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Dynamic behavior in two-route bus traffic system with real-time information

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HIGHLIGHTS

- We studied the bus dynamics in the two-route bus traffic system with real-time information.
- We proposed the physical model described by a couple of nonlinear maps for the bus traffic system.
- We clarified the dynamic behavior of the two-route bus traffic induced by a bus choice.

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ABSTRACT

We study the dynamics of two-route bus traffic system with two buses using a bus choice scenario. The two-route bus traffic system with real-time information is not consistent with the two-route vehicular traffic system but is similar to the vehicular system. The two-route bus traffic system is mimicked by the physically dynamic model. The dynamics of two-route bus traffic system is described by a couple of nonlinear maps. A bus runs a neck- and neck race with another bus. The motion of two buses displays an irregular behavior in a complex manner. We clarify the effect of real-time information on the bus traffic.

1. Introduction

Recently, traffic system has been investigated by physicists. Physicists have proposed the simplified traffic models to clarify the cause and effect. The physical concepts and methods have been applied to transportation systems [1–41]. Information is a key commodity in vehicular traffic systems. Advanced traveler information systems provide real-time information about the traffic conditions to road users by means of communication such as variable message signs or on-board computers. The real-time information helps the individual road users to minimize their personal travel time. The dynamic model has been proposed for two-route traffic flow with real-time information by Wahle et al. [42]. The traffic system with real-time traffic information has been studied using a route choice scenario [43–47].

In elevator traffic system with a few elevators, the real-time information helps the elevator users to choose one of the elevators [48–54]. The display board at the front of elevator's door provides real-time information about the elevator's position. Elevator users can know which of the elevators arrives faster at the floor. Users can choose one of the elevators successfully. Real-time information helps individual elevator users to go to an (a) upper (down) floor as soon as possible. Utilization of elevators depends highly on real-time information. It has been studied how the real-time information affects the dynamics and the motion of elevators [55]. The two-elevator traffic system is similar to the two-route vehicular traffic system. However, the dynamics of elevators is definitely different from that of the two-route vehicular traffic system [55].

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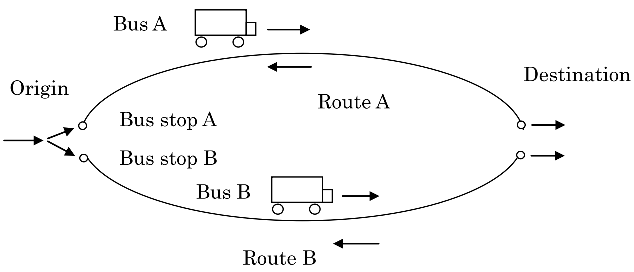

Fig. 1. Schematic illustration of the two-route bus traffic system. The length of route A (B) is $L_A(L_B)$. There are two bus stops at the origin. The position information of buses will be generated, transmitted, and displayed on the board at the origin in real time.

Similarly, the real-time information is important to choose a bus in the two-route bus traffic system [56,57]. The display board at the bus stop provides real-time information about the bus's position. Bus users can know which of the buses arrives faster at the bus stop. Users may be able to choose one of the buses successfully using real-time information. Real-time information helps individual bus users to go to the destination as soon as possible. Utilization of buses depends highly on real-time information. However, it is unknown how the real-time information affects the dynamics and the motion of buses. There are no dynamic models for the two-route bus traffic system with real-time information. It is necessary and important to make the dynamic (physical) model for the two-route bus traffic system with real-time information.

In this paper, we present the dynamic model to describe the two-route bus traffic system with real-time information. We show that the dynamic model is described by a couple of nonlinear maps. We investigate the dynamic behavior of two buses using the nonlinear-map model. Also, we study the effect of real-time information on the two-route bus traffic system. We derive the dependence of the travel time on the loading parameter and road-length ratio. We clarify the effect of real-time information on the bus choice for the two-route bus traffic system.

2. Two-route bus system model

We consider the two-route bus traffic system. Two buses serve the destination from the origin. Bus A (B) shuttles repeatedly from the origin to the destination. Buses A and B move on routes A and B respectively. Fig. 1 shows the schematic illustration of the two-route bus traffic system. The length of route A (B) is $L_A(L_B)$. There are two bus stops at the origin. Bus users choose one of the two bus stops. Passengers line up at one of the two bus stops. We assume that passengers are inhibited to change the queue at the bus stop. The position information of buses will be generated, transmitted, and displayed on the board at the origin in real time. Bus users (passengers) board one of the two buses at the origin and get off buses at the destination. The flow of passengers is one way. Two types of bus users are introduced: fast and normal passengers. When bus users arrive at the origin, a so-called fast passenger will make a choice on the basis of the display boards and line up in the front of bus stop at which the bus arrives fastest. While normal passengers line up in the front of one of the two bus stops at random with probability 1/2 ignoring any signals. The fast passenger always chooses the bus with the fastest arrival at the origin. The fractions of fast and normal passengers are S_f and $1 - S_f$ respectively.

We derive the dynamic model of two-route bus traffic system. It is assumed that all the passengers waiting at the bus stop can board the bus when the bus arrives at the origin. New passengers arrive at the origin with inflow rate μ [persons/min]. The arrival time of bus A (B) at the origin and trip n is defined by $t_{A(B)}(n)$. If bus A arrives at the origin faster than bus B at trip n, $W_A(n)$ is the number of passengers that have lined up at bus stop A since the previous bus left the origin. This is expressed by

$$W_A(n) = S_f \mu(t_A(n) - t_p(n-1)) + \frac{1}{2}(1 - S_f)\mu(t_A(n) - t_A(n-1)), \tag{1}$$

where $t_p(n-1)$ is the arrival time of the previous bus. The previous bus is which of the two buses because a bus runs a neck- and neck race with anther bus. The first term on the right hand side represents the number of fast passengers waiting at bus stop A. Fast passengers line up at bus stop A as soon as the previous bus left the origin because bus users can know that bus A arrives at the origin faster than bus B. The second term on the right hand side represents the number of normal passengers. Normal passengers line up at bus stop A as soon as bus A left from the origin at the previous trip.

Similarly, when bus B arrives at the origin faster than bus A at trip m, $W_B(m)$ is the number of passengers that have lined up at bus stop B since the previous bus left the origin. This is expressed by

$$W_B(m) = S_f \mu(t_B(m) - t_p(m-1)) + \frac{1}{2}(1 - S_f)\mu(t_B(m) - t_B(m-1)). \tag{2}$$

If all passengers lining up at the bus stop can board the bus, the number of passengers boarding the bus is consistent with the number of passengers waiting at the bus stop.