Study on Driving Behavior in Follow State Driving Condition in Bangkok

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Abstract

Since, each driver has his/her individual characteristic. This will lead to different driving behavior which significantly affects to the safety on the road and also traffic system. Nowadays, driving behavior is considered in designing active safety systems. Thus, the objective of this experiment is to study on driving characteristic by using drive recorder. The study was conducted concerning the follow state (car-follow-car situation) driving characteristic focus on Bangkok driving. The specific urban route had been chosen and experiment time is fixed to obtain data from a similar traffic condition, participants in the same range of age [20-30] performed an experiment on the same vehicle. The data were collected by using drive recorder to collect velocity and video capture in order to apply image processing technique. Image processing is the technique to calculate distance by transforming perspective view from video into bird's-eye view so distance can be measured directly. The terms called headway distance and time headway is investigated. Headway distance is the distance between experiment vehicle and preceding vehicle, obtained by image processing technique. Time headway [sec] is obtained from headway distance divided by velocity of experimental vehicle, then use time headway to conduct histogram comparing the occurrence of driving time headway of each driver. For the result, time headway range of participants is around 0.5-1.5 sec. with peak at 1 sec. Note that lower time headway may lead to frontal accident also.

Keywords*:* Follow state driving, driving behavior, drive recorder, image processing, time headway

1. Introduction

Nowadays, there are many people using roads to reach their destinations and are increasing everyday. Thus, study on human driving behavior is very interesting in term of traffic congestion, accident and so on.

For everyday driving, the most occupied situation of urban driving is to drive follow to the preceding vehicle because avoiding the fellow traveler is inevitable. Moreover, due to the fact that a following control model identified for each driver offers a means to extract a deeper understanding of the driver's individual behavior.

By using drive recorder, web camera and range detector program, all integrated together to perform analysis, based on distance between preceding vehicle and experimental vehicle defined as headway distance. Combining each divided categories data together to make a database to be reference for Thai people.

Because this study is only the pre-liminary of the database construction, thus, this study can be continued and become tools for database construction for car-follow-car situation in specified road, district etc.

2. Following state driving

Follow state is defined as the driving states that occur in car-follow-car situation (fig. 1). Drivers will try to control the speed of vehicle in specific headway distance to match with the speed of preceding vehicle. In order to analyze the follow state driving, there is the numerical data to represent; which is time headway.

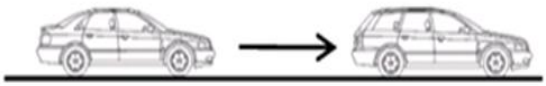


Fig. 1 Follow state driving diagram

2.1 Time headway

Time headway can be defined as headway distance divided by velocity of experiment vehicle, as shown in eq. 1. From equation, if velocity is constant, time headway will be proportional to the headway distance. This means the closer to the preceding vehicle, the lower the time headway will be. In contrast, if headway distance is constant, time headway will be decreased when the velocity is higher.

$$\text{Time headway} = \frac{\text{headway distance}}{\text{Host vehicle velocity}} \quad (1)$$

In conclusion, time headway decrease either velocity is increased or headway distance is decreased. By observing the change of two parameters, for velocity, higher velocity will lead to more risk to the accident, same as reduced in headway distance may lead to frontal accident also.[1-2]

3. Condition of study

For studying the behavior in follow state driving condition, the specific scope of experiment must be defined in order to analyze and compare data precisely. Moreover, various types of data from different sources will lead to complexity in comparison and may cause error in result. Thus, controlling the condition criteria, which are driver, route and vehicle, is necessary.

3.1. Driver

For analyzing driving behavior, drivers for this experiment are controlled by gender and age range. Because this study was done in university lab, age range is limited to 20-30 years old and must had both male and female equally for better comparison, drivers profile are shown in table 1.

Table.1 Driver profile

Driver	Gender	Age (yr.)	Experience (yr.)
M1	M	22	4
M2	M	22	4
M3	M	21	3
M4	M	22	4
F1	F	20	2
F2	F	21	2
F3	F	26	8
F4	F	22	4

3.2. Route

In order to analyze follow state driving, suitable route and traffic was selected by considering the condition below.

- Must be the well-known route in order to be reference of Bangkok driving characteristic
- Follow state driving condition at speed around 60-80 km/h

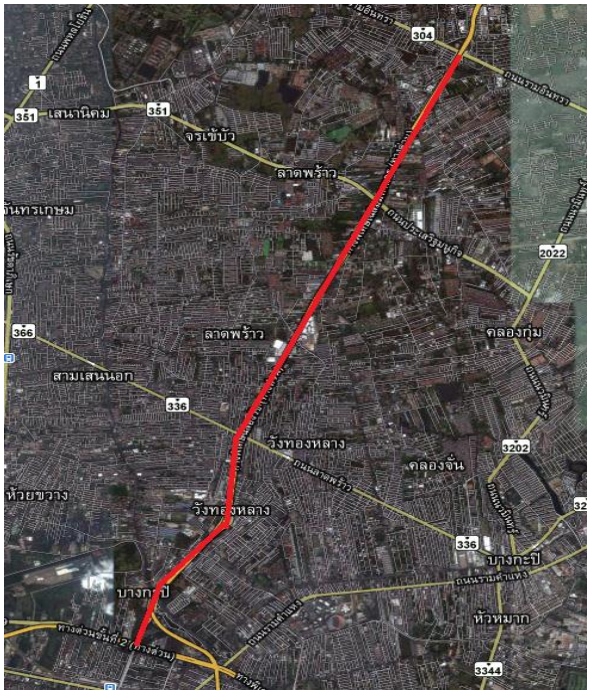


Fig 2. Experiment route (Praditmanutham Rd.)

Following the criteria, Praditmanutham Rd. (fig. 2) is the section that following state driving can be observed because the density of traffic is not much high, which allow drivers to use their desired speed for comfort driving and also has enough distance (about 20 km) for experiment. Additionally, street isle will prevent cars from opposite direction not to disturb the driving so drivers can concentrate only on preceding vehicle.

3.3. Vehicle

Vehicle is one of the factors that affect the driving characteristic because different size of vehicle can lead to the difference estimation of the size during driving from driver. Thus, the same vehicle is fixed for the experiment and also should be commercial car in Thailand market, which is 2006 Toyota Yaris, as shown in fig. 3.

Fig 3. Experiment vehicle (2006 Toyota Yaris)

4. Drive recorder

In order to inspect the accident, evidence is the most necessary. Thus, drive recorder is invented for this purpose. It can record the situation before and after accident occurred, which will be helpful for classifying the cause of accident and also become evidence for arresting absconding litigant. Drive recorder is not only a tool that can record the driving situation, but driving behavior of the host is also recorded. Thus, studying the driving characteristic is possible in terms of behaviors that lead to the action of the vehicle.

For this study, the commercial drive recorder (HORIBA DR-9100 drive recorder), as shown in fig. 4 is used. Data will be recorded and opened using software “drecplayer” (fig. 5) and can be converted it into .csv format later, which is necessary for analyzing time headway.

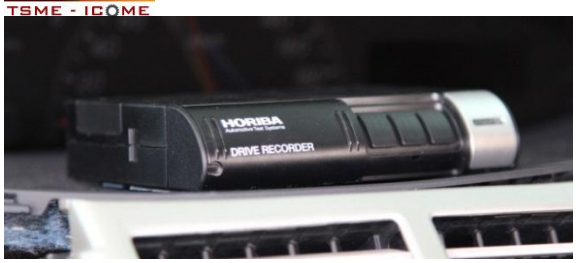


Fig 4. HORIBA DR-9100 drive recorder

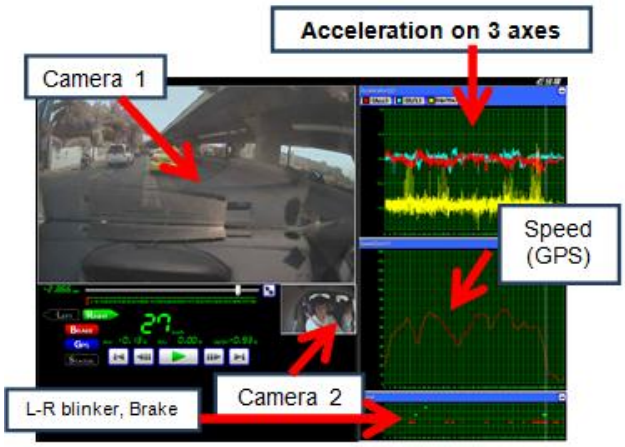


Fig 5. Drive recorder program interface (drecplayer)

4.1 Primary parameters

In order to analyze the time headway, one of required parameters; which is velocity of experiment vehicle, can be achieved from drive recorder. The method of measuring vehicle velocity can be achieved by two methods; from speedometer and GPS signal. However, only GPS speed signal is supported with continuous recording

4.2 Secondary parameters

Moreover, this drive recorder can also record two cameras simultaneously, acceleration in 3-axis, and also input signal from driver such as turning and brake signal. These data can be used to verify the driving behavior at the instant.

5. Image processing

For another required parameters, the headway distance, image processing technique is involving as a processing unit to convert webcam video into headway distance data.

Image processing is any form of signal processing for which the input is an image, such as a photograph or video frame; the output of image processing may be either an image or, a set of parameters related to the image.

For this experiment, video is obtained separately from webcam attached to the roof of experiment vehicle, as shown in fig. 6 and by software processing, the output is headway distance, will be described later in this paper.

Fig. 6 webcam for detecting headway distance

5.1 Bird's-Eye View Transform

To measure distance, converting the camera view of the scene into a top-down "bird's-eye" view is necessary by processing the two-dimensional map image. Display processing operation is applied to the birds-eye view.

Fig. 7 Raw image from webcam

Fig. 8 Transformed image

Projective transform convert one type of trapezoid to another type of trapezoid to get a linear relationship from bird's eye view. This means the distance in y-coordinate is varies linearly with real distance. The examples are shown in fig. 7 and 8.

5.2 Edge detecting

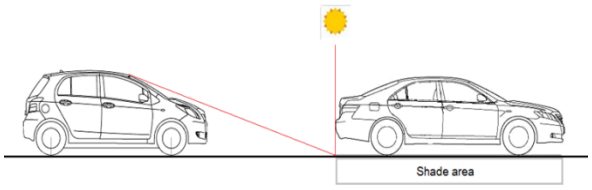


Fig. 9 sketch of shaded area for measuring distance

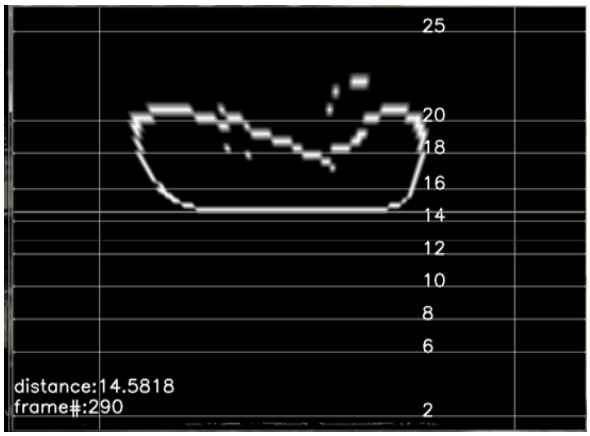


Fig. 10 Transformed, Edge-only image

For the experiment, shadow of rear skirt is selected to be the reference of headway distance measuring. The reason is because the experiment time is about noon, which the sun is right above to the car and the shadow is shaded almost exactly to the edge of vehicle (fig. 9).

For image processing, edge of shadow of preceding vehicle must be verified in order to determine the headway distance. By converting transformed image into edge-only image (fig. 10), edge of object can be detected and measuring the distance is achieved.

5.2.1 Searching edge condition

In order to classify the edge of object whether it is the car or not, boundary condition must be specified as below

- For y-axis, the measuring range is from 2 m to 25 m in front of vehicle. For greater than 25 m is specify as 99 and lower than 2 m is -1.
- For x-axis, only lateral range of 2.5 m (as the standard of Thai road lane width) from the center of vehicle will be measured. Moreover, line implied to be edge of the car must occupy at least 30% of the road lane or length approximately more than 75 cm.

5.3 Headway distance

The result of searching data will be put in .xls format. When viewing recorded data (fig. 11) in Microsoft Excel, Column A display the number of frame of each row, define as 1/30 seconds, which is the same as drive recorder recording rate (about 30 Hz). Column B is assigned to display the headway distance value in meters.

	A	B	C
1456	1456	23.2387	
1457	1457	23.1278	
1458	1458	22.7202	
1459	1459	99	
1460	1460	22.3286	

A: No. of frame (30 frame per sec)

B: Headway Distance (meter)

Fig. 11 Sample of processed headway distance

6. Result

In order to analyze individual behavior of driver, time headway will be mainly used to describe following state characteristic of driver as described before.

6.1 Sample result of the experiment

For the result, because there were 8 trips of experiment, each trip can be described in three types of graph, which is not inconvenience to explain all data in this paper. Thus, only one sample trip will be presented.

6.1.1 Histogram of time headway

By plotting time headway value using histogram chart, it will show the frequency time headway of each driver, which can be classified as “behavior”.

This part will show the histogram of time headway of each trip. For time headway greater than 5 sec, data will be considered as 6 sec and will be combined on the right part of each graph.

For histogram of driver M1 (fig. 12), the most preferred time headway is about 0.7 – 0.9 sec. and also the most frequent is at about range 0.5 – 1.1 sec., which is relatively low compare with typically safe value which is above 1 sec[2].

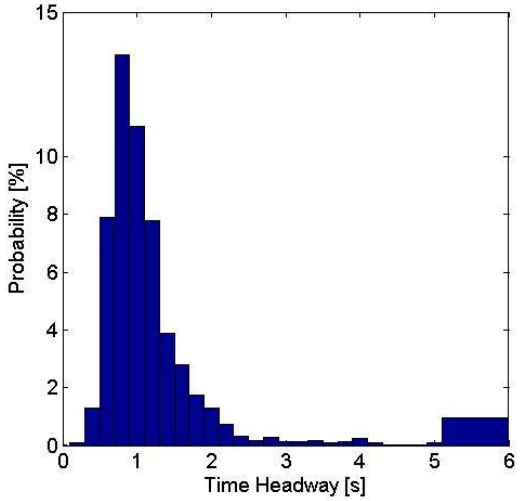


Fig. 12 histogram of time headway of driver M1

6.1.2 Contour line between headway distance and velocity

Next, by plotting the contour of headway distance and velocity of experiment vehicle, the information about the frequency of the headway distance in different velocity is presented. In addition, the slope of the data is the time headway of the driving. Thus, the slope of the most dense data is the preferred time headway of the driver.

For driver M1, the most frequent velocity was around 15 – 20 m/s (54 – 72 km/h) at headway distance about 10 – 15 m. By analyzing, the desired level of velocity and headway distance of this driver can be stored in database and then can be compared to the other drivers.

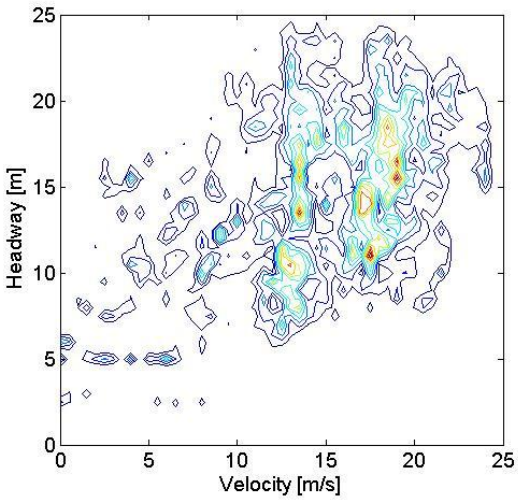


Fig. 13 Contour line between headway distance and velocity of driver M1

6.1.3 Contour line between time headway and velocity

Contour line between time headway and velocity is plotted also in order to study the trend of time headway that will it be correlated with vehicle velocity or not. From the results, time headway of all data will slightly decrease when the velocity is increased. This can be concluded

that the relation between time headway and velocity is unique and are not constant.

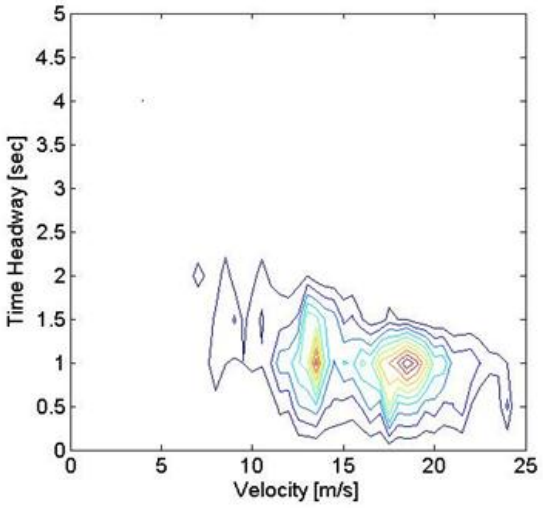


Fig. 14 Contour line between time headway and velocity of driver M1

From fig. 14, time headway was in the range of 0.5 – 1.5 sec but the upper value is reduced to 1 sec when the velocity was increased. This can clearly show the trend of time headway relates with velocity. It noted that the lower time headway, the higher chance in frontal accident will be.

6.2 Result of all samples

The results from all participants were analyzed and presented as below.

6.2.1 Histogram of time headway

For the time headway histogram, the results will be presented only the most preferred time headway of participants, shown in table 2.

Table. 2 Prefer time headway(s) of participants

Driver	Male	Female
1	0.7 - 0.9	0.9 - 1.5
2	0.9 - 1.5	1.1 - 1.7
3	0.9 - 1.1	0.7 - 0.9
4	1.1 - 1.5	0.9 - 1.1
Average	1.075	1.1
SD	0.192	0.224

6.2.2 Contour line between headway distance and velocity

By dividing the result in the same gender and combined, the data is more simplified and can be compared in each category.

For combined contour line of headway distance and velocity (fig. 15 and 16), preferred velocity of both male and female are the same, about 10 - 20 m/s (36 – 72 km/h) but the preferred headway distance of male (15 m) is higher than female (10 m).

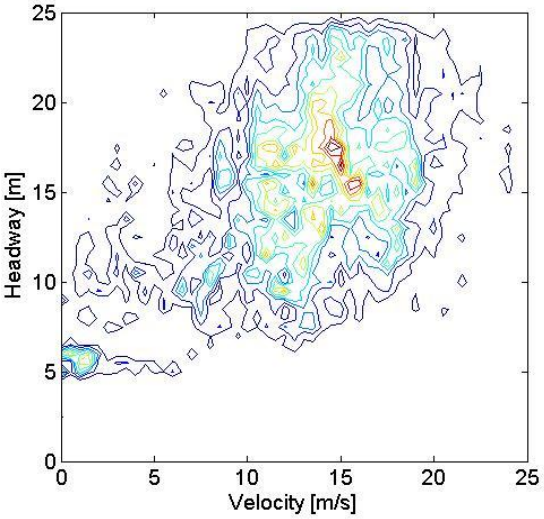
6.2.3 Contour line between time headway and velocity

For the same purpose, the data of contour line between time headway and velocity will be classified as gender and will be collapsed into two graphs; one from male and one from female, as shown in fig. 17 and 18.

For contour line of time headway and velocity (fig. 17 and 18), both male and female give the same result, 0.5 – 1.5 sec in time headway and 10 – 20 m/s in velocity. It noted that there is time headway in velocity lower than 5 m/s (18 km/h) for female contour. The reason was female trip faced traffic congestion.

7. Conclusion

In conclusion, the average of the time headway of participants is about 1.088 sec and male average is slightly lower than female. However, the most preferred headway distance of female is lower. This means even female drive closer to the preceding vehicle, time headway is almost the same as male. Moreover, contour of time headway and velocity show that time headway of all participants were decreased when velocity is higher.



and velocity of male driver

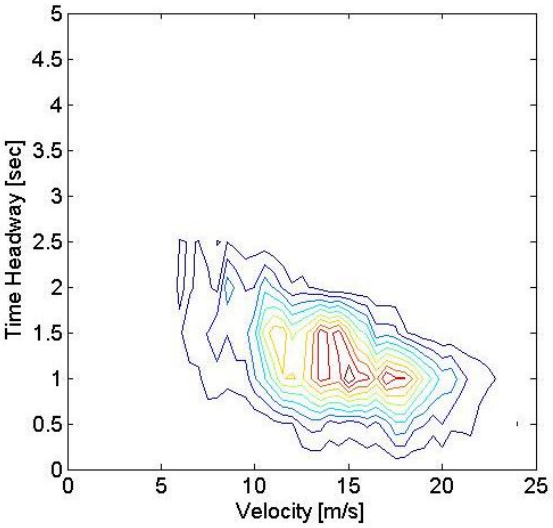


Fig. 17 Contour line between time headway and velocity of male driver

However, in order to state that this time headway is the behavior of driver and male always lower are not appropriate because the amount of data is too low, more and more trip are required in order to confirm this is the behavior of the driver.

8. Acknowledgement

Special thanks to Pongsathorn Lab and Nagai Lab, Department of Mechanical System Engineering, Tokyo University of Agriculture and Technology for drive recorder.

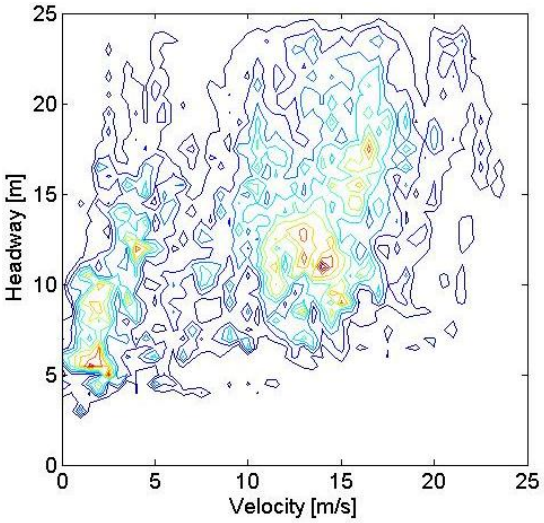


Fig. 16 Contour line between headway distance and velocity of female driver

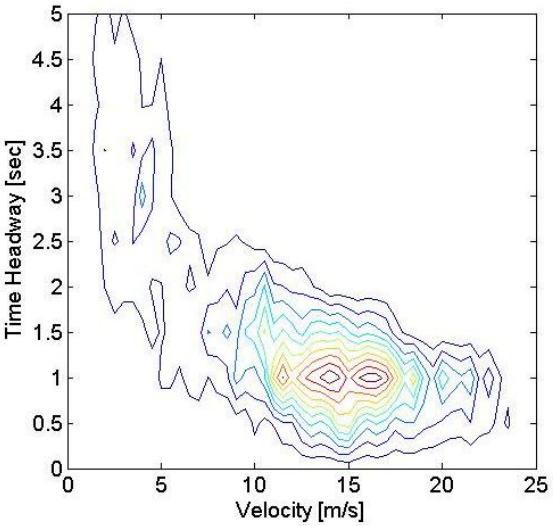


Fig. 18 Contour line between time headway and velocity of female driver

9. References

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[2] Motoki Shino[1] Minoru Kamata[1] Masao Nagai[2] Yohei Michitsuji[2] Katsumi Moro[3]
RESEARCH ON INCIDENT ANALYSIS USING DRIVE RECORDER
PART3: Analysis on relationship driving behavior and traffic circumstance based on forward collision near-miss incident data in car following situation