Memoirs of the Faculty of Engineering,
Fukuyama University, Vol.20(1996)No.1

Dynamic Route Guidance System on a Traffic Control System

Hikaru SHIMIZU*, Masa-aki KOBAYASHI**, Yoh YONEZAWA**

Abstract

The dynamic route guidance system is proposed from the viewpoint of the traffic control system. The traffic control system is synthesized by combining a dynamic route guidance system and a signal control system. The traffic network is represented by considering the effects of the moving directions of motor-cars and the offset control. Two dynamic route guidance algorithms are presented in a traffic network; one is "the shortest distance route algorithm", the other is "the shortest mean travel time route algorithm". The mean travel time from a driver's current position to his destination is evaluated by summing up the mean travel time of each link. The two dynamic route guidance algorithms are simulated in the traffic network.

Keywords: traffic control system, traffic network representation, dynamic route guidance algorithm, evaluation algorithm of mean link travel time

1. Introduction

The congestion has increased steadily in urban traffic networks. Dynamic route guidance systems and traffic control systems were proposed to avoid congestion links and inform the shortest travel time route of traffic networks[1],[2]. This paper studies the dynamic route guidance system on a traffic control system of traffic networks. The traffic control system of the traffic network is presented by combining the dynamic route guidance system and the signal control system.

The signal control system is an effective method to control the congestion of traffic networks. The signal control system of the congestion length is synthesized in a traffic network. 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. Two dynamic route guidance algorithms which play an essential role in the dynamic route guidance system are presented; one is "the shortest distance route algorithm", the other is "the shortest mean travel time route algorithm". The shortest distance route algorithm gives the recommendable routes using the Dijkstra's algorithm[3] weighted by the link distance. On the other hand, the shortest mean travel time route algorithm gives an optimal route of the traffic network using the Dijkstra's algorithm weighted by the mean link travel time.

The mean travel time from a driver's origin to his destination is evaluated by summing up the mean travel time of each link. The mean link travel time is evaluated by considering the moving directions of motor-cars and the offset control.

The two dynamic route guidance algorithms are simulated at twelve signalized intersections in Fukuyama city, Japan. The necessary traffic information such as the signal control parameters, the starting delays, the outgoing time, the congestion lengths, the running speeds, the saturation flows etc. are arranged for the simulation. From the simulation results of the two dynamic route guidance algorithms, it is confirmed that the mean travel time from one's origin to his destination

* Department of Information Processing Engineering
** Department of Mechanical Engineering

vary remarkably depending on the traffic flow conditions, the signal control parameters and the number of time for the right-turn.

2.Traffic Control System

A traffic control system is synthesized combining a signal control system and a dynamic route guidance system. In the signal control system, the incoming volumes, the queue lengths and the link running speeds are inputted, and the capacities are evaluated for each signalized intersection. The optimal signal control parameters which minimize the sum of congestion lengths of the traffic network are outputted to signal controllers. In the dynamic route guidance system, the optimal signal control parameters, the queue lengths, the link running sppds and the capacities are inputted to computers. The travel time of recommendable routes including the shortest mean travel time route are outputted to drivers. The process scheme of the traffic control system is drawn in Fig.1. The signal control parameters are controlled so as to minimize the sum of congestion lengths of the traffic network. The mean travel time evaluated under the optimal signal control are outputted to drivers. As the results, the concentration of motor cars on a specified link is avoided and the traffic network is used most efficiently.

3. Representation of Traffic Networks

The representation of traffic networks is considered to develop dynamic route guidance algorithms. The traffic network is drawn using nodes and links as shown in Fig.2. The travel time from a driver's origin to his destination is effected by the moving directions of the motor-car and the offset control. The traffic networks have to be represented by considering the above-mentioned effects. We propose the representation of traffic networks shown in Fig. 3. The offset is controlled between two bold circles and not controlled between two fine circles in Fig. 3.

4. Dynamic Route Guidance Algorithms

Two dynamic route guidance algorithms are presented to search the recommendable routes including the shortest mean travel time route of the traffic network.

4.1 *The Shortest Distance Route Algorithm*

Step 1. A driver inputs his origin and destination from the input device equipped with vehicle.

Step 2. The possible routes from his origin to his destination are sorted in order of the shortness of the distance using the Dijkstra's algorithm weighted by the link distance.

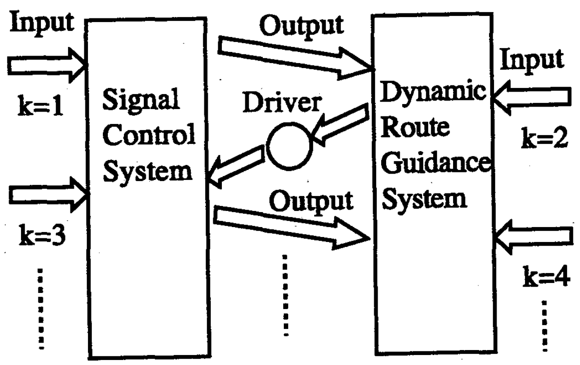


Fig.1 Process scheme of traffic control system.

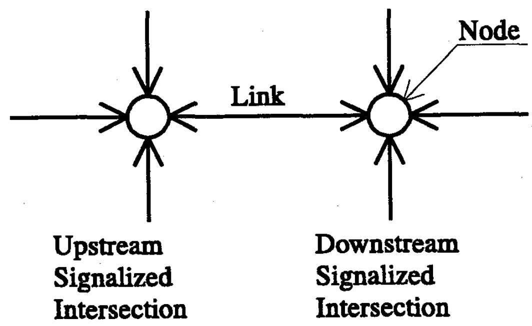


Fig. 2 Conventional representation of traffic network unit.

Step 3. The necessary traffic information are inputtedto evaluate the mean travel time of the possible routes.

Step 4. The mean travel time of the possible routes are evaluated using the evaluation algorithm of the mean link travel time mentioned later.

Step 5. Recommendable routes of the traffic network are outputted in order of the shortness of the mean travel time at the output device equipped with vehicle.

4.2 *The Shortest Mean Travel Time Route Algorithm*

Step 1. A driver inputs his origin and destination from the input device equipped with vehicle.

Step 2. The necessary traffic information are inputted to evaluate the mean travel time of the possible routes.

Step 3. The possible routes from his origin to his destination are sorted in order of the shortness of the mean travel time using the Dijkstra's algorithm weighted by the mean link travel time.

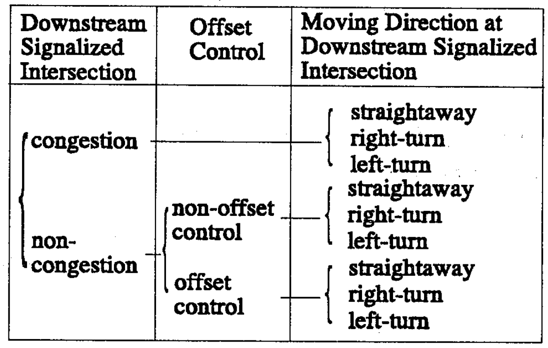
Step 4. The recommendable routes including the shortest mean travel time route of the traffic network are outputted in order of the shortness of the mean travel time at the output device equipped with vehicle.

5. Evaluation Algorithm of Mean Link Travel Time

The mean travel time from the driver's origin to his destination is evaluated based on the classification for the evaluation of the mean travel time of each link as shown in Fig. 4.

5.1 *In the Case of Congestion at the Downstream Signalized Intersection*

It is assumed that drivers can not pass the downstream signalized intersection even if the traffic signal is green. The variables used for the evaluation algorithm of the mean travel time are listed in Table1. Although these variables vary depending on the location and time, they are omitted here for simple descriptions.



Fg. 4 Classification for evaluation of mean travel time of each link.

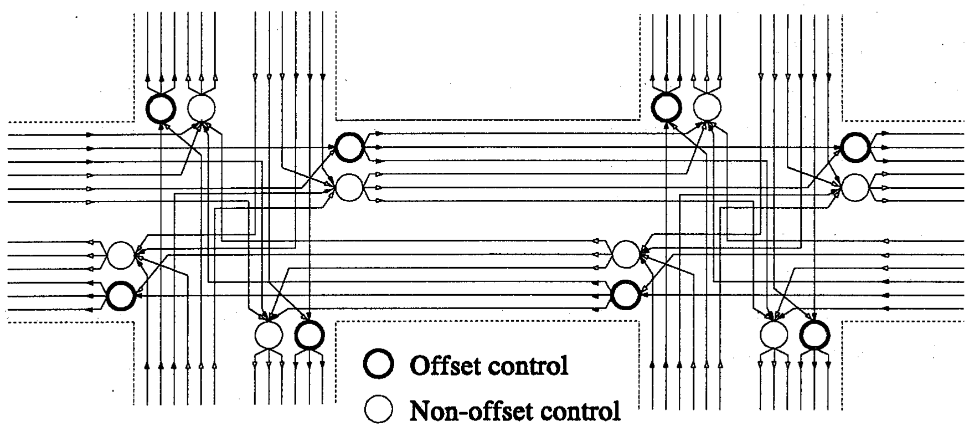


Fig. 3 Proposed representation of traffic network unit.

In the case of straightaway

$$T_l(i,j,m,l,k) = P_g(t_{run} + t_g/2 + t_y + t_r + t_s + t_{cs}) + P_y(t_{run} + t_y/2 + t_r + t_s + t_{cs}) + P_r(t_{run} + t_r/2 + t_s + t_{cs}) \quad (1)$$

with

$$t_{run} = (d - y_l) / v \quad (2)$$

$$t_{cs} = q / \psi \quad (3)$$

In the case of right-turn

$$T_l(i,j,m,l,k) = P_g(t_{run} + t_g/2 + t_y + t_r + t_{dr} + t_s + t_{cr}) + P_y(t_{run} + t_y/2 + t_r + t_{dr} + t_s + t_{cr}) + P_r(t_{run} + t_r/2 + t_{dr} + t_s + t_{cr}) \quad (4)$$

In the case of left-turn

$$T_l(i,j,m,l,k) = P_g(t_{run} + t_g/2 + t_y + t_r + t_{dl} + t_s + t_{cl}) + P_y(t_{run} + t_y/2 + t_r + t_{dl} + t_s + t_{cl}) + P_r(t_{run} + t_r/2 + t_{dl} + t_s + t_{cl}) \quad (5)$$

5.2 *In the Case of Non-congestion at the Downstream Signalized Intersection*

5.2.1 *In the case of non-offset control*

In the case of straightaway

$$T_l(i,j,m,l,k) = P_g \cdot t_{run} + P_y(t_{run} + t_y/2 + t_r + t_s) + P_r(t_{run} + t_r/2 + t_s) \quad (6)$$

In the case of right-turn

$$T_l(i,j,m,l,k) = P_g\{t_{run} + \alpha_r(t_g/2 + t_y + t_r + t_{dr} + t_s + t_{cr}) + t_g(1 - \alpha_r)/4\} + P_y(t_{run} + t_y/2 + t_r + t_{dr} + t_s + t_{cr}) + P_r(t_{run} + t_r/2 + t_{dr} + t_s + t_{cr}) \quad (7)$$

In the case of left-turn

$$T_l(i,j,m,l,k) = P_g\{t_{run} + \alpha_l(t_g/2 + t_y + t_r + t_{dl} + t_s + t_{cl}) + t_g(1 - \alpha_l)/4\} + P_y(t_{run} + t_y/2 + t_r + t_{dl} + t_s + t_{cl}) + P_r(t_{run} + t_r/2 + t_{dl} + t_s + t_{cl}) \quad (8)$$

5.2.2 *In the case of offset control*

In the case of straightaway

$$T_l(i,j,m,l,k) = t_{run} \quad (9)$$

Table 1 Notation

t_{run}	Running time
t_g	Green time
t_y	Yellow time
t_r	Red time
P_g	Probability of green time
P_y	Probability of yellow time
P_r	Probability of red time
t_{dr}	Time difference of the green initiation between straightaway and right-turn directions
t_{dl}	Time difference of the green initiation between straightaway and left-turn directions
t_{cs}	Outgoing time of straightaway lane queue
t_{cl}	Outgoing time of left-turn lane queue
t_{cr}	Outgoing time of right-turn lane queue
t_s	Starting delay
q	Queueing number of motor cars while the signal at the downstream intersection has been red
ψ	Saturation flow on the approach at the downstream intersection
d	Link length
v	Running speed
y_l	Queue length
α_r	Probability of non-passing through the right-turn lane at the downstream signalized intersection
α_l	Probability of non-passing through the left-turn lane at the downstream signalized intersection

In the case of right-turn

$$T_l(i,j,m,l,k) = t_{run} + t_{dr}/2 + t_s + t_{cr} \qquad (10)$$

In the case of left-turn

$$T_l(i,j,m,l,k) = t_{run} + t_{dl}/2 + t_s + t_{cl} \qquad (11)$$

The mean travel time from the driver's origin to his destination $T_{OD}(l,k)$ is evaluated by summing up the mean travel time of each link $T_l(i,j,m,l,k)$

$$T_{OD}(l,k) = \sum_i \sum_j \sum_m T_l(i,j,m,l,k) \qquad (12)$$

6. Simulation Results

The two dynamic route guidance algorithms are simulated at twelve signalized intersections in Fukuyama city, Japan. The driver's origin and destination are assumed to be the (1,1) and the (3,4) signalized intersections respectively. The link lengths, the coordinate numbers, the congested links and the offset control routes are shown in Fig. 5 and Fig. 6. The necessary traffic information such as the signal control parameters, the starting delays, the congestion lengths, the running speeds, the saturation flows etc. are arranged for the simulation.

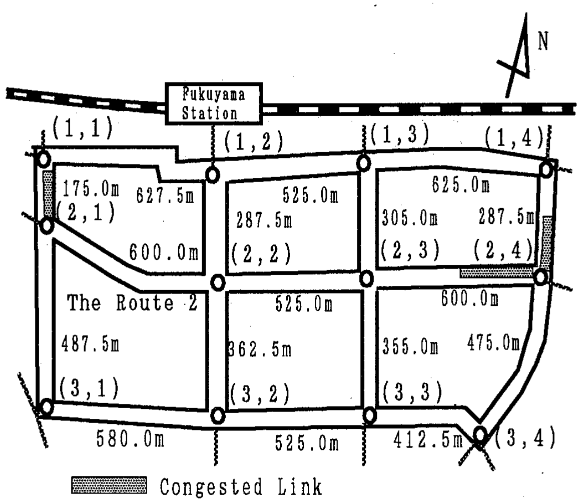


Fig. 5 Traffic network of twelve signalized intersections in Fukuyama city.

The best three of recommendable routes by "the shortest distance route algorithm" are shown in fig. 7. From the simulation results of "the shortest distance route algorithm", the shortest mean travel time route changes under the influence of the congestion during morning rush hours (see Fig. 8). From the simulation results of "the shortest mean travel time route algorithm", the No.1 to the No.3 are plotted in order of the shortness of the mean travel time in each time (see Fig. 9). The best three of recommendable routes searched by the shortest mean travel time route algorithm are shown in Fig. 10. The order of the best three of recommendable routes changes from time to time under the influences of the congestion and the offset control. The shortest mean travel time routes are different between the two algorithms because the number of recommendable routes are restricted in the present simulation.

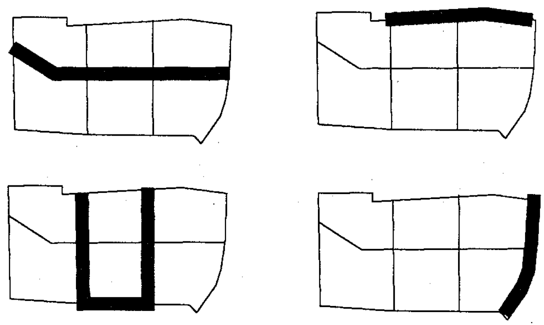


Fig. 6 Offset control routes.

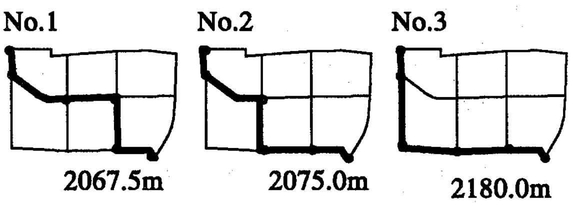


Fig. 7 The best three of recommendable routes by the shortest distance route algorithm.

7. Conclusions

The traffic control system is synthesized by combining the dynamic route guidance system and the signal control system in this paper. The two dynamic route guidance algorithms and the evaluation algorithm of the mean travel time are presented and simulated in the traffic network. From the simulation results, it is confirmed that the shortest mean travel time route algorithm and the evaluation algorithm of the mean travel time work well in the traffic network. The comparison between the simulation values and the measurement values of the mean travel time is a future problem.

References

[1]H.S.Mahmassani and S.Peeta: System Optimal Dynamic Assignment for Electronic Route Guidance in a Congested Traffic Network, Urban Traffic Networks, Springer-Verlag, pp.3-37 (1995)

[2]M.Al-Malik and N.H.Gartner: Development of a Combined Traffic Signal Control-Traffic Assignment Model, Urban Traffic Networks, Springer-Verlag, pp.155-186 (1995)

[3]E.W.Dijkstra: A Note on Two Problems in Connexion with Graphs, Numerische Mathematik 1, pp.269-271 (1959)

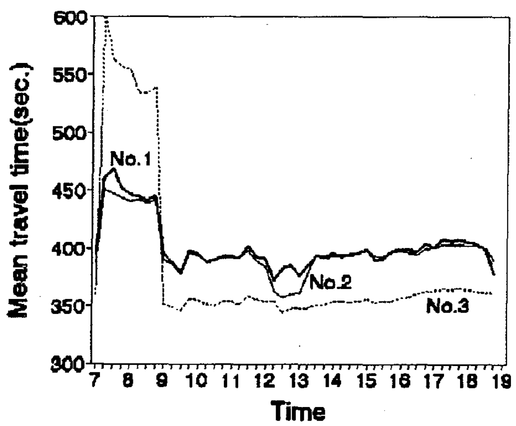


Fig. 8 Recommendable routes by the shortest distance route algorithm.

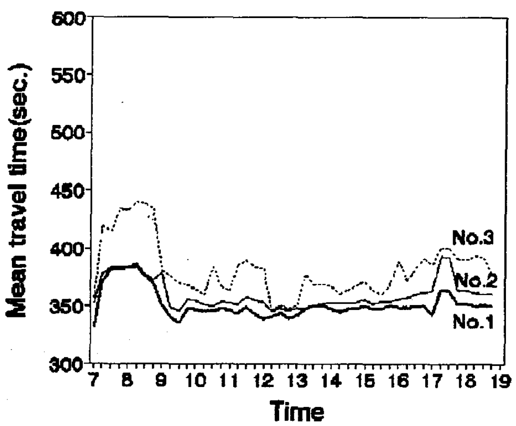


Fig. 9 Recommendable routes by the shortest mean travel time route algorithm.

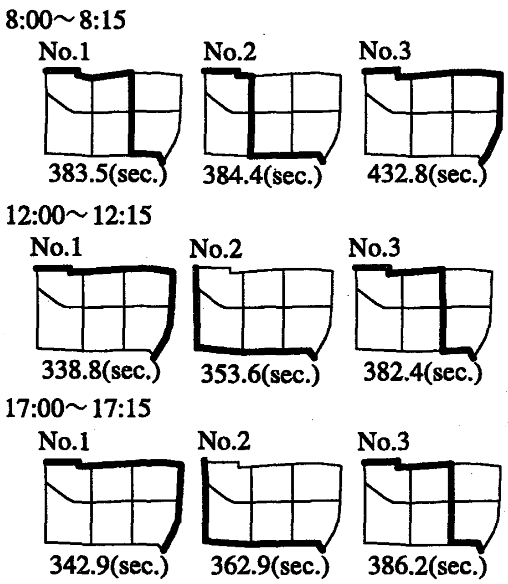


Fig. 10 The best three of recommendable routes by the shortest mean travel time route algorithm.