Transportation Research Part C 19 (2011) 1202–1214

Contents lists available at ScienceDirect

Transportation Research Part C

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

# A safety-based approaching behavioural model with various driving characteristics

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ARTICLE INFO

*Article history:*
Received 13 April 2010
Received in revised form 1 February 2011
Accepted 2 February 2011

*Keywords:*
Driving behaviour
Deceleration
Acceleration
Car-following
Safety spacing
Driver assistance

ABSTRACT

In order to understand driver's safety-related approaching behaviour during car-following process in more depth, it is necessary to achieve the comprehensive analysis of vehicle-to-vehicle dynamic interactions. Based on qualitative description of driving shaping behaviour associated with driving human factors of influencing driver's car-following behaviour, this paper presents briefly the fundamentals of simulation modelling of driver's safety approaching behaviour in urban traffic operation. The emphasis on our research is placed on the development of a driver's safety approaching behavioural model by considering the variability of following vehicle's speed to the leading vehicle's one and the relative distances among vehicles. Furthermore, we have carried out simulation and analysis of driver's deceleration and acceleration behaviour under different driving situations after identified the key safety-related parameters. Finally the developed model has been validated by using detailed vehicle trajectory data that was collected in naturalistic driving environment. The results show that the safety-based approaching behavioural model could be used to analyze driver's car-following behaviour for driving support and to reveal the essence of traffic flow characteristics at the microscopic level.



## 1. Introduction

Traffic congestion is a condition in urban traffic network that is characterized by slower speeds, longer trip times and increased queuing. It adversely affects urban mobility and become a major quality of everyone life issue. Regardless of the cause of traffic congestion, congested traffic usually shows sharp traffic flow change and prolonged stop-and-go motion of vehicles. Since different drivers with diverse driving skills drive their vehicles through the congested roadways while interacting with other drivers, traffic operations in such sections of roadways are very complex (Wang et al., 2010a; Aycin and Benekohal, 2001; Ahmed, 1999; Dijker et al., 1998). First of all, nearly all drivers have no freedom of choice with respect to driving decisions in congested traffic. Second, all drivers are forced to follow the leading vehicles; they can hardly maintain desired speed and adjust lane choice. It is found that nearly half of vehicle crashes were due to drivers following their leaders too closely (Bham and Benekohal, 2004). In such cases, drivers are not able to decelerate fast enough when their leaders decelerate at unexpectedly high rates (Wang, 2002). Therefore, advanced driver support technologies are being developed actively, the adaptive cruise control (ACC) system is especially highlighted among these technologies (Bubb, 2010; Kesting et al., 2008; Zheng and McDonald, 2005; Li and Shrivastava, 2002). However, the control algorithm of the ACC system does not match thoroughly the driver's actual behaviour (Hoedemaeker and Brookhuis, 1998).

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doi:10.1016/j.trc.2011.02.002

Driver's car-following behaviour is the most elementary driving behaviour (Wang et al., 2010b; Brackstone and McDonald, 1999). In this community of research, spacing and safety control strategy approaches are used by most of car-following models. Car-following models based on safety control strategy are derived by calculating a safe speed with respect to the leading vehicle, but it is based on the assumption that the following vehicle could stop while the leading vehicle comes to a sudden stop. The first prototype car-following model that was put forward in the 1950s by the researchers at the General Motors (GM) research labs. The GM researchers used position, speed, and acceleration parameters of two-vehicle platoons to estimate driver behavioural responses through field data that collected from test tracks and tunnels. The psychophysical or action point model is a type of car-following models based on individual mental characteristics (Winsum, 1999). The Corridor Traffic Simulation Model (CORSIM) is one of the most popular models that use several complex car-following equations to describe vehicle movement on a step by step basis (Owen et al., 2000; FHWA, 1998). The drawback is that the CORSIM does not examine aspects of multivehicle platoons to learn how traffic stream characteristics are affected by various car-following scenarios.

In order to develop behavioural algorithms for micro-simulation of traffic operation, US DOT (Department Of Transportation) initiated the NGSIM (Next Generation SIMulation) program (NGSIM, 2002). The NGSIM program developed and validated several driver behavioural algorithms based on collected real-world datasets. Such program can improve the quality and trust simulation tools and foster an environment of cooperation. In brief, over the past 50 years, the development and refinement of car-following models have extensively evolved from the earlier deterministic relationships to the recent stochastic relationship (Brackstone et al., 2009; Xin et al., 2008; Bonsall et al., 2005; Wang et al., 2004; Alvarez et al., 2003; Newell, 2002; Winsum and Brouwer, 1997). The previous work concerning the car-following models and calibration made an active contribution to driving behaviours or related to the traffic safety, traffic behaviour and psychology (Wang, 2010; Dowling et al., 2004).

It is also instructive to note that the understanding of driver dynamic behaviour is increasingly being recognized as a potential strategy for describing the longitudinal speed–distance relationship between leading vehicles and following vehicles in the same lane (Winsum, 1999). Enroute the driver's decision on whether or not to acceleration depends on a large number of factors: the distance between the following vehicle (subject) and the leading vehicle (or leader), the speeds of the subject and the leader, the preferred speed of the subject, and the traffic stream characteristics in the area (Winsum and Heino, 1996; Ranney, 1994). While drivers face such situations regularly and make good decisions with little conscious thought, modelling of driver's car-following behaviour should explicitly attempt to take driving situation awareness and driver's choice reaction time into account (Wang et al., 2010c; Bonsall et al., 2005; Sukthankar, 1997).

The study of driving behaviour analysis began in the mid-20th century (Wang, 2001; Ranney, 1999; Koppa, 1996; Summala, 1996; Rumar, 1988). A lot of research on driving behaviour has been done from a psychological point of view and has generated a substantial amount of knowledge that is applied into driver's car-following models. It is found that drivers apply heuristics to cope with their limitations in an adaptive and flexible manner. However, only certain elements of car-following behaviour have been studied, the consistent and elaborated models are still lacking (Winsum, 1999). Moreover, it has never been clear whether these models could explain everyday on-road car-following behaviour. Drivers' ability to judge relative speed is inversely proportional to the inter-vehicle spacing; the primary cue cannot simply be the change in visual angle subtended by the leading vehicle (Brookhuis et al., 1994; Gunay, 2008). Therefore, while car-following models incorporate some assumptions about underlying behavioural mechanisms, they are clearly not intended to be purely behavioural models of car-following (Ranney, 1994). As a matter of fact, car-following models relate to interdisciplinary endeavour involving a number of fields such as traffic engineering, human factors, information technology. It is necessary for scientists with interdisciplinary problems solving background and engineering experience to explore it in more depth.

The main objectives of our research are to investigate drivers' car-following safety behaviour in more detail, and then to develop an integrated safety-based approaching behavioural model and simulation procedures for devising traffic accident solution and evaluating urban traffic at the microscopic level. This paper is structured as follows: the next section discusses the driving human factors of influencing drivers' car-following behaviour according to analysis of action point model. It is followed by the development of deceleration and acceleration algorithms for driver's safety approaching behaviour. In Section 3, the simulation framework and safety-related parameters for car-following model are presented. After that the detailed simulations and relative results are discussed with different driving situations, and then the developed model is verified by using the empirical vehicle trajectory data. Finally, some concluding remarks and future work are summarized in brief.

## 2. Deceleration and acceleration algorithms for driver's car-following safety behaviour

### *2.1. Analysis of action point model*

While vehicles are operating on road, the point at which the driver takes action is defined as the action point where the acceleration changes sign. Since action point model (AP model) is able to describe most of the features that we see in everyday driving behaviour, it is regarded as a successful car-following model in the past (Brackstone et al., 2009; Brackstone and McDonald, 1999). This model is based on the assumption that a driver will perform an action when a threshold is expressed as a function of speed difference and distance variation. The first discussion of the underlying factors that would eventually