,1,l,k)] \end{aligned} \tag{22}$$

$$p(i,j,2,l,k) \triangleq \frac{r_{gs}(i,j,2,l,k)}{r_{gs}(i,j,2,l,k) + r_{gr}(i,j,2,l,k)} \tag{23}$$

$$r_y(i,j,1,l,k) = \frac{t_y(i,j,1,l,k)}{c_y^{(n)}(i,j,1,l,k)} \tag{24}$$

$$r_c(i,j,1,l,k) = \frac{t_c(i,j,1,l,k)}{c_y^{(n)}(i,j,1,l,k)} \tag{25}$$

$$\begin{aligned} r_{gr}(i,j,2,l,k) = 1 &- r_{gs}(i,j,2,l,k) \\ &- r_{gs}^{(n)}(i,j,1,l,k) - r_{gr}^{(n)}(i,j,1,l,k) \\ &- 2r_y(i,j,1,l,k) \\ &- 2r_c(i,j,1,l,k) \end{aligned} \tag{26}$$

$$c_y(i,j,2,l,k) = c_y^{(n)}(i,j,1,l,k) \tag{27}$$

$$g_r(i,j,2,l,k) = c_y(i,j,2,l,k) r_{gr}(i,j,2,l,k) \tag{28}$$

$$\begin{aligned} g_s(i,j,2,l,k) = c_y(i,j,2,l,k) &- g_r(i,j,2,l,k) \\ &- g_s^{(n)}(i,j,1,l,k) - g_r^{(n)}(i,j,1,l,k) \\ &- 2t_y(i,j,2,l,k) \\ &- 2t_c(i,j,2,l,k) \end{aligned} \tag{29}$$

where, $t_y(i,j,2,l,k)$ and $t_c(i,j,2,l,k)$ denote the yellow time and the clearance time respectively. The signal control parameters are assumed to be equal between m=2 and m=3 directions.

This control algorithm is executed from $k = 1$ to $k = k_f$, $j = 1, 2, \ldots, N$, $m = 1, 2, 3$.

3.2 Balance Control Algorithm

The balance control of the congestion length means that two congestion lengths which cross each other on a road are controlled so as to become equal. In order to accomplish this balance control, the three signal control parameters are systematically and sequentially controlled so as to minimize the following performance criterion.

$$J_a(i,l,k) = \sum_{j=1}^{N} \sum_{m=1}^{K} g(i,j,m,l,k) \tag{30}$$

From Step 1. to Step 6. The same as the priority control algorithm.

Step 7. The congestion length is evaluated from Equation (16).

Step 8. The green time, green splits and cycle length are evaluated for the cross directions to the arterial direction based on the relationships among the signal control parameters at each signalized intersection.

Step 9. If the following control index

$$\begin{aligned} max\{|e^{(\kappa)}(i,j,1,l,k)|, &|e^{(\omega)}(i,j,2,l,k)|, \\ &|e^{(\lambda)}(i,j,3,l,k)|\} \leq \epsilon \end{aligned} \tag{31}$$

is satisfied, we apply the green splits and the cycle length at optimum time values and proceed to Step12.

Step 10. Otherwise

$$max\{|e^{(\kappa)}(i,j,1,l,k)|, |e^{(\omega)}(i,j,2,l,k)|, |e^{(\lambda)}(i,j,3,l,k)|\} > \epsilon \quad (32)$$

then the green splits are corrected using Equation (18).

If $r_{gs}^{(n)}(i,j,m,l,k) > r_{gs,max}$, proceed to Step11.
If $r_{gs}^{(n)}(i,j,m,l,k) \leq r_{gs,max}$, return to Step4.

Step 11. The cycle length is corrected using Equation (19) and return to Step2.

Step 12. The optimum relative offset is evaluated from Equation (20).

This control algorithm is executed from $k = 1$ to $k = k_f, j = 1, 2, \ldots, N$.

3.3 Network Control Algorithm

The network control of the congestion length means that the three signal control parameters are stepwise controlled so as to minimize the performance criterion of the traffic network described by Equation(6).

Step 1. The three signal control parameters are evaluated so as to minimize the performance criterion on each arterial described by Equation(30) using the balance control algorithm.

Step 2. The maximum value of the cycle lengths evaluated at Step1 is commonly set to all signalized intersections of the traffic network, and two other signal control parameters are evaluated again so as to minimize the same performance criterion as Step1 using the balance control algorithm.

Step 3. The offsets between two parallel arterials are evaluated so as to minimize the performance criterion of the traffic network described by Equation(6) as follows:

i) First, optimum relative offsets are evaluated for the link which has the maximum value of the index $\frac{\acute{x}_i(i,j,m,l,k)}{c_x(i,j,m,l,k)}$ between two parallel arterials.

ii) Second, other offsets are evaluated under the constraint of the offset for all links except the above-mentioned link.

This control algorithm is executed from $k = 1$ to $k = k_f$. The hierarchical structure of the network control algorithm is shown in Fig.3. The performance criteria of the network control algorithm is shown in Table 1.

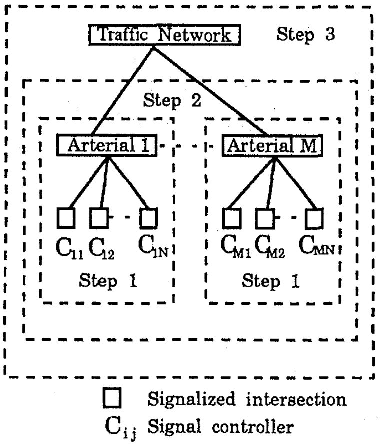

Fig. 3 Hierarchical structure of network control algorithm

Table 1 Performance criteria of network control algorithm

Step	Performance criteria
Step 1	Minimize $J_a(i,l,k)$ c_y , r_g , t_{off}
Step 2	Minimize $J_a(i,l,k)$ r_g , t_{off}
Step 3	Minimize $J_n(l,k)$ t_{off}

4. Simulation Results

4.1 Arterial

The priority and balance control algorithms of the congestion length are simulated at four adjacent signalized intersections from 7:00 a.m. to 7:00 p.m. in Fukuyama city, Japan (see Fig.4). In Fig.4, the circle shows the signalized intersection and the number of line shows the lane number of each link. The link length and the legal speed are shown on each link. The reference input and parameters are set as follows.

$$\begin{cases} 100\ sec \leq c_y(i,j,m,l,k) \leq 200\ sec \\ l_m(i,j,m,l,k) = 6.46\ m \\ l_r(i,j,1,l,k) = 0\ m \quad \textit{for the priority control} \\ l_r(i,j,m,l,k) = 0\ m \quad \textit{for the balance control} \end{cases}$$

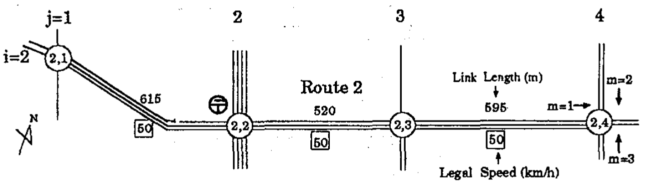

Fig. 4 Arterial consisting of four signalized intersections

The cycle length is set at four steps of 100, 120, 150, 200 seconds. The other parameters and the incoming volumes are arranged for the simulation at each signalized intersection. Incoming volumes at the (2,1) signalized intersection to the (2,4) signalized intersection are shown in Fig.5 to Fig.8 . The incoming volumes along the arterial (m=1) vary widely during a day. The incoming volumes along the arterial become much larger than the cross directions'ones at the (2,1) and (2,3) signalized intersections. In the priority control algorithm, the cycle length is commonly set to 200 seconds at four signalized intersections as shown in Fig.9. The green splits are controlled so as to minimize the performance criterion of Equation(9) according to the variation of incoming volumes (see Fig.10 to Fig.13). The green time are evaluated multiplying the cycle length by the green splits at each signalized intersection. The optimum relative offset between the upstream and the downstream signalized intersections is controlled according to the variation of queue motor cars at the downstream signalized intersection. The offset values during a morning rush hour are shown in Fig.14. The offset value corresponding to the square length of Fig.14 is equal to 100 seconds. As the results, in the case of the priority control, the congestion disappears for the arterial direction m=1 at four signalized intersections; the following result

$$J_a(i,l,k) = \sum_{j=1}^{4} g(i,j,1,l,k) = 0 \tag{33}$$

is obtained (see Fig.15 to Fig.18 and Table 2). In the balance control algorithm, the cycle length is commonly controlled according to the variation of incoming volumes at such critical signalized intersections that have the maximum values of the index $\frac{\dot{x}_i(i,j,m,l,k)}{c_x(i,j,m,l,k)}$ (see Fig.19). The green splits are controlled finely to minimize the performance criterion of Equation (30) (see Fig.20 to Fig.23). The optimum relative offsets between two adjacent signalized intersections are controlled according to Equation (20). The offset values during a morning rush hour are shown in Fig.24. As the results, in the case of the balance control, the congestion lengths of the three directions at four signalized intersections are controlled so as to minimize the performance criterion described by Equation (30). From the comparison of the simulation results for two proposed control algorithms, it is confirmed that the balance control algorithm works more effectively to minimize the sum of the congestion lengths for both the arterial and the cross directions (see Fig.25 to Fig.28 and Table 3).

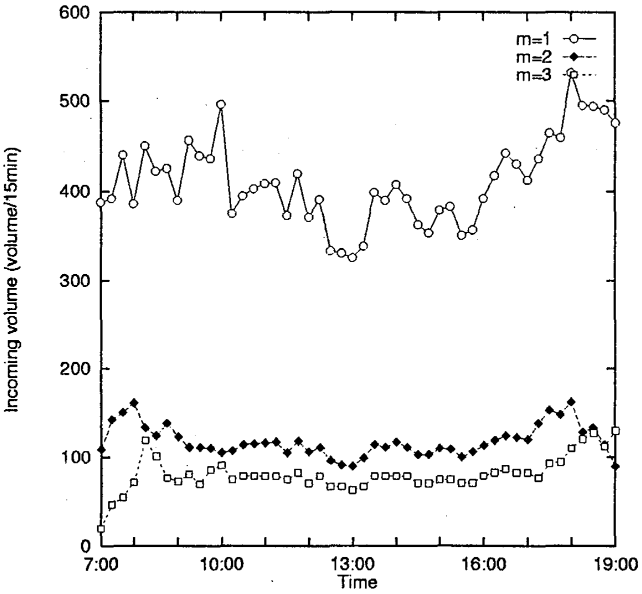

Fig. 5 Incoming volumes at (2,1) signalized intersection

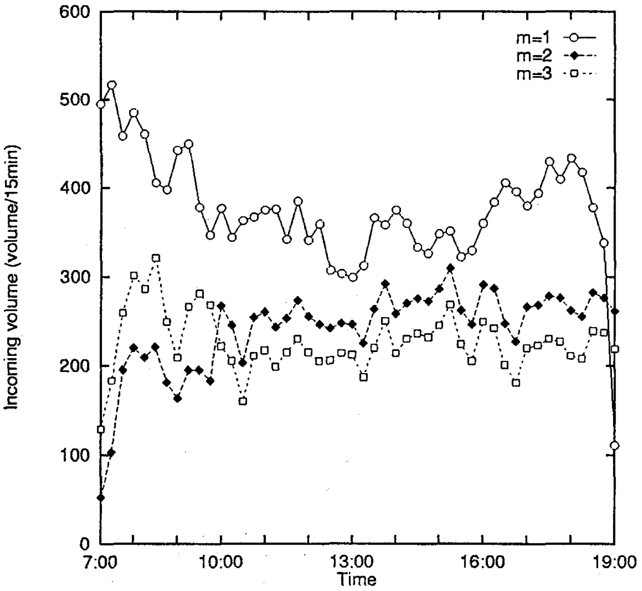

Fig. 6 Incoming volumes at (2,2) signalized intersection

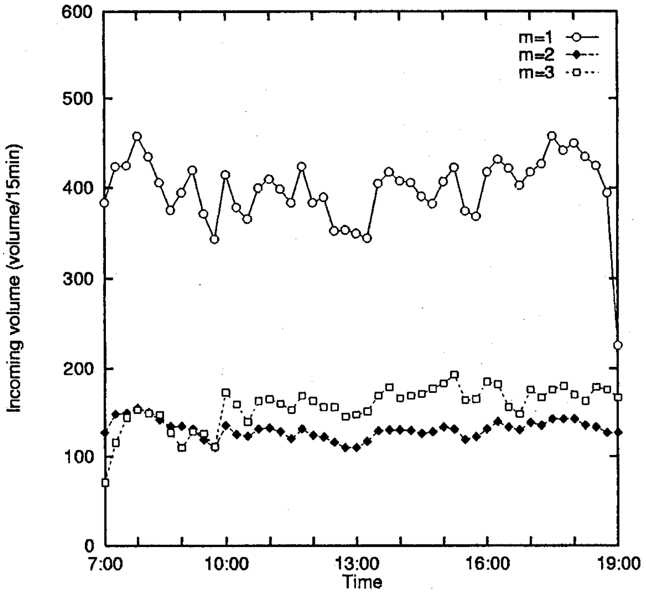

Fig. 7 Incoming volumes at (2,3) signalized intersection

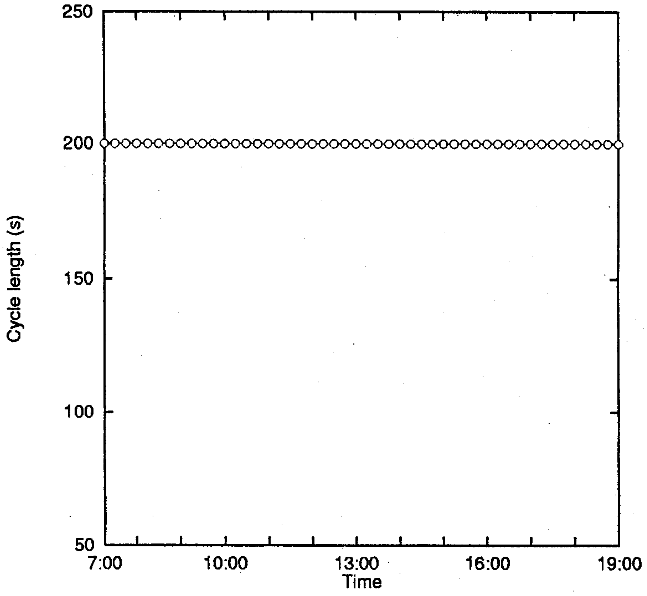

Fig. 9 Common cycle length of the priority control algorithm

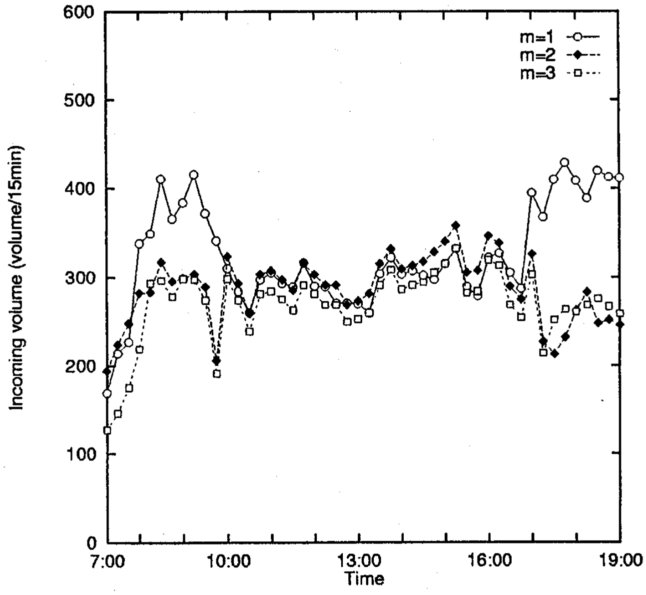

Fig. 8 Incoming volumes at (2,4) signalized intersection

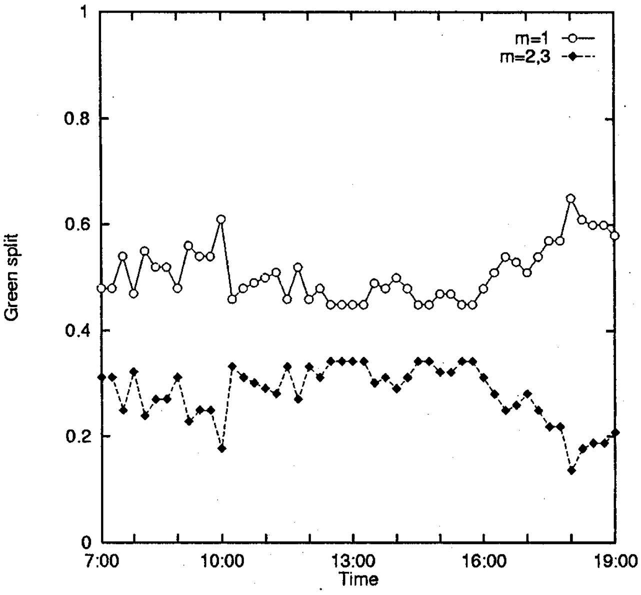

Fig. 10 Green splits at (2,1) signalized intersection for the priority control algorithm

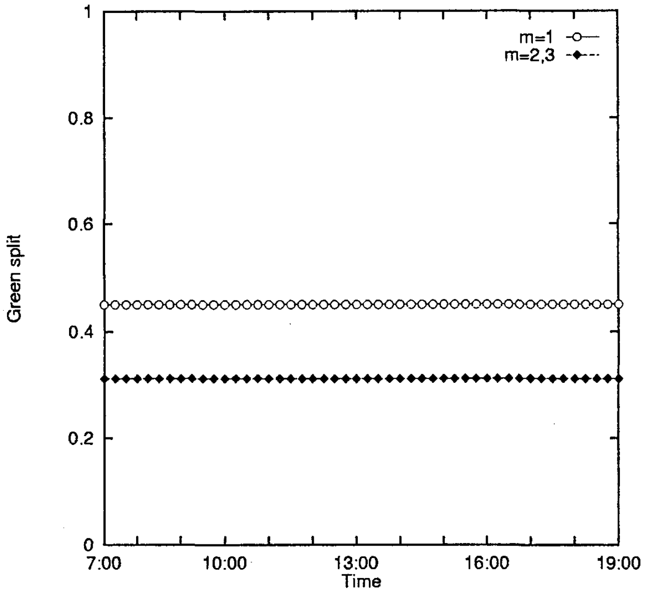

Fig. 11 Green splits at (2,2) signalized intersection for the priority control algorithm

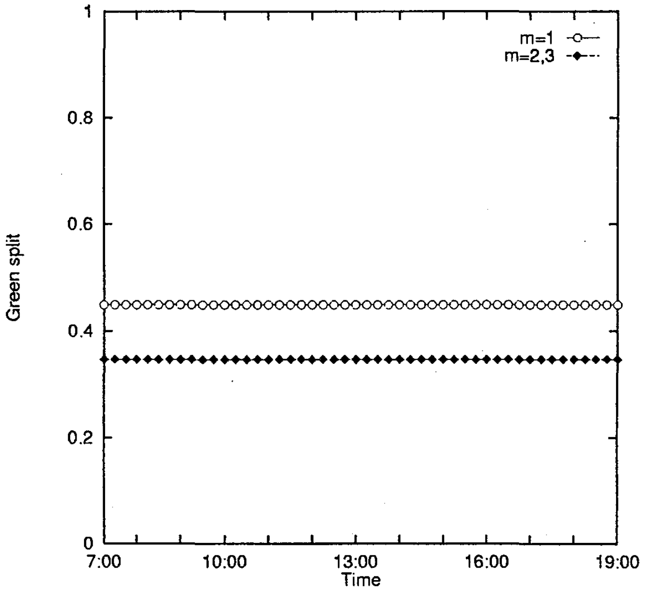

Fig. 12 Green splits at (2,3) signalized intersection for the priority control algorithm

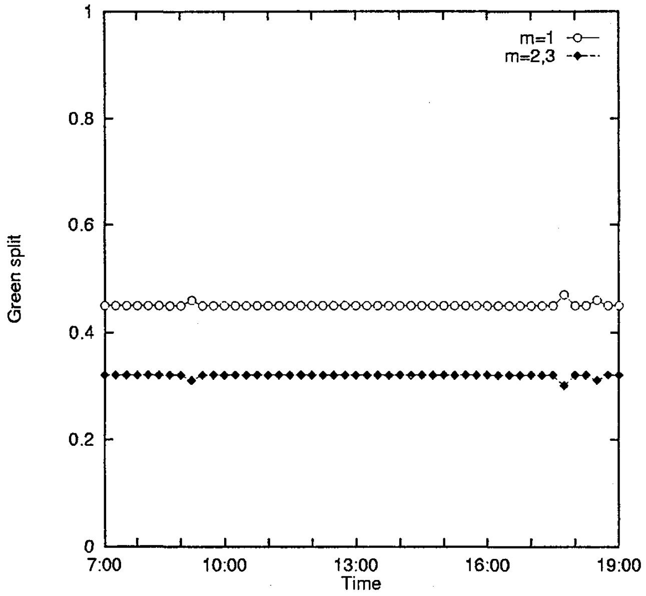

Fig. 13 Green splits at (2,4) signalized intersection for the priority control algorithm

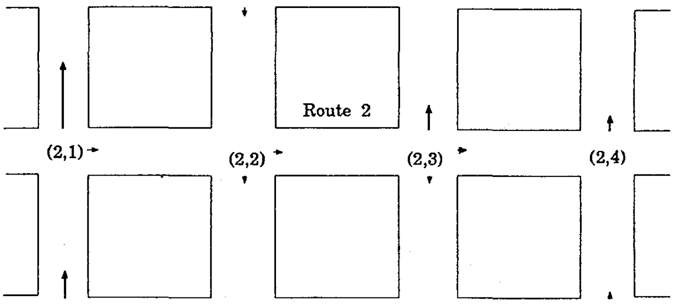

Fig. 14 Optimum relative offsets of the priority control algorithm

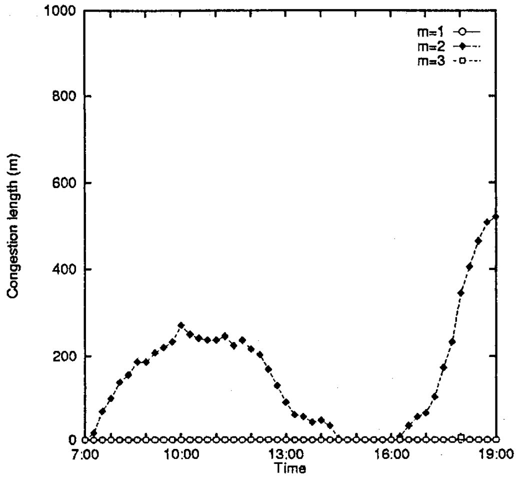

Fig. 15 Congestion lengths at (2,1) signalized intersection for the priority control algorithm

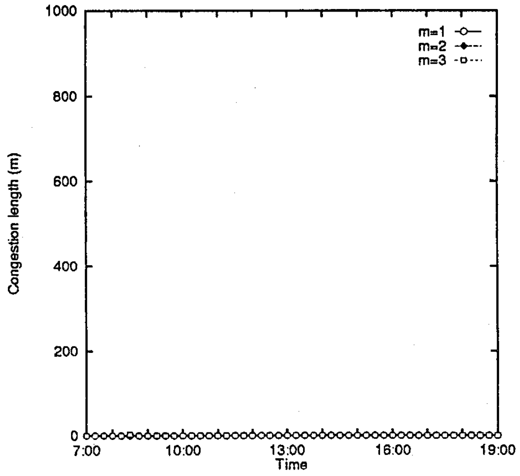

Fig. 16 Congestion lengths at (2,2) signalized intersection for the priority control algorithm

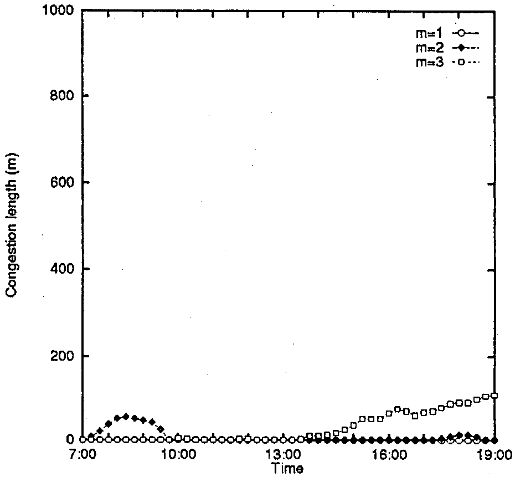

Fig. 17 Congestion lengths at (2,3) signalized intersection for the priority control algorithm

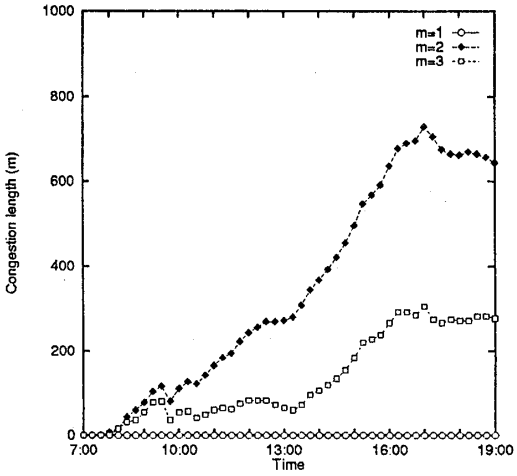

Fig. 18 Congestion lengths at (2,4) signalized intersection for the priority control algorithm

Table 2 Maximum values of congestion length for the priority control algorithm (m/cycle)

		j=1	j=2	j=3	j=4
i=2	m=1	0	0	0	0
	m=2	521.7	0	55.9	728.7
	m=3	6.5	2.8	108.5	292.0

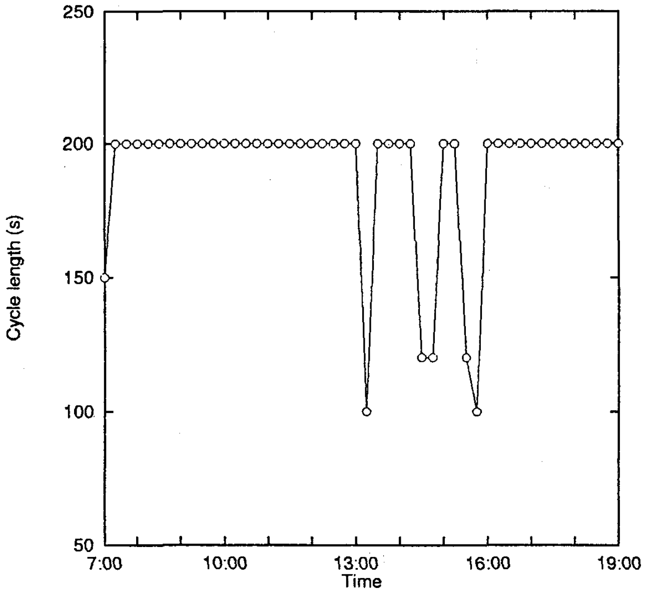

Fig. 19 Common cycle length of the balance control algorithm

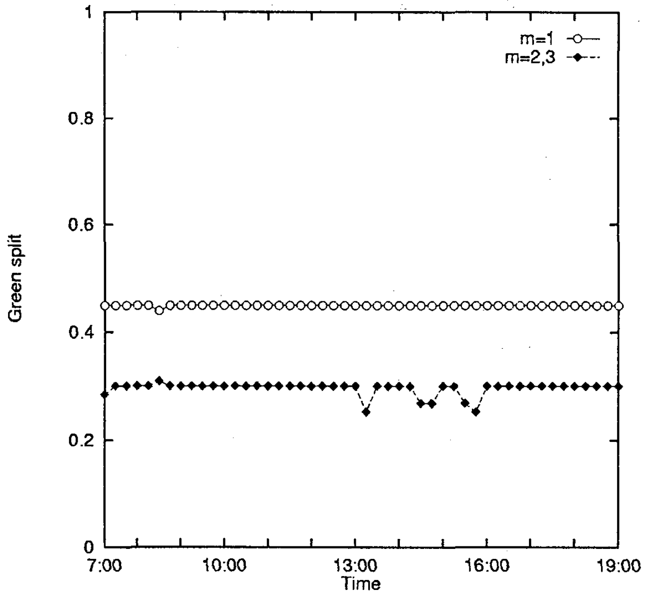

Fig. 21 Green splits at (2,2) signalized intersection for the balance control algorithm

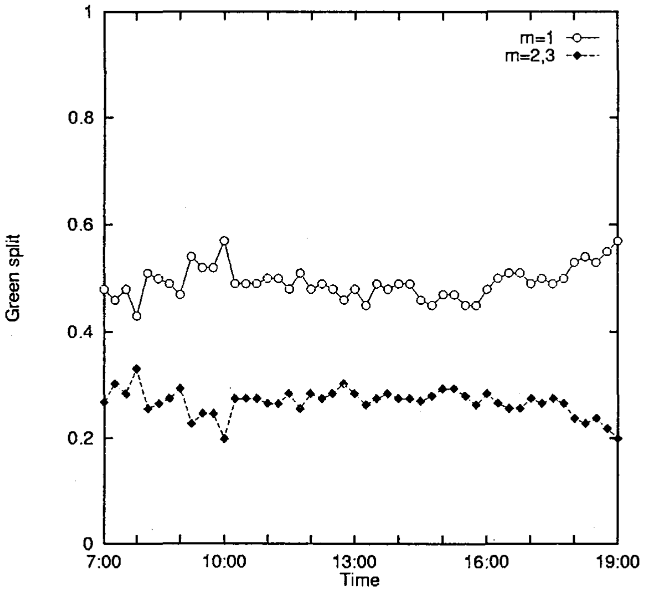

Fig. 20 Green splits at (2,1) signalized intersection for the balance control algorithm

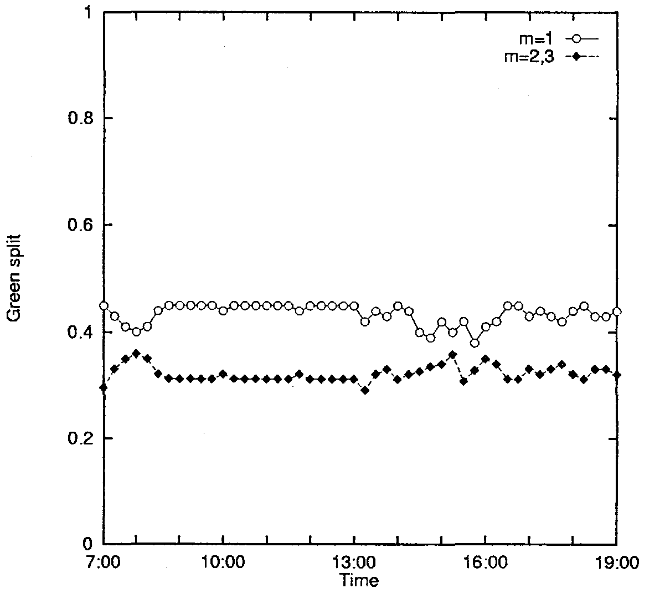

Fig. 22 Green splits at (2,3) signalized intersection for the balance control algorithm

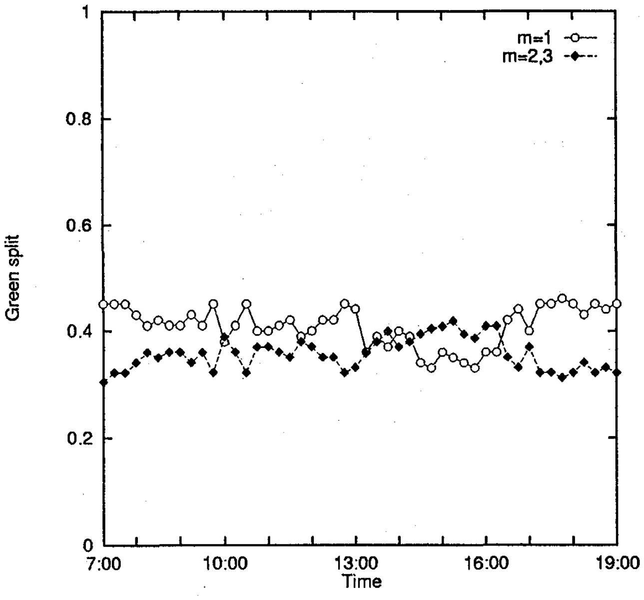

Fig. 23 Green splits at (2,4) signalized intersection for the balance control algorithm

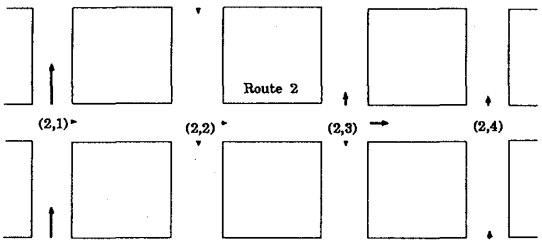

Fig. 24 Optimum relative offsets for the balance control algorithm

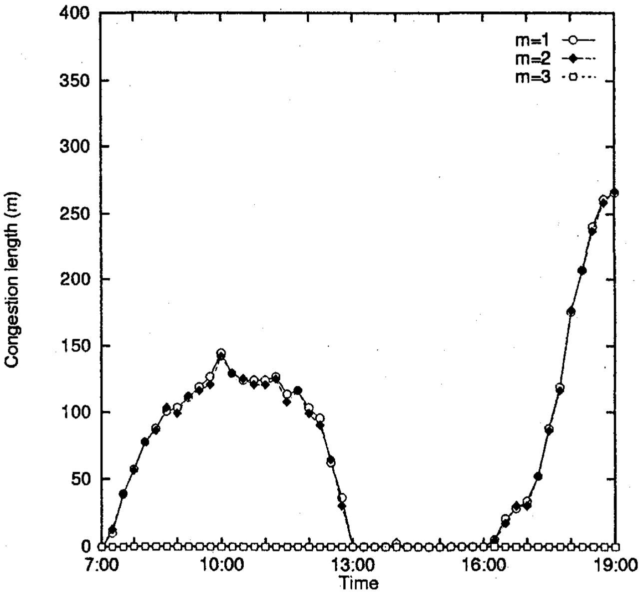

Fig. 25 Congestion lengths at (2,1) signalized intersection for the balance control algorithm

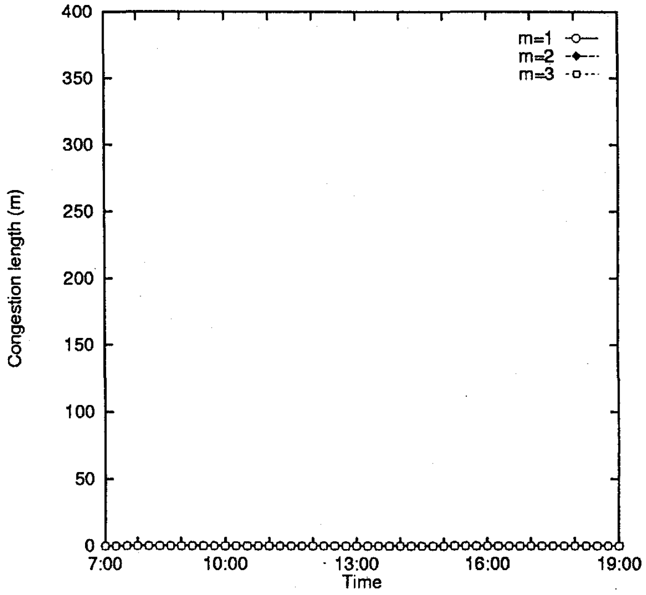

Fig. 26 Congestion lengths at (2,2) signalized intersection for the balance control algorithm

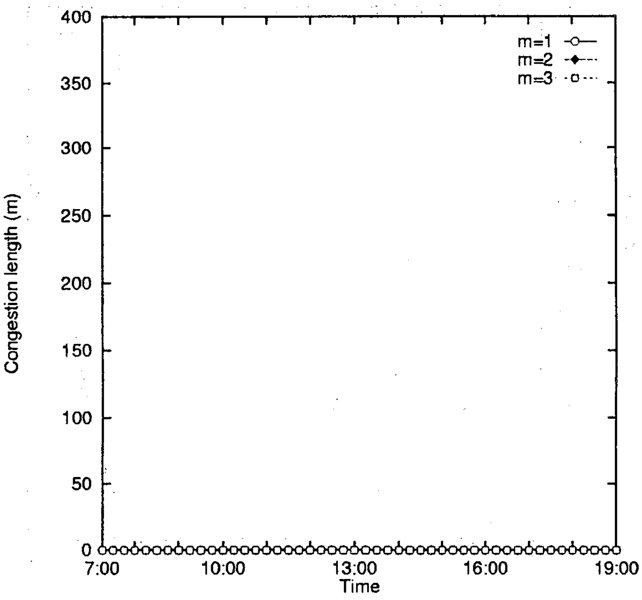

Fig. 27 Congestion lengths at (2,3) signalized intersection for the balance control algorithm

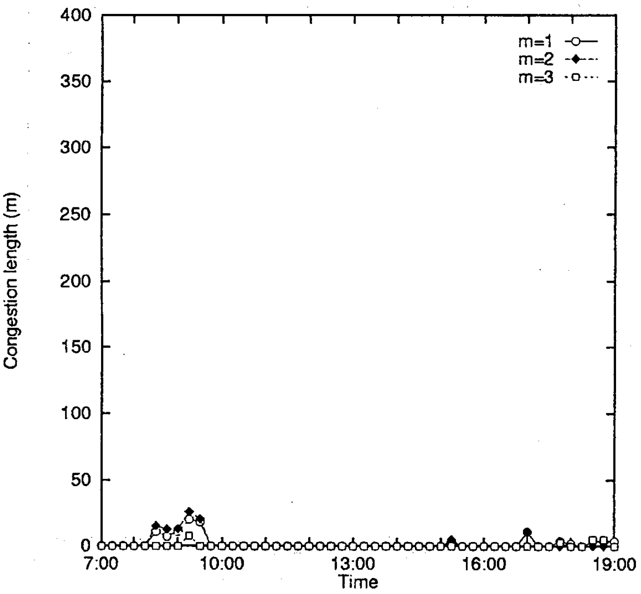

Fig. 28 Congestion lengths at (2,4) signalized intersection for the balance control algorithm

Table 3 Maximum values of congestion length for the balance control algorithm (m/cycle)

		j=1	j=2	j=3	j=4
i=2	m=1	266.2	0	0	20.3
	m=2	267.0	0	0	25.8
	m=3	0	0	0	7.8

4.2 Traffic Network

The network control algorithm based on the concept of the balance control is simulated at twelve signalized intersections in Fukuyama city (see Fig.29). The parameters and the reference input are set in the same way as the arterial case. The incoming volumes and the average speeds are arranged for the simulation (see Fig.30 to Fig.33). From the simulation results, it is confirmed that the cycle lengths are controlled in a wide range according to the variation of incoming volumes in the traffic network. During morning and evening rush hours, the cycle lengths become the maximum values (see Fig.19). The green splits are controlled satisfactorily to minimize the performance criteria of Table 1 (see Fig.34 to Fig.37). The optimum relative offsets are also controlled so as to minimize the performance criteria of Table 1. The absolute values of the offset between i=1 and i=2, that is for the direction of m=2, become large because of the restrictive condition of the values (see Fig.38 to Fig.42). The offset value corresponding to the square length of Fig.42 is equal to 200 seconds. As the results, the congestion lengths are controlled effectively at all signalized intersections in the traffic network. The maximum values of the congestion length at some signalized intersections are fairly reduced compared with measurement data (see Table 4). Congestions occur at the (2,1) and the (2,4) signalized intersections because of the shortage of the capacity and the restrictive condition of the offset respectively.

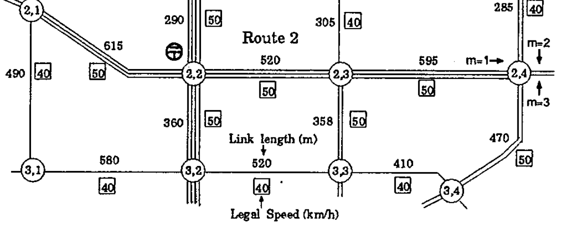

Fig. 29 Traffic network consisting of tweleve signalized intersections

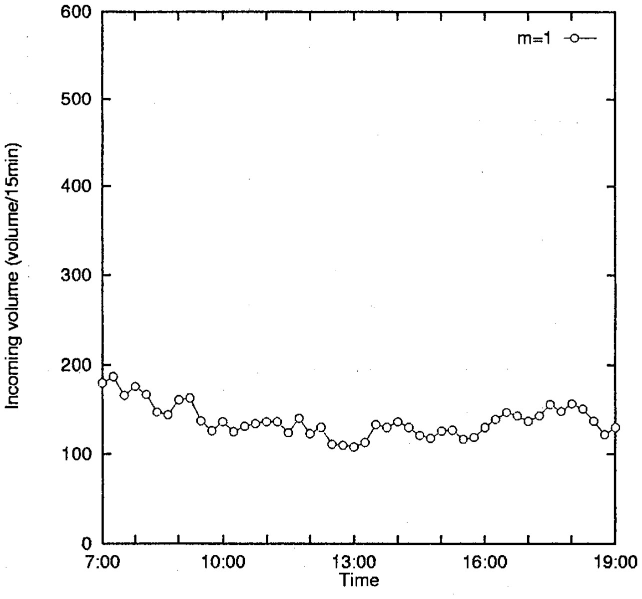

Fig. 30 Incoming volume at (3,1) signalized intersection for the network control algorithm

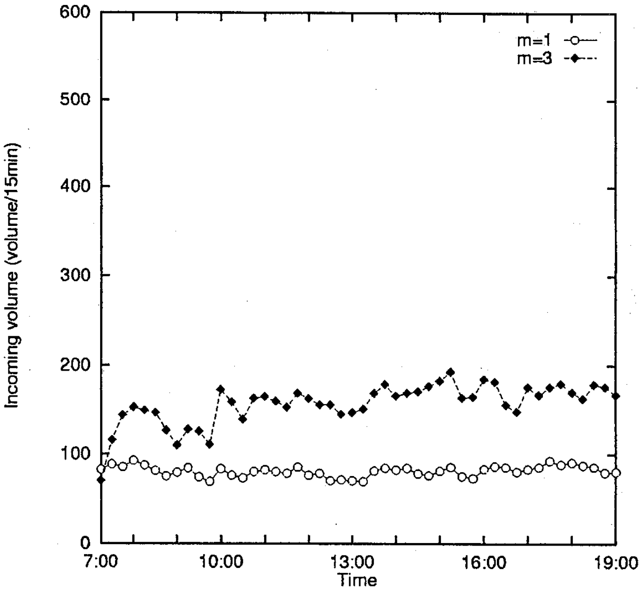

Fig. 32 Incoming volumes at (3,3) signalized intersection for the network control algorithm

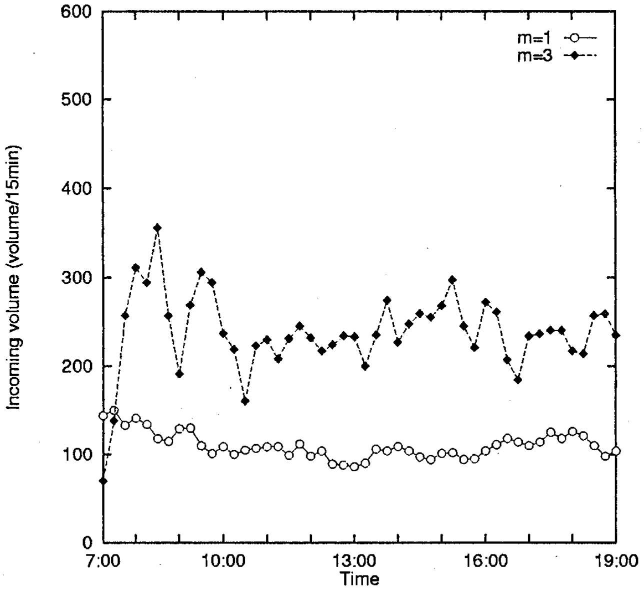

Fig. 31 Incoming volumes at (3,2) signalized intersection for the network control algorithm

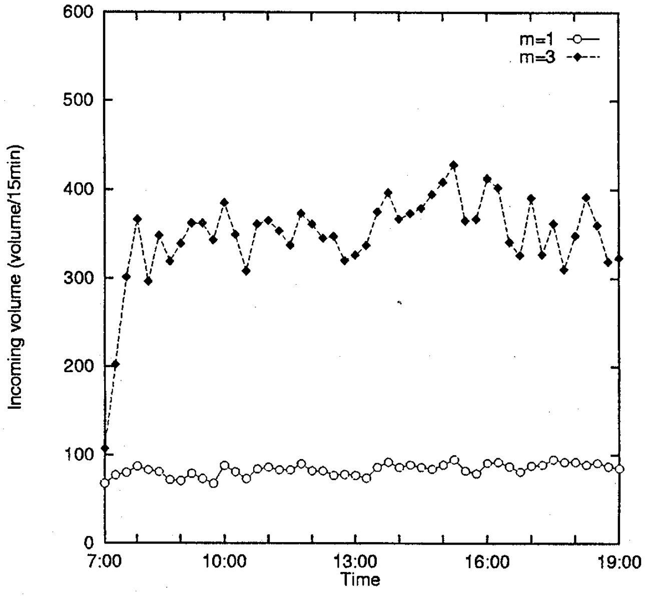

Fig. 33 Incoming volumes at (3,4) signalized intersection for the network control algorithm

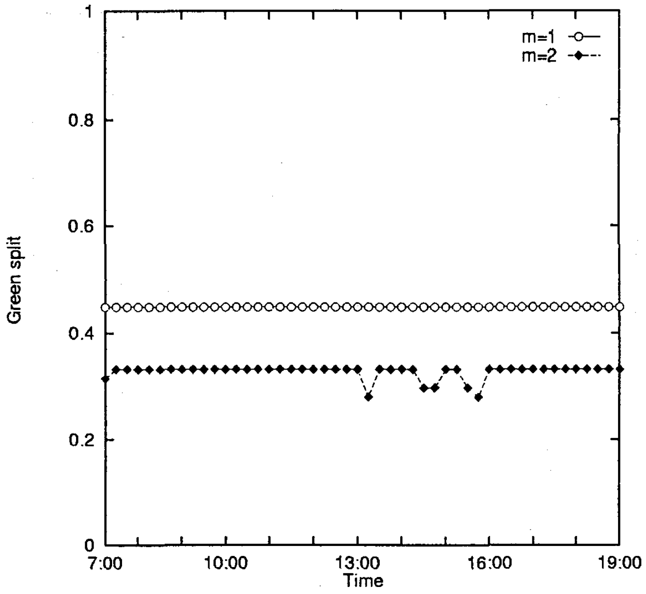

Fig. 34 Green splits at (3,1) signalized intersection for the network control algorithm

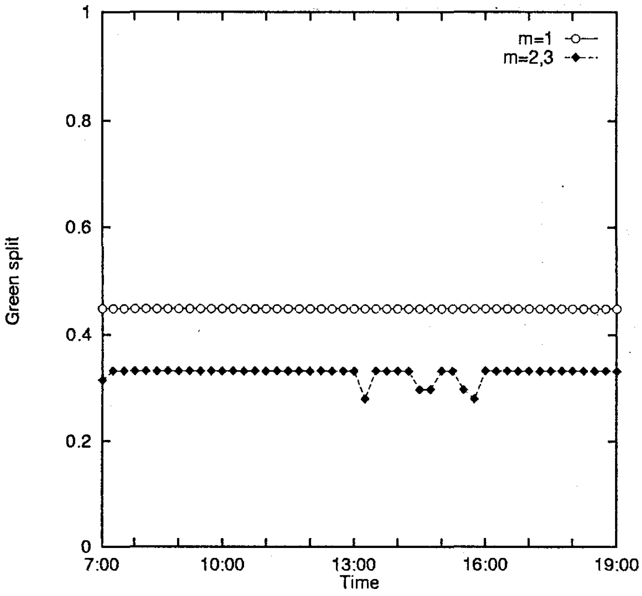

Fig. 36 Green splits at (3,3) signalized intersection for the network control algorithm

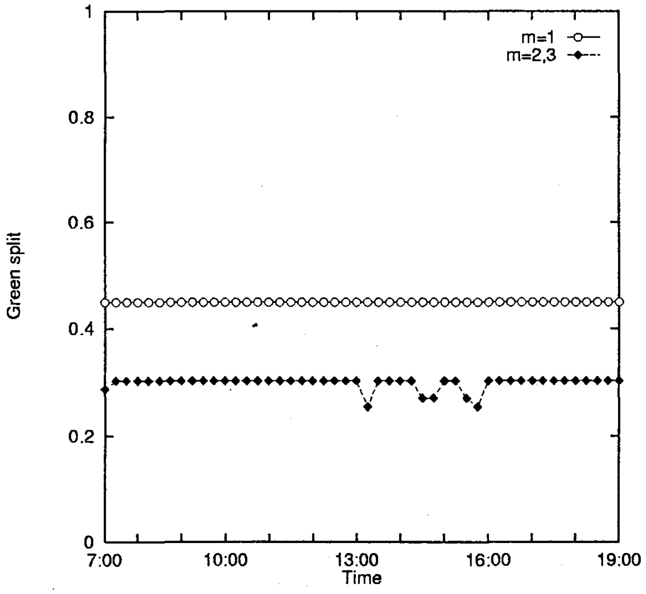

Fig. 35 Green splits at (3,2) signalized intersection for the network control algorithm

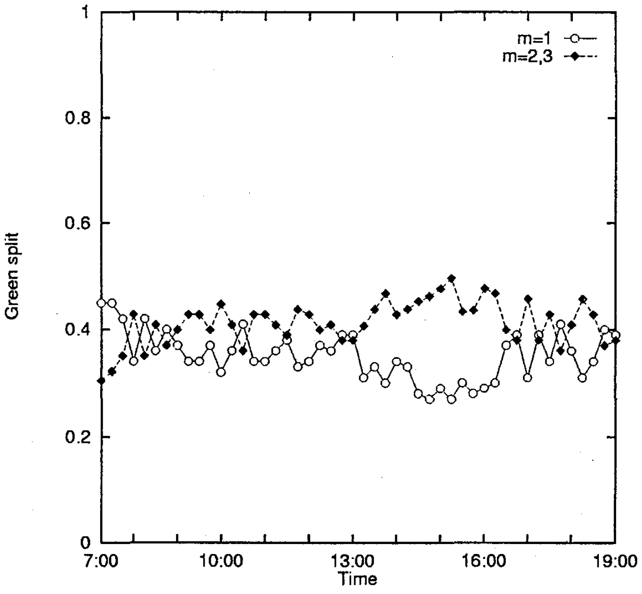

Fig. 37 Green splits at (3,4) signalized intersection for the network control algorithm

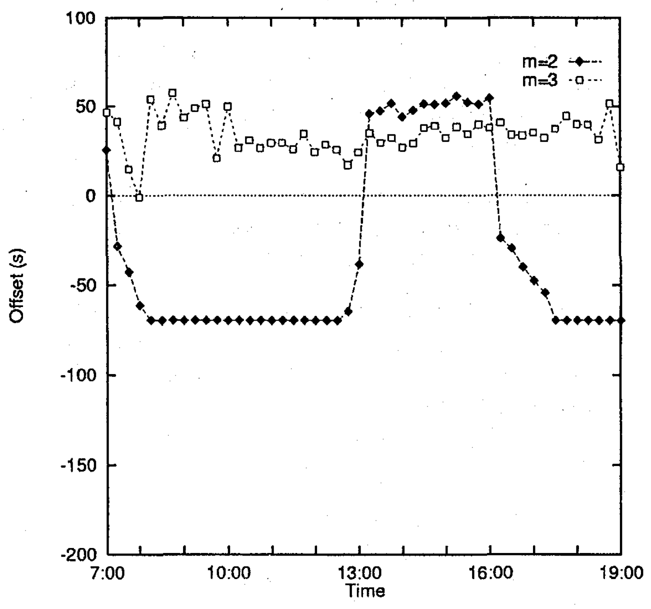

Fig. 38 Optimum relative offsets at (2,1) signalized intersection for the network control algorithm

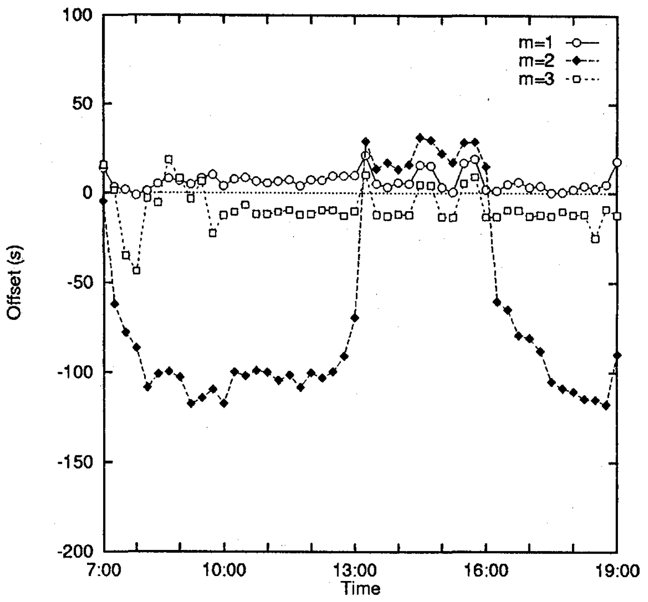

Fig. 40 Optimum relative offsets at (2,3) signalized intersection for the network control algorithm

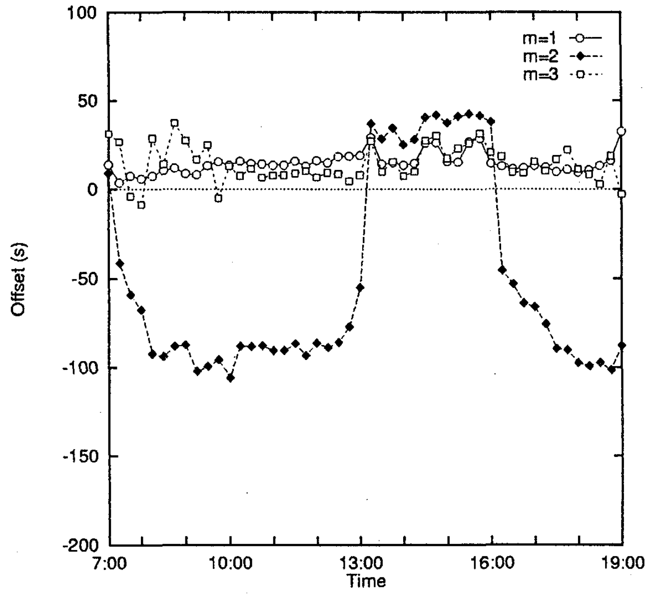

Fig. 39 Optimum relative offsets at (2,2) signalized intersection for the network control algorithm

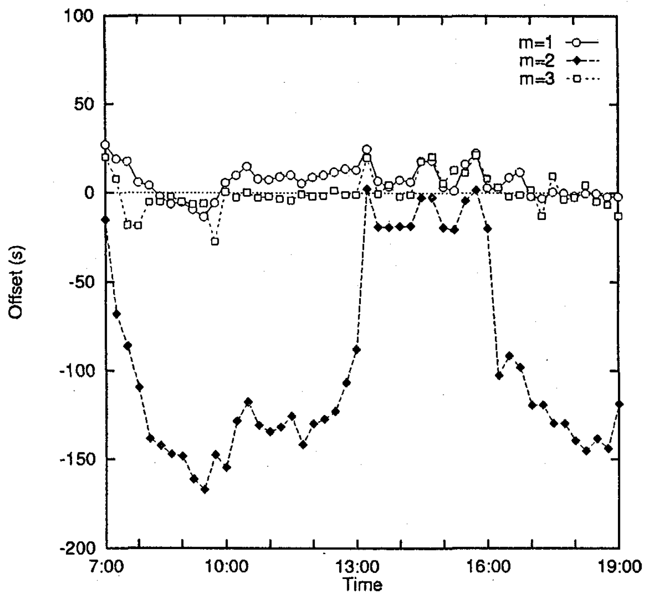

Fig. 41 Optimum relative offsets at (2,4) signalized intersection for the network control algorithm

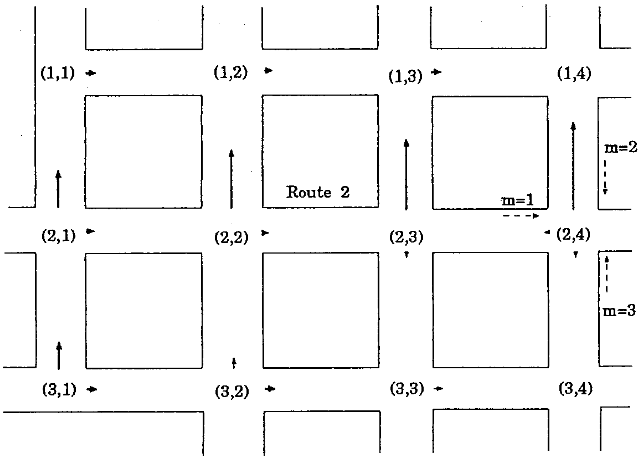

Fig. 42 Optimum relative offsets of the network control algorithm

Table 4 Maximum values of congestion length for the network control algorithm (m/cycle)

		j=1	j=2	j=3	j=4
i=1	m=1	—	0	0	0
	m=2	138.0	0	0	0
i=2	m=1	266.2	0	0	20.3
	m=2	175.0	22.9	65.8	141.3
	m=3	0	31.5	23.0	36.7
i=3	m=1	0	0	0	0
	m=3	—	0	0	0

5. Conclusions

The signal control system of the congestion length and the signal control algorithms of a one-way traffic network are considered from a deterministic control viewpoint in this paper. The following have been shown.

i) A signal control system of the congestion length is synthesized for both a one-way arterial and traffic network using the feedback control.

ii) The two signal control algorithms for the arterial and the network control algorithm for the traffic network are presented to control the congestion length systematically and sequentially.

iii) From the simulation results, it is confirmed that the three signal control algorithms work to satisfy each performance criterion both on the arterial and in the traffic network.

It is a future problem to study the relationship between the restricted condition of the relative offset and the queue length.

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