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Car following theory with lateral discomfort

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Abstract

A car following model has been developed with particular reference to weak discipline of lane-based driving. The theory is based on the discomfort caused by lateral friction between vehicles. The movement of the following vehicle was formulated as a function of the off-centre effects of its leader(s). This incorporation of lateral friction offers a potential breakthrough in the fields of car following theory and microscopic simulation of traffic flow. Using a stopping-distance car following approach, the simulation presented in the paper pointed out the effect of the travel path width on the speed of the following vehicle, and the reduced following distance with increased lateral separation between the leader and follower. It was also shown that a special case of the proposed model (i.e. when the maximum escape speed is zero) produced the same results as the base model did for the conventional car following case. The simulation behaved rationally giving credibility to the author's staggered car following theory.

Keywords: Car following; Lane discipline; Lane-based driving; Lateral position of traffic

1. Introduction

The key assumptions of car following theory state that vehicles travel in the middle of the lane, each vehicle is influenced directly by the one in front, and no passing is allowed. From qualitative observations of any road traffic, however, it is not difficult to notice that not every vehicle is positioned in the centre of the lane. These deviations from the centre become considerable especially in places where non-lane-based driving is predominant (the term will be defined later in this section). Best examples of this kind are from developing countries where poor road surface and markings as well as irregular driver attitudes are the reasons behind the problem (Khan and Maini, 1999; Gunay, 2004). Even in developed countries, lateral friction may play a role in car following or passing behaviour, unless the lanes are clearly separated by road markings with good visibility, lane widths are wide enough, and drivers have perfect driving discipline.

Case et al. (1953) stated that drivers veered around objects near their path located on the roadside, and reacted to curbing height, shoulder width, lane width, centre line, and variations in pavement surface. In a

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similar study, Taragin (1955) reported that depending on the size and distance of the objects from the carriageway platform, some drivers encroached on the lane used by oncoming traffic in two-lane two-way highways. He found that as the flow increased on a two-lane unidirectional highway, vehicles in the shoulder lane, on an average, travelled closer to the shoulder, and those in the median lane travelled closer to the median. May (1959) introduced four types of friction as internal, medial, marginal, and intersectional. Internal friction was defined as that friction which exists between vehicles moving in the same direction. He outlined the possible factors influencing the internal friction, such as number and width of lanes, horizontal and vertical alignment, and uniformity and smoothness of traffic flow. Nevertheless, there was no further elaboration on mathematical representation of internal friction in his paper. Later, Michales and Cozan (1963) investigated the relationship between the speed of a vehicle and lateral clearance, stating that it was possible, when necessary, to control the speed of traffic by means of a channel constructed by plastic cones. The width of this channel and the longitudinal distances between each consecutive cone are the factors affecting the speed of traffic. Mahalel (1984) developed a simulation model to evaluate the quality of traffic flow. His evaluation was based on the number of potential speed changes and the number of times a vehicle is limited in changing lanes. But two-dimensional car following concept was not treated. Refer to Martens (1997) who provided a detailed review on the effects of road design on speed behaviour.

Gunay (2003) defined the term lane-based driving discipline as the tendency to drive within a lane by keeping to the centre as closely as possible (unless in lane changing), and introduced four possible scales to quantify this discipline. Irregular distribution of traffic across the roadway was the most important indications of weak discipline. For example, central positions of vehicles were recorded in Germany (Fig. 1a) and these vehicles positioned themselves laterally within their lanes according to a normal distribution. When similar analyses were carried out for the data collected from Turkey, his findings exhibited less tidy distribution where some vehicles travelled over the lane lines or even on the shoulder (Fig. 1b). He categorised traffic flow into tidy and untidy depending on whether the lateral distribution of vehicles fits a normal curve or not. He summarised defining characteristics of weak discipline of lane-based driving as: (a) irregular lateral position of vehicles across the carriageway; (b) driving on lane lines for long time; (c) usage of the shoulder as a traffic lane; (d) when lateral clearance is restricted speeds may be affected, and (e) shorter following headways with more central separations between two consecutive vehicles.

Three sets of data, collected earlier for another piece of research, were analysed to see the characteristics of varying lane discipline. Sites were straight sections of multilane highways with uninterrupted traffic flows on A167(M), Newcastle, Britain; A5-Bruchsal, Karlsruhe, Germany; and a number of different sites (mainly on E5, Atakoy), Istanbul, Turkey. It was revealed that the overtaking vehicles laterally located themselves with respect to the lateral position of the vehicle being overtaken (Fig. 2). Regarding the relationship between side clearance, i.e. frictional clearance (FC in Fig. 2), and the overtaking speeds, speeds of passing vehicles remained unchanged in tidy flows as long as vehicles do not encroach on the adjacent lanes. Untidy traffic, however, exhibited a different picture, as Fig. 3 shows two examples. Both graphs suggest some increase in

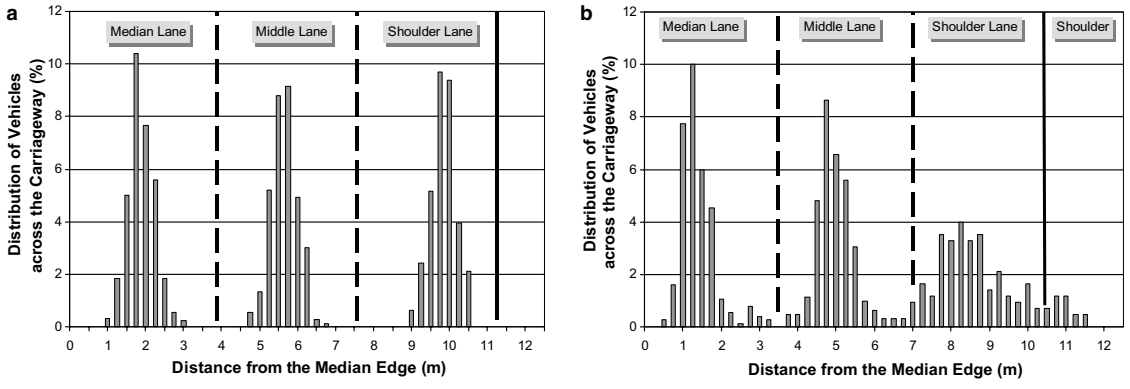

Fig. 1. Demonstration of good and poor disciplines of lane-based driving. Adapted from Gunay (2003).