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TECHNICAL NOTE

Close Following Behavior: Estimation of Desired Gap Headway Using Loop Detector Data

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ABSTRACT

The desired gap headway of drivers, while close following, represents the main parameter in determining the following distance between vehicles. This paper uses the raw individual vehicles data taken from loop detectors for millions of vehicles used M25 and M42 in order to estimate the gap headway distributions between successive pairs of vehicles. The data used in this paper were filtered so as to focus on the cases of close following behavior only and more than quarter million pairs of close following cases is used to presents the results. Such huge sample size taken from loop detectors will increase the results reliability as previous research used limited sample size. The results presented the cumulative distribution of drivers' gap headway and suggested that the mean gap headway of drivers is about 1.1 s with standard deviation of 0.42 s. The lane choice found to be significantly influencing the desired gap headway for speed higher than 70km/h only. The effect of the follower vehicle type of the desired gap headway was also examined and the results suggested that such effect is insignificant. The findings of this paper are suggested to be used as inputs for traffic micro-simulation models.

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1. INTRODUCTION

Gap headway (in seconds), as shown in Figure 1, represents the time spacing from the rear of the leading vehicle to the front of the following vehicle. This is different from the time headway that represents the time spacing from front to front of successive vehicles. Based on gap headway values, the movements of vehicles regarded as either "free following" or "close following". Free following represents the cases with high values of gap headway while low values of gap headways represent the close following situations. Previous literatures [1-3] suggested a range for gap headway varies from 2 to 5 seconds to distinguish between these two situations. Therefore, desired gap headway drivers, in close following situations, could directly describe the following distance (clear spacing as shown in Figure 1) which is an essential skill in driving [4]. This explains why some traffic agencies in some countries make this parameter as a driving guide for safety reasons. For example, the UK highway code adopted the 2-second rule to advise drivers to keep a safe separation distance between vehicles [5]. It is obvious that most drivers prefer not to react with such policies and that explains the increasing of accidents rates everywhere [6-7].

Gap headway represents one of the important parameters used traffic microsimulation models. As a part of such microsimulation models and in applying most of the existing car following rules (see for example Gipps [8] and Al-Obaedi & Yousif [9]), the gap headway, at steady state condition (i.e. when the speeds of the leading and the following vehicles are approximately equal) is used to describe the reaction time for the follower's driver. Therefore, in such simulation models, the terms of reaction time and gap headway were both used in similar manner. For example, Gipps [8] developed a car following model and assumed that the follower will leave a clear spacing with a vehicle ahead equal to 1.5 the follower's reaction time. Al-Obaedi and Yousif [9] developed a simulation model for motorway merges and assumed that the minimum gap headway is equal to the follower reaction time. The reaction time was estimated based on Johansson and Rumer [10], which suggested that the mean reaction time is 0.73 s.

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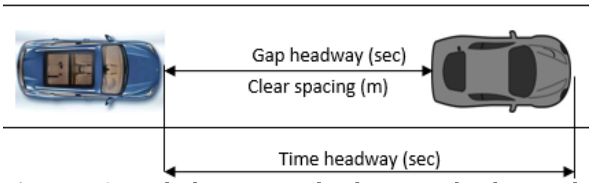

Figure 1. A graph showing time headway, gap headway and clear spacing

Considering previous research focused on close following behavior, Brackestone *et al.* [3] used instrumented vehicles for limited sample size and reported that the mean gap headway is about 1.25 s for speeds higher than 55km/h. Their work did not focus on the distribution of this factor among the drivers. Zhang and Bham [11] used car-following following trajectory data at steady state (when the difference in speed does not exceeding 5.4 km/h between the leader and the following vehicle) and found the mean gap headway of 0.6 s. Considering the effect of vehicle type on close following behavior, Yousif and Al-Obaedi [12] examined the effect of leading vehicle's type (i.e. small car or a truck) on the following distance behavior and reported no significant difference. Similar findings were also obtained by Brackestone *et al.* [3] when examined the effect of "Vans" on the following behavior. Little attention was paid to the effect of follower's vehicle types. Robert, et al. [13] examined the effect of three values of gap headways on following behavior and reported that drivers feel less comfort with short headways while following slower vehicles. Risto and Martens [14], based on data obtained from forty participant drivers, reported that drivers cannot always maintain a desired headway even when they are informed. While there is a remarkable research focuses on distribution of time headway (see for example, Badhrudeen, et al. [15]), the gap headway distribution for drivers at close following situations got little attention in previous research, so far. As a continuum to the previous work by Yousif and Al-Obaedi [12], this paper uses the raw individual vehicles data taken from loop detectors for millions of vehicles used M25 and M42 in order to estimate the gap headway distributions between successive pairs of vehicles. In addition, the effect of driving lane and follower's vehicle type on gap headway are considered. The findings of this will help in providing the most important parameter based on real traffic data to be applied by traffic micro-simulation models.

2. METHODOLOGY

The data used in this work represents a full 14 days of individual vehicles raw data, extracted from inductance loop detectors on sections from two UK motorways. There are M25 and M42 motorways that have four and three lanes per direction, respectively. The data extracted from inductance loop detectors on sections from the so called "Managed Motorways" [16] of M42 between Junctions 5-6 and M25 between Junctions 15-16. The data represents about four million cases of leader/follower cases where speeds, headways and length of vehicles for all vehicles were given in the data. Since the data represents a full 14 days of successive vehicles, the flow rates at these two motorways were varied from minimal to maximum volumes reaching the capacity of about 6000 veh/h and 8000 veh/h for M42 and M25, respectively. According to UK regulation, the heavy vehicles are banned from using the offside lanes at these motorways.

It should be noted here that this source of data is more reliable to estimate drives' gap headway than other sources of data since drivers' behavior is usually not affected by loop detectors. The gap headway (GH) is estimated using Equation (1) as follows:

$$GH = hd - \frac{L_L}{S_F} \tag{1}$$

In order to focus on situations of close following behavior only, the data should be filtered properly to remove the cases of free following. As reported elsewhere [3], the close following situations could be determined by selecting appropriate maximum gap headway and maximum speed differences between the pairs of leader/follower vehicles moving at the same lane.

The use of a maximum gap headway threshold is important in defining close following situations since it is well known that with an increasing in spacing between vehicles, the follower vehicle becomes free to increase its speed. In addition, the use of a threshold to define a maximum speed difference between the leader and follower pairs of vehicles is essential as the traffic at close following situations nearly has similar speeds. Therefore, similar method has been used to that suggested by Brackstone, et al. [3] and Yousif and Al-Obaedi [12] when they used a value of 2 seconds as the maximum gap headway at car following situations (i.e. close following). This means that the cases when the gap headways were greater than the maximum limit, such cases are excluded from the data. The use of 2 seconds value is consistent with the finding of Johansson and Rumer [10] when they found that the maximum drivers' brake reaction time of 2 seconds. It is believed that the use of such 2 seconds' limit will not influencing the accuracy of estimation average gap headway as it is widely reported that higher values may not representing "close following situations".

Considering speed difference between the successive peers of vehicles, a value of 1.5 m/s (5.4 km/h) is selected as the maximum relative speed difference between the leading and the following vehicles as suggested by previous studies (see for example [2] and [11]). This means that the cases when the speed differences were greater than the maximum limit, such cases are excluded from the data. In addition, and to be confident that the data used in estimating drivers' gap headway represents only vehicles which are influenced by their leaders (i.e. vehicles ahead), all vehicles with speeds higher that 100km/h were excluded from the data. This is based on previous research work when suggested that motorways' speed at capacity is mostly less than 90km/h (refer to [12] and [17], for example). The selection of 100km/h value is not affecting the results of other speed groups as each group were analyzed individually.

Considering the effect of leading vehicle type, Yousif and Al-Obaedi [12] found no considerable effect for the leading vehicle type on clear spacings between vehicles for all ranges of speeds. Therefore, the effect of leading vehicle type (i.e. Car or HGV) is ignored in this study. However, the effect of follower vehicle type is examined in this work as will be discussed later.

Using manual analyzing or even using of Excel worksheet to analyze data with millions of vehicles is a time consuming process. Therefore, a computer program using FORTRAN is written and used for data analyses purposes. The program is prepared to separate the successive vehicles according to their lanes and their directions to apply the methodology as described above.

3. RESULTS AND DISCUSSION

This section presents the results obtained by applying the methodology described above. It should be noted here that the sample size used in this study after filtering the data represents more than quarter million pairs of close following. Such huge sample size taken from loop detectors will increase the results reliability as previous research used limited sample size.

3. 1. Average Gap Headway with Average Traffic Speed Figure 2 shows the mean gap headway and standard deviation for average speed ranges from 10 to 100 km/h for M25 motorway based on middle lane data (Lane 2). The mean gap headway for all ranges of speeds from 60 to 100km/h were about 1.15s with standard deviation of 0.43 s. The maximum and minimum values were 0.2 and 2.0 s, respectively. For M42 motorway, the results seem similar to those for M25 as shown in Figure 3. The results of average gap headway for the other lanes has also considered as will be discussed in this paper.

Figure 2 also shows that the average gap headway is increased with an increase in congestion severity (i.e. with reducing of speeds). For example, the average desired gap headway for average speed of 15km/h is about 1.5 s, while the average gap headway is 1.1 s for the speed of 75km/h. This may be due to a fact that drivers during traffic congestion may feel by the uselessness of keeping their desired gap headway.

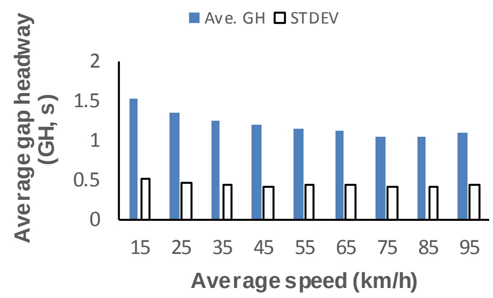

Figure 2. Average gap headway and standard deviation based on M25 data

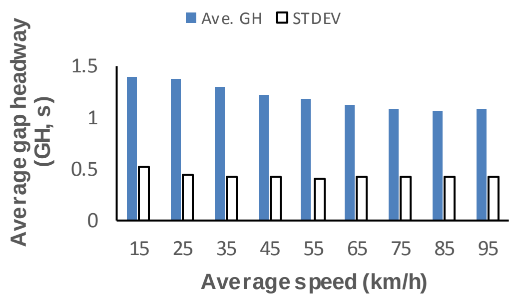

Figure 3. Average gap headway and standard deviation based on M42 data

The differences in average gap headway between normal and congested traffic conditions, seems to be not practically important when considering their effect on the following distance (i.e. clear spacing between vehicles). For example, when the average speed is 15km/h, the gap headway differs from that for the average speed of 75km/h by about 0.3 s; which means only about 1.25m difference in the gap headway. Such small difference could easily be considered by applying the following regression equation (Equation (2)) which suggests strong relationship (r^2=0.99) between speed and gap headway for speeds below 70km/h.

Considering the mean value of 1.1 s as a mean drivers' gap headway for speed higher than 70km/h, the desired gap headway could be corrected during traffic congestion using the following regression equation (Equation (2)) which is derived based on results in Figure 2.

$$GH = \begin{cases} 1.5 - 0.006speed & speed \leq 70km/hr \\ 1.1 & speed > 70km/hr \end{cases} \quad (2)$$

3. 2. Effect of Desired Lane on Gap Headway Selection This section examines the effect of desired lane on the average gap headways for each speed range. Figure 4 shows the average gap headway with speed ranges on lane bases using the data from M42. This figure suggests that even for the same average speeds, drivers in the offside lanes, for speeds higher than 70km/h, tend to choose lower gap headway than that selected on the inside lanes. For speeds less than 70km/h, similar gap headways were observed. This indicates that drivers in congested situations (at low speeds) choose to keep their minimum gap headways as there are insufficient gaps in other lanes operating more or less with similar speeds [18].

3. 3. Distribution of Gap Headway Figure 5 shows the distribution of drivers' gap headway for M42 motorways and for speed ranges of 60-70 km/h and 70-80km/h. This figure suggests identical distributions for both of these speed ranges. The figure suggests that about 15 percent of drivers maintain gap headway of 0.5 s or less. This supports the close following behavior reported by some literatures (e.g. Brackstone and McDonald [19]). It should be noted here that the same findings were also obtained based on M25 motorway's data.

The normality of the distribution has also been tested. Figure 6 shows the histogram for actual and predicted (from normal distribution) gap headway' frequencies. This figure shows that the actual curve skew to the left compared with the normal distribution curve. The hypothesis of having normal distribution for gap headway is rejected with confidence level of 95%.

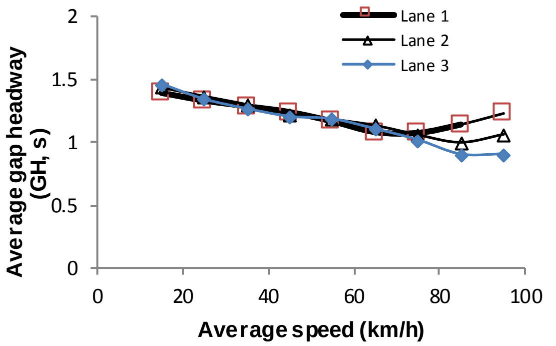

Figure 4. Average gap headway on the lane bases for M42

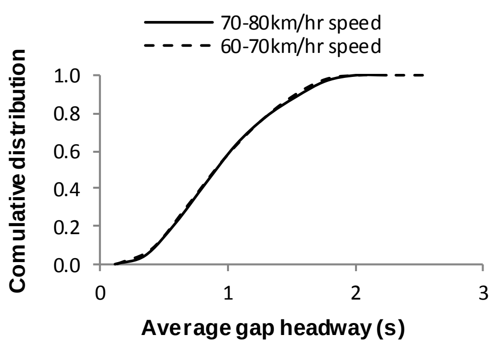

Figure 5. Gap headway distribution based on M42 data

Therefore, in applying the results in traffic micro-simulation models, it is suggested to use Figure 5 with generated random numbers derived from uniform distribution.

3. 4. Effect of the Follower Vehicle's Type on Gap Headway The effect of the follower vehicle type of the gap headway was also examined. Figure 7 compares the gap headway distribution between small cars and heavy goods vehicles (HGVs) drivers for speed ranges from 60 to 70km/h. This figure suggests only slight differences, for example, the 70th percentile of gap headway for HGVs drivers is only higher than that for "small cars" drivers by less than 0.1 s. Such slight differences are regarded as "insignificant" according to Kolmogorov-Smirnov statistical test with confidence level of 95%. Therefore, the effect of the follower vehicle type on the gap headway is recommended to be ignored.

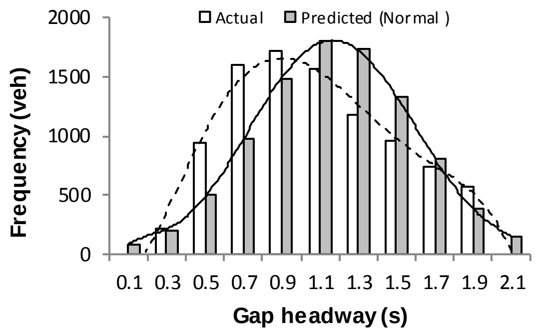

Figure 6. Histogram for actual and predicted gap headway' frequencies

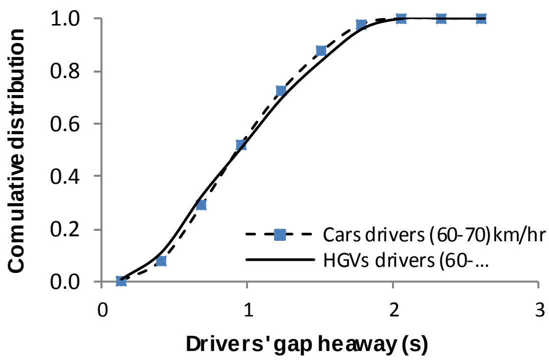

Figure 7. Gap headway distribution based of follower's vehicle type

4. Summary

This paper used the raw individual vehicles data taken from loop detectors for millions of vehicles used M25 and t M42 in order to estimate the gap headway distributions between successive pairs of vehicles. The data used in this paper were filtered so as to focus on the cases of close following behavior only and more than quarter million pairs of close following cases is used to presents the results. The results presented the cumulative distribution of drivers' gap headway and suggested that the mean gap headway of drivers is decreasing with increasing of traffic speeds of upto 70km/h with about 1.1 s with standard deviation of 0.42 s at that speed. The lane choice found to be only significantly influencing the desired gap headway for speed higher than 70km/h. The effect of vehicle type of the desired gap headway has also been examined and the results suggested that such effect is insignificant. The findings of this paper are suggested to be used as inputs for traffic micro-simulation models for either desired gap headway or reaction time parameters. Further research is recommended to test the applications of these findings on traffic micro-simulation models' behavior.

5. ACKNOWLEDGMENT

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چکیده

گشتاور مورد نظر رانندکان در حالی که نزدیک بودن، نشان دهنده پارامتر اصلی در تعیین فاصله بین وسایل نقلیه است. این مقاله از داده های خودروهای خام فردی گرفته شده از آشکارساز حلقه برای میلیون ها خودرو استفاده شده از M25 و M42 به منظور تخمین توزیع پیشرفت شکاف بین جفت های متوالی وسایل نقلیه استفاده می کند. داده های مورد استفاده در این مقاله فیلتر شده اند تا تمرکز بر موارد رفتاری نزدیک باشد و بیش از یک چهارم میلیون جفت موارد زیر برای ارائه نتایج استفاده می شود. اندازه نمونه ای بزرگ از آشکارسازهای حلقه به عنوان تحقیق قبلی استفاده از اندازه نمونه محدود افزایش اعتبار نتایج را افزایش می دهد. نتایج نشان داد که توزیع تجمعی ریزپردازنده رانندگان، نشان می دهد که متوسط رانندگی شکاف رانندگان حدود ۱/۱ ثانیه با انحراف معیار ۰/۴۲ ثانیه است. انتخاب لاین نشان داد که به طور قابل توجهی تحت تاثیر سرعت پیشرفت مورد نظر برای سرعت بیش از ۷۰ کیلومتر در ساعت تنها است. اثر نوع وسیله نقلیه دنباله ای از مسیر پیشرفت مورد نظر نیز مورد بررسی قرار گرفت و نتایج نشان داد که چنین اثر ناچیز است. یافته های این مقاله پیشنهاد می شود که به عنوان ورودی برای مدل های شبیه سازی ترافیک ترافیکی استفاده شود.

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