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Green-wave control of an unbalanced two-route traffic system with signals

Kazuhiro Tobita, Takashi Nagatani *

Department of Mechanical Engineering, Division of Thermal Science, Shizuoka University, Hamamatsu 432-8561, Japan

HIGHLIGHTS

- We proposed the unbalanced two-route traffic model to take into account the driver's preference for the route choice.
- We studied controlling the unbalanced two-route system by the green-wave strategy of signals.
- We derived the relationship between the mean tour time and the offset time.

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ABSTRACT

We introduce the preference parameter into the two-route dynamic model proposed by Wahle et al. The parameter represents the driver's preference for the route choice. When the driver prefers a route, the traffic flow on route A does not balance with that on route B. We study the signal control for the unbalanced two-route traffic flow at the tour-time feedback strategy where the vehicles move ahead through a series of signals. The traffic signals are controlled by both cycle time and phase shift (offset time). We find that the mean tour time can be balanced by selecting the offset time successfully. We derive the relationship between the mean tour time and offset time (phase shift). Also, the dependences of the mean density and mean current on the offset time are derived.

1. Introduction

Recently, physicists have devoted much attention to traffic flow [1–5]. The physical models and concepts have been applied to transportation systems. The traffic flow and pedestrian flow have been studied from a point of view of statistical mechanics and nonlinear dynamics [6–21].

In a city traffic network, signals (traffic lights) control traffic flow to give priority to a road. The control strategy of signals affects the traffic flow highly. The optimization of signals for city traffic has been studied using a CA model [22] and optimal velocity model [23]. The effect of cycle time on vehicular traffic has been clarified [24–29]. It has been shown that the irregularity of a signal's configuration has an important effect on the vehicular motion [30]. Also, Lammer and Helbing have studied the effect of self-controlled signals on vehicular flow [31].

The dynamics of traffic flow with real-time traffic information has been studied by Wahle et al. using a route choice scenario [32]. The route-choice strategy has been extended to the three-route and crossing traffic systems [32–35]. In the two-route and three-route traffic systems, there are no traffic signals. However, it is important and necessary not only to obtain the real-time traffic information but also to know the control strategy of signals because city traffic is generally controlled by many signals. The traffic flow on two routes with a series of signals has been studied for a low-density traffic without the real-time information [36]. Tobita and Nagatani have extended the two-route traffic system with real-time

* Corresponding author. Tel.: +81 53 478 1048; fax: +81 53 478 1048.
E-mail addresses: tmtnaga@ipc.shizuoka.ac.jp, wadokeioru@yahoo.co.jp (T. Nagatani).

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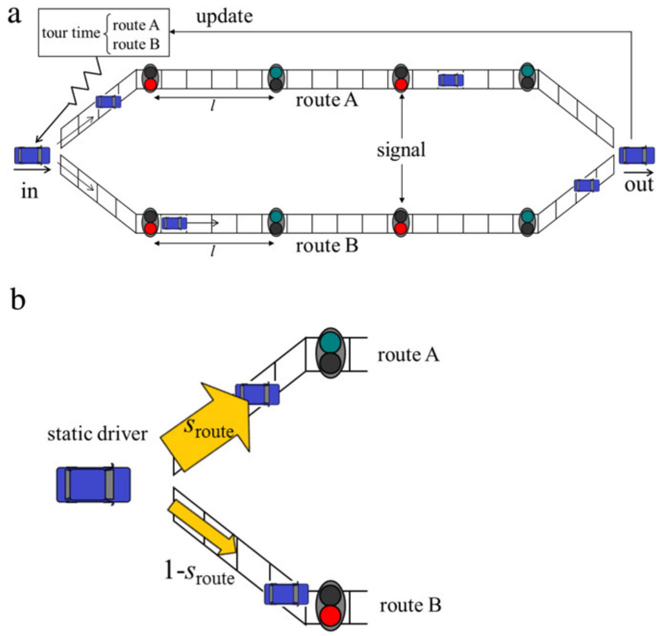

Fig. 1. (a) Schematic illustration of the two-route traffic system with a series of signals. Two types of vehicles are introduced: dynamic and static vehicles. When vehicles enter the system, a so-called dynamic driver will make a choice on the basis of the tour-time feedback. (b) Enlargement of the entrance. A static driver enters route A (B) with probability S_{route} (probability $1 - S_{route}$) ignoring any advice.

traffic information to that controlled by signals [37]. They have clarified the effect of signals on the two-route traffic flow. The vehicular motion varies not only with the route choice but also with signal's characteristic in the two-route traffic system using real-time traffic information.

In the previous studies about the two-route traffic system, the traffic flow on two routes varies periodically and alternately. The mean values of tour time, density, and current on route A are consistent with those on route B. The traffic flow on two routes is in balance. This is due to selecting a route with the same probability. However, drivers will choose one route with an inclined probability because they prefer route A (B) rather than route B (A). In this case, the traffic behavior on route A is different from that on route B. The balance of traffic flow on two routes breaks down. The traffic flow on two routes results in an unbalanced state. In real traffic, the unbalanced two-route traffic system controlled by signals is important and necessary for operators and drivers. However, the unbalanced two-route traffic system has not been studied until now.

In this paper, we study the signal control of the unbalanced two-route traffic system at the tour-time feedback strategy. We introduce the preference probability for the route choice into the dynamic model proposed by Wahle et al. We propose the green-wave control method for the unbalanced two-route traffic flow. We derive the dependence of the tour times, the currents, and the densities on the phase shift (offset time) on each route. We clarify the effect of phase shift on the route choice for the unbalanced two-route traffic system.

2. Dynamic model controlled by signals

We consider the two-route traffic system controlled by signals. There are many signals on two routes with the same interval. When vehicles enter the system, vehicles move through the series of signals either on route A or B. We apply the tour-time feedback strategy to the route choice. In order to demonstrate the effect of the feedback loop, Wahle et al. have studied the two-route traffic system using the scenario with dynamic information. Tobita and Nagatani have extended the dynamic model to the two-route traffic system with signals [37].

Fig. 1 shows the schematic illustration of the two-route traffic system with a series of signals. Two types of vehicles are introduced: dynamic and static vehicles. When vehicles enter the system, a so-called dynamic driver will make a choice on the basis of the tour-time feedback, while a static driver enters route A (B) with probability S_{route} (probability $1 - S_{route}$) ignoring any advice. The dynamic driver always chooses the route with the shortest tour time at the entrance. The densities of dynamic and static drivers are S_{dyn} and $1 - S_{dyn}$ respectively. Here, we introduce new parameter S_{route} into the original model proposed by Wahle et al. The parameter represents the driver's preference for a route. When S_{route} is 1/2, the dynamic model is consistent with that proposed by Wahle et al. The static driver enters route A (B) with probability 1/2. The density of the static drivers on route A equals that on route B. The traffic flow on route A balances that on route B and displays the same behavior as that on route B.

However, if S_{route} is higher (less) than 1/2, the static driver prefers route A (B). Then, The traffic flow on route A does not balance that on route B and displays different behavior from that on route B. By introducing the preference parameter, the