Physica A 495 (2018) 278–293

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Non-lane-discipline-based car-following model under honk environment

Ying Rong *, Huiying Wen

School of Civil Engineering and Transportation, South China University of Technology, Guangzhou 510640, China

HIGHLIGHTS

- A non-lane-discipline-based car-following model under honk environment is presented.
- To obtain the stable condition, linear stability analysis has been conducted.
- The relation among driver's characteristics, visual angles and honk effect is analyzed.
- The numerical simulation is carried out.

ARTICLE INFO

Article history:
Received 22 August 2017
Received in revised form 14 December 2017
Available online 20 December 2017

Keywords:
Non-lane-discipline-based
Traffic flow
OV model
Driver's characteristics
Visual angles
Stability analysis

ABSTRACT

This study proposed a non-lane-discipline-based car-following model by synthetically considering the visual angles and the timid/aggressive characteristics of drivers under honk environment. We firstly derived the neutral stability condition by the linear stability theory. It showed that the parameters related to visual angles and driving characteristics of drivers under honk environment all have significant impact on the stability of non-lane-discipline traffic flow. For better understanding the inner mechanism among these factors, we further analyzed how each parameter affects the traffic flow and gained further insight into how the visual angles information influences other parameters and then influences the non-lane-discipline traffic flow under honk environment. And the results showed that the other aspects such as driving characteristics of drivers or honk effect are all interacted with the "Visual-Angle Factor". And the effect of visual angle is not just to say simply it has larger stable region or not as the existing studies. Finally, to verify the proposed model, we carried out the numerical simulation under the periodic boundary condition. And the results of numerical simulation are agreed well with the theoretical findings.

1. Introduction

With traffic continuously increasing, the traffic problem has occurred resulting in a increased and serious problem in modern cities. In particular, traffic congestion induce lots of traffic oscillations and crash risks, which has become the bottleneck of city development in recent years. It not only increases energy consumption and emissions but also imposes safety hazards, which has received considerable attention of scientists and researchers because of its complex mechanism. Therefore, in order to solve the serious problems by the mechanism behind the phenomena of vehicular flow, many traffic models have been developed to capture the complex traffic phenomena. These models can be classified as microscopic, mesoscopic and macroscopic models [1–5]. The car-following model is one of the major branch of the microscopic models,

* Corresponding author.
E-mail address: ry22511@163.com (Y. Rong).

https://doi.org/10.1016/j.physa.2017.12.075
0378-4371/

which is aimed to use the dynamic method to describe the interactions with preceding vehicles in the road, and further research the property of traffic flow. Its main idea is that each driver controls his vehicle under the stimuli from the preceding vehicle. And it can establish a bridge between the microscopic behavior of drivers and the macroscopic phenomenon of traffic flow. The optimal velocity (OV) model, among the existing car-following models, firstly proposed by Bando et al. [6], was a significant one in the traffic flow theory. After that, many models have been developed to investigate the properties of traffic flow based on it. In 1998, Helbing et al. [7] calibrated several optimal velocity models. He found that these models may result in unrealistic acceleration and decoration, and proposed the generalized force (GF) model. However, the GF model could not decelerate though the headway was small than the safe distance, when the velocity of leading vehicle was much larger than the velocity of following vehicle. To overcome this deficiency, in 2001, Jiang et al. [8] developed a full velocity difference (FVD) model based on the GF model. Besides, many researchers proposed a lot of models to study the traffic phenomenon from different aspects [9–13]. For human interaction aspect, the drivers are the makers and deciders of driving behavior, and their subjective consciousness will play a significant role on traffic environment. In 2013, Gupta et al. [14] proposed a new two-lane lattice hydrodynamic traffic flow model to analysis the driver's anticipation effect in sensing the relative flux. And they found that it could largely stabilize the traffic flow to consider the driver's anticipation effect. In 2015, Sharma [15] analyzed the effect of timid/aggressive driving behavior of drivers on the two-lane lattice hydrodynamic model. In 2016, Wen et al. [16] proposed a modified optimal velocity model by considering the drivers' characteristics under the honk environment. The horn is found to instigate the traffic congestion. And the characteristic of driver also has significant influence in the traffic flow under the honk environment.

The aforementioned models are all lane-discipline-based traffic flow models, which restricted to the assumption that vehicles follow the lane discipline and move in the middle of the road. However, in many developing countries, this assumption may not be valid since the lanes may be unclearly demarcated and drivers will try to travel ahead by utilizing the lateral space as much as possible. This results in multiple vehicles may travel in parallel and the following one maybe have more than one leader. Therefore, it needs to explore appropriate model to better describe the complex traffic flow under the non-lane-discipline traffic condition. Based on this understanding, in order to investigate the mechanism of the traffic flow under this situation, several non-lane-discipline-based traffic flow models have been proposed in recent years. Jin et al. [17] proposed a non-lane-based full velocity difference car-following model (NL-FVDM) to analyze the impact of lane width in traffic. This study elucidates that the lateral separation effects greatly enhance the realism of car-following model. But it was supposed that the traffic flow is homogeneous. Thus, later, Gupta et al. [18] firstly extended the NL-FVDM to the heterogeneous case and developed a continuum model for the non-lane-based system by considering lateral separation from the perspective of heterogeneous traffic. It was effectively considered the vehicle's classes and studied the effect of lane width for different compositions of heterogeneous traffic. And in 2015, Li et al. [19] incorporated two-sided lateral gaps into consideration, and presented a new non-lane-discipline-based car-following model. And they found that it has larger stable region and can more rapidly dissipate the perturbation from the leading vehicle than only consider one-sided lateral gap. By considering the effect of drivers to the traffic flow, Anderson et al. [20,21] successively explore the visual information for car following by drivers. Jin et al. [22] investigated how the visual angle impact in the non-lane-based situation. And they all found that the driver's optical information indeed influence the traffic flow. After that, Zhou [23] put forward an extended visual angle model for car-following theory. And the non-lane-discipline one by considering the effect of visual angle was proposed in 2016 [24]. Besides, Borowsky et al. [25] analyzed the effect of brief visual interruption tasks on drivers' ability to resume their visual search for a pre-cued hazard. Yu et al. [26] even evaluated the safety reliability when vehicles turn right from urban major roads onto minor ones based on driver's visual perception.

Indeed, the interaction of drivers is profound on the traffic system. And we conjecture that the driver's characteristics which is an intuitive reflection of driver's subjective consciousness, as well as the visual angles of drivers, may have significant impact on the traffic flow analysis, especially under the honk environment. Therefore, we cannot ignore the visual angles of driver and his characteristic during the varied traffic if we intend to better investigate the real traffic phenomena. However, these existing models have no one to study the effect of visual angles of driver and his characteristic synthetically on the non-lane-discipline traffic flow under honk environment up to our best knowledge. Thus, in this paper, a non-lane-discipline-based optimal velocity (NLD-OV) model by synthetically considering the visual angles and the timid/aggressive characteristics of drivers under honk environment is proposed. Then, we derive the neutral stability condition by the linear stability theory. We further analyze how each parameter affects the traffic flow and gain further insight into how the visual-angle factor influences other parameters and then the non-lane-discipline traffic flow under honk environment.

The rest of this paper is organized as follows: In Section 2, the non-lane-discipline-based optimal velocity model under honk environment is established in details. In Section 3, the stability condition of traffic flow is derived by means of linear stability theory. In Section 4, the further analysis are carried out to find out the inner mechanism about the parameters and traffic flow. We, then, carry out the numerically simulation to verify the theoretical analysis in Section 5. And finally, the conclusions are drawn in Section 6.

2. Model formulation

The optimal velocity model [6] is the simplest but significant one, given by

$$\frac{dv_n(t)}{dt} = \beta[V(\Delta x_n(t)) - v_n(t)], \tag{1}$$