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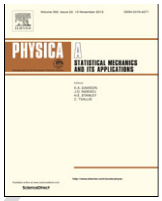

Analysis of the traffic running cost in a two-route system with feedback strategy

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HIGHLIGHTS

- We defined MVFS and NVFS based on the car-following model in a two-route system.
- We explored the effects of MVFS on each vehicle's running cost and each route's total cost.
- We explored the impacts of NVFS on each vehicle's running cost and each route's total cost.

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ABSTRACT

In this paper, we apply the FVD (full velocity difference) model to study the influences of MVFS (mean velocity feedback strategy) and NVFS (the number of vehicles feedback strategy) on each vehicle's running cost and each route's total cost in a two-route system from the numerical perspective. The numerical results illustrate that MFVS and NVFS have significant effects on each vehicle's running cost and each route's total cost, and that the impacts, each vehicle's running cost and each route's total cost are related to the gap of each vehicle's departure time at the origin.

1. Introduction

To date, traffic congestion has been a challenged topic in many fields (e.g., transportation, internet, communication, etc.). In real traffic system, traffic congestion produces some related traffic issues (e.g., safety, energy, emissions, etc.) and the traffic problems have been a big issue all over the word and attracted researchers to propose many traffic flow models or to develop many related technologies (e.g., intelligent transportation system, ITS) [1–4]. The information guidance strategies have been looked on as a better way of relieving congestion and reducing energy consumption and emissions with the rapid development of ITS, so some feedback strategies (FSs) have been proposed to explore the traffic phenomena in a two-route network [5–19]. In the above FSs, researchers assumed that the feedback information is completely accurate and that drivers can definitely choose their best-condition route [20]. In fact, the traffic information is not very accurate. In order to accurately describe the traffic information, Zhao et al. introduced the bounded rationality into the FSs to study the approaching system equilibrium with accurate or not accurate feedback information in a two-route system [21,22].

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CA (cellular automaton) model has been used to study each vehicle's motion in the FSs, but car-following model is not introduced into the FSs. Car-following model can reproduce many complex traffic phenomena, so we in this paper use it to study each vehicle's running cost under different FSs in a two-route system. In comparison with the existing studies, this paper has a contribution, i.e., car-following model is used to explore each vehicle's motion under different FSs in a two-route system and the effects of FSs on each vehicle's running cost. This paper is organized as follows: the related models and the related running costs are introduced in Section 2; some numerical tests are conducted to explore the effects of FSs on the related running costs in a two-route system in Section 3; and conclusions are summarized in Section 4.

2. Model formulation

The car-following model on a single-lane road can be formulated as follows:

$$\frac{\mathrm{d}v_n}{\mathrm{d}t} = f\left(v_n, \Delta x_n, \Delta v_n, \ldots\right), \tag{1}$$

where $\frac{\mathrm{d}v_n}{\mathrm{d}t}$, v_n, Δx_n, Δv_n, are the nth vehicle's acceleration, speed, headway, and relative speed, respectively. Eq. (1) just indicates that the nth vehicle's acceleration is determined by its speed, headway, relative speed and other factors. If we define Eq. (1) as different equations, we can obtain different car-following models, e.g., the optimal velocity (OV) model [23] and its extended versions [24,25], the generalized force (GF) model [26] and the full velocity difference (FVD) model [27]. The model [27] is very simple and can reproduce many complex traffic phenomena, so we in this paper use it to describe each vehicle's motion in a two-route system, where the FVD model [27] can be formulated as follows:

$$\frac{\mathrm{d}v_n}{\mathrm{d}t} = \kappa\left(V\left(\Delta x_n\right) - v_n\right) + \lambda \Delta v_n, \tag{2}$$

where κ, λ are two reaction coefficients and $V\left(\Delta x_n\right)$ is the nth vehicle's optimal speed. Jiang et al. [27] defined κ, λ, $V\left(\Delta x_n\right)$ as follows:

$$\kappa = 0.41, \qquad \lambda = \begin{cases} 0.5, & \text{if } \Delta x_n \le 100 \\ 0, & \text{otherwise}, \end{cases} \tag{3}$$

$$V\left(\Delta x_n\right) = V_1 + V_2 \tanh\left(C_1\left(\Delta x_n - l_c\right) - C_2\right), \tag{4}$$

where l_c is the vehicle's average length; V_1, V_2, C_1, C_2 are four parameters. Here, the parameters V_1, V_2, C_1, C_2, l_c are defined as follows [27]:

$$V_1 = 6.75\ \mathrm{m/s}, \qquad V_2 = 7.91\ \mathrm{m/s}, \qquad C_1 = 0.13\ \mathrm{m}^{-1}, \qquad C_2 = 1.57, \qquad l_c = 5\ \mathrm{m}. \tag{5}$$

Note: we can obtain similar results if in this paper, we use other car-following models to describe each vehicle's motion. In this paper we explore each vehicle's running cost in a two-route system, so we should here define the running costs. For simplicity, we here assume that each driver and each vehicle are both homogeneous, so we can define each driver's three running costs in a two-route system as follows:

$$T_n^{\mathrm{I}} = \alpha t_n, \tag{6a}$$

$$T_n^{\mathrm{II}} = \alpha t_n + \beta\left(\mathrm{FC}\right)_n, \tag{6b}$$

$$T_n^{\mathrm{III}} = \alpha t_n + \beta\left(\mathrm{FC}\right)_n + \gamma_1\left(\mathrm{HC}\right)_n + \gamma_2\left(\mathrm{CO}\right)_n + \gamma_3\left(\mathrm{NO}_X\right)_n, \tag{6c}$$

where T_n^{I}, T_n^{II}, T_n^{III} are the nth driver's first, second and third running costs, respectively; α is the value of time; t_n is the nth driver's running time; β is the fuel price; $(\mathrm{FC})_n$ is the nth vehicle's fuel consumption; γ_1, γ_2, γ_3 are the tolls of HC, CO and NO_X, respectively; $(\mathrm{HC})_n$, $(\mathrm{CO})_n$, $(\mathrm{NO}_X)_n$ are the nth vehicle's HC, CO and NO_X, respectively. As for the three running costs, we here give the following notes:

(1) The first running cost only considers the cost of the travel time.
(2) The second running cost includes the cost of the travel time and the cost of the fuel consumption because each driver should care the fuel consumption in his running cost except for the cost of his travel time.
(3) Based on the second running cost, the third running cost includes the toll of emissions. Each driver does not care the toll of emissions in his running cost and few governments charge for emissions, but the pollution resulted by the vehicle's emissions has been very serious and attracted the transportation departments and many researchers to care the emissions, so we consider the toll of emissions in each vehicle's third running cost, but we do not further calibrate the parameters γ_1, γ_2, γ_3 since we do not have the related data. Therefore, we should collect some related data (including the experimental and empirical data) to calibrate the three parameters and further study the third running cost.

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