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LATERAL ANALYSIS OF LONGITUDINAL HEADWAYS IN TRAFFIC FLOW

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Abstract

Mainstream car following theories have assumed that each vehicle is influenced directly by the one in front and vehicular headways have been studied as same-lane-based. These are true only when lane discipline is extremely ideal and lane widths are large. Real traffic, however, poses a more complex picture. The paper, based on empirical observations, attempted to explore the issue of two-dimensional headway analysis in detail for better realism in traffic flow modelling. It was found that below a certain value of same-lane time headways, fewer numbers of drivers were willing to keep short headways with respect to the neighbouring lane vehicles. This may mean that, except light flow traffic where the offside lane is primarily used for overtaking, drivers prefer to pass or lag behind the vehicle in the adjacent lane, rather than driving side by side. In addition to its safety concerns, especially in relatively narrow lanes, this issue may have capacity implications. Hence, existing traffic flow models may require further adjustments.

Keywords: lateral friction, psychological friction, pick up effect of headways, microscopic simulation

1. Introduction

A time headway is defined as the time interval between successive vehicles (from a reference point of the first vehicle to the same reference point of the second vehicle) as they pass a point along the lane [1]. Existing traffic simulation models (microscopic models in particular) are by in large lane-based models. They treat multilane (unidirectional) traffic flow lane by lane. Although models such as PTV's VISSIM takes lateral friction into account such as the presence of bicycles or large vehicles, the vehicular headway relationships are all same-lane-based. In other words, the longitudinal location of each vehicle is governed by well-known car following theories (as a function of the longitudinal position of the preceding vehicle travelling in the same lane). The presence of neighbouring lane vehicles are not taken into account for these position updates in modelling. However, we believe that drivers do not like driving side by side with other vehicles in the adjacent lanes for long periods of times even in moderate or heavy traffic. They either pass the vehicle travelling in the neighbouring lane or lag behind it. There may be two reasons for this behaviour: the physical lateral discomfort effect of the vehicle in the adjacent lane as it narrows down the effective width of the travel corridor, and the psychological 'shy' effect of being looked at by the occupants of the neighbouring vehicle. Hence, in modelling, an adjustment exercise should be considered for the calculation of the longitudinal positions of vehicles by taking this 'pick up' effect from the adjacent lane vehicles. The present paper surveys this issue. Here, we only introduce the matter to show that there may be unique appearances of time headways when these pick-up effects are taken into account. The application and testing of the findings are subject to further work.

2. Previous research

The existence of (non-physical) lateral friction between vehicles travelling in unidirectional multilane highways attracted special interest in the past. May [2] introduced internal, marginal and medial friction between vehicles. Mahalel and Hakkert [3] found that the arrival of vehicles across the road (laterally) is not random. Hall [4] studied lateral throughput in addition to the conventional (longitudinal) throughput. But not many researchers attempted to define those headways with particular reference to the presence of other vehicles in the vicinity, though Gunay and Woodside [5] looked at time headways between vehicles travelling in the same direction but in neighbouring lanes. They used three sets of data, collected earlier, in Istanbul, Turkey; Karlsruhe, Germany, and Newcastle upon Tyne, Britain, by means of video recording and manual analysis of video frames. They observed vehicular arrivals spatially in that a certain section of the carriageway (15 m) was divided into two sectors on the computer screen. Each sector consisted of a number of sub-parts which was equal to the number of lanes of that particular carriageway. Each sector was represented by a matrix, each cell of which is set to either '1' or '0', depending on whether the particular part was occupied by a vehicle or not. Then the second sector was also represented by another matrix which is designed in the similar way denoting whether a vehicle arrives on a particular part of the sector or not. The readings were then recorded in the form of a matrix. These occupation and arrival matrices consisted of zeros and ones. Readings were taken three times a minute by stopping the tape at regular intervals, and hence each row represents a separate reading. Rows were then distributed over a number of groups, the number of which is the all possible permutations of Sector 1. For example, for a there-lane carriageway, there are 7 different possibilities of vehicle occupations in Sector 1. Table 1 shows the percent analysis of the arrivals on a three-lane road in Istanbul.

Table 1 – Observed lateral arrival patterns on a three-lane highway, from [5]

	Inside Lane	Middle Lane	Outside Lane	Probability (%) that the next vehicle arrives on the			Total %
				Inside Lane	Middle Lane	Outside Lane	
Currently Occupied Lane				12.5	46.1	41.4	100
	1			2.9	32.4	64.7	100
		1		21.6	9.8	68.6	100
			1	30.5	54.2	15.3	100
	1	1		0	33.3	66.7	100
	1		1	15.4	53.8	30.8	100
		1	1	30.8	30.8	38.4	100
	1	1	1	26.3	35.1	38.6	100

Without needing for significance tests, by visual inspection of the table, it is possible to suggest that the probability of the next arrival on a lane that is already occupied by a preceding vehicle is less than the probability of the next arrival on a non-occupied lane. This implies that lane by lane vehicular arrivals are not very independent. The presence of other vehicles in the surrounding may affect the (longitudinal) position of the vehicle in question.

As seen in Fig. 1, also, they [5] drew the distribution of time headways between vehicles travelling in the same lane (the curves) and between the vehicles travelling in adjacent lanes (the bars). In both English and German cases, the shape of the headway distribution (the curves in Fig. 1) for all lanes was in a typical headway distribution shape reported in literature by others. However, it was the interaction between the neighbouring vehicles (travelling in the same direction but in different lanes) that attracted attention.

Through empirical observations and simulation, Gunay [6], afterwards, modelled lane-based and non-lane-based driving disciplines. He first showed that vehicles travelling in a traffic lane position themselves laterally according to a bell-shape distribution at best (or worse in developing countries) which results in lateral friction and interaction, to a degree, between the vehicles travelling in neighbouring lanes. He then incorporated this into a safe stopping-distance-based car following model, known as staggered car following theory. Later, Garber and Hoel [7] stated that narrow lanes make it difficult for two vehicles to travel alongside each other. Based on similar studies, The Highway Capacity Manual [8] established threshold values and relationships between lane widths and throughput.

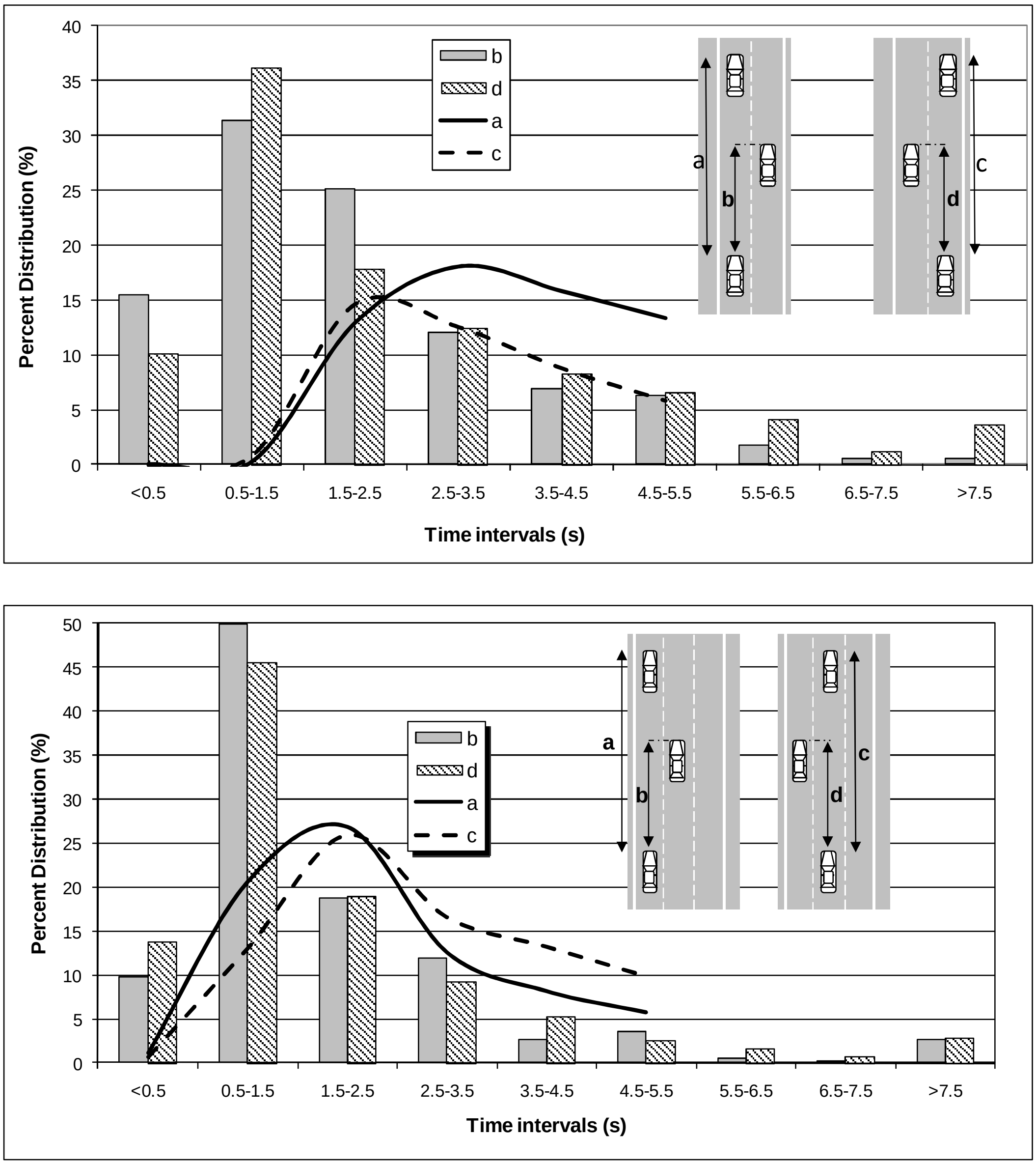

Fig. 1. Distribution of time headways, Newcastle upon Tyne and Karlsruhe, respectively, adapted from [5]

3. Further data

The findings reported above, in Fig. 1 for example, were based on data collected by video recordings and manual analyses which usually have a drawback of limits in data size. However, for a thorough microscopic analysis of traffic flow, a clear and defining scrutiny is needed. Having access to better resources and technological facilities, we therefore decided to collect additional data (by more automated ways) to scrutinise the case with larger sample sizes. These data were gathered at two sites on A55, the South East of Belfast, Northern Ireland (Fig. 2), using inductive loop surface detectors, shown in Fig. 3. The data contained around 43838 vehicles (at Site 1) and 42408 vehicles (at Site 2). Both sites were two straight sections of dual carriageways. This data set was collected by the involvement of Roads Service (Northern Ireland) in July 2007 and the readings were passed to us in spreadsheet data format.

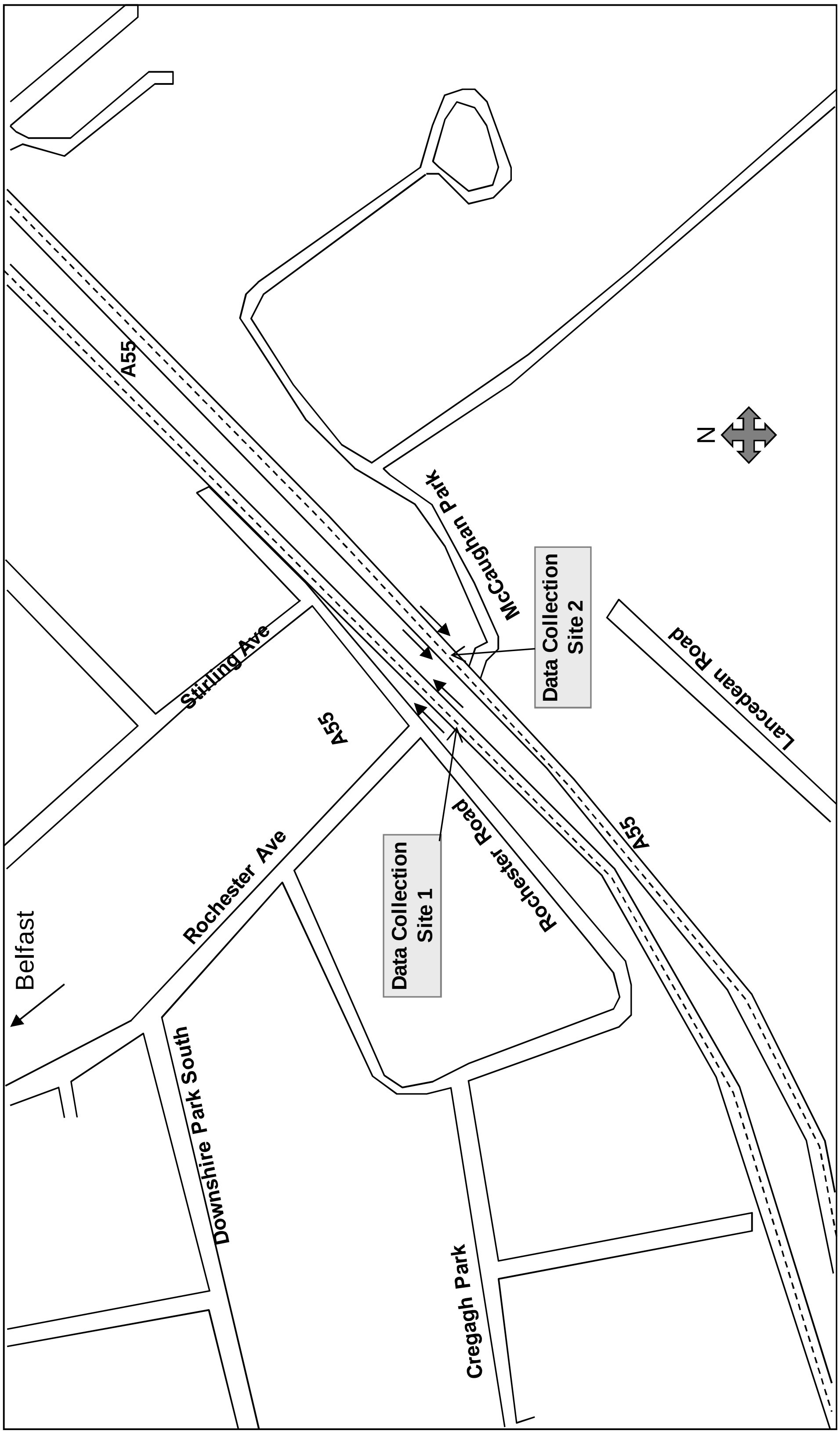

Fig. 2. The data collection sites, Belfast, Northern Ireland

Fig. 3. The data collection sites (inductive lops and the processing unit located in the median)

Due to the big data size, rather than manual investigations, we developed a piece of software to carry out the analyses in a more efficient way. Not only it saved time, but also the chance of making human errors in the analyses was eliminated. Fig. 4 depicts a snapshot of this program.

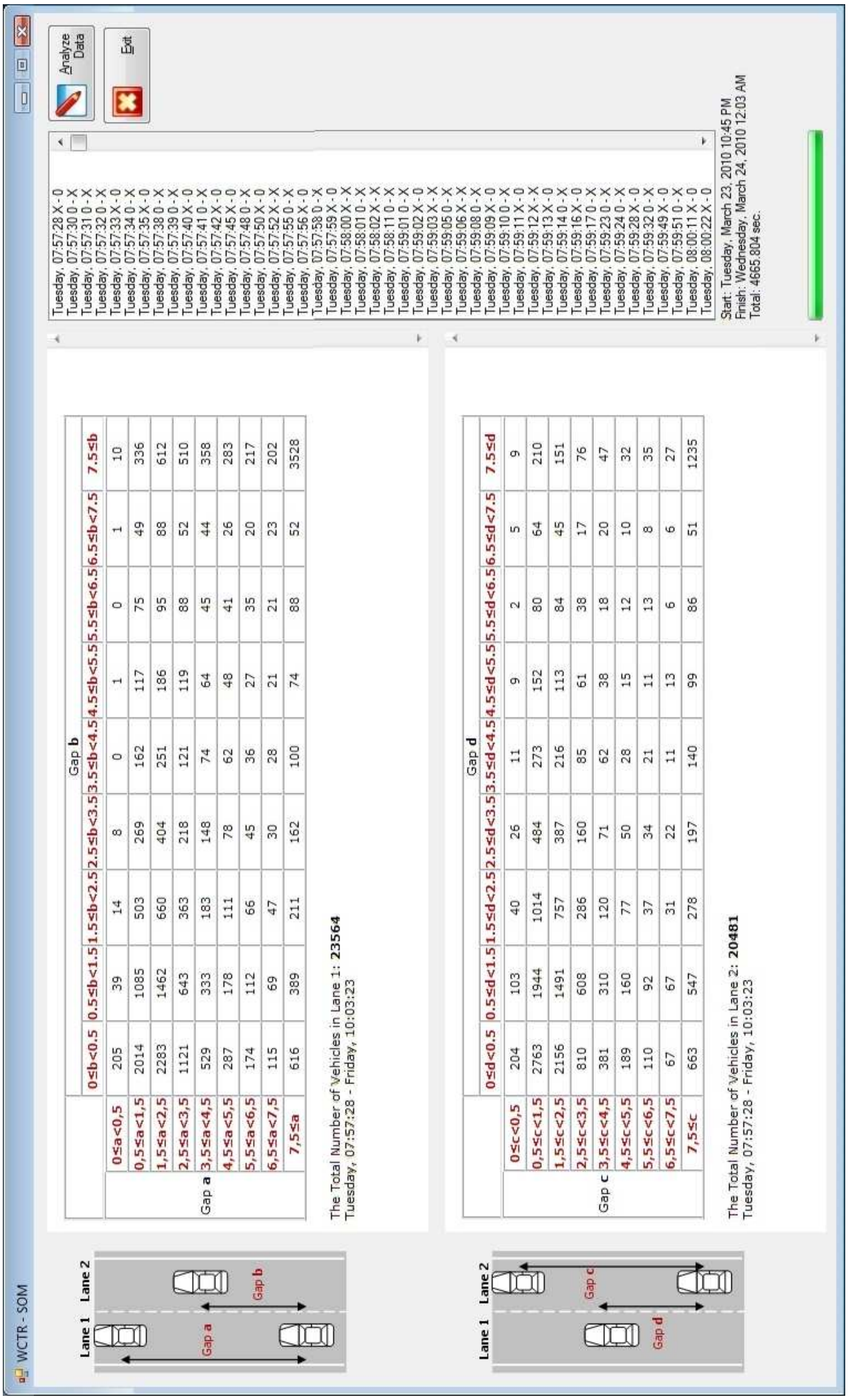

Fig. 4. A screenshot of our data analysis tool GAPPER

4. The findings

First of all we analysed time headways ('b' in Fig. 5 and 'd' in Fig. 6) between the neighbouring vehicles without taking the same lane leading vehicle's position into account. In other words, the relationship between 'a' and 'b' headways, and between 'c' and 'd' headways were not considered. When these two figures are compared with the English and German counterparts (Fig. 1), the findings did not show strong similarities especially for the < 0.5 second interval, although the bars for the first category in Fig. 7 did not exceed 25% (unlike Site 1). This showed that further scrutiny is needed. It may be a good idea to remind the reader here that the lower the percentages for the first category (i.e., the <0.5 second interval), the stronger the argument we put forward become, that is the interaction between the neighbouring lanes, leading to the need of adjustments in microscopic simulation models.

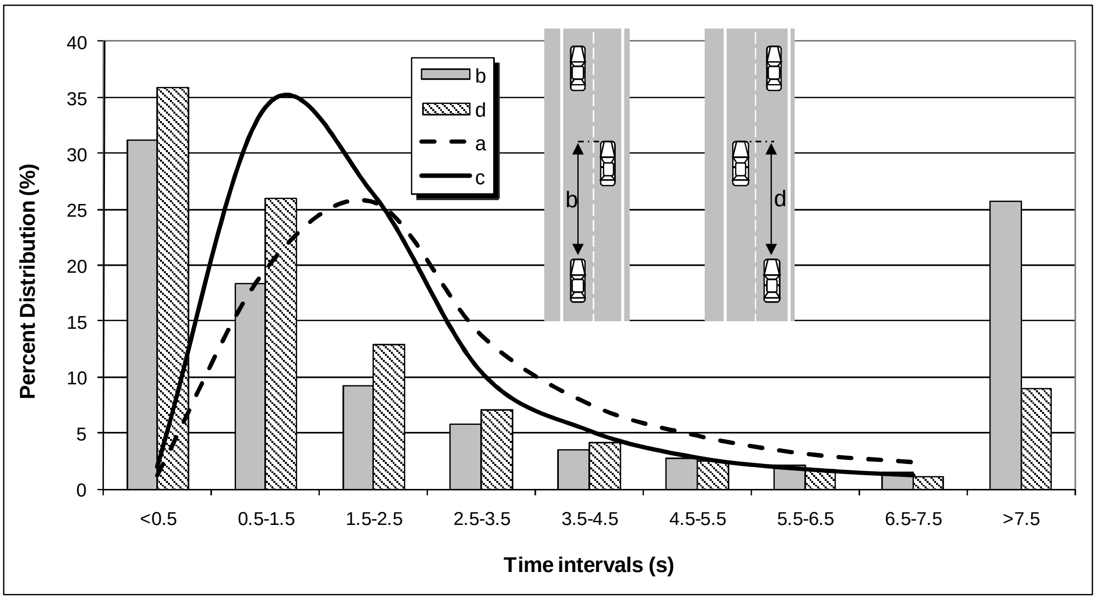

Fig. 5. Site 1 (A55)

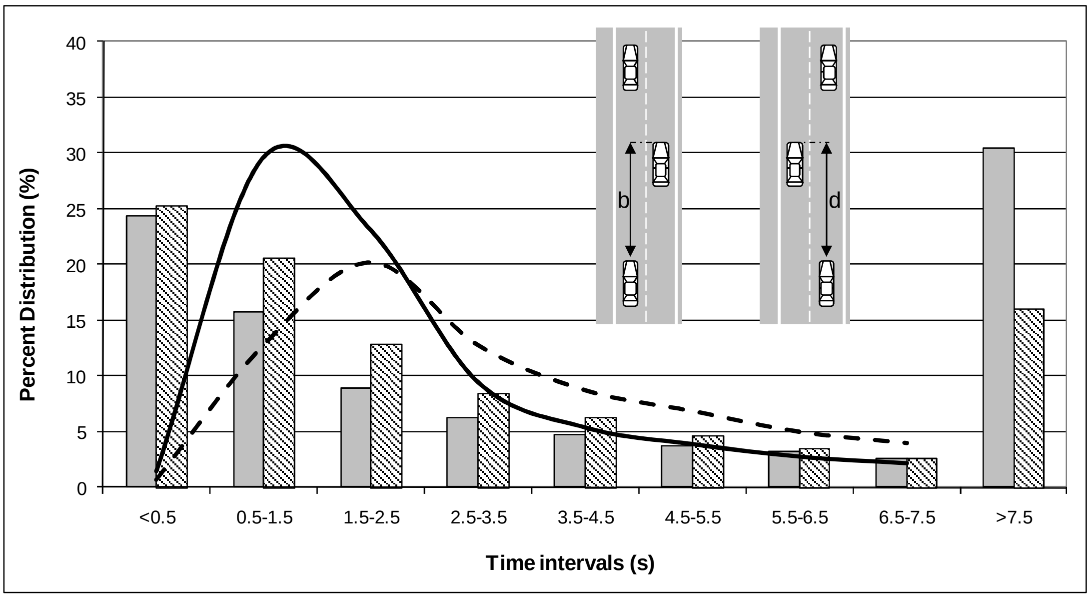

Fig. 6. Site 2 (A55), the legend is the same as Fig. 5

However, when we examine the data in more detail (with the inclusion of the longitudinal position of the leading vehicle travelling in the same lane as the follower), interesting results were discovered. When the gap between the two same lane vehicles is small (i.e. 0 < a < 1.5 seconds), the number of vehicles (travelling in the faster lane) with short neighbouring headways of (i.e. 0 < a < 1.5 seconds) are smaller than the next interval (i.e. 1.5 < a < 2.5 seconds) as shown in Fig. 7. This means that when there is a close following situation in the shoulder lane, the median lane vehicles preferred to stay (longitudinally) away from this vehicle pair. We interpret this as an evidence for strong relationship (interaction) between the two neighbouring lanes running in the same direction.

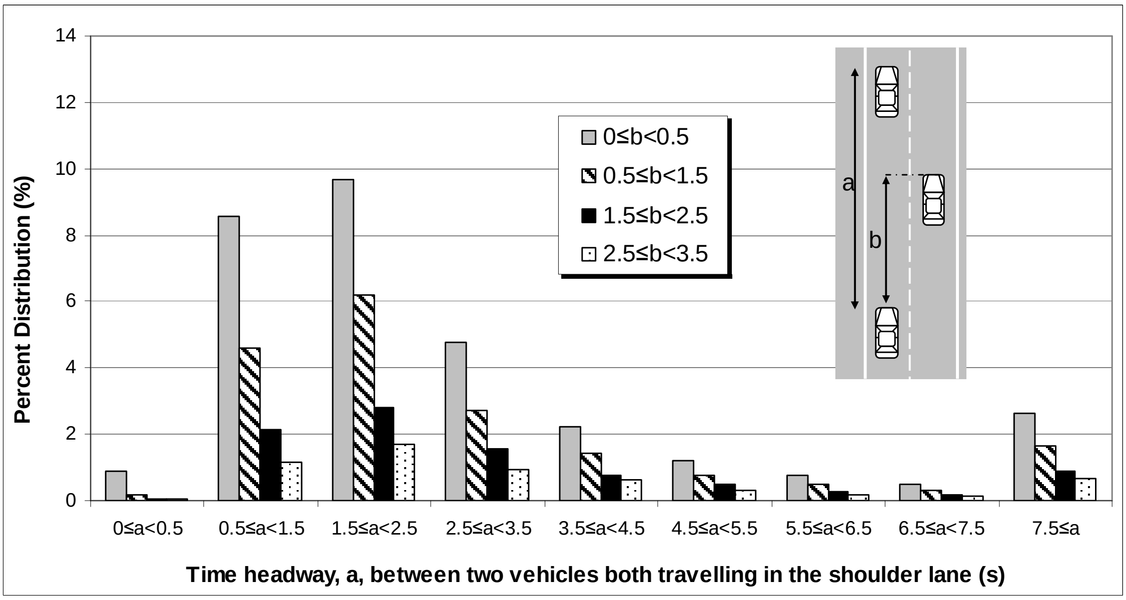

Fig. 7. Site 1, A55 (23564 vehicle pairs)

The existing microscopic models currently lack incorporating such interactions. This feature was less clear in Fig. 8 to 10, implying that more median lane (offside lane) vehicles adjust their position with respect to the situation in the shoulder lane (inside lane) rather than vice versa (i.e. the shoulder lane vehicles adjusting their position with respect to the situation in the median lane).

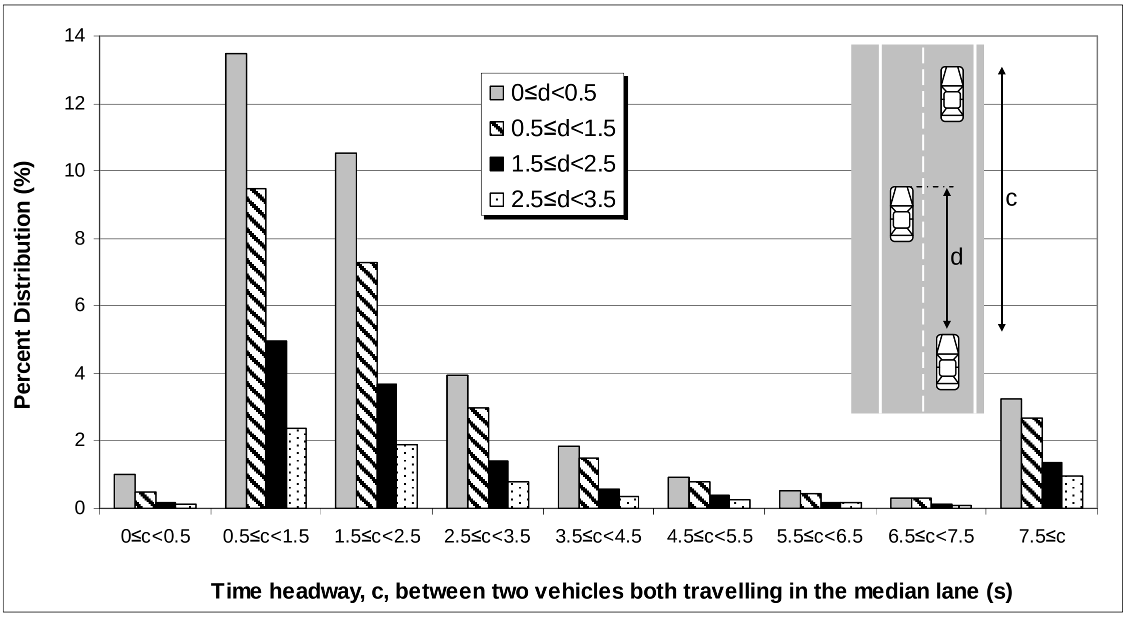

Fig. 8. Site 1, A55 (20481 vehicle pairs)

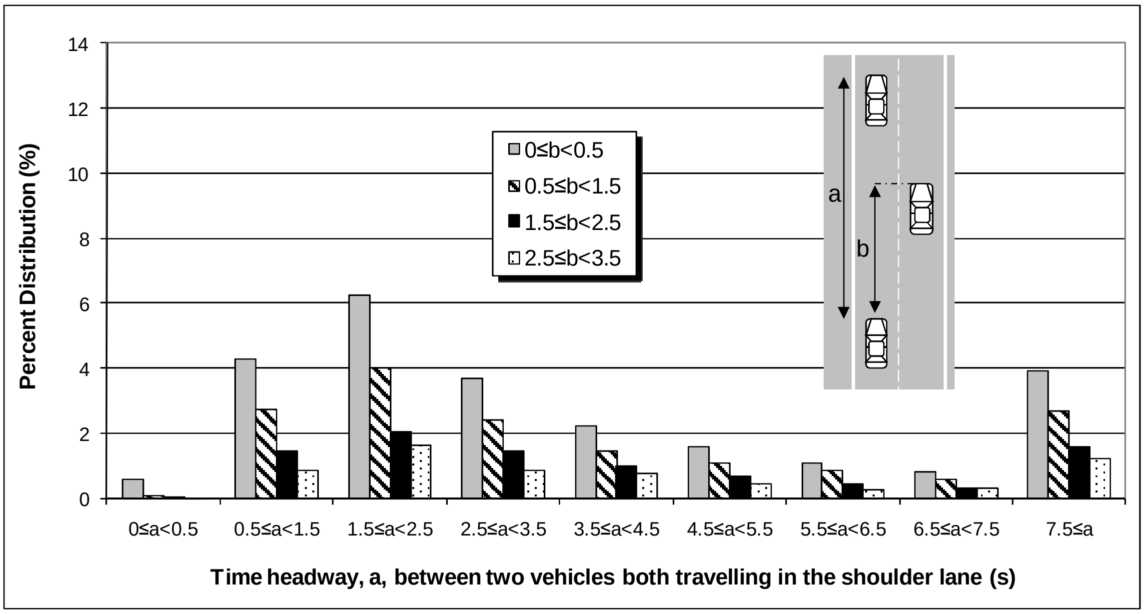

Fig. 9. Site 2, A55 (20878 vehicle pairs)

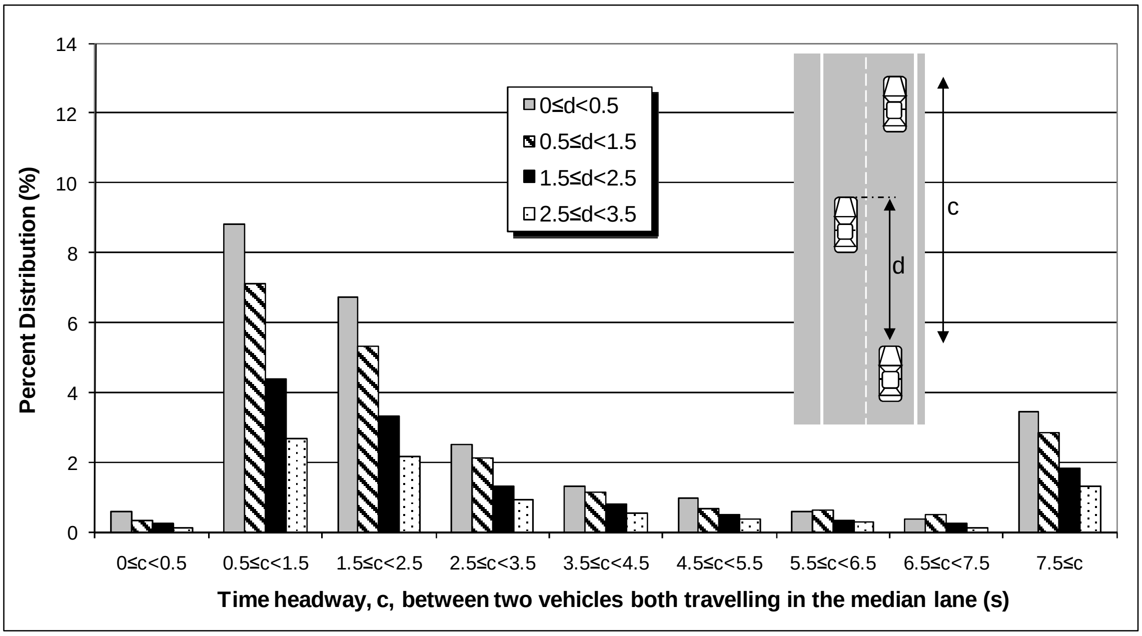

Fig. 10. Site 2, A55 (21653 vehicle pairs)

Finally, to be able to mimic an imaginary situation where two lanes are totally (physically) separated, we picked the inside lane of Site 1 and the outside lane of Site two (as if there is a physical barrier between the two unidirectional lanes), and compared the findings on the same diagram as shown in Fig. 11. The most striking finding is the percentage levels, which remained below 15%, whereas the values reached 25-30% in Fig. 5 and Fig. 6. This difference highlights the fact that traffic (time headways in particular) in two unidirectional lanes shows interactions between them and should not be treated in isolation in a lane by lane fashion, as is the case at the moment in modelling arena.

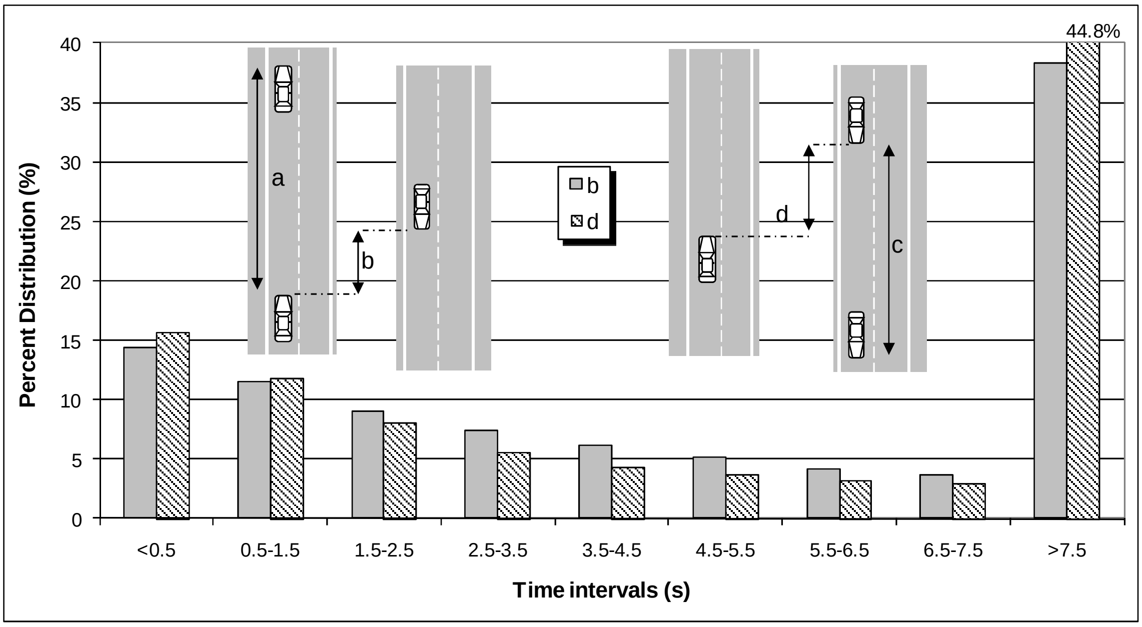

Fig. 11. Virtual combination of the shoulder lane of Site 1 and the median lane of Site 2 for comparison purposes

5. Concluding remarks

Existing car following theories may not be applicable in many situations due to some of the assumptions they posses. For instance, each vehicle is expected to be influenced directly by the one in front, which only happens in traffic flow where lane discipline is extremely ideal and the lanes are separated. In reality, however, analyses become more complex and further research is worth undertaking. If there was no interaction between the vehicles travelling in different lanes, the headways between the consecutive two neighbouring vehicles would have been random. The only factor would have been the flow level. Namely, with increasing flow, more vehicles would have been expected to keep shorter headways, resulting in some increase in the distribution with decreasing time headways. However, below a certain value of time headways, fewer numbers of drivers were willing to keep short headways as opposed to the above expectation. This means that considerable amount of drivers preferred to lag behind the vehicle in the adjacent lane, rather than driving side by side. The paper therefore is an attempt to mimic multilane traffic flow for better microscopic modelling. Further research can formulate this with the support of wavelet analogy for better interpretation of the results and this is subject to our ongoing work. Gunay and Erdemir [9] have recently applied this technology on an enhanced interpretation of traffic microsimulation of a sample network. But to analyse vehicular headways by means of wavelet transformation will be the first of its kind in the field of traffic engineering.

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