Review and New Insights of the Car-Following Model for Road Vehicle Traffic Flow

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***Abstract*—This paper reviews the car-following model for road vehicle traffic flow, describes the advantages and disadvantages of these models; and based on the research of the effects of drivers' behavior including drivers' disturbance risk preference heterogeneity and drivers' rear view behavior depending on complex real traffic situations on traffic flow instability, which have been researched by the authors, discusses the reality conformity of some model assumptions and proposes some new insights and views about the car-following model.**

Keywords—traffic congestion; the car-following model; road vehicle traffic flow; model assumptions; the reality conformity

I. INTRODUCTION

In modern society, traffic congestion has become an extremely serious social problem to be urgently solved. Traffic congestion is a performance of traffic flow instability, and ease and inhibit traffic congestion is equivalent to reducing traffic flow instability. To strengthen the research of traffic flow is one of the effective measures to ease and inhibit traffic congestion. According to the research hierarchy, the modern road vehicle traffic flow model can be divided into macroscopic, mecroscopic and microscopic traffic flow model. The microscopic traffic flow model researches the characteristics of traffic flow by dealing with traffic flow as dispersed particles and studying the effect of single vehicles on the following vehicles. It mainly includes the car-following model and the cellular automata model; its advantages are that it can analyze the transitions and the separation of the traffic flow phase and describe various traffic waves, and its disadvantages is the car-following model only applies to analyzing the behavior of the traffic including a small number of vehicles and is not suitable to analyze the traffic including a large number of vehicles and the cellular automata model is difficult to obtain analytical results, which make it is complex in solving and usually have to carry out numerical simulation. All kinds of the road vehicle traffic flow model have their own advantages and disadvantages, and are connected with each other, not contradictory. How to better base on these advantages and disadvantages of these models, and propose more reliable traffic flow model is one of important research directions.

II. REVIEW

In this section, we review the car-following model for road vehicle traffic flow. The characteristics of driver's driving behavior and the vehicle running are the basis of the traffic flow study. In real traffic, the motion of the vehicle is generally not in a free state, namely in general, the driving is not in a free state. At this time, the direct effect of the vehicle and the change of traffic flow caused by it is the key point of research. Vehicle movement behavior can be divided into the following behavior and the lane-changing behavior, and the one researched by the car-following model is the following behavior. Broadly speaking, the car-following model is a kind of the generalized stimulus-response model, and concretely can be divided into: the stimulus-response model, the safety distance model namely behavior model or collision avoidance model, the psycho-physical model namely the action point model and the artificial intelligence-based model. Because of its good traffic physical and mathematical characteristics, the optimal velocity model of the stimulus-response model gets more attention and it has become one of hot researches of traffic flow model, which will be discussed emphatically.

The earliest stimulus-response car-following model was proposed by Reuschel [1] and Pipes [2], respectively, and assumed that the following driver tried to adjust the vehicle velocity consistent with the preceding vehicle velocity. The dynamic equation of the model is

$$a_n(t+T) = c\Delta v_n(t) \tag{1}$$

where T is the reaction delay time, c is an undetermined parameter, $a_n(t)$ is the acceleration of the following vehicle n at time t, $\Delta v_n(t) = v_{n+1}(t) - v_n(t)$, $v_{n+1}(t)$ and $v_n(t)$ are the velocity of the preceding vehicle $n+1$ and the following vehicle n at time t, respectively. This model is relatively simple and the driver's acceleration of the model is not consistent with real traffic driver's acceleration characteristics [3], but it has established two recognized assumptions of the following model research: drivers adjust velocity according to the velocity difference between the following vehicles and the preceding vehicles, and drivers have the reaction delay time. For the bad compliance of the model with the real traffic, many scholars put forward some improved models [4-9].

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The earliest safety distance car-following model was proposed by Kometani and Sasaki [10], whose basic assumption was in order to keep safe, when the diver couldn't predict the preceding vehicle motion completely, a reasonable safety distance would be kept. The expression of the reasonable safety distance is

$$\Delta x(t-T) = \alpha v_{n-1}^2(t-T) + \beta_l v_n^2(t) + \beta v_n(t) + b_0 \quad (2)$$

where α 、 β_l 、 β 、 b_0 are the undetermined parameters. The problem of the model is the change of the above parameters value identified under different speeds is big, and therefore the model is not very practical. For this, scholars have proposed more complex safety distance models [11-12].

The earliest psycho - physical car-following model was proposed by Michaels [13], and the model through the analysis of the potential factors of driver's physiological and psychological, think that the drivers sense the change of the relative speed between the preceding vehicles and the following vehicles by analyzing the change in size of the preceding vehicles in the field of vision, and when the traffic speed difference exceeds a critical value of the perspective change, the driver will choose acceleration or deceleration. One basic assumption of this kind of model is that the driver adjust the velocity according to the relative stimulus including the distance difference and the velocity difference between the preceding vehicles and the following vehicles, and drivers' adjust only occurs when the stimulus is more than the critical value. Many scholars have studied about this [14-16], one of the often mentioned model is Leutzbach and Wiedmann model [15]:

$$a_n(t+T) = [\Delta v_n(t)]^2 \Big/ 2[S - \Delta x_n(t)] + a_{n-1}(t) \quad (3)$$

where S the expected minimum safe following distance, $\Delta x_n(t) = x_{n+1}(t) - x_n(t)$, $x_{n+1}(t)$ and $x_n(t)$ are the location of the preceding vehicle $n+1$ and the following vehicle n at time t , respectively.

The earliest research of the artificial intelligence-based car-following model began in the 1990 s, which applied the various methods of the artificial intelligence field such as the fuzzy theory and the artificial neural network method to the driver behavior modeling. The theoretical basis of this model is that in the following process, the driver can be regarded as a complex nonlinear system, which controls the process of the following vehicle following the preceding vehicle according to the traffic environment and the information of the preceding vehicle and the following vehicle state and so on. The traditional differential equations models sometimes can't well describe the driver's psychological and physiological uncertainty and inconsistency, such as the feeling and understand. However, the fuzzy theory and the artificial neural network method have some simple and feasible advantage in dealing with complex nonlinear problems. Many scholars proposed the corresponding models [17-19]. For example, Kikuch and Chakroborty [18] proposed the following fuzzy inference model: If $\Delta x_{n,n-1}$ is Adequate, then

$$a_n(t) = (\Delta v_{n,n-1}(t) + a_{n-1}(t)T) \big/ \gamma \quad (4)$$

where T is the reaction delay time and often assumed to be $1s$; γ is the time in which that the drivers want to keep up with the preceding vehicle and often assumed to be $2.5s$.

Treiber, Helbing and Kesting [20-23] proposed an intelligent driver model namely ID model, which only needs few meaningful parameters and easy to be calibrated. They tried to uniformly describe the phase transformation of traffic flow from free flow to completely congested flow with the model. The control equation of the model is

$$\begin{aligned} a_n(t) = a_n(0)[1 - (v_n(t) \big/ v_0)^{\delta} \\ - ((s_n^*(v_n(t), -\Delta v_n(t))) \big/ s_a)^2] \end{aligned} \quad (5)$$

where

$$s_n^*(v_n(t), -\Delta v_n(t)) = s_0 + v_n(t)T' - \frac{v_n(t)\Delta v_n(t)}{2\sqrt{a_n(0)b}} \quad (6)$$

v_0 is the ideal driving speed, $s_a = \Delta x_n(t)$, s_n^* is the expected headway under the current condition, s_0 is the still safe distance, T' is the safety time interval, $a_n(0)$ is the start acceleration, b is the comfortable deceleration, δ is the acceleration index. The intelligent in the model means the expected headway s_n^* changes with different traffic conditions, namely according to Eq.(6) , we have when $\Delta v_n(t) = v_{n+1}(t) - v_n(t) < 0$, the following vehicle goes near the preceding vehicle, the expected headway s_n^* increases; when $\Delta v_n(t) = v_{n+1}(t) - v_n(t) > 0$, the preceding vehicle goes away from the following vehicle, the expected headway s_n^* reduces.

Tomer et al [24] proposed the intertial car- following model, and the control equation of the model is

$$a_n(t) = A(1 - \frac{\Delta x_n^0}{\Delta x_n(t)}) - \frac{z^2(\Delta v_n(t))}{2(\Delta x_n(t) - D)} - kZ(v_n(t) - v_{per}) + \eta \quad (7)$$

where A is the sensitive coefficient, D is the minimum distance between two adjacent cars, k is a constant, v_{per} is the permissible velocity, η is the white noise, $\Delta x_n^0 = v_n(t)T' + D$, the function $Z(x) = (x + |x|)/2$. Simulation shows that the traffic flow of the model has three states namely the free flow state and the non-uniform congested flow state and the uniform congested flow state.

Next, discuss the optimal velocity model of the stimulus-response model which is more to be focused on and researched. Newell [6] proposed a car-following model considering drivers' time lag of response and firstly defined the optimal velocity function. Bando et al [25] thought there were two major types of theories for car-following regulations. The first type was based on the idea that each vehicle must maintain the legal safe distance of the preceding vehicle, which depends on the relative velocity of these two successive vehicles. These theories are called the follow-the leader theory, which was used by Newell [6] model and so on, and had to take the time lag of response into account to become a realistic theory. The other type for regulation is that each vehicle has the legal velocity, which depends on the following distance from the preceding vehicle. Bando et al investigated the equation of traffic dynamics based on the latter assumption and found a realistic model of traffic flow. In their model the stimulus was a function of a following distance and the sensitivity was a constant and did not introduce the time lag of response. Nagatani [26] proposed an extended model considering the headway of the nearest preceding vehicle and the following vehicle and studied on traffic flow instability. Helbing and Tilch[27] carried out a calibration of OV model with the empirical follow-the-leader data and proposed an extended model considering the headway and the velocity of the following car and the relative velocity between the preceding vehicle and the following vehicle when the following vehicle was faster than the preceding vehicle, which was called the generalized force (GF) model. Jiang et al. [28] studied on the startup process of traffic flow with GF model and found that the starting wave velocity of GF model was too small and therefore proposed an extended model considering the headway and the velocity of the following car and the relative velocity between the following vehicle and the preceding vehicle, which was called full velocity difference (FVD) model. Xue et al. [29-31] also proposed a similar model. FVD model takes the usual factors considered by the following model into account and can better explain many phenomena such as traffic jam, dredge, phantom jam, go and stop and so on, and many models, based on FVD model, carry out a lot of related research. The models which are often cited are Newell model, OV model and FVD model.

In 1961, Newell [6] proposed a car-following model, whose control equation is

$$v_n(t+T) = V(\Delta x_n(t)) \quad (8)$$

The model firstly proposed the optimal velocity function $V(\cdot)$, which is a monotonically increasing function and has an upper bound.

In 1995, Bando et al [25] proposed an optimal velocity model called OV model, whose control equation is:

$$a_n(t) = a[V(\Delta x_n(t)) - v_n(t)] \quad (9)$$

where a is the sensitive coefficient. The optimal velocity function is

$$V(\Delta x_n(t)) = \frac{v_{\max}}{2}[\tanh(\Delta x_n(t) - h_c) + \tanh(h_c)] \quad (10)$$

where $v_{\max}$ is the maximum velocity, h_c is the safety distance. For the problem that OV model has too high acceleration and unreasonable deceleration, which does not conform to the reality, Helbing et al [27] proposed the general force (GF) model. Jiang et al [28] with GF model, studied the process of start-up and found the flow starting velocity wave was too small, so they proposed the full velocity difference (FVD) model, whose control equation is:

$$a_n(t) = a[V(\Delta x_n(t)) - v_n(t)] + r\Delta v_n(t) \quad (11)$$

where r is the sensitive coefficient of the velocity difference.

III. New insights

Model is a simulation and simplify of reality, which mainly reflects in the model assumptions. As a part of the extremely complex reality, traffic flow is also very complicated, so traffic flow model also need assumptions. Model's ultimate goal is close to the reality as possible as it can, so it is an important research direction about how to base on the real traffic, put forward more realistic assumptions, and then propose the traffic flow models which are more conformity with real traffic.

There are three basic assumptions in the car-following model:

1) The vehicle follows the preceding vehicles driving in the single lane, and does not overtake;

2) Drivers only respond to the information of the preceding vehicles, and don't respond to the one of the following vehicles;

3) Don't consider different drivers' heterogeneity, and assume the road conditions are ideal, and vehicles performance is the same.

For assumption 1 and 3, many extended models have been proposed. Tang et al [32] proposed a two lanes car-following model and analyzed traffic flow stability. Peter [33] researched fluctuations caused by a small disturbance and results showed that fluctuations were much larger than these models predicted by analyzing data from loop detectors as well as data from vehicle trajectories. A final model-based analysis supported the hypothesis that the preferred headway of the driver was the parameter that was not kept constant but fluctuated strongly, thus causing the even macroscopically observable randomness in traffic flow. Deng et al [34] considering the heterogeneity of data sources, proposed a quantitative method of the traffic state estimation and uncertainty. Chiabaut et al [35] estimated Newell's car-following model [36] parameters in congestion at a microscopic scale and established relations between stochastic Newell's model with heterogeneous drivers and its associated macroscopic pattern. Zeng et al [37] firstly define the concepts of drivers' disturbance risk preference and its heterogeneity, and based on these concepts and OV model, proposed the disturbance risk preference model considering drivers' heterogeneity. By analytical analysis and simulation analysis, they got some useful conclusion to inhibit traffic congestion, namely the smaller the ratio of the preceding driver's coefficient of the disturbance risk preference to the following driver's coefficient of the disturbance risk preference is, the smaller traffic flow instability is, and the more conducive to inhibit traffic congestion, and vice versa.

For assumption 2, only few scholars have proposed some extended models to discuss it. Hayakawa and Nakanishi [38], Nakayama et al [39], Hasebe et al [40], Ge et al [41] based on

OV model and Sun et al [42] based on FVD model, proposed some extended models, whose conclusions proved that considering the headway of the nearest following vehicle is conducive to reduce traffic flow instability. Furthermore, in actual driving, drivers not only look forward (usually three vehicles [43-45]) but also look backward (usually a vehicle [46]). According to the traffic survey, every 5-10 seconds, drivers look back the nearest following vehicle through rearview mirrors no more than 2 seconds. Drivers do receive the information of the nearest following vehicle [47] and therefore drivers are affected by the information of the nearest following vehicle, and traffic flow instability is also affected by the information of the nearest following vehicle. However, [38-42] did not consider the effect of the velocity difference between the vehicle and the nearest following vehicle on traffic flow instability and didn't explain reasons, which means the information of the nearest following vehicle considered by [38-42] is not incomplete. For this, Zeng et al[48] proposed a model, based on the condition of inhibiting traffic flow instability and under the real conditions that the probability of paying attention to the information of the preceding vehicle is greater than the probability of paying attention to the information of the following vehicle and drivers' sensitive coefficient is greater than 0, by the analytical and simulation analyses, many insights including the following can be gotten: 1) the information of the nearest following vehicle headway reduces traffic flow instability, and the bigger the attention probability is, the smaller traffic flow instability is; by contrary, the information of the velocity difference between the vehicle and the nearest following vehicle increases traffic flow instability , and the more the attention probability, the bigger traffic flow instability is; 2) the reducing effect of comprehensive information of the nearest following vehicle is greater than its increasing effect on traffic flow instability; 3) the bigger driver' sensitive coefficient of the distance difference is, the bigger the reducing effect of the information of the nearest following vehicle on traffic flow instability is; 4) the bigger driver' sensitive coefficient of the velocity difference is, the bigger the increasing effect of the information of the nearest following vehicle on traffic flow instability is.

IV. CONCLUSIONS

This paper reviews the car-following model for road vehicle traffic flow, describes the advantages and disadvantages of these models; and based on the research of the effects of drivers' behavior depending on complex real traffic situations on traffic flow instability, which have been done by the authors, discusses the reality conformity of some model assumptions and proposes some new insights and views.

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REFERENCES

[1] A. Reuschel, "Vehicle movements in a platoon," Oesterreichisches Ingenieeur-Archir, vol. 4, pp. 193-215, 1950.

[2] L. A. Pipes, "An operational analysis of traffic dynamics," Journal of Applied Physics, vol. 24, no.3, pp. 274-281, 1953.

[3] R. E. Chandler, R. Herman, and E. W. Montroll, "Traffic dynamics: Studies in car following," Operations Research, vol. 6, no.2, pp.165-184, 1958.

[4] R. Herman, E. W. Montroll, and R. W. Rothery, "Traffic dyanmics: Analysis of stability in car following," Operations Research, vol.7, no.1, 86-106, 1959.

[5] D. C. Gazis, R. Herman, and R. B. Potts, "Car following theory of steady state traffic flow," Operations Research, vol.7, no.4, 499-505, 1959.

[6] G. F. Newell, "Nonlinear effects in the dynamics of car following," Operations Research, vol.9, no.2, 209-229, 1961.

[7] D. C. Gazis, R. Herman, and P. W. Rothery, "Nonlinear follow-the-leader models of traffic flow ," Operations Research, vol.9, no.4, pp.545-567, 1961 .

[8] S. Bexelius, "An extended model for car-following," Transportation Research, vol.2, no.1, pp. 545-567, 1968.

[9] B. Sultan, M. Brackstone, and M. McDonald, "Drivers' use of deceleration and acceleration information in car-following process," Transportation Research Record, vol.1883, pp. 31-39, 2004.

[10] E. Kometani, and T. Sasaki, "On the stability of traffic flow," Journal of Operations Research Japan, vol.2, no.1, pp. 11-26, 1958.

[11] P. G. Gipps, "A behavioural car following model for computer simulation," Transportation Research Part B, vol.15, no.2, pp.105-111, 1981.

[12] B. Gunay, "Car following theory with lateral discomfort," Transportation Research Part B, vol.41, pp.7, pp.722-735, 2007.

[13] P. M. Michaels, "Perceptual factors in car following," Proceedings of International Symposium on the theory of Road Traffic Flow, pp.44-59, 1963.

[14] L. Evans, and R. Rothery, "Perceptual thresholds in car following: A recent comparsion," Transportation Science, vol.11, no.1, pp.44-59, 1977.

[15] W. Leutzbach, and R. Wiedmann, "Development and application of traffic simulation models at Karlsruhe Institut fur Verkehrwesen," Traffic Engineering and control, vol. 27, no.5, pp. 270-278, 1986.

[16] E. R. Boer, "Car following from the driver's perspective," Transportation Research Part F, Traffic Phychology and Behavior, vol.2, no.4, pp.201-206, 1999.

[17] R. E. Bellman, and L. A. Zadel, "Decision-making in a fuzzy environment," Management Science, vol.17, no.4, pp.141-164, 1970.

[18] C. Kikuchi, and P. Chakroborty, "Fuzzy neural network control of complex systems: a study longitudinal vehicle control," Proceeding of the World Congress on Neural Networks, vol. 3, pp. 84-92, 1992.

[19] X. Ma, and I. Andréasson, "Behavior measurement, analysis, and regime classification in car following," IEEE Transaction on Intelligent Transportation System, vol.8, no.1, 144-156, 2007 .

[20] M. Treiber, A. Hennecke, and D. Helbing, "Congested traffic states in empirical observations and microscopic simulations," Physical Review E, vol. 62, pp.1805-1824, 2000.

[21] M. Treiber, and D. Helbing, "Memory effects in microscopic traffic models and wide scattering in flow density data," Physical Review E, vol.68, id.046119, 2003.

[22] M. Treiber, A. Kesting, and D. Helbing, "Delays, inaccuracies and anticipation in microscopic traffic models," Physica A, vol. 360, pp. 71-88, 2006.

[23] A. Kesting, and M. Treiber, "Calibrating car-following models by using trajectory data," Transportation Research Record, vol. 2088, pp.148-156, 2008.

[24] E. Tomer, L. Safonoy, and S. Havlin, "Presence of many stable nonhomogeneous states in an inertial car-followig model," Physical Review Letters, vol.84, pp.382-385, 1999.

[25] M. Bando, K. Hasebe, A. Nakyaama, A. Shibata, and Y. Sugiyama, “Dynamical model of traffic congestion and numerical simulation,” Physical Review E, vol.51, pp.1035–1042, 1995.

[26] T. Nagatani, “Stabilization and enhancement of traffic flow by the next-nearest-neighbor interaction,” Physical Review E, vol. 60, 6395-6401, 1999.

[27] D. Helbing, and B. Tilch, “Gneralized force model of traffic dynamics,” Physical Review E, vol.58, no.1, pp.133-138, 1998.

[28] R.Jiang, Q. S. Wu, and Z. J. Zhu, “Full velocity difference model for car-following theory,” Physical Review E, vol.64, pp. 017101, 2001a.

[29] Y. Xue, “A car-following model with stochastically considering the relative velocity in a traffic flow,” Acta Physica Sinica, vol.52, no.11, pp.2750 -2756, 2003.

[30] Y. Xue, L. Y. Dong, Y. W. Yuan, and S. Q. Dai, “Numerical simulation on traffic flow with the consideration of the relative velocity,” Acta Physica Sinica, vol.51, pp. 492-495, 2002.

[31] Y. Xue, “Analysis of the stability and density waves for traffic flow,” Chinese Physical B, vol.11, pp. 1128-1137, 2002.

[32] T. Q. Tang, H. J. Huang, and Z. Y. Gao, “Stability of the car- following model on two lanes,” Physical Review E, vol.72, 066124, 2005.

[33] W. Peter, “Analyzing fluctuations in car-following,” Transportation Research Part B, vol.46, pp. 1384-1392, 2012.

[34] W. Deng, H. Lei, and X. S. Zhou, “Traffic state estimation and uncertainty quantification based on heterogeneous data sources: A three detector approach,” Transportation Research Part B, vol.57, no.132-157, 2013.

[35] N. Chiabaut, L. Leclercq, and C. Buisson, “From heterogeneous drivers to macroscopic patterns in congestion,” Transportation Research Part B, vol.44, pp. 299-308, 2010.

[36] G. F. Newell, “A simplified car –following theory: a lower order model,” Transportation Research Part B, vol.36, pp. 195-205, 2002.

[37] Y. Z. Zeng, N. Zhang, and L. J. Liu, “A new car following model considering drivers’ heterogeneity of the disturbance risk appetite,” Acta Physica Sinica, vol.63, no.6, 068901, 2014.

[38] H. Hayakawa, and K. Nakanishi, “Universal Behavior in Granular Flows and Traffic Flows,” Progress of theoretical physics supplement, vol.130, no.1, pp. 57-75, 1998.

[39] A. Nakayama, Y. Sugiyama, and K. Hasebe, “Effect of looking at the car that follows in an optimal velocity model of traffic flow,” Physical Review E, vol. 65, 016112, 2001.

[40] K. Hasebe, A. Nakayama, and Y. Sugiyama, “Dynamical model of a cooperative driving system for free traffic,” Physical Review E, vol.68, 026102, 2003.

[41] H. X. Ge, H. B. Zhu, and S. Q. Dai, “Effect of looking backward on traffic flow in a cooperative driving car following model,” European Physics Journal B, vol.54, no.4, pp. 503-510, 2006.

[42] D. H. Sun, J. C. Zhang, M. Zhao, and C. Tian, “Effect of backward looking and velocity difference in an extended car following model,” Journal of Sichuan University (Natural Science Edition), vol.49, no.1, pp. 115-120, 2012.

[43] G. H. Peng, “Stabilization analysis of multiple car-following model in traffic flow,” Chinese Physics B, vol.19, no.5, 056401, 2010.

[44] G. H. Peng, and D. H. Sun, “Multiple car-following model of traffic flow and numerical simulation,” Chinese Physics B, vol.18, no.12, 5420-5430, 2009.

[45] G. H. Peng, “Stability analyzing of multiple look-ahead car-following models,” System Engineering-Theory&Practice, vol.31, no.3, pp.569-576, 2011.

[46] 016112http://blog.163.com/pedou@126/blog/static/17109272120110443311271/

[47] H. M. Zhang, “Anisotropic property revisited-does it hold in multi-lane traffic?,” Transportation Research Part B, vol.37, pp. 561-577, 2003.

[48] Y. Z. Zeng, N. Zhang, and L. J. Liu, “Effects of comprehensive information of the nearest following vehicle on traffic flow instability,” Acta Physica Sinica, accepted.

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