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Complex motion induced by elevator choice in peak traffic

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HIGHLIGHTS

- We presented the dynamic model of the two-elevator system to take into account the elevator choice of passengers.
- We studied the effect of both preference and fastness on the elevator motion.
- We clarified the dependence of elevator motion on both preference and fastness of passengers.

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ABSTRACT

We study the dynamic motion of two elevators by an elevator-choice strategy of passengers. An elevator is correlated with another elevator by the elevator choice. The dynamics of the elevator traffic system is described by a pair of deterministic nonlinear maps. The motion of two elevators is determined by the three parameters: the passenger's preference, the fraction of fast passengers, and the inflow rate. The dynamics of two elevators depends highly on the elevator-choice strategy. The motion of two elevators displays a complex behavior by a neck-and-neck race between two elevators. We explore the dependence of elevator motion on the passenger's preference, the fraction of fast passengers, and the inflow rate.

1. Introduction

Recently, transportation system has attracted much attention of physicists [1–5]. Various physical models have been presented to the traffic flow. The physical concepts and methods have been applied to transportation systems [6–40]. The cause of the traffic congestion of vehicles has been clarified by the physical models. The reduction of the traffic jam has been discussed. To avoid the traffic congestion, it is necessary and important to use the traffic information. In vehicular traffic system, advanced traveler information systems provide real-time information about the traffic conditions to road users by means of communication such as variable message signs, radio broadcasts or on-board computers. The real-time information helps the individual road users to minimize their personal travel time. Wahle et al. have proposed the dynamic model for two-route traffic flow with real-time information [41]. The traffic flow with real-time traffic information has been studied using a route choice scenario [42–46].

Congestion and jam occur but only in the vehicular traffic but also in elevator traffic. In elevator traffic system with a few elevators, elevator users can obtain the real-time information about elevator's position by means of the display board. Elevator users can know which of elevators arrives faster at the floor. Users can choose one of elevators. Elevator information helps individual users to go to an (a) upper (down) floor as soon as possible. Utilization of elevators depends highly on both elevator information and passenger's preference. There are a few models of elevator traffic [47–55]. However, it is little known on how both elevator information and passenger's preference affect the dynamics and motion of elevators. There

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are no dynamic models for the elevator traffic system accounting both elevator information and passenger's preference. It is necessary and important to make the dynamic (physical) model for the elevator traffic system including both elevator information and passenger's preference. 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.

In this paper, we present the dynamic model to describe the two-elevator traffic system taking account of both elevator information and passenger's preference. We show that the dynamic model is described by the deterministic nonlinear maps. We investigate the dynamic motion of two elevators using the deterministic nonlinear-map models. Also, we study the effect of both elevator information and passenger's preference on the dynamic motion of two elevators. We derive the dependence of the elevator motion on the passenger's preference, the fraction of fast passengers, and the inflow rate. We explore the effect of both elevator information and passenger's preference on the elevator motion for the two-elevator traffic system.

2. Deterministic nonlinear maps

We consider the transportation system of two elevators during the up peak period. We derive the dynamic model of the elevator traffic system. Two elevators serve the top floor from the lobby floor. Elevator users (passengers) board one of two elevators at the lobby floor and get off elevators at the top floor. Then, the empty elevator returns to the lobby floor. The flow of passengers is one way during the up peak period. The position information of elevators will be generated, transmitted, and displayed on the board in real time. Elevator users can know which of elevators arrives faster at the floor. Users can choose one of elevators. Two types of elevator users are introduced: fast and slow passengers. Fast passengers intend to go to the top floor as soon as possible, using the elevator information. When fast passengers arrive at the lobby floor, they will make a choice on the basis of the display boards and line up in the front of elevator which arrives fastest at the lobby floor. While slow passengers ignore any signals of elevators and they line up in the front of one of two elevators with their preference. The fast passenger always chooses the elevator with the fastest arrival at the entrance. The fractions of fast and slow passengers are S_{fast} and $1 - S_{fast}$ respectively. We introduce the preference factor of slow passengers as S_p for representing the preference of slow passengers. Slow passengers choose the first elevator with preference factor S_p and the second elevator with $1 - S_p$. Thus, we take account of both preference of passengers and fraction of fast passengers using the elevator information. Fig. 1 shows the schematic illustration of the dynamic model for the elevator traffic taking account of both fraction of fast passengers and preference factor.

It is assumed that all the passengers waiting at the front of an elevator can board the elevator when the elevator arrives at the lobby floor. New passengers arrive at the lobby floor with inflow rate μ [persons/min]. The arrival time of first (second) elevator at the lobby floor and trip n is defined by $t_{1(2)}(n)$. If the first elevator arrives at the lobby floor faster than the second elevator at trip n, fast passengers line up in the front of the first elevator as soon as the previous elevator left on the lobby floor because elevator users can know that the first elevator arrives at the lobby floor faster than the second elevator. The number of fast passengers is given by

$$S_{fast}\,\mu(t_1(n) - t_p(n-1)) \quad \text{with } t_p(n-1) = \max[t_1(n-1), t_2(m-1)],$$

where $t_p(n-1)$ is the arrival time of the previous elevator. The previous elevator is which of two elevators because an elevator runs a neck-and-neck race with another elevator.

Slow passengers line up in the front of the first elevator as soon as the first elevator left from the lobby floor at the previous trip. The number of slow passengers is given by

$$(1 - S_{fast})S_p\mu(t_1(n) - t_1(n-1)).$$

The sum of above terms is the number $W_1(n)$ of passengers that have lined up at the front of the first elevator since the previous elevator left the lobby floor. This is expressed by

$$W_1(n) = S_{fast}\,\mu(t_1(n) - t_p(n-1)) + (1 - S_{fast})S_p\mu(t_1(n) - t_1(n-1)). \tag{1}$$

The first term on the right hand side represents the number of fast passengers. The second term on the right hand side represents the number of slow passengers.

Similarly, when the second elevator arrives at the lobby floor faster than the first elevator at trip m, number $W_2(m)$ of passengers that have lined up at the front of the second elevator is expressed by

$$W_2(m) = S_{fast}\,\mu(t_2(m) - t_p(m-1)) + (1 - S_{fast})(1 - S_p)\mu(t_2(m) - t_2(m-1)). \tag{2}$$

All passengers lining up at the front of an elevator can board the elevator. The number of passengers boarding the elevator is consistent with the number of passengers waiting at the front of the elevator. The time it takes for passengers to board the elevator is proportional to the number of passengers. The time of the first (second) elevator is given by $\gamma W_1(n)$ ($\gamma W_2(m)$) where γ is the time it takes one person to board the elevator. Generally, when the number of passengers is more, the time to board the elevator is longer. Similarly, the time it takes passengers to leave the first (second) elevator is given by $\beta W_1(n)$ ($\beta W_2(n)$) where β is the time it takes one person to leave the elevator.

The moving time of the elevator is $2H/V$ where H is the height between the lobby and top floors and V is the speed of the elevator. The tour time equals the sum of these periods. Then, the arrival time $t_1(n+1)$ of the first elevator at lobby floor